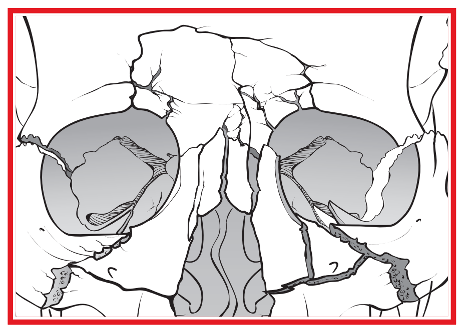
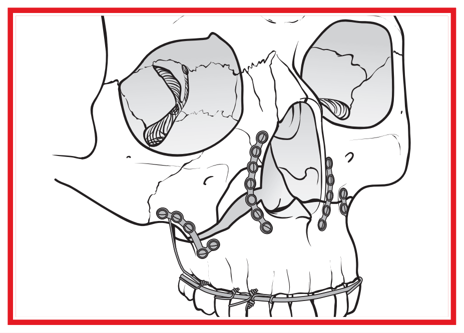
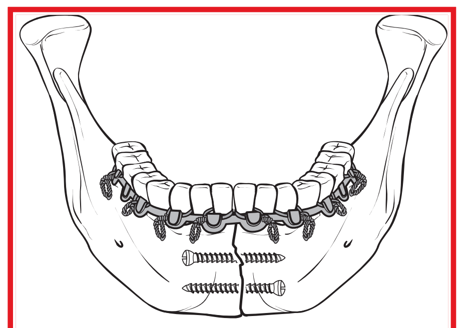
Essentials of Craniomaxillofacial TRAUMA







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To Jill, Ana-Maria, and Annette.
This book is dedicated to you and to our families.
Patients do not always arrive at convenient times.
Your love is our greatest gift. Without your love and support,
we would not be able to pursue our goals.

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Preface

Even those of us who have spent many years caring for patients with facial trauma can remember the initial months of specialty training, when we responded to the trauma bay to care for patients with facial trauma for the first time. After assessing a situation to the best of our abilities, we would contact our chief resident or attending surgeon to discuss the situation. We quickly realized that we were unable to speak the language and that the knowledge needed to develop a succinct plan resided in a (seemingly) insurmountable volume of literature. In addition, we recognized that practice standards were a moving target, with modern trends continually being layered on historical principles.

Craniomaxillofacial trauma is a unique subspecialty shared by plastic surgeons, otolaryngologists, and oral and maxillofacial surgeons. Although we have different backgrounds and different acquired expertise, we all hope to be able to offer the same full spectrum of care to patients and produce optimal outcomes. This book is written to provide practical knowledge to surgeons in the three core specialties at all levels of experience. It is our goal to provide a resource that allows a surgeon to quickly gather the knowledge needed to reliably provide care at the highest modern standard. Readers may find it particularly useful in the front lines on a case-by-case basis.

The editors and authors of this book come from all three specialties at two major teaching institutions: Duke University and Johns Hopkins University. This allows us to give a shared perspective from credible sources who have a history of collaboration. In addition, specialists in pediatric dentistry and orthodontics provide valuable chapters especially for those coming from nondental backgrounds. Each chapter in this book is written by a senior-level surgeon in partnership with a fellow or resident. This allows the book to address readers who have a range of experience, without making assumptions about their preexisting knowledge base.

When I arrived at Duke in 2002, I was asked by then chief of plastic surgery, Dr. L. Scott Levin, to be the director of the craniomaxillofacial trauma program. I inherited a clinic and program run primarily by residents and fellows in plastic surgery and otolaryngology with limited organization and guidance. These trainees worked tirelessly, earnestly, and cooperatively to provide good care. However, because of the limited structure, their learning process was inefficient, and they were stressed needlessly. With an effort, the Duke craniomaxillofacial program evolved to become a highly structured, yet still resident-run, program, fully integrated into the divisions of otolaryngology and plastic surgery. The process has been a model for teamwork, emphasizing consistency in care, reliable protocols, communication, and minimization of problems. Many of the guiding principles have been taught for many years by Dr. Paul Manson at Johns Hopkins University and the R. Adams Cowley Shock Trauma Center, and now by his successor, Dr. Eduardo Rodriguez. This book attempts to illustrate the principles and protocols employed at our institutions.

Relative to other aspects of our clinical practices, the field of craniomaxillofacial trauma is not rich in financial incentives. However, craniomaxillofacial surgery provides the educational basis for much of our other work. It teaches us about the symbiosis of form and function through an understanding of skeletal anatomy, meticulous soft tissue repair, safe exposures, and restoration of structural support. Modern aesthetic techniques and principles are integral components of trauma care. The tools we gain in caring for facial trauma patients enable us to be better surgeons while serving our communities with a critical need and providing every patient the opportunity to live without the stigma of facial disfigurement.

We feel that we are privileged to teach others, and we derive immeasurable personal satisfaction from doing so. We hope that this book will help us enhance the education of our residents and provide others with the same opportunities.

Jeffrey R. Marcus

Acknowledgments

I am grateful for the help and support of my co-editors and friends, Dr. Detlev Erdmann and Dr. Eduardo Rodriguez. Dr. Rodriguez is a rising star in plastic surgery who has consistently achieved inspiring results in the most difficult cases by blending his expertise of maxillofacial surgery, microsurgery, and facial aesthetics. Dr. Erdmann has been my close friend, confidante, and partner since my arrival at Duke. We have worked and learned together and been available to one another unconditionally.

I am grateful for the support and friendship of Dr. L. Scott Levin, who always had faith in us and inspired teamwork and vision. Dr. Gregory Georgiade is a mentor to me in many ways; thankfully, when needed, his facial trauma knowledge was always accessible on his mental "hard drive." My teachers at the University of Michigan, Northwestern, and the University of Toronto provided me with the skills that I can now pass to our residents.

I am grateful to the faculty at Duke who comprise our team. Dr. Tom McGraw, an oral surgeon and a true gentleman, has been available 24/7/365 to assist in any way needed. Our pediatric dentists, Dr. Martha Ann Keels and Dr. Cynthia Neal, are one of the most skilled and caring teams with whom I have worked. My colleagues in otolaryngology, originally Dr. Tom Hung and now Dr. Liana Puscas, have been valuable partners. The nurses and staff of the craniomaxillofacial clinic at Duke cannot be thanked enough for the fine care and attention that they give to all of our patients. Similarly, thanks go to our operating room nursing staff for their skill, diligence, patience, friendship, and ability to use internet radio. Thanks also must be given to Dr. Michael Hocker and the Duke emergency department, the Duke trauma surgery team, and our superb anesthesia faculty and staff.

Finally, I am grateful to the residents in the divisions of plastic surgery and otolaryngology who have spent countless hours, day and night, striving to perform to high expectations and care for our patients. It was one of our residents, Dr. Jack Taylor, who originally suggested that a succinct written manual would be a valuable resource to the team. Our residents have helped author the chapters in this book and have been its inspiration.

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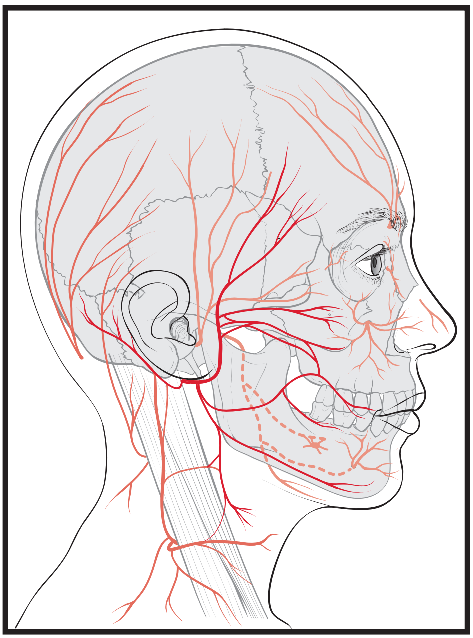
Part One

Basic Principles



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1 Demographics of Facial Injuries

Keith E. Follmar, Eduardo D. Rodriguez

THE SCOPE OF TRAUMA AND FACIAL TRAUMA

Trauma is the single leading cause of death in persons between the ages of 1 and 44 in the United States, and it is the fifth most common cause of death for all age groups. Injury accounts for 25% of all emergency department visits and 1 in 8 hospital admissions nationally.[1] Trauma causes 150,000 deaths annually, approximately three times that many individuals are permanently disabled each year, and 1 of every 10 U.S. residents is treated in an emergency department for a traumatic injury in any given year.

Annual medical expenditures attributable to injury and postinjury rehabilitation exceed $200 billion annually, which is more than 10% of United States health care costs. When lost wages and other costs are included, the annual cost of trauma is more than $400 billion.

Traumatic injury is more common in males than in females and is most common in the second through fourth decades of life. Other risk factors for traumatic injury include low socioeconomic status, low educational level, illicit drug use, heavy alcohol use, handgun ownership, infrequent seat belt use, and (among females) history of domestic violence.

The demographic makeup of a craniomaxillofacial trauma population varies based on geography and largely mirrors that of the trauma population as a whole. In one recent analysis of facial fracture demographics at Duke University Medical Center, the facial trauma population was 72% male and 28% female. Ethnic composition was 46% white, 34% black, 13% Hispanic, and 7% other. The average age was 34 ± 17 years.[2] A similar analysis of the facial trauma population at the R Adams Cowley Shock Trauma Center showed similar demographics; 78% of patients were male, the median age was 35 years (Fig. 1-1), and the racial makeup was 59% white and 34% black.[3]

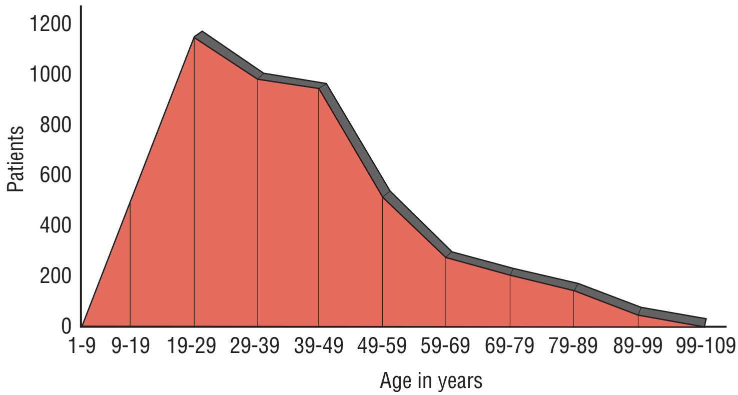

Fig. 1-1 Age distribution of patients with craniomaxillofacial injuries at the R Adams Cowley Shock Trauma Center between 1998 and 2005. (From Mithani SK, St-Hilaire H, Brooke BS, et al. Predictable patterns of intracranial and cervical spine injury in craniomaxillofacial trauma: analysis of 4786 patients. Plast Reconstr Surg 123:1293-1301, 2009.)

MECHANISMS OF FACIAL INJURY

Major causes of facial trauma include assault, motor vehicle collisions (MVCs), falls, sports injuries, occupational injuries, and gunshot wounds (GSWs) to the face. The relative prevalence of injury type varies by geography and practice setting. Falls and sports injuries are more likely to result in soft tissue–only trauma or relatively minor fracture patterns (such as isolated nasal bone fractures), which are more commonly treated in smaller emergency departments or in an ambulatory setting. Assaults, MVCs, and GSWs are more commonly treated in large, urban, level 1 trauma centers and more commonly result in more severe injuries. Demographic studies of facial trauma are almost exclusively performed in large urban level 1 trauma centers, so the literature is biased accordingly.

In the Shock Trauma series, MVC was the most common mechanism of facial fracture, followed by blunt assault, and then falls. In the Duke series, assault was the most common mechanism of facial fracture, followed closely by MVC[2] (Fig. 1-2). When patients are analyzed by severity of facial injury,[4] GSWs and MVCs can be shown to cause the highest severity of injury (Fig. 1-3). Sports injuries are most commonly associated with isolated upper midface trauma (such as nasal bone fracture). Assault is most commonly associated with isolated fractures of the mandible (Fig. 1-4).

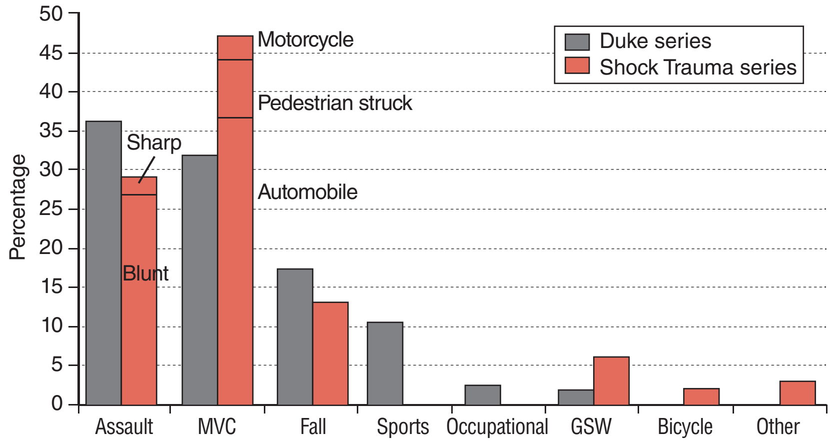

Fig. 1-2 Mechanisms of injury causing facial fracture in the Duke University Medical Center series, 2003-2005, and in the R Adams Cowley Shock Trauma Center Series, 1998-2005.

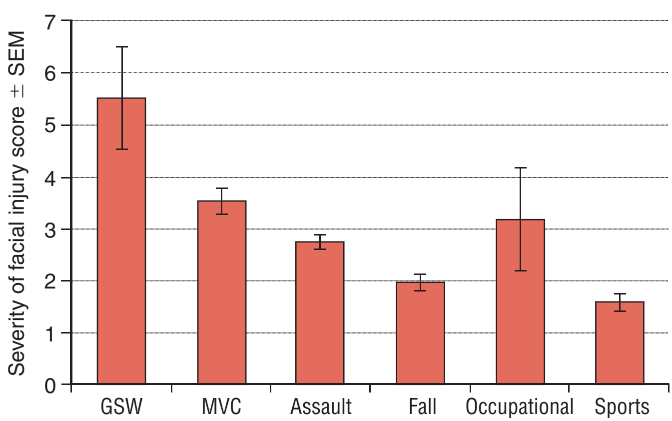

Fig. 1-3 Facial injury severity score for each cause of trauma. Error bars show standard error. (From Erdmann D, Follmar KE, DeBruijn M, et al. A retrospective analysis of facial fracture etiologies. Ann Plast Surg 60:398-403, 2008.)

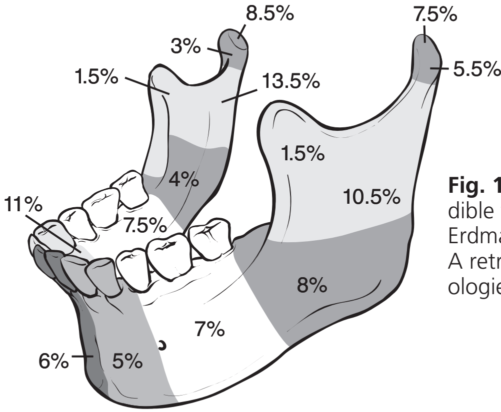

Fig. 1-4 Anatomic distribution of 200 mandible fractures in 111 patients. (Modified from Erdmann D, Follmar KE, DeBruijn M, et al. A retrospective analysis of facial fracture etiologies. Ann Plast Surg 60:398-403, 2008.)

PEDIATRIC FACIAL INJURIES

The craniofacial skeleton of a growing child is a dynamic structure that is biomechanically distinct from the adult facial skeleton. The pediatric facial skeleton is less pneumatized and less ossified (and therefore more flexible) than the adult skeleton. Children have a larger cranial mass–to–body mass ratio than adults. The malar region is more protected by a relatively larger malar fat pad. Furthermore, children do not engage in the same risky behaviors as adults and therefore have a different distribution of injury mechanisms.

A review of the U.S. National Trauma Data Bank found a 4.6% rate of facial fractures among pediatric trauma admissions (12,739 of 277,008 admissions).[5] The rate of facial fracture among hospitalized patients was higher among the older pediatric age groups, with only 2.4% of admitted infants and toddlers having facial fractures, but 6.9% of older teens having facial fractures. The most common facial fractures were mandible (33%), nasal (30%), and maxillary/zygoma (29%). The most common mechanisms of injury were MVCs (55%), violence (12%), and falls (9%) (Fig. 1-5). A large single-institution review of craniofacial fractures from the University of Bern (2001-2003) showed a very different distribution of injury mechanisms: fall (64%), MVC/bicycle (22%), sports (9%), and violence (5%).[6] The differences between the result of these two studies may reflect that the Bern study included fractures of the skull vault in addition to facial fractures, as well as cultural differences between Europe and the United States and different study methodologies (Fig. 1-6).

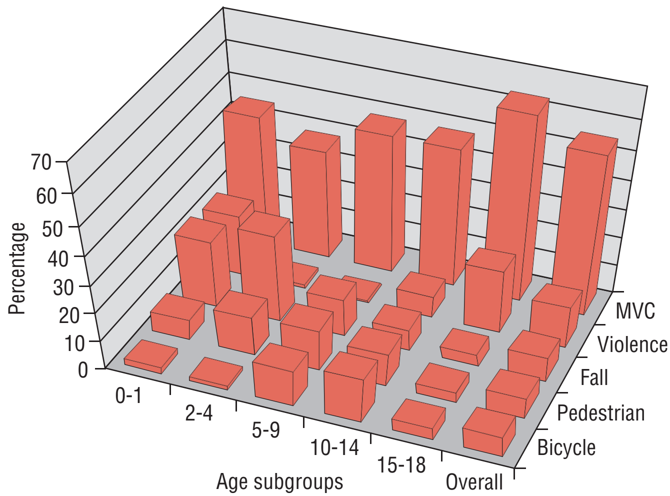

Fig. 1-5 Mechanism of injury causing pediatric facial fractures in the U.S. National Trauma Data Bank, stratified by age group, 2001-2005. (From Imahara SD, Hopper RA, Wang J, et al. Patterns and outcomes of pediatric facial fractures in the United States: a survey of the National Trauma Data Bank. J Am Coll Surg 207:710-716, 2008.)

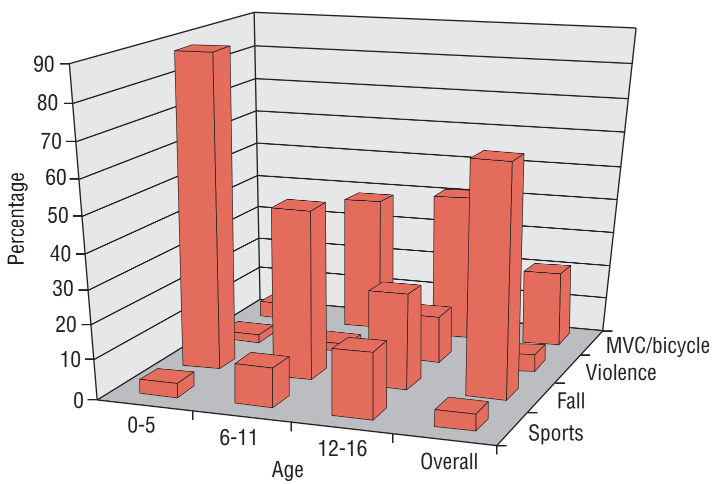

Fig. 1-6 Mechanism of injury causing cranial and facial fractures in a pediatric population, stratified by age group at the Inselspital, University of Bern, 2001-2003. (Modified from Eggensperger Wymann NM, Hölzle A, Zachariou Z, et al. Pediatric craniofacial trauma. J Oral Maxillofac Surg 66:58-64, 2008.)

The anatomic distribution of pediatric facial fractures is markedly different from that of adults and varies by age. In both studies, cranial and midface injuries were more common in the younger age groups. Mandible injuries were more common in the adolescent age group. Most notably, fractures of the skull vault were extremely common in children. Orbital roof fractures were also markedly more prevalent in children than in the adult facial fracture population (Fig. 1-7).

The U.S. study showed that, compared with patients without facial fractures, patients with facial fractures had a greater severity of injury, as measured by the injury severity score. In addition, patients with facial fractures had longer hospital stays (5.9 versus 3.4 days), longer ICU stays (2.9 versus 0.9 days), more days on ventilatory support (1.8 versus 0.1 days), higher hospital charges ($22,839 versus $11,405), more severe injuries to the head and chest, and higher overall mortality (4.0% versus 2.5%; Table 1-1).

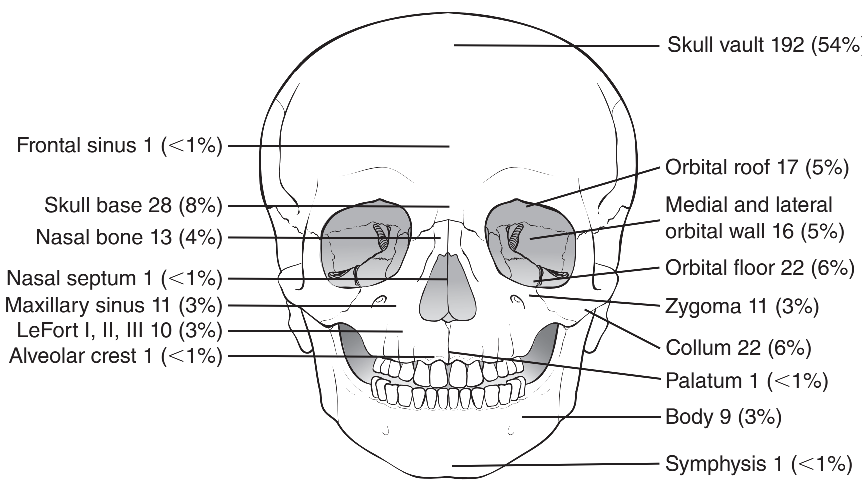

Fig. 1-7 Distribution of pediatric facial fractures at the Inselspital, University of Bern, 2001-2003. There were a total of 192 fractures of the skull vault, 132 fractures of the upper and middle facial thirds, and 32 mandible fractures. Absolute numbers of fractures are listed, with percentages in parentheses. (Modified from Eggensperger Wymann NM, Hölzle A, Zachariou Z, et al. Pediatric craniofacial trauma. J Oral Maxillofac Surg 66:58-64, 2008.)

TABLE 1-1 CHARACTERISTICS OF PATIENTS WITH AND WITHOUT FACIAL FRACTURES AMONG 277,008 PEDIATRIC TRAUMA PATIENTS

Characteristic	Facial Fractures	No Facial Fractures	*p* Value
Number	12,739	264,269	
Age (yr), mean ± SD	12.6 ± 5.5	10.2 ± 6.0	<0.001
Male (%)	68.6	65.7	<0.001
White (%)	62.2	59.1	<0.001
Blunt (%)	95.0	84.8	<0.001
Mechanism (%)			<0.001
MVC	55.1	35.4	
Fight/assault	11.8	3.5	
Fall	8.6	26.1	
Pedestrian	7.5	7.7	
Bicycle	7.2	6.6	
Weapon	2.7	3.5	
Bite	1.5	1.5	
MVC restrained	27.3	32.2	<0.001
Region (%)			<0.001
South	30.9	37.2	
Midwest	27.1	29.1	
West	18.9	16.5	
Northeast	7.0	7.1	
Not reported	16.1	10.1	

From Imahara SD, Hopper RA, Wang J, et al. Patterns and outcomes of pediatric facial fractures in the United States: a survey of the National Trauma Data Bank. J Am Coll Surg 207:710-716, 2008.
MVC, Motor vehicle collision.

CONCOMITANT INJURIES

Facial fractures are commonly associated with concomitant injuries, which can be severe and even life threatening (Table 1-2). Trauma that involves sufficient energy to fracture the bones of the facial skeleton is also likely to distribute a substantial amount of force to other parts of the body. This is especially true in MVCs, which involve the random dissipation of a large amount of kinetic energy. Facial injuries that occur as a result of assault (nonrandom energy intentionally directed at the face, such as from a fist) are less likely to be associated with concomitant injuries to other parts of the body.

The management of these concomitant injuries can directly affect the timing and modality of facial fracture management. Life-threatening injuries should generally be addressed before treatment of facial injuries can begin. One exception to this is emergency evacuation of a retrobulbar hematoma, which is an eyesight-threatening emergency and should be addressed immediately after airway, breathing, and circulation have been secured. In addition, if a neurosurgical craniotomy is indicated for other reasons, frontal sinus fractures can be performed concurrently, but only in a stable patient with minimal intracranial trauma.

Intracranial Trauma

The Shock Trauma series showed an overall 46% rate of head injury associated with craniomaxillofacial trauma.[3] This included a 15% rate of coma on presentation (a Glasgow Coma Scale [GCS] score of 3 through 8), an 18% rate of subarachnoid hemorrhage, a 13% rate of subdural hematoma, and 5% rates each of intracerebral hematoma, intraventricular hemorrhage, and epidural hematoma. The overall rate of skull fracture associated with craniomaxillofacial trauma was 16%. The Shock Trauma data demonstrate an overall higher rate of head injury than most previous studies; this probably reflects the fact that the prevalence of head injury in facial trauma patients is higher than was previously appreciated in the literature. It also reflects the overall higher level of acuity seen at this institution in particular.

In addition to showing a very high overall rate of head injury associated with craniomaxillofacial trauma, several specific anatomic associations were demonstrated by the Shock Trauma data. Fractures of the upper face were associated with an increased likelihood of severe intracranial injuries and increased mortality rates. Unilateral midface injuries were associated with high rates of basilar skull fracture and intracranial injury. Bilateral midface injuries were associated with basilar skull fractures and increased mortality rates.

Review of pediatric trauma admissions in the U.S. National Trauma Data Bank found a 32.3% rate of brain injury associated with facial fractures, which was twice that found in the non–facial fracture population. Fractures to the skull base

TABLE 1-2 PREVALENCE OF CONCOMITANT INJURIES AMONG PATIENTS WITH PANFACIAL FRACTURE

Injury Type	Prevalence (%)
Intracranial injury/hemorrhage	18
Abdominal organ injury	16
Pneumothorax	13
Pulmonary contusion	13
Cervical spine fracture	13
Rib/sternum fracture	11
Lower extremity fracture	11
Upper extremity fracture	11
Pelvic fracture	8
Noncervical spine fracture	8

Modified from Follmar KE, DeBruijn M, Baccarani A, et al. Concomitant injuries in patients with panfacial fractures. J Trauma 63:831-835, 2007.

were seen in 27.3% of patients, compared with only 3.3% of those with no facial fractures.[5]

CERVICAL SPINE INJURY

Cervical spine injuries commonly occur in association with facial fractures. In the Duke series, cervical spine fractures were present in 13% of patients with severe facial injury.[7] In the Shock Trauma series, there was an overall 10% rate of cervical spine injuries associated with craniomaxillofacial trauma.[3]

Fractures of the upper face are associated with the highest likelihood of cervical spine injury. Upper facial fractures are specifically associated with middle and lower cervical spine injuries. Lower facial fractures and unilateral mandible fractures are associated with increased likelihood of upper cervical spine injuries.

Because of these associations, and because of the serious nature of spinal cord injury, *all patients with facial fractures must be assumed to have cervical spine injury until it is proven otherwise.*

Clearance of the cervical spine typically consists of radiographic clearance by CT scan plus clinical clearance by physical examination. In situations in which cervical spine tenderness and distal neurologic function cannot be assessed (such as in a comatose patient), an MRI of the cervical spine can be used to rule out ligamentous injury in lieu of a physical examination.

In cases in which cervical spine injury is present or when an adequate disposition of the cervical spine cannot be obtained, treatment of facial fractures may proceed with strict immobilization of the cervical spine in the operating room. This makes the case more difficult, both for the surgeon and for the anesthesiologist, but it is a necessary precaution to avoid injury to the spinal cord.

Review of pediatric trauma admissions in the U.S. National Trauma Data Bank found a 3.3% rate of cervical spine fracture associated with facial fractures, compared with 1.3% seen in those without facial fractures.[5] Although cervical spine injury is much less common in the pediatric age group, we recommend adhering to the same high level of vigilance until the cervical spine has been cleared clinically and radiographically.

Ocular Injury and Blindness

Forty-five percent of patients with facial fractures have fractures involving one or both orbits.[8] Because of the high potential for ocular injury, formal ophthalmologic examination is encouraged before operative fracture reduction. Common ocular injuries that should be ruled out by ophthalmologic examination include corneal abrasion, hyphema, globe rupture, extraocular muscle injury or entrapment, retrobulbar hematoma, and optic neuropathy. Most ocular injuries are of a self-limited nature and are not vision threatening if properly treated.

Immediate posttraumatic blindness occurs in 1.6% to 5% of patients with midface fractures. It is more commonly seen with higher-energy mechanisms, such as MVCs, compared with lower-energy mechanisms, such as assault. Posttraumatic blindness can be caused by direct injury to the globe, retinal vascular occlusion, orbital compartment syndrome (retrobulbar hemorrhage), retinal detachment, or injury to proximal structures (the optic nerve, optic tract, or central vision centers).

Blindness following operative fracture reduction is extremely uncommon but has been reported in the literature.[8] Mechanisms of postoperative blindness include direct injury to the optic nerve during fracture reduction, retinal arteriolar occlusion associated with orbital edema, and delayed presentation of an optic nerve injury from the initial trauma.

Pearls

- *Trauma is a leading cause of morbidity, mortality, disability, and medical expenditures in the United States.*
- *Risk factors for trauma include male sex, age in the teens through thirties, low socioeconomic status, low education level, illicit drug use, heavy alcohol use, handgun ownership, infrequent seat belt use, and (among females) history of domestic violence.*
- *Depending on the study, assault and motor vehicle collisions are the leading causes of facial fractures. Other major causes are falls, sports injuries, occupational injuries, and gunshot wounds.*
- *Motor vehicle collisions and gunshot wounds cause the highest severity of facial injury. Assault is most commonly associated with isolated mandible fractures.*
- *The facial skeleton of a child is biomechanically different from that of an adult, and fracture patterns can be quite different. Cranial and midface injuries are more common in the younger age groups. Mandible injuries are more common in the adolescent age group.*
- *When other injuries are present concomitantly with facial fractures, life-threatening injuries must be addressed before treatment of facial injuries can begin.*
- *All patients with facial fractures must be assumed to have cervical spine injury until it is proven otherwise. Clearance of the cervical spine typically consists of radiographic clearance by CT scan plus clinical clearance by physical examination.*
- *When orbital fractures are present, formal ophthalmologic examination is encouraged before operative fracture reduction. Blindness following operative fracture reduction is extremely uncommon, but has been reported in the literature.*

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2 Classification of Facial Fractures

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Background

René Le Fort published his classical description of facial fracture patterns in 1901.[1] By the 1950s, principles of facial fracture diagnosis and management were well described.[2] Since that time, much progress has been made in the diagnosis and treatment of facial fractures. The advent of computed tomography (CT),[3] thin-cut facial CT scans,[4] and, most recently, three-dimensional CT re-formations[5] has allowed improved diagnosis and has shifted the primary diagnostic modality of facial fractures from physical examination, plain radiographs, and operative exploration to CT.

In clinical practice, almost all facial fracture diagnoses and descriptions are performed by radiologists, and thus any classification system is rooted in radiographic diagnosis. The goal of fracture classification and description is to facilitate succinct descriptions of site-specific radiographic diagnoses with clinically relevant factors used in the treatment of patients with facial fractures. Radiographic diagnoses can then be communicated among specialists of various disciplines.

Facial fractures are classified according to the anatomic structures of the face involved. Facial fractures occur in recognizable patterns, and their classification and description respect these patterns. In some cases, what is referred to as a single facial fracture is actually two or more fracture lines that reliably occur in association with one another, and these are therefore described as a single fracture entity. For example, a zygomatic arch fracture typically comprises two fractures of the zygomatic arch (one anterior and one posterior), so that the arch itself is disconnected from the remainder of the facial skeleton. Yet we describe this as a single fracture, because only one structure (the zygomatic arch) is fractured.

A number of classification systems have been devised for specific anatomic fracture types, including frontal sinus fractures,[6,7] frontobasal fractures,[8] orbital fractures,[9] nasal fractures,[10,11] nasoorbital ethmoid fractures,[12,13] zygomatic arch fractures,[14] zygomaticomaxillary complex fractures,[9,15] palatal fractures,[16] mandibular condyle fractures,[17,18] and LeFort (pterygofacial) fractures.[1,19] Some of these site-specific classification systems are discussed elsewhere in this manual, according to their anatomic locations. The purpose of this chapter is more broad: it aims to provide a context for analyzing a fractured facial skeleton and describing that fracture in terms of one or more well-recognized injury patterns.

SIMPLE AND COMPLEX FRACTURES

The term *simple fracture* can be used to refer to fractures that involve only a single anatomic structure. A simple fracture may involve one or multiple fracture lines (as in the case of a zygomatic arch fracture). There are 17 types of simple fracture (see Box 2-1). These definitions vary slightly by author but are mostly universal.

There are certain fracture types in which a number of fracture sites involving multiple anatomic structures combine to form a common recognizable pattern. These can be termed *complex fractures.* For example, a unilateral LeFort III hemifracture is a complex fracture comprising fractures along the lateral orbital wall, the posterior zygomatic arch, the nasoorbital ethmoid region, and the pterygoid plate. Such a fracture is best described as a single complex fracture. Listing the component fracture sites of this complex fracture as though they were four separate fractures is redundant and can lead to confusion. There are five types of complex fracture:

- Nasoorbital ethmoid fractures
- Zygomaticomaxillary complex fractures
- LeFort I, II, and III hemifractures

LeFort fractures most often (but not always) occur bilaterally.

Box 2-1 presents the 17 types of simple fracture and the five types of complex fracture. Five fracture types (frontal sinus, nasal, nasoorbital ethmoid, palatal,

Box 2-1 Simple and Complex Fracture Types

Simple Fracture Types

- Frontal sinus*
- Orbital roof
- Medial orbital wall
- Lateral orbital wall
- Orbital floor
- Nasal*
- Zygomatic arch
- Maxillary sinus
- Palatal*
- Mandibular symphyseal
- Mandibular parasymphyseal
- Mandibular body
- Mandibular angle
- Mandibular ramus
- Maxillary sinus
- Mandibular coronoid process
- Mandibular subcondylar
- Mandibular condylar

Complex Fracture Types

- Nasoorbital ethmoid*
- Zygomaticomaxillary complex*
- LeFort I
- LeFort II
- LeFort III

*Midline structure. All other fracture types are of bilateral structures.

and mandibular symphyseal) are of midline structures and therefore cannot occur bilaterally. The remaining fracture types involving nonmidline structures can occur on either or both sides.

THE DUKE CLASSIFICATION SYSTEM

The Duke Classification System is a reporting system for describing facial fractures.[20] It was designed to clarify and standardize facial fracture terminology. This classification provides an organizational structure to guide radiologists in the description of facial fractures. It is particularly useful for cases in which multiple complex fractures are present. In these cases, the Duke Classification System provides a hierarchical system that defines which fractures should be described first (Table 2-1). As such, it allows simplicity of characterization in simple clinical circumstances as well as in more complicated multifracture settings.

When two fractures in this table share common elements and are present concomitantly in the same patient (on the same side), the fracture pattern is best described in terms of the higher-order complex fracture. The remaining elements of the fracture pattern should then be described in terms of their lower-order components to minimize redundancy. As mentioned previously, simple fractures should not be described or listed separately when they are part of a complex fracture. The details of this system are beyond the scope of this handbook and can be found in the classification system's published description.[20]

TABLE 2-1 HIERARCHICAL SYSTEM FOR DESCRIBING COMPLEX FRACTURES, ACCORDING TO THE DUKE CLASSIFICATION SYSTEM

When complex fractures include elements of multiple fractures, redundancy is minimized by first describing the highest order (lowest numbered) complex fracture, and then describing the remaining fractures that are necessary to fully describe the patient's remaining fracture components.

Order 1	LeFort I
Order 2	LeFort II
Order 3	LeFort III
	Zygomaticomaxillary complex
Order 4	Nasoorbital ethmoid
Order 5	All simple fractures

FRACTURE DIAGNOSIS

A radiologist can interpret a facial CT scan by listing which fractures are present. Such a list could perhaps be arranged in a cephalad-to-caudal manner to further facilitate understanding. Following the name of each fracture type in the interpretation of a CT scan, a short descriptive narrative should be provided. We call this a *modifying description.* This short narrative should include the exact anatomy of the fracture (for example, exactly which portion of the zygomatic arch is fractured), the degree to which the fracture is displaced, the number of comminuted pieces (when appropriate), the presence and degree of soft tissue involvement (such as the presence or absence of extraocular muscle herniation), and any other information germane to the fracture.

When the same fracture type is present bilaterally, it is best listed as two separate fractures so that each may have its own modifying description.

A listing of the 22 types of facial fractures follows. Each fracture type is followed by a short definition, identification of the complex fractures of which it may be a part (in which case it should generally not be listed as a separate fracture), and the information that may be included in its modifying description.

Frontal Sinus Fracture

The modifying description of a frontal sinus fracture should state whether the fracture involves only the anterior table or both the anterior and posterior tables. The anatomic portion of the frontal sinus that is involved, the approximate number of comminuted pieces, and a description of the overlying soft tissue should be provided. Comminution into the frontal bone and/or involvement of the frontonasal duct should be evaluated and mentioned when present (Fig. 2-1).

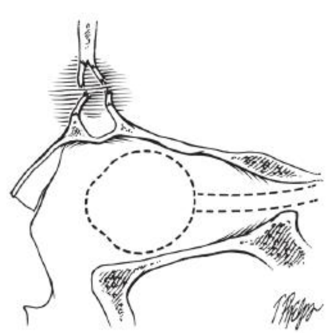

Fig. 2-1 Parasagittal view of an anterior and posterior table frontal sinus fracture.

Orbital Fractures

Orbital Roof Fracture

The side the fracture is on (left or right), the portion of the roof that is fractured, and the degree of displacement should be specified. Any herniation of extraocular muscles or fat should be described. The presence of orbital rim involvement and/or a concomitant frontobasal fracture should be mentioned when appropriate (Fig. 2-2).

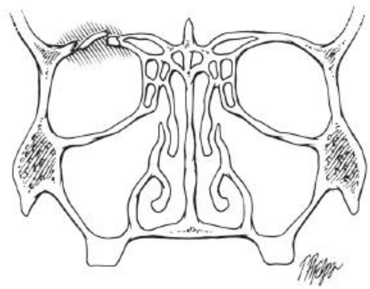

Fig. 2-2 Coronal view of a displaced right orbital roof fracture.

Lateral Orbital Wall Fracture

An isolated fracture of the lateral orbital wall is rare. It is more commonly seen in association with one of the complex fracture patterns. The anatomy of the fracture and any comminution into the orbital rim and a concomitant orbital floor or roof fracture should be described. Soft tissue herniation should be noted. Lateral orbital wall fractures do not need to be listed separately when part of a zygomaticomaxillary complex fracture or a LeFort III hemifracture, unless there are comminuted pieces separate from those of the other fractures (Fig. 2-3).

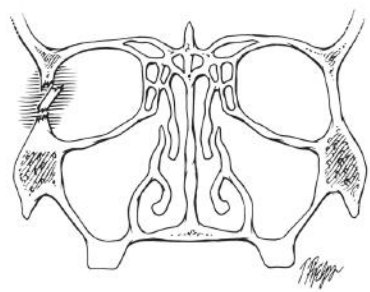

Fig. 2-3 Coronal view of lateral orbital wall fracture.

Medial Orbital Wall Fracture

The side, anatomy of the fracture, any comminution into the orbital rim, lacrimal bone, and any concomitant orbital floor or roof fracture should be described. Herniation of soft tissue into the ethmoid sinus region should also be noted. Medial orbital wall fractures should generally not be listed separately when part of a nasoorbital ethmoid fracture or a LeFort II or III hemifracture, unless there are comminuted pieces separate from those of the other fractures (Fig. 2-4).

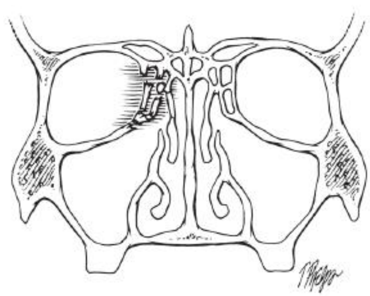

Fig. 2-4 Coronal view of a comminuted right medial orbital wall fracture.

Orbital Floor Fracture

The side, anatomy of the fracture with respect to the infraorbital nerve, size of the defect, and extent of displacement of any comminuted pieces should be described. Soft tissue herniation should be noted. An orbital floor fracture does not need to be listed separately when present as part of a nasoorbital ethmoid fracture, zygomaticomaxillary complex fracture, or a LeFort II or III hemifracture, unless there are separate comminuted pieces, displacement of the orbital floor, or herniation of orbital contents (all of which are quite common). In cases of complex fractures in which the orbital floor injury does not warrant description as a separate fracture, the orbital floor (and rim) must be described in the modifying description of the complex fracture of which it is a part (Fig. 2-5).

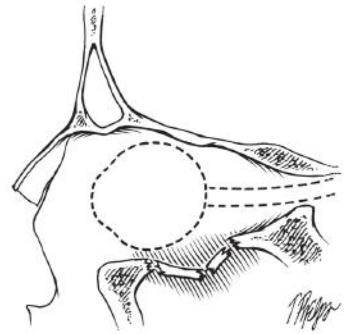

Fig. 2-5 Parasagittal view of a comminuted orbital floor blowout fracture.

Nasal Fracture

The nose is a symmetrical structure comprising paired nasal bones; one or both of the nasal bones may be fractured, generally depending on the direction and force of impact. Nasal fractures are best described as a single fracture, not as separate bilateral fractures. However, the exact bones involved should be specified, as should their degree of displacement. Any fracture involving any combination of the nasal bones, the nasal septum, and the nasal processes of the maxillary bones is classified as a nasal fracture. Nasal fractures are commonly seen without septal injury, but septal fractures are generally not seen in isolation. The presence of septal fracture should be indicated, and the fracture may be termed nasal-septal, as a subcategory of nasal fractures. The status of the airway and the degree of soft tissue and cartilaginous involvement should be described. It is not necessary to describe a nasal fracture separately if a nasoorbital ethmoid fracture is present; however, the same details of the nasal portion of this complex fracture should be described in the modifying description, particularly when comminution of the nasal bone (or bones) is present (Fig. 2-6).

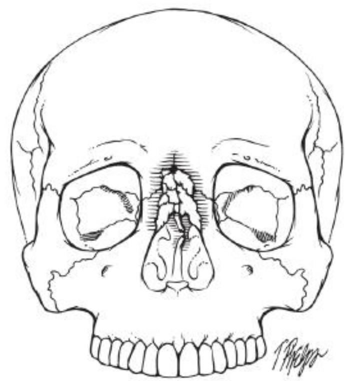

Fig. 2-6 Nasal fractures involving comminution of both left and right nasal bones.

Nasoorbital Ethmoid Fracture

Fractures involving any combination of the bones listed previously under Nasal Fracture, plus either the ethmoid bone (lamina papyracea) or one of the lacrimal bones, constitute a single nasoorbital ethmoid fracture. The exact anatomy and degree of displacement should be described, as should airway and soft tissue involvement. The presence of a unilateral or bilateral lamina papyracea fracture is especially important for planning treatment. A nasoorbital ethmoid fracture does not need to be described as a separate fracture if it is part of an intact LeFort II or III hemifracture segment, because these are higher-order complex fractures (Fig. 2-7).

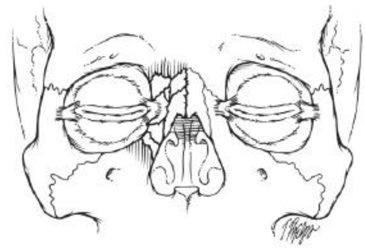

Fig. 2-7 Nasoorbital ethmoid fracture involving the right lamina papyracea and lacrimal bones.

Isolated Zygomatic Arch Fracture

The side must be specified. When the arch is fractured in two locations, as is often the case, the exact location of the anterior and posterior fracture lines should be specified. If only an anterior or midarch fracture is present (greenstick fracture), this should be noted. If the arch is fractured in three or more places, the pattern should be described. The degree of soft tissue involvement and bony displacement must be specified. A zygomatic arch fracture should not be described as a separate fracture if it is part of a zygomaticomaxillary complex fracture or a LeFort III hemifracture, because these are higher-order complex fractures. The presence or absence of impingement on the coronoid process of the mandible (especially in cases of midarch fractures) should be assessed (Fig. 2-8).

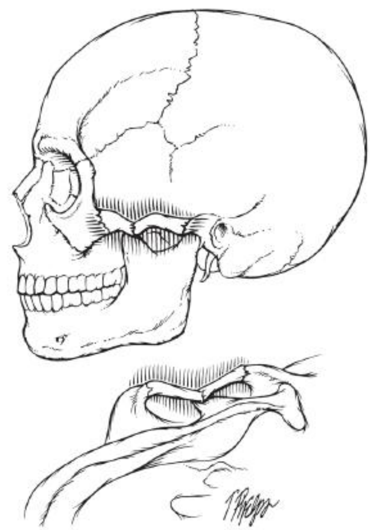

Fig. 2-8 Depressed left zygomatic arch fracture.

Zygomaticomaxillary Complex Fracture

The side must be specified. Zygomaticomaxillary complex fractures are defined by dislodgement of the zygomaticomaxillary complex from the remainder of the craniofacial skeleton. When the zygomaticomaxillary complex has been completely mobilized, fractures generally have occurred at four buttresses: the zygomaticofrontal buttress, the zygomaticomaxillary buttress, the infraorbital rim, and the zygomatic arch. The pattern is complete with fractures along the zygomaticosphenoid suture traversing the lateral orbital wall and orbital floor and along the anterolateral walls of the maxillary sinus, which spans from the infraorbital rim to the zygomaticomaxillary buttress. Often the zygomaticomaxillary complex is not completely displaced at all four buttresses, but when each site is carefully inspected, a fracture is generally found. As with other fracture types, the exact bony and soft tissue anatomy should be described in the modifying description. An orbital floor fracture, by definition, is involved in all fractures of the zygomaticomaxillary complex, but it need not be described separately unless separate comminuted pieces, displacement, or herniation of orbital contents are present. Regardless, the extent of the orbital floor component of this injury should be described in detail. This is of great clinical utility, because the orbital floor component of the injury may be exacerbated intraoperatively when the malar eminence is elevated for reduction, and this tends to open and enlarge the orbital floor defect (Fig. 2-9).

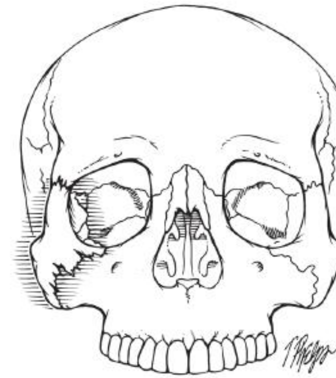

Fig. 2-9 Nondisplaced right zygomaticomaxillary complex fracture.

Maxillary Sinus Fracture

Fractures of the maxillary sinus that occur as part of an orbital floor, zygomaticomaxillary complex, and LeFort fracture do not need to be described as separate fractures. Truly isolated maxillary sinus fractures are typically of little consequence, and intervention is seldom indicated. The exact bony and soft tissue anatomy should be described, taking note of dentition involvement (Fig. 2-10).

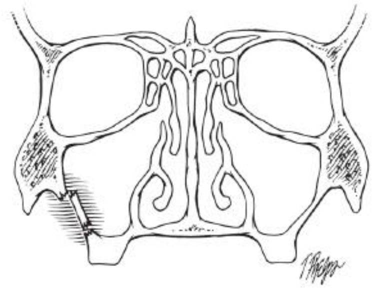

Fig. 2-10 Coronal view of an anterior maxillary sinus wall fracture involving the zygomaticomaxillary buttress.

Palatal Fracture

The bony palate should be treated as a single midline structure for the purposes of listing fractures. The anatomy of the fracture should be described, with attention to the involvement of the alveoli and the dentition. Palatal fractures should be listed separately when they occur concomitantly with LeFort fractures, because they significantly affect the treatment plan and are not customarily considered as components of such fractures (Fig. 2-11).

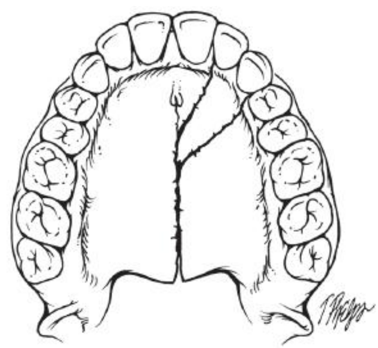

Fig. 2-11 Nondisplaced palatal fracture.

Mandible

Mandibular Symphyseal Fracture

The presence of dental or soft tissue involvement should be noted. If the fracture is more than a single transverse fracture (that is, if there is a basal triangle), the bony anatomy should be described. The degree of dislocation should be described. The fracture is, by definition, an open one if it traverses along a tooth root or is seen in association with clinically recognized intraoral laceration (Fig. 2-12).

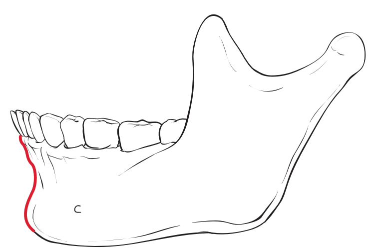

Fig. 2-12 Mandibular symphysis.

Mandibular Parasymphyseal Fracture

Mandibular parasymphyseal fractures are fractures of the mandible medial to the canines (or the mental foramen in edentulous patients), but not at the midline itself (symphyseal). The side, presence of dental or soft tissue involvement, fracture pattern, and degree of dislocation should be described (Fig. 2-13).

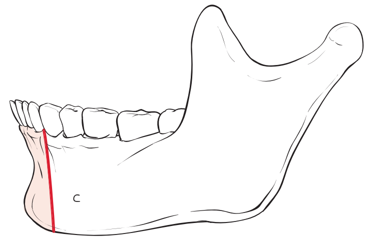

Fig. 2-13 Mandibular parasymphysis.

Mandibular Body Fracture

Mandibular body fractures are defined as fractures of the mandible between the canine and the second molar (approximately 4 mm anterior to the alveolar foramen in edentulous patients). The side, presence of dental or soft tissue involvement, fracture pattern, and degree of dislocation should be described (Fig. 2-14).

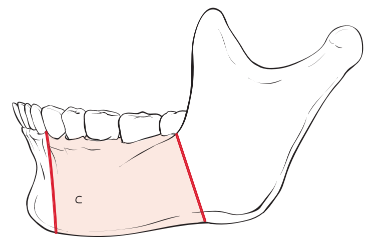

Fig. 2-14 Mandibular body.

Mandibular Angle Fracture

Mandibular angle fractures are defined as fractures posterior to the second molar, but inferior to the ramus. The side, presence of third molar or soft tissue involvement, fracture pattern, and degree of dislocation should be described (Fig. 2-15).

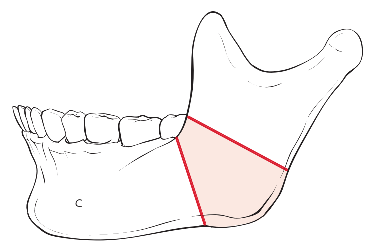

Fig. 2-15 Mandibular angle.

Mandibular Ramus Fracture

Mandibular ramus fractures are defined as fractures posterior to the mandibular angle and inferior to the coronoid process and condylar neck. The side, fracture pattern, and degree of dislocation should be described (Fig. 2-16).

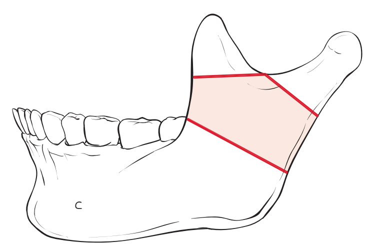

Fig. 2-16 Mandibular ramus.

Mandibular Coronoid Process Fracture

The side, fracture pattern, and degree of dislocation should be described (Fig. 2-17).

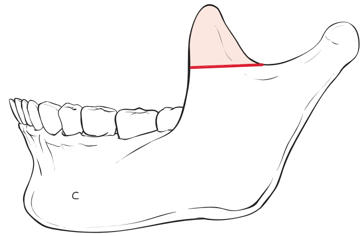

Fig. 2-17 Mandibular coronoid process.

Mandibular Subcondylar Fracture

The side, fracture pattern, and degree and direction of dislocation and angulation should be described (Fig. 2-18).

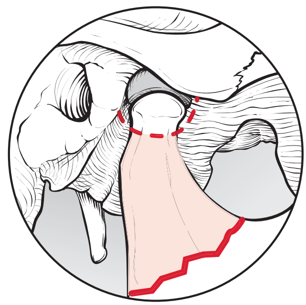

Fig. 2-18 Subcondylar region of the mandible.

Mandibular Condylar Fracture

The side, fracture pattern, degree and direction of dislocation and angulation, and presence of temporomandibular joint involvement should be described (Fig. 2-19).

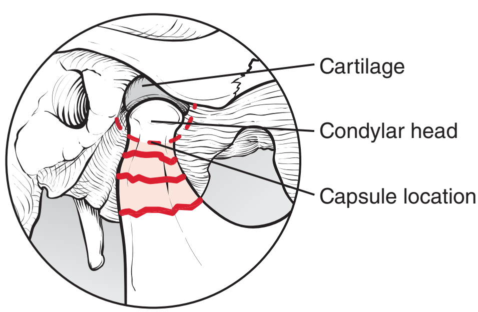

Fig. 2-19 Condylar region of the mandible.

LeFort Fractures

LeFort I Hemifracture

A LeFort I hemifracture is defined by the concomitant presence of a comminuted maxillary sinus fracture (involving the lateral and medial maxillary buttresses) and a pterygoid plate fracture on the same side. If the maxillary subunit is entirely comminuted, then a bilateral LeFort I hemifracture is present. A LeFort I hemifracture should be listed in all cases when the necessary components are present, because it is the highest-order complex fracture (see Table 2-1). In the modifying description, the bony details of the maxillary fracture, the degree of displacement, and the involvement of soft tissue should be described (Fig. 2-20).

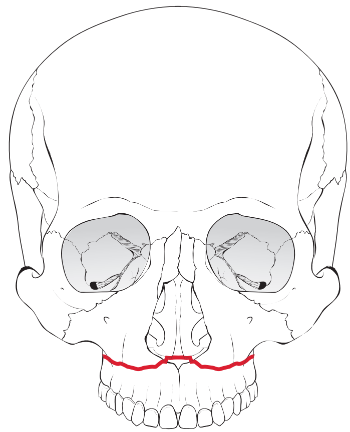

Fig. 2-20 LeFort I fracture.

LeFort II Hemifracture

A LeFort II hemifracture is defined by the concomitant presence of fractures through the nasoorbital ethmoid region that proceed along the orbital floor, through the infraorbital rim and zygomaticomaxillary buttress, and posteriorly through the pterygoid plate on the same side. Like LeFort I fractures, LeFort II hemifractures can be unilateral or bilateral. In the case of a bilateral LeFort II fracture, if the two halves are comminuted separately through a vertical midline fracture along the medial maxillary buttress (piriform rim), these fracture components should be described as separate nasoorbital ethmoid and palatal fractures (Fig. 2-21).

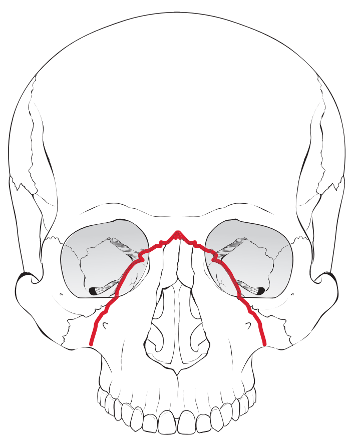

Fig. 2-21 LeFort II fracture.

LeFort III Hemifracture

A LeFort III hemifracture is defined by the concomitant presence of fractures through the nasoorbital ethmoid region that proceed along the orbital floor and the zygomaticosphenoid articulation and lateral orbital wall. The zygomaticofrontal buttress and zygomatic arch are fractured, and there is a fracture of the pterygoid plate on the same side. Comminution is frequently seen after a high-impact injury, occurring along lines of structural instability; this yields fracture segments that must be described separately. The relevant bony and soft tissue details of the component fractures should be described. As with LeFort II hemifractures, if the two halves are comminuted separately through a vertical midline fracture along the medial maxillary buttress (piriform rim), separate nasoorbital ethmoid and palatal fractures should be described. An orbital floor fracture should be listed separately if there are separate comminuted bony fragments in the orbital floor, displacement of the orbital floor, or herniation of orbital contents (Fig. 2-22).

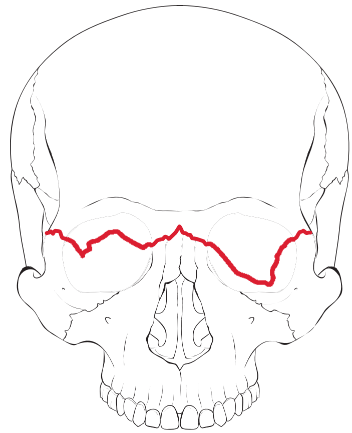

Fig. 2-22 LeFort III fracture.

OTHER FRACTURES

Chip fractures and alveolar ridge fractures are not listed among the 22 types of facial fractures, because they do not correspond to specific anatomic locations. When present, these fracture types should be preceded by a description of their anatomic location (for example, “left mandible alveolar ridge fracture,” or “right zygoma chip fracture”). Any other relevant descriptive information should be provided.

Pearls

- *The diagnosis of facial fractures remains difficult, even for trained surgeons and radiologists.*
- *Facial fractures occur in recognizable patterns and locations.*
- *Accurate and precise diagnosis of each component fracture is essential. The true value of the radiographic interpretation is in the higher-order thinking necessary to reduce complex data into a succinct and clinically relevant list of fractures.*
- *The Duke Classification System was designed to clarify existing facial fracture terminology and to standardize terminology where it was redundant.*

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3 Systematic Examination of Facial Trauma

Matthew W. Blanton, Jeffrey R. Marcus

Background

A systematic examination of the facial skeleton and soft tissue provides the initial insights for the diagnosis and treatment of craniomaxillofacial (CMF) trauma. Learning and performing an accurate facial physical examination are paramount for any CMF surgeon. The CMF surgeon is not simply interested in identifying and treating facial injuries; the determination of associated injuries is the critical first step.

This chapter will provide a method for step-by-step evaluation to guide the surgeon's clinical judgment for individualizing treatment according to the severity of the fracture and associated injuries. We will address primary evaluations that are intended to identify life-threatening injuries or those requiring emergent attention. Secondary evaluations can further detail any and all craniomaxillofacial injuries based on clinical findings. The findings are then used to help guide diagnostic imaging, which can confirm the physical findings and/or disclose other injuries that were not appreciated. The CMF surgeon must be alert and sensitive to the presence of particular physical signs that suggest specific regional injuries.

INITIAL MANAGEMENT: PRIMARY CRANIOMAXILLOFACIAL SURVEY

The initial evaluation of a patient with facial trauma should follow a systematic approach. A high index of suspicion for other injuries should be maintained throughout the evaluation process. The assessment begins with the primary survey standard trauma protocol for evaluating the airway, breathing, circulation, central nervous system status, and cervical spine.[1]

The primary survey is intended to identify all injuries, particularly those requiring immediate attention, with only limited emphasis on specific facial injuries. The mechanism of injury, time of injury, and any prior treatment the patient received must be documented.

Patients brought to a level 1 trauma center for initial evaluation should undergo a full trauma workup led by the emergency department and/or a trauma surgery team according to Advanced Trauma Life Support (ATLS) protocols.[1] This should then be followed by specialist evaluations, such at the CMF surgical assessment.

There are two situations in which injuries may be missed because of failure to follow a standardized trauma assessment protocol. The first occurs in cases of perceived isolated or minor facial injury, in which trauma assessment is deferred and specialist evaluation is requested at the initial presentation. In such cases, it is the responsibility of the CMF surgeon to personally provide comprehensive evaluation and rule out associated injury or to request that full trauma evaluation be conducted by the emergency department and/or trauma surgery team. The second compromising circumstance occurs when initial care is provided at another facility and the patient is subsequently transferred. In such cases, some or all elements of the primary trauma survey may have been deferred before a craniomaxillofacial consultation. All CMF trauma teams must have a protocol in place specifically for trauma transfer patients. If there is any question related to the completeness of the initial evaluation at the transferring institution or thereafter, a full primary trauma workup should be repeated to avoid missing an injury.

For craniomaxillofacial trauma transfer patients, radiographs should be evaluated personally by the CMF surgeon after the systematic examination is completed. If any portion of the radiographic examination has been excluded and there is apparent injury to the involved region, such studies should be performed. Radiographic assessment is discussed in Chapter 5.

Injuries Requiring Immediate Attention

Airway Compromise

Airway compromise is the result of either direct laryngeal injury, foreign bodies (such as aspirated teeth or bone fragments), or excessive bleeding from an upper airway source.[2] In practical terms, evaluation of the airways must be initiated by mechanical cleaning and aspiration of the oral cavity when necessary. Significant laryngeal tenderness, hoarseness, lacerations, crepitus, swelling, or ecchymosis of the neck are all signs of a potential laryngotracheal injury, which, while very rare, can cause precipitous airway compromise. The CMF surgeon should therefore maintain a high index of suspicion for laryngeal fractures when evaluating all CMF trauma patients with any of these neck findings. Verschueren et al[3] found that more than 95% of patients with laryngotracheal injuries had concomitant CMF injuries. A stable patient with these symptoms should undergo flexible fiberoptic evaluation of the airway, whereas an unstable patient for whom there is a suspicion of laryngeal injury should undergo emergent awake tracheostomy.[3]

If an immediate (emergent) airway must be established, nasotracheal intubation should be avoided, unless guided by fiberscopic assistance. This does not necessarily apply to the operating room in preparation for fracture repair. Under such circumstances, several management options exist; these are discussed in Chapter 9.

Hemorrhage

Hemorrhage originating from the facial region must be precisely located before definitive hemostasis can be established. The proximity of other important structures such as the facial nerve precludes vascular clamping or field cauterization. For an external facial hemorrhage, it is strongly recommended that a compressive dressing or packing be applied and that only selective vessel ligation or bipolar cautery be employed under direct loupe magnification once bleeding has been controlled. In some circumstances where there is minimal bleeding, compression dressings may be left in place until injuries are treated in the operating room. If injury to the facial nerve is suspected, the patient's injuries should be explored in the most controlled setting (that is, the operating room). Nasal packing is frequently necessary to control epistaxis. In most circumstances, the bleeding resolves on its own; however, if continued bleeding poses a problem, packing of the anterior nasal cavity is effective and sufficient. Massive hemorrhage should be approached with emergent intubation, followed by packing and direct pressure. The source of bleeding is most commonly a branch of the external carotid system, which is most appropriately controlled with angiographic embolization.[4]

Blindness

Blindness in patients with craniomaxillofacial trauma is usually caused by direct injury to the globe, retinal vascular occlusion, orbital compartment syndrome from retrobulbar hemorrhage, retinal detachment, or injury to the optic nerve or central vision centers. It is an uncommon complication of facial trauma, with a reported incidence of 2% to 5%. The visual loss mechanism can be classified as direct (contusion, concussion, or laceration) or indirect (extension of intracerebral bleeding, nerve sheath hemorrhage, vascular insufficiency, compressive edema or hemorrhage, bone fragment impingement, or bone callus formation).

The onset of blindness may be immediate, delayed, or postoperative. There are differing opinions about the exact timing of treatment for patients with traumatic optic nerve injuries. Options include observation, corticosteroids, osmotic diuretic agents, surgical decompression, or different combinations of these modalities. When the injury seems to be iatrogenic in nature, the management of postsurgical visual loss must proceed rapidly to decompression in the hope of returning visual function. A CT scan is required to document optic nerve and bone pathologic findings.[5]

A thorough eye examination should be performed, including visual acuity, inspection of the anterior chamber, retina, papillary reflexes, and extraocular movement. An ophthalmologic consultation is advised in cases of orbital injury. Visual testing in a patient who is able to communicate and participate is the most appropriate clinical evaluation and permits early recognition of decreased visual acuity. However, patients who have sustained facial fractures are frequently intoxicated with drugs or alcohol, unconscious because of head trauma, or sedated with anesthesia after operative reduction of their fractures. In these instances, clinical assessment of the pupillary size and reactivity to light is essential. The presence of a Marcus Gunn pupil is pathognomonic for afferent optic nerve injury. The evaluation for an afferent defect is performed using the "swinging flashlight" test.[6] If there is a partial or total loss of vision in one eye, the opposite pupil will not react consensually. A pupil that is the least bit sluggish in its reaction to light should be documented and careful serial examinations should be performed, because this physical finding is often the first herald of progressive nerve injury. The presence of papilledema or a macular "cherry red" spot is also a sign of nerve impairment.[5]

Neurologic Injury

Neurologic injury is commonly associated with severe facial trauma. Cervical spine injuries are known to occur concomitantly with facial fractures. The incidence of cervical spine injuries in patients presenting with facial fractures ranges between 2% and 10%. However, the incidence of facial fractures among patients presenting with cervical injuries is 15% to 20%. Motor vehicle accidents and falls are the most common mechanisms leading to combined facial fractures and cervical spine injuries.[7,8]

A thorough clinical neck palpation examination that elicits suspicious signs of an injury warrants further radiographic evaluation. Most patients should have a cervical spine CT in conjunction with their craniomaxillofacial CT. The cervical spine evaluation is the responsibility of the emergency department and/or trauma team. Until complete evaluation has been performed, the CMF surgeon must maintain cervical spine precautions until the presence of a spine injury is cleared both clinically and radiographically.

The timing for repair of facial fractures in patients who have sustained a traumatic brain injury remains controversial. Historically, concerns about the long-term neurologic outcome of these patients had led to a dictum of delayed operative repair. However, increased morbidity of functional outcome in facial fractures, especially of the mandible, in which repair was delayed has led to a push toward earlier fixation.[9] Derdyn et al[10] recommended that a patient with a Glasgow Coma Scale (GCS) of 6 or higher, with no evidence of intracranial hemorrhage, midline cranial shift, or basal cistern effacement, and an intracranial pressure (ICP) of less than 15 mm Hg without an obvious cerebrospinal fluid (CSF) leak is a candidate for early facial fracture reduction. Alternatively, the patient with a GCS score of 5 or lower, evidence of intracranial hemorrhage, midline cranial shift, or basal cistern effacement and an ICP above 15 mm Hg is a poor candidate for early fracture reduction. However, even a patient with a poor neurologic outcome (except a clinically brain dead individual) should still be considered for delayed repair of facial fractures, when the ICP permits, to minimize the development of a facial deformity.[10]

DETAILED FACIAL TRAUMA EVALUATION: SECONDARY CRANIOMAXILLOFACIAL SURVEY

The secondary craniomaxillofacial survey is performed after the primary survey issues have been addressed. This section identifies specific regional injuries that can be tied into unique aspects of the patient's subjective complaints and systematic physical examination.

History

After the patient has been stabilized, as complete a history as possible should be obtained. The history should be obtained from the patient; often, however, because of the patient's loss of consciousness or impaired neurologic status, information must be obtained from family members or witnesses. Five important questions should be considered:

1. How did the accident occur?
2. When did the accident occur?
3. What are the specifics of the injury, including the type of object contacted, the direction from which contact was made, and similar logistic considerations?
4. Was there a loss of consciousness?
5. What symptoms does the patient now have, including pain, altered sensation, visual changes, hearing changes, and malocclusion? Specific questions include these: Is there pain when you move your eyes? Are there areas of numbness or tingling on your face? Are you able to bite down without any pain? Is there pain when you move your jaw?

A complete review of systems should be obtained, including information about allergies, medications, and previous tetanus immunization, medical conditions, and prior surgeries. Obtaining this history will guide the examiner to specific injury patterns and lead the CMF surgeon to suspect certain diagnoses before radiographs are taken.

Subjective Complaints

Specific subjective complaints are important to note. They can provide information suggestive of specific injuries even before physical or radiographic examinations are performed. Examples of such symptoms are listed in Table 3-1.

Table 3-1 Subjective Complaints Suggesting Craniomaxillofacial Injury

Complaint	Suggestive of
Diplopia	Orbital fracture
Numbness of the cheek/maxillary teeth	Zygomaticomaxillary fracture (infraorbital nerve)
Numbness of the chin	Mandible fracture (mental nerve)
Malocclusion	Mandible or maxillary fracture
Visual change/blindness	Orbital fracture, Globe injury
Loss of hearing or otorrhea	Temporal bone fracture
Rhinorrhea	Cribriform fracture, frontal sinus fracture
Trismus	Mandible or zygomatic arch fracture

Detailed Craniomaxillofacial Physical Examination

The craniomaxillofacial physical examination includes a *regional examination,* followed by several *systems examinations.* The regional examination should proceed from cranial to caudal and should include two principle components: *inspection* and *palpation* performed region by region. This is followed by evaluation of the intraoral/dental, ocular, and neurologic systems.

Regional Examination

Signs that suggest facial trauma must be noted, such as edema, ecchymosis, facial asymmetry, bruising, lacerations, skeletal contour irregularities, crepitation, pain, and mobility. The regional examination should be conducted as follows:

- Cranium and cranial base
- Frontal region
- Orbits
- Nasal region
- Maxillary region
- Ear region

Cranium and cranial base The scalp is inspected for lacerations, swelling, and ecchymoses, including Battle's sign, which suggests a basilar skull fracture. The skull is palpated for contour irregularities suggestive of skull fracture.

Frontal region The frontal region is inspected for lacerations or visible depressions, and the integrity and regularity of the head and scalp are observed. The frontal sinus area is palpated for depressions or crepitus that might suggest an anterior and/or posterior wall frontal sinus fracture. A fracture of the posterior wall implies a possible fracture of the dura and may be manifested by CNS depression, CSF rhinorrhea, or visible brain matter.

Orbits The orbits are inspected for ecchymosis and edema of the eyelids or subconjunctival hemorrhage (Fig. 3-1); enophthalmos (Fig. 3-2) suggestive of possible zygomaticomaxillary complex (ZMC) fracture or orbital blowout fracture; diplopia with limitation in upward gaze, suggestive of inferior rectus muscle entrapment; infraorbital nerve anesthesia, which may indicate an orbital floor fracture; and emphysema of the orbits or eyelids. The supraorbital and infraorbital rims are palpated to access the skeletal contour and detect any irregularities, bone deviation, or impaction. The canthal attachments should be tested for stability.[11]

Fig. 3-1 Subconjunctival hemorrhage and periorbital ecchymosis following a left orbital floor fracture.

Fig. 3-2 Enophthalmos of the left eye following a zygomaticomaxillary complex fracture with an orbital blowout fracture.

Nasal region The nasal area is inspected for epistaxis (Fig. 3-3), CSF rhinorrhea, swelling, nasal airway obstruction, septal deviation or septal hematoma, and telecanthus suggestive of a nasoorbital-ethmoid fracture. The region is palpated for tenderness, deformity, and crepitus.

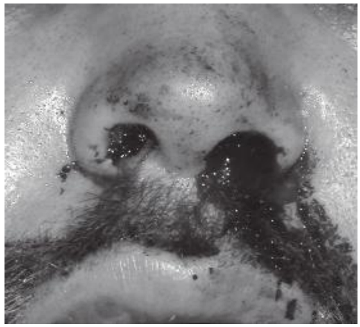

Fig. 3-3 Epistaxis following a nasoorbital ethmoid fracture.

Maxillary region The examiner inspects for malar depression of the inferior orbital rim (Fig. 3-4) or paresthesia in the distribution of the infraorbital nerve, suggestive of a ZMC fracture. The zygoma is palpated along its arch and its articulations with the maxilla and frontal and temporal bone. Additionally, ZMC fractures (zygomatic arch) may impinge on the coronoid process of the mandible, resulting in trismus. LeFort fracture findings may include facial distortion in the form of an elongated face, a mobile maxilla, or midface instability and malocclusion. The examiner tests for maxillary mobility by manually grasping the central incisors and rocking the maxilla gently.

Fig. 3-4 Left malar depression following zygomaticomaxillary complex fracture.

Ear region The external ear is examined for hematoma formation. The external auditory canal and tympanic membrane should be inspected for the presence of blood, CSF, laceration of the canal, or perforation of the tympanic membrane. Gross hearing is also assessed during the examination.

Mandible The mandible is inspected for external lacerations, swelling, ecchymosis, or hematoma (Fig. 3-5). The oral mucosa is evaluated for any ecchymosis or gingival tears that might indicate a mandibular body or symphyseal fracture. The inferior border of the mandible is palpated from the symphysis to the angle on each side. The examiner looks for any areas of swelling, step deformity, tenderness, or asymmetry (such as a marginal mandibular nerve injury; see Fig. 3-5). Any areas of paresthesia are noted along the distribution of the inferior alveolar nerve; numbness in this region is almost pathognomonic for fracture distal to the mandibular foramen. The movement of the condyle is palpated through the external auditory meatus. Pain of the preauricular area should alert to possible condylar fracture. Observe any deviation on mouth opening. Classically, deviation on opening is toward the side of the mandibular condyle fracture. Note any limiting of mouth opening, articular clicking, and trismus. Changes in occlusion from a displaced fracture, fractured teeth, and alveolus are suggestive of mandibular fracture. Mandibular fracture instability is evaluated through anterior traction by grasping the mandible on each side of the suspected site and assessing mobility.[12]

Fig. 3-5 Mandible (parasymphyseal) fracture. Note left-sided mandibular ecchymosis, malocclusion, and marginal mandibular nerve palsy.

Systems Examination

Intraoral examination The teeth are inspected for malocclusions, bleeding and step-off deformities. The examiner should manipulate each tooth and examine for bone fragments, or foreign bodies. Identification and removal of prosthetics (such as dentures) is essential to improve visualization and aid in fracture management. The oral mucosa is inspected for lacerations, ecchymosis, and bone fragments. The presence of dental, mandibular, and maxillary mobility is verified. The presence of any dental injury is noted, including loose or absent teeth, and this is documented clearly, identifying the teeth involved.

Occlusal examination The occlusion and intercuspation is carefully evaluated, as well as dental and articular problems, dental and orthodontic treatments in conjunction with the oral examination. Checking the occlusal situation must be done in neutral position and any irregularities are noted. It is beneficial if recent close-up photographs are available, both profile and frontal, to determine the patient's preinjury appearance and the presence of any preexisting maxillofacial problems. It is important to ask the patient to bite down, asking if they notice any difference in occlusion or pain. Any occlusional discrepancy such as a crossbite can lead to the suspicion of specific fractures of the maxilla and mandible (Fig. 3-6). Please see Chapter 4 for further details and management options.

Fig. 3-6 Crossbite resulting from a comminuted LeFort I fracture.

Ocular examination A complete ocular examination includes evaluation of the patient's ocular history, acuity, light and red light perception, ocular motility, a pupillary exam, and assessment of the conjunctiva and eyelids. Additionally, the area around the entire orbit should be palpated. If an ocular injury is suspected, an ophthalmologist should be consulted to examine the cornea for abrasions and lacerations and the anterior chamber for blood or hyphema. A fundoscopic examination is also performed to examine the posterior chamber and the retina.

Neurologic examination A neurologic examination of the face should include careful evaluation of all cranial nerves (Table 3-2). We suggest examining the patient by bundling the cranial nerve tests into their respective facial units. Work from cranial to caudal incorporating all aspects of the cranial nerve examination. We have highlighted the important and least important cranial nerve tests with relation to facial trauma.

Important cranial nerve examinations Vision, extraocular movements, and pupillary reaction to light should be assessed. The patient's preinjury visual history can provide helpful information in assessing eye trauma. Visual acuity or pupillary changes may suggest intracranial (CN II or III dysfunction) or direct orbital trauma. Abnormalities of ocular movements may also indicate either central neurological issue (CN III, IV, VI) or mechanical restriction of the ocular muscles from orbital fracture. The patient's preinjury visual history can provide helpful information in assessing eye trauma. Additional assessment of neurologic deficits, including the trigeminal nerve (CN V) and facial nerve (CN VII) should be performed. Sensory disturbances in the forehead (ophthalmic division of CN V), cheek (maxillary division of CN V), upper (infraorbital nerve) and lower lip (mandibular division of CN V) should be documented. Sensitive alterations on the lower lip may be related to traumatic compromise of the inferior alveolar nerve or the mental nerve, suggesting a mandibular fracture.

The function of the facial musculature is directly related to function of the facial nerve. Function of the frontal branch can be evaluated by asking the patient to elevate the frontal region and elevate the eyebrows. The orbital branches are evaluated through forced palpebral closure. Intact buccal branches allow the contraction of the orbicular and zygomatic musculature in kissing and smiling movements. The inferior mandibular branch is evaluated through inferior lip eversion and depression, while cervical branches are evaluated through the contraction of platysma.

Other cranial nerve examinations The acoustic nerve (CN VIII) can simply be examined by asking the patient to compare their hearing from both ears. Detailed conductive hearing tests are not needed during the initial examination. The glossopharyngeal (CN IX) and vagus (CN X) can be tested by having the patient open his or her mouth and say "awe," and observe the patient swallowing saliva. The accessory nerve (CN XI) is examined by asking the patient to shrug the shoulders. Finally, the hypoglossal (CN XII) nerve is examined by having the patient move the tongue vertically and horizontally.

TABLE 3-2 CRANIAL NERVES I-XII EVALUATION

Nerve	Function
I. Olfactory (sensory)	Sense of smell
II. Optic (sensory)	Sense of sight
III. Oculomotor (motor)	Superior rectus, inferior rectus, medial rectus, inferior oblique, ciliary, and sphincter pupillae muscles
IV. Trochlear (motor)	Superior oblique muscle
V. Trigeminal (motor/sensory)	Ophthalmic division (V1)—sensation to upper one-third face Maxillary division (V2)—sensation to midportion of face Mandibular division (V3)—sensation to lower face; motor supply to mastication muscles
VI. Abducens (motor)	Lateral rectus muscle
VII. Facial (motor/sensory)	Motor supply to facial expression muscles Taste to anterior two-thirds of tongue
VIII. Acoustic (sensory)	Cochlear division—sense of hearing Vestibular division—sense of equilibrium
IX. Glossopharyngeal (motor/sensory)	Sensation to oropharynx Motor supply to pharynx muscles
X. Vagus (motor/sensory)	Sensation to larynx, trachea, aerodigestive mucous membranes Motor supply to larynx muscles, levator veli palantini, palatoglossus, palatopharyngeus
XI. Accessory (motor)	Sternocleidomastoid and trapezius muscles
XII. Hypoglossal (motor)	Muscles of tongue

Facial Fracture Clinical Presentations

Frontal sinus fractures

Observation of facial lacerations, upper face edema and ecchymosis can suggest frontal sinus fractures. Physical findings can include palpable frontal bone deformity, supraorbital or supratrochlear nerve paresthesias, CSF rhinorrhea, or globe displacement.

Nasoorbital ethmoid fractures

Physical findings can include telecanthus, loss of dorsal nose projection, periorbital edema or ecchymosis, orbital rim step-offs, and subconjunctival hemorrhage.

Nasal fractures

Observed findings suggestive of nasal fractures include visible nasal deformity, nasal edema, and nasal lacerations. Physical exam findings can include epistaxis, crepitus, tenderness, septal deviation, and possible septal hematoma.

Orbital fractures

Observation of periorbital edema or ecchymosis should suggest the possibility of orbital fractures. Physical exam findings can include orbital rim step-offs, subconjunctival hemorrhage, limited eye excursions, enophthalmos or exophthalmos, diplopia, and infraorbital nerve paresthesia.

Zygomaticomaxillary complex fractures

Physical exam findings can include malar flattening, step-offs at orbital rims, zygomatic arch, zygomaticomaxillary buttress; enophthalmos or dystopia; trismus, down-sloping palpebral fissure, and infraorbital paresthesia.

Maxillary fractures

Observed findings suggestive of maxillary fractures can include midfacial edema, and periorbital ecchymosis. Physical exam findings can include epistaxis, malocclusion, tenderness along buttresses, crepitus, maxillary mobility, and palpable step-offs.

Temporal bone trauma

Physical exam findings can include otorrhea, hemotympanum, Battle's sign, and facial palsy.

Mandibular fractures

Classic physical exam findings include occlusion deviation, floor of mouth ecchymosis, and occasionally mental nerve paresthesia.

Pearls

- *Cleaning patients of dried blood and dirt before examination helps identify underlying injuries that may otherwise be missed.*
- *Be aware of potential of airway loss in patients with multiple mandible fractures.*
- *Bimanual facial palpation helps identify side-to-side differences that may indicate fractures.*
- *Personally evaluate all craniomaxillofacial trauma radiographs both before and after examination to assist with the treatment plan.*
- *Identify injuries to the facial and trigeminal nerve before administering local anesthesia.*
- *Be careful of significant blood loss because of increased facial vascularity.*
- *Remove all embedded facial debris to minimize tattooing.*
- *Tongue blades are useful for a complete oral examination.*
- *Confirm cervical spine status with the trauma service before initiating any treatment.*

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4 Dental Anatomy and Occlusion

Pedro E. Santiago, Lindsay A. Schuster

Background

Medical and dental professionals have worked together closely for many years to provide optimal solutions to complex craniomaxillofacial problems. This chapter is for nondental professionals who work with the craniofacial complex, in which dentition and its functional relationships are critical. Our goal is to provide basic and useful information on dental anatomy and occlusion.

ANATOMY

Human dentition is a complex system of sophisticated curved surfaces, cusps, inclined planes, grooves, and valleys that relate to create a functional bite or *occlusion.* Each tooth has a *crown,* which is the portion visible on a fully erupted tooth, and one or more *roots* located inside bony sockets in the maxillary and mandibular alveolar bone. The outer layer of the crown is composed of *enamel,* and the roots are covered by *cementum.* The crown and the root meet at the cementoenamel junction. The second tooth layer is the *dentin,* and the inner central part is the *pulp,* which provides nerves and blood supply to the tooth (Fig. 4-1).

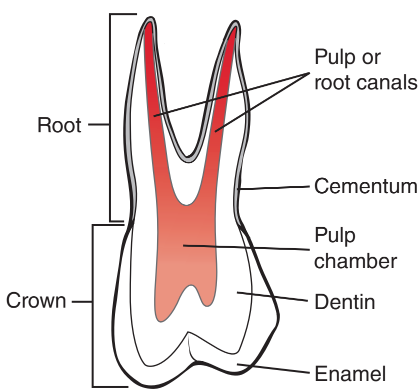

Fig. 4-1 Cross section of a premolar tooth showing the crown and root layers.

Dentition is divided into two groups: anterior and posterior. The anterior teeth are the central incisors, lateral incisors, and canines (also called cuspids). The premolars (also called bicuspids) and molars are the posterior teeth. Tooth crowns have multiple surfaces. The facial surfaces are those that are toward the lips *(labial)* and cheeks *(buccal).* Incisors and canines have labial surfaces; premolars and molars have buccal surfaces. *Lingual* surfaces are those facing the tongue in the mandibular arch, and *palatal* surfaces are those facing the palate in the maxillary arch (Fig. 4-2).

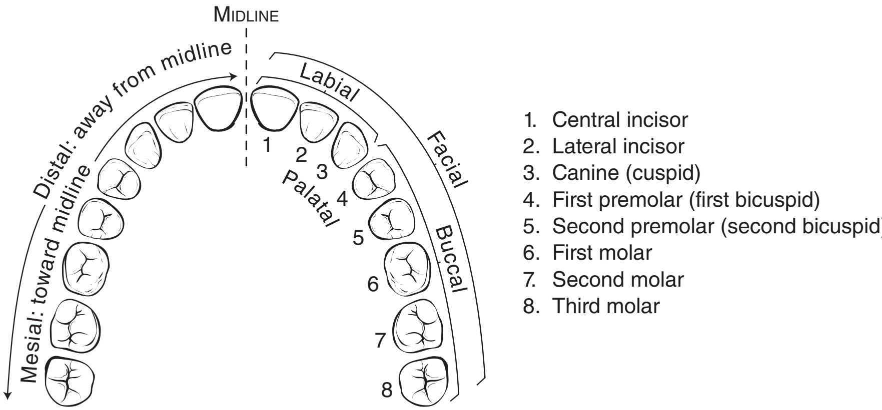

Fig. 4-2 Maxillary arch with its 16 teeth and their surfaces. (Modified from Nelson SJ, Ash MM Jr. Dental Anatomy, Physiology, and Occlusion, 9th ed. St Louis: Saunders, 2010.)

The cutting surface of maxillary and mandibular central and lateral incisors is called the *incisal edge* (Fig. 4-3).

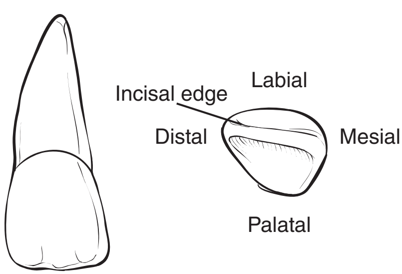

Fig. 4-3 Dental anatomy and surfaces of a maxillary central incisor.

The comparable surface on canines, premolars, and molars is the *cusp tip,* of which there is one on each canine, there are two or three on premolars, and there are three to five on molars (Fig. 4-4). The surfaces used for mastication are those that contact each other when maxillary and mandibular teeth occlude during closure. These are called *occlusal* surfaces in premolars and molars (see Fig. 4-4) and are the incisal edges of incisors and canines.

Tooth surfaces adjacent to one another in the same arch are called *proximal* surfaces, and they are named according to their position relative to the midsagittal plane of the face. Ideally, the midsagittal plane coincides with the maxillary and mandibular dental midlines (that is, between the central incisors). The surfaces of the teeth closer to the median line are called *mesial,* and the ones more distant are called *distal.* Each mesial tooth surface faces the distal surface of an adjacent tooth. The only exceptions to this are the central incisors, which contact one another at the median line through their mesial contacts (see Fig. 4-2).[1]

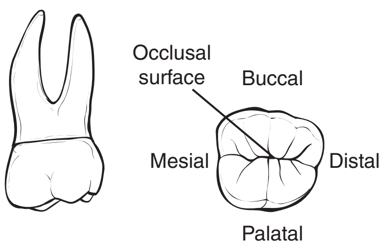

Fig. 4-4 Dental anatomy and surfaces of a maxillary first permanent molar.

Teeth are set in bony jaw sockets. The dental roots are enclosed in a supporting structure called the *periodontium,* which consists of alveolar bone, periodontal ligament, cementum, a gingival attachment to the tooth, and gingiva (gum tissue). These tissues surround and anchor the tooth in the alveolar process (Fig. 4-5).

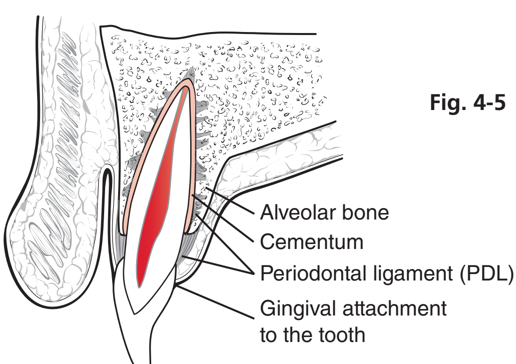

Fig. 4-5 Periodontium.

DENTAL NUMBERING SYSTEMS

Primary dentition consists of 20 teeth; 10 in the upper jaw (the maxilla) and 10 in the lower jaw (the mandible). They are named with uppercase letters A through T, from the maxillary right second primary molar to the mandibular right second primary molar (Fig. 4-6). This nomenclature is called Universal Notation.

Another commonly used system, called the Palmer Notation, divides the dental arches into four quadrants and uses only letters A through E (Fig. 4-7). Each quadrant consists of one central incisor, one lateral incisor, one cuspid, and two primary molars (the first and second). Palmer Notation is popular among orthodontists for its ease of use. In this system, a letter enclosed by two perpendicular lines identifies a particular quadrant and tooth. For example, a maxillary right primary central incisor is A⌋, and a mandibular left primary canine is ⌈C.

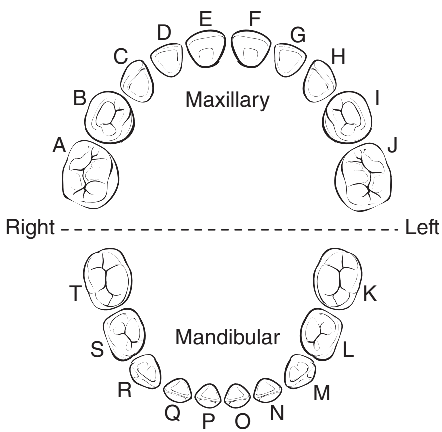

Fig. 4-6 Universal Notation for primary teeth.

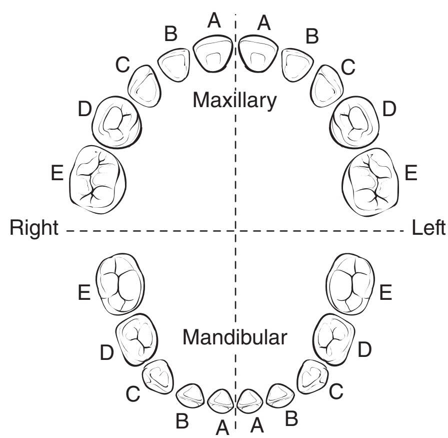

Fig. 4-7 Palmer Notation for primary teeth.

Permanent dentition consists of 32 teeth, 16 in the maxilla and 16 in the mandible. In the Universal Notation system, teeth are numbered 1 through 32, from the maxillary right permanent third molar to the mandibular right permanent third molar (Fig. 4-8).

In the Palmer Notation for permanent dentition, the teeth are numbered 1 through 8 in each quadrant (Fig. 4-9). Each quadrant consists of one central incisor, one lateral incisor, one cuspid, two premolars (first and second), and three molars (first, second, and third). A maxillary right central incisor is described as $\underline{1|}$, and a mandibular left second premolar is $\overline{|5}$.

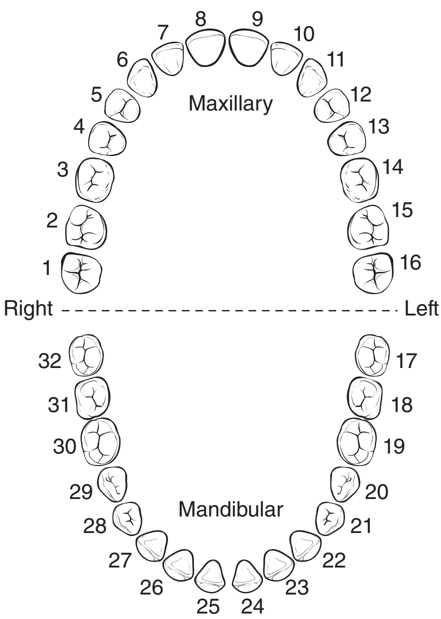

Fig. 4-8 Universal Notation for permanent teeth.

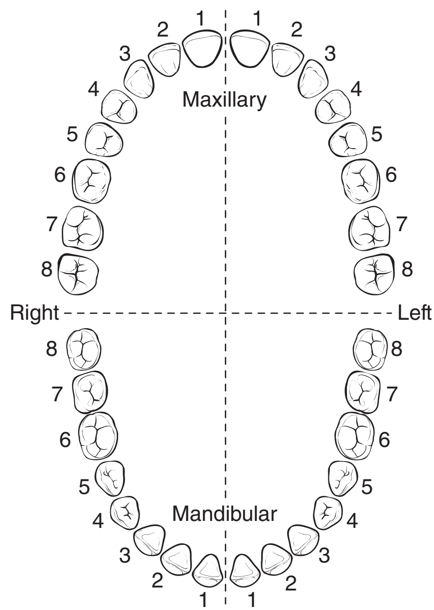

Fig. 4-9 Palmer Notation for permanent teeth.

OCCLUSION

Although dental occlusion is defined as the way the maxillary and mandibular teeth articulate as they are brought together into functional contact, or intercuspation, it is much more complex than this. Occlusion involves the close interrelation between different tooth surfaces, their associated skeletal structures, the muscles of mastication, and the temporomandibular joints (TMJs). As the teeth come into close contact, their inclined planes, valleys, and edges determine the final occlusion, or bite, under the influence of a sophisticated neuromuscular system.

One of the most influential figures in the field of orthodontics and dental occlusion was Edward H. Angle. He described normal occlusion as a harmonious relationship between maxillary and mandibular teeth based on the anterior-posterior relationship of maxillary and mandibular first permanent molars.

Angle's system describes three basic types of occlusions: class I or neutroclusion, class II, and class III[2] (Fig. 4-10). In a class I (or normal) molar relationship, the mesiobuccal cusp of the maxillary first permanent molar occludes with the buccal groove of the mandibular first molar (see Fig. 4-10, *A*). In a class II molar relationship, the mesiobuccal cusp of the maxillary first permanent molar occludes mesial to, or anterior to, the buccal groove of the mandibular first molar (see Fig. 4-10, *B*). In a class III molar relationship, the mesiobuccal cusp of the maxillary first permanent molar occludes distal to, or posterior to, the buccal groove of the mandibular first molar[2] (see Fig. 4-10, *C*).

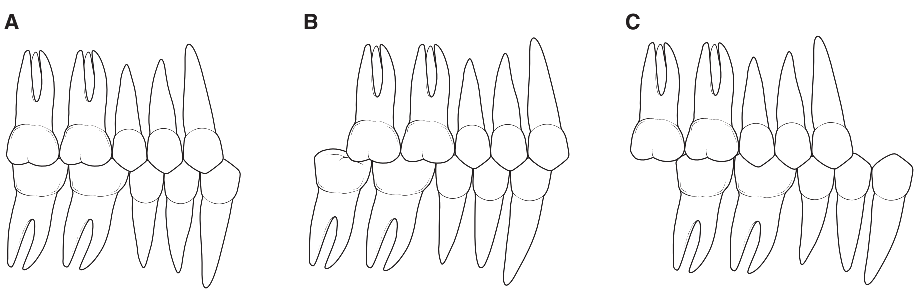

Fig. 4-10 Angle's classification system. **A,** Class I; **B,** class II; **C,** class III.

The position of the cuspids or canines during occlusion has also been used to describe a proper relationship between maxillary and mandibular dentition. When the first permanent molars are in a class I relationship, the mandibular canine occludes mesial to the maxillary canine in the embrasure between the maxillary canine and lateral incisor (see Fig. 4-10, *A*).

These three types of occlusions are usually associated with three different facial profiles (Fig. 4-11). A class II malocclusion is associated with a convex profile, in which there is a discrepancy between the maxilla and the mandible caused by a retrusive mandible, a protrusive maxilla, or both. This results in an excessive overjet or horizontal overlap of the anterior teeth (see Fig. 4-11, *A*). This skeletal relationship is also known as a *retrognathic* profile. A class I occlusion is associated with a slightly convex or straight profile (see Fig. 4-11, *B*), which is also referred to as *orthognathic*. A class III malocclusion is usually associated with a straight or concave profile caused by a protrusive mandible, a retrusive maxilla, or a combination of both—known also as *prognathic.* The discrepancy between the jaws could result in an anterior crossbite (see Fig. 4-11, *C*).

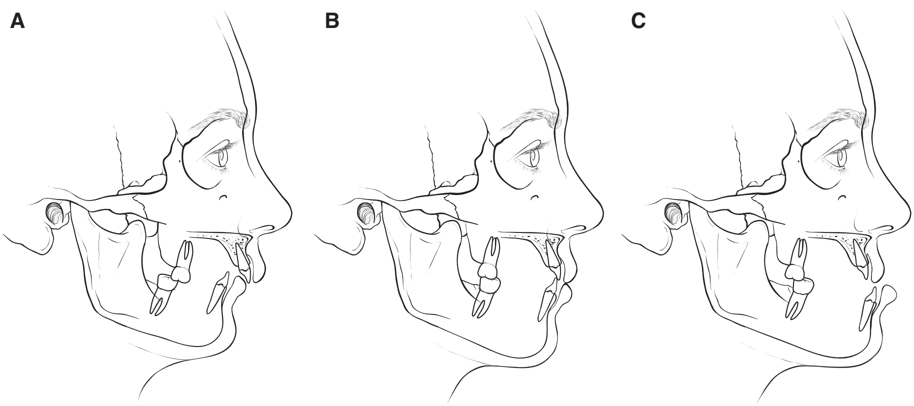

Fig. 4-11 Types of facial profiles. **A,** Retrognathic or convex; **B,** orthognathic; **C,** prognathic or concave.

It is important to observe that Angle's classification is not an accurate representation of a person's occlusal pattern, because it only takes into consideration the sagittal relationship of maxillary and mandibular molars. Dental occlusion is much more complex, because it is influenced by transverse, vertical, and axial dental relationships. Because of the complex, three-dimensional interaction of the skeletal, dental, and soft tissue components, it is vital to perform thorough clinical, radiographic, and soft tissue analyses to create an adequate treatment plan.

Human dentition undergoes significant changes from childhood to adulthood. The most dramatic changes occur during the mixed dentition stage when primary and permanent teeth are both present in the oral cavity. These changes directly affect occlusal patterns. Once all primary teeth have been replaced by their permanent counterparts and skeletal maturity has been reached, a more definitive occlusion is established.[3]

Mastication and the way teeth occlude are mainly determined by dental form and position in the alveolar processes and by the size and shape of the maxilla and mandible. In an ideal occlusion, both skeletal and dental arches exhibit proper correlation, jaws and teeth are positioned in a normal functional relationship, and teeth meet in a class I relationship. This position is also determined by the way the mandibular condyle rotates and translates at the TMJ.

As our knowledge of dental occlusion has matured, two important concepts have developed: centric occlusion and centric relation. *Centric occlusion* is a person's habitual bite. It is the position determined by dentition, when the maxillary and mandibular teeth are in maximum intercuspation. It is dentally determined and is independent of condylar position. *Centric relation* is the relation of the mandible to the maxilla when the condyles are in a physiologically stable position, independent of tooth contact. This relation has been described as the most superoanterior position of the condyles in the articular fossae with the discs correctly interposed (Fig. 4-12).[4]

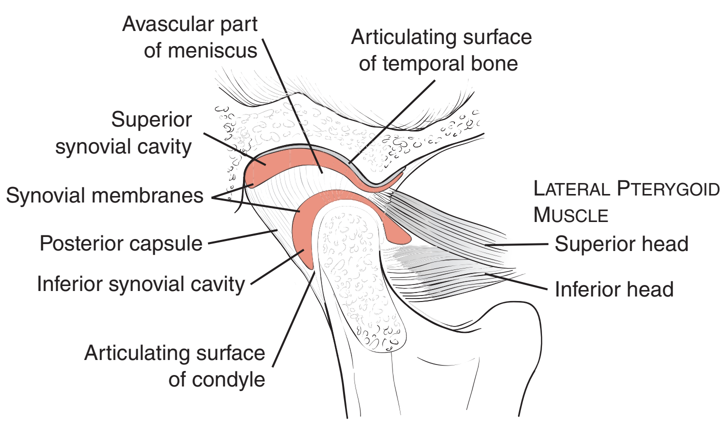

Fig. 4-12 Temporomandibular joint.

In patients with facial trauma in which the mandible, TMJ, and/or the muscles of mastication have been affected, centric relation may be extremely difficult to assess.

The vertical, sagittal, and transverse relationships between the maxillary and mandibular teeth at maximum intercuspation (centric occlusion) are most valuable when describing malocclusion.

Overbite is the amount of vertical overlap between the maxillary and mandibular central incisors, expressed as a percentage or in millimeters (Fig. 4-13). A normal overbite is 1 to 3 mm. When the upper incisors overlap most of the labial surface of the lower incisors, it is called a *deep bite.* An anterior opening with no overlap is an *open bite,* which is measured in millimeters (Fig. 4-14). Open bites may be of a dental or skeletal nature. An anterior dental open bite may include only a few teeth, and it is usually caused by habits (such as thumb sucking or tongue thrusting) or other factors. An anterior skeletal open bite might be caused by hyperdivergence of the maxilla and mandible (apertognathia), which is usually more difficult to treat orthodontically and might require orthognathic surgery. When there is no contact between posterior teeth, it is called a posterior open bite.

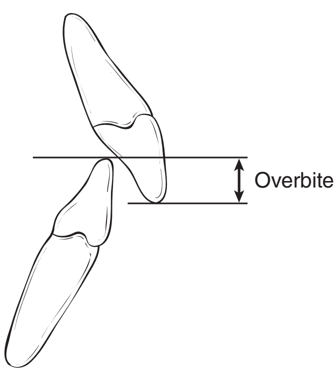

Fig. 4-13 Overbite, or vertical overlap.

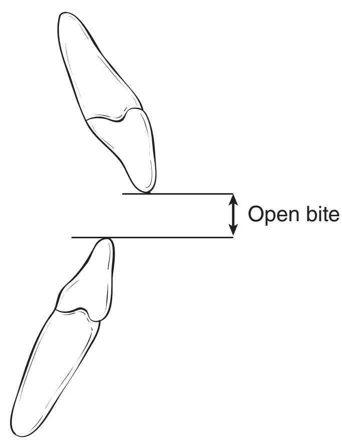

Fig. 4-14 Anterior open bite.

Overjet is the horizontal relationship (sagittal or anteroposterior), or the distance between the incisal edge of the most anteriorly positioned maxillary central incisor and the labial surface of the opposing mandibular central incisor, when the teeth are in centric occlusion (Fig. 4-15). The relationship is expressed in millimeters. Mean overjet in adults with normal occlusion is 2.2 mm for men and 2.5 mm for women. *Negative overjet,* also known as *anterior crossbite,* is when the maxillary central incisor occludes behind the lower central incisor (Fig. 4-16). It is given as a negative number in millimeters. If there is no anterior vertical or horizontal overlap, the relationship is called *edge to edge.*

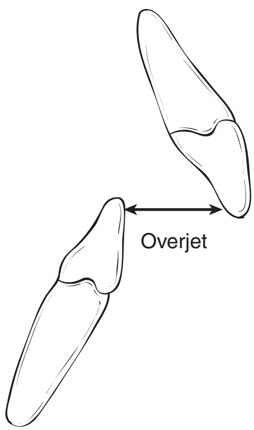

Fig. 4-15 Overjet, or horizontal overlap.

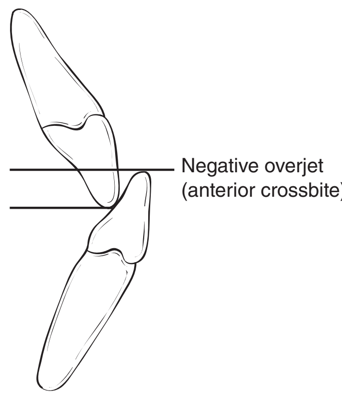

Fig. 4-16 Negative overjet, or anterior crossbite.

In normal occlusion, all maxillary teeth overlap the mandibular teeth. When one or more teeth of one arch has an abnormal transverse or anteroposterior relationship with the opposing arch, it is described as a *crossbite.* Crossbites may have dental or skeletal origins. A dental crossbite is caused by improperly inclined and/or malpositioned teeth, and is usually resolved through orthodontic dental movement. Skeletal crossbites are caused by a difference in size between the maxilla and the mandible. The discrepancy could be sagittal or transverse, creating an anterior or posterior crossbite that may be unilateral or bilateral. An anterior crossbite is when the labial surface of a maxillary anterior tooth occludes posterior to the lingual surface of a mandibular anterior tooth (see Fig. 4-16). A posterior crossbite is when the buccal surface of a maxillary tooth occludes with the lingual surface of a mandibular tooth. Correcting these crossbites usually requires a palatal expander or orthognathic surgery (Fig. 4-17).

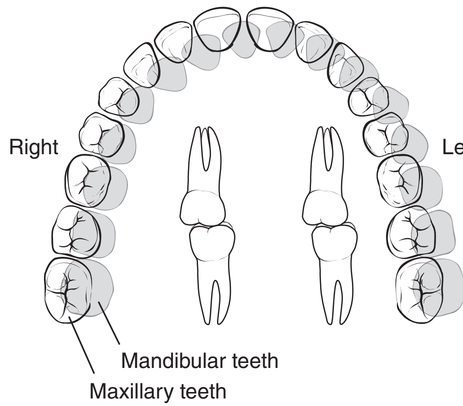

Fig. 4-17 Left unilateral posterior maxillary crossbite. (Modified from Daskalogiannakis J. Glossary of Orthodontic Terms. Berlin: Quintessenz Verlag, 2000.)

A normal dental arch has adequate space for the eruption of both primary and permanent dentition. When the space available is less than the space needed, it results in dental *crowding,* which is evidenced by tooth rotation and malalignment (Fig. 4-18). If excess space is available, it is called *spacing* (Fig. 4-19).

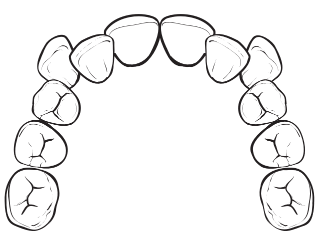

Fig. 4-18 Dental crowding.

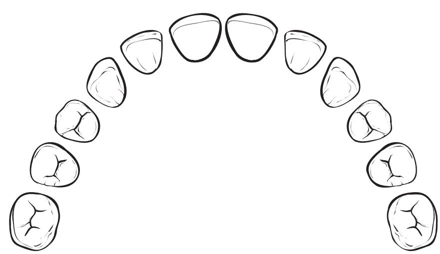

Fig. 4-19 Spacing.

Diurnal or nocturnal recurrent physiologic or parafunctional occlusal contact between tooth surfaces may cause dental wear. This *attrition* is characterized by flat areas on the surfaces of the teeth. A common parafunctional activity that includes grinding and clenching of the teeth is called *bruxism.* Common characteristics of this condition may include dental wear, muscle fatigue and pain, inflammation of supporting structures, and TMJ dysfunction.

Pearls

- *There are 20 primary teeth (A through T) and 32 permanent teeth (1 through 32).*
- *The adult mouth is divided into four quadrants with eight permanent teeth in each: a central incisor, lateral incisor, canine, first premolar, second premolar, first molar, second molar, and third molar.*
- Overjet *is the horizontal overlap between the maxillary and mandibular central incisors, and* overbite *is the vertical overlap.*
- *Dental occlusion in the sagittal plane is classified as class I (normal), class II, or class III.*
- *Facial profiles are classified as orthognathic (normal), retrognathic or convex, and prognathic or concave.*

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5 Radiographic Examination

Mark Schoemann, Thomas C. Lee, Srinivasan Mukundan, Jr.

Background

Radiographic imaging in craniomaxillofacial (CMF) trauma plays an indispensable role in the diagnosis of fractures and fracture patterns. However, imaging is not a substitute for a systematic and detailed physical examination. Findings on physical examination should guide the clinician to look for particular fracture patterns during a methodic review of the available imaging.

Computed tomography (CT) scanning has been the benchmark for the diagnosis and characterization of midface and upper facial fractures, but more recently has been shown to have superior sensitivity compared to panoramic tomography in diagnosing mandibular fractures. With the liberal use of CT in emergency departments, there has been increased public concern for unnecessary radiation exposure. The radiation dose imparted by a standard head CT scan is 100-fold greater than by a single chest radiograph. Recently, however, low-dose radiation protocols have been tested in a variety of clinical settings and have demonstrated acceptable radiographic accuracy. Even with a 90% reduction in amperage (mA, a measurement describing the quantity of x-ray beams produced in the acquisition of a CT scan), osseous details of the skull can be discerned by a trained radiologist.[1]

Because of the mechanisms of injury commonly involved, patients who sustain facial fractures often have associated non-CMF injuries; 1% to 4% of patients with facial fractures have an associated cervical spine injury, and up to 10% of patients with mandibular fractures have concomitant cervical spine injury. Panfacial fractures, which are fracture patterns that involve at least three of the four axial segments of the facial skeleton—frontal, upper midface, lower midface, and mandible—are associated with concomitant injuries in 50% of patients. Furthermore, 18% of patients with panfacial fractures have intracranial injury, and 13% have cervical spine injury.[2]

IMAGING MODALITIES

Plain Films

Plain films have largely been replaced by CT scans for the evaluation of facial trauma. Occasionally, plain films will accompany a patient transferred from a referring hospital and should serve as a complement to CT evaluation. A full plain film evaluation of the face divides the face into upper, middle, and lower thirds. A modified Caldwell view and lateral projection are used for the upper third of the face, occipitomental 10-degree and lateral views for the middle third, and a PA mandible and Panorex images for the lower third.

Panoramic Tomography

Although helical CT has been well established as the benchmark for diagnosing midface fractures, it has only recently been shown to be superior to panoramic tomography for diagnosing mandible fractures. Most clinicians incorrectly refer to all panoramic tomography films of the mandible as a "Panorex." Panorex is a trade name for a tomographic machine previously made by S.S. White (Holmdel, NJ) that takes panoramic images of the mandible with the patient upright. Panoramic tomography of the mandible projects the entire mandible on a single film and allows evaluation of the mandibular teeth in relation to the fracture line. Image quality is technician dependent, and poorly performed panoramic tomography can lead to blurring in the midline and cause difficulty in visualizing symphyseal and parasymphyseal fractures. Previously, panoramic tomography had been shown to have superior sensitivity and specificity when compared with plain films and conventional CT. With the advent of high-resolution CT, several studies have been performed to discover the role of panoramic tomography in the diagnosis of mandible fractures. Helical CT has been shown to have 100% sensitivity in diagnosing mandible fractures compared with panoramic tomography, which is 86% sensitive.[3] Furthermore, helical CT has decreased interpretation error and greater interphysician agreement in the identification of mandible fractures.[4] Fractures missed on panoramic tomography are more likely to be located in the posterior mandible.

Computed Tomography

CT has the advantage of avoiding the superimposition of structures that inevitably occurs with plain films; imaging can be done rapidly and can be reformatted to provide images in an alternate plane. Axial, coronal, and sagittal cuts are each useful for diagnosing specific fractures. An orbital floor fracture is difficult to appreciate on axial cuts but will be obvious when viewed in the coronal and sagittal planes. (Orientation of the CT slices and their relation to diagnosing facial fractures is discussed with the specific fractures in the following pages.) CT data are obtained in axial slices; other planes, such as coronal and sagittal, are produced by digital layering (stacking). Therefore the thickness of the slices affects the quality of the product in these planes (thick slices produce a stepped appearance). A slice thickness of 2 to 4 mm can be adequate for the diagnosis of facial fractures. However, if reformatting is needed for alternative planes or for three-dimensional reconstruction, a slice thickness of 1 to 1.5 mm is preferable.

Although CT provides the most information of any imaging modality, it does not replace a thorough physical examination. Once a thorough history is taken and a physical examination is performed, the clinician should methodically review the CT scan. Information from the history and physical examination should further guide the clinician to be alert for particular fractures or fracture patterns while scrolling through the CT images.

Those who take facial trauma calls not only provide primary consultation for definitive management of injuries on initial presentation, but also secondary consultation with patient transfer. The latter is particularly relevant in level 1 trauma centers and requires certain special considerations. Patients with head trauma undergoing an initial clinical and radiographic workup at a level 1 trauma center will often have both a head CT scan to rule out intracranial injury and a cervical spine CT scan to rule out spinal injury.

A standard head CT scan extends from the vertex of the skull to the mid to upper orbits. Such studies provide limited visualization of CMF structures, including the frontozygomatic (FZ) suture and the zygomatic arch. The complete maxilla and mandible are not visualized, although the superior portion of the condyles may be seen. Therefore, the initial head CT scan may be useful as a screening tool; if a fracture of the zygomatic arch, FZ suture, nasal bones, or condyle is seen, further imaging will be needed to completely visualize the area in question and rule out any other facial fracture. The specific study required will be influenced by the clinical examination and by the imaging protocols of the institution. One must be familiar with the imaging protocols and the specific regions included. A complete CT evaluation of the craniofacial skeleton is performed if a clinical suspicion of injury remains or if the initial head CT scan revealed fractures, as mentioned earlier. A complete CT scan of the CMF extends from the vertex of the skull to the symphysis of the mandible.

When a trauma patient has had a radiographic evaluation elsewhere and has been transferred, the onus is on the CMF trauma consultant to thoroughly review the films that accompany the transferred patient. The films should be assessed not only for the injuries that are seen, but also for the areas that are not included in the studies. If the quality is insufficient, or if the studies are incomplete, and there is concern of an injury in an area not visualized, then appropriate repeat studies should be obtained.

> Repeat studies for CMF injuries can be performed using low-dose protocols if the initial head CT scan shows no evidence of intracranial injury or if repeat imaging of the brain is not needed.

Three-Dimensional Computed Tomography

With the technologic advances in CT data acquisition and reformatting, three-dimensional computed tomography (3DCT) reconstructions of facial trauma can be rapidly and economically performed. 3DCT is superior to two-dimensional CT in demonstrating the spatial relationships of fracture fragments in complex mandibular and midface fractures. Although 3DCT fails to show disruption of the soft tissues, it allows full appreciation of the altered bony architecture of facial fractures, which is essential for preoperative planning. 3DCT is specifically useful in the evaluation of zygomaticomaxillary complex (ZMC) fractures, LeFort fractures, and panfacial fractures. Rotation and inferior displacement of the ZMC fracture segment are easily seen on 3DCT images. Comminution and displacement of LeFort fracture segments are also well demonstrated on 3DCT images; this information is extremely useful in planning placement of internal fixation plates.

SPECIFIC FRACTURES

Frontal Sinus

Axial views with CT provide the optimal method for assessing injury to the frontal sinus, and coronal views are most useful for determining the status of the nasofrontal outflow tract. Indicators that a frontal sinus fracture is present are an air-fluid level in the sinus and pneumocephalus. Evaluation of the frontal sinus begins by looking at the anterior and posterior walls. If a fracture is present, the degree of comminution and displacement of the walls should be noted. In most patients there is usually an intersinus septation that divides the frontal sinus into a right and left half. However, in approximately 20% of patients the frontal sinus is rudimentary or entirely absent. The frontal sinus drains inferiorly via paired hourglass shaped structures, the nasofrontal recesses, which travel through the anterior ethmoidal labyrinth and ultimately drain into the middle meatus. The frontal sinus infundibulum forms the cephalad portion of the hourglass and narrows to form the true frontal sinus ostium. The nasofrontal recess splays out caudal to the frontal sinus ostium and enters the ethmoid infundibulum. The nasofrontal recess is extremely short in 85% of individuals and represents a recess rather than a true ductal structure. Indicators of nasofrontal recess injury are involvement of the base of the frontal sinus or anterior ethmoid complex. Evaluation of the nasofrontal recess is best done with coronal cuts, because the frontal sinus floor and ethmoid complex are better visualized, as seen in Fig. 5-1.

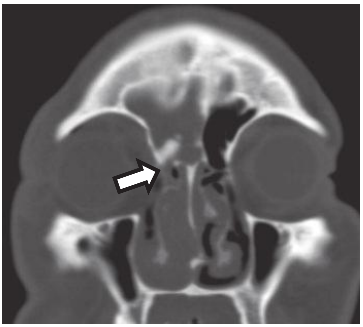

Fig. 5-1 Coronal CT of the frontal sinus showing injury to the nasofrontal recess *(arrow).* The nasofrontal recess is an hourglass-shaped structure and is not a true duct. The caudal portion is composed of the frontal sinus infundibulum; the cephalad portion is composed of the ethmoid infundibulum. Injury to the nasofrontal recess is best assessed with coronal cuts. Notice that the nasofrontal recess is patent on the contralateral uninjured side.

Nasoorbital Ethmoid

Nasoorbital ethmoid (NOE) fractures result from significant blunt force to the central upper midface that disrupts the connection between the medial maxillary buttress and the upper transverse maxillary buttress. Assessment of an NOE fracture begins with axial and coronal CT imaging to evaluate the degree of comminution/displacement of the medial vertical maxillary buttress. Axial views typically show splaying of the medial vertical maxillary buttress when an NOE fracture is present, as seen in Fig. 5-2. Although the canthus itself cannot be seen,

Fig. 5-2 Nasoorbital ethmoid fracture seen on axial CT image. Axial views typically show splaying of the medial vertical maxillary buttress *(arrow),* which appears as an inverted Y. The vertical segment of the inverted Y represents the nasomaxillary buttress, and the anterior and posterior lacrimal crests form the two limbs of the inverted Y.

the canthal bearing segment of bone appears as an inverted Y in axial imaging. The vertical segment of the inverted Y represents the nasomaxillary buttress, and the anterior and posterior lacrimal crests form the two limbs of the inverted Y. Type I NOE fractures consist of a large bone fragment with the medial canthus intact, while in a type II NOE fracture the medial canthal tendon is attached to a small comminuted bone fragment. Type III NOE fractures are diagnosed clinically when the medial canthal tendon is completely avulsed from the lacrimal fossa. Severe NOE fractures can cause injury to the lacrimal sac or to the lacrimal outflow tract. In such cases, the patient may develop a lacrimal outflow obstruction fracture and therefore should be informed of this preoperatively. Because of the close proximity, NOE fractures can also be associated with disruption of the anterior ethmoid complex and nasofrontal recess. Therefore, as with frontal sinus injuries, drainage of the frontal sinus can be obstructed. The normal anatomy of the nasofrontal recess as seen on coronal CT images is demonstrated in Fig. 5-3, *A.* The nasofrontal outflow tract should be assessed for disruption if an NOE fracture is diagnosed as seen in Fig. 5-3, *B.*

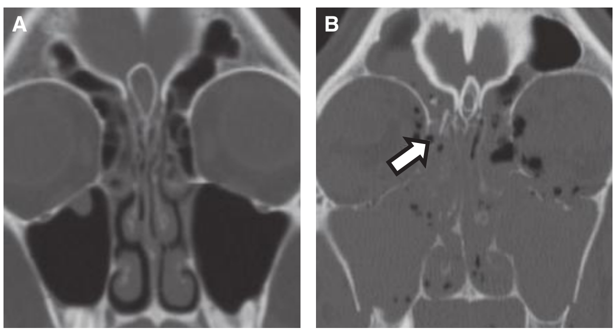

Fig. 5-3 **A,** Normal nasofrontal recess anatomy as seen on coronal CT. The frontal sinus drains inferiorly through paired hourglass-shaped structures, the nasofrontal recesses, which ultimately drain into the middle meatus. **B,** Nasoorbital ethmoid fracture with disrupted nasofrontal recess as seen with coronal CT. Notice the fractures of the anterior ethmoid complex *(arrow),* indicating injury to the nasofrontal recess.

Nasal

Nasal fractures are the most common fracture of the face. Plain film radiography and CT imaging are usually unnecessary for diagnosing an isolated nasal fracture. Nasal fractures are usually apparent on a thorough clinical examination, and the need for treatment is based largely on the clinical appearance. Therefore routine use of imaging for diagnostic purposes for all suspected nasal fractures is not cost effective. Nasal bone fractures can be seen incidentally on CT imaging done for other indications, such as intracranial injury. If the nasal bones are fractured, the direction of displacement should be noted, because this can indicate the direction of the impact and pattern of injury. For example, when a high-energy blow from a right-handed assailant strikes the left side of the nose, it can often cause both right and left nasal bones to be displaced to the right. The same strike, but with lower energy, may only displace the left nasal bone. A high-energy impact anteriorly (such as from a steering wheel) often splays both nasal bones outward. In addition, anterior force is more likely to cause buckling of the septum. On a CT image, this gives an accordion appearance to the perpendicular plate of the ethmoid. Understanding the mechanism of the injury fully helps one plan for effective reduction. When a nasal fracture is diagnosed clinically, and it is unclear from physical examination and preinjury photographs what reduction maneuvers are needed, a CT scan can be useful.

Mandible

Although panoramic tomography has previously been the standard diagnostic technique for imaging mandible fractures, the advent of high-resolution CT has allowed mandible fractures to be diagnosed with superior sensitivity. Furthermore, most trauma patients have rigid cervical collars in place, or may be unable to sit upright, which makes panoramic tomography more difficult. At our institution we use panoramic tomography to evaluate patients postoperatively after open fixation of mandible fractures. Our protocol is to obtain a panoramic tomography film during the patient's hospital admission and another one 6 to 8 weeks later. This provides a baseline film of the internal fixation hardware and fracture reduction. This film can then be compared with the follow-up film to assess the adequacy of bony healing and maintenance of the initial reduction. Patients who are treated nonoperatively also undergo baseline panoramic tomography with the initial evaluation, and then one at 6 to 8 weeks as well.

Evaluation of the mandible with axial CT imaging starts at the temporomandibular joint (TMJ) to assess for displacement of the condyle. Evaluation of the ramus, angle, body, and symphysis is then performed, noting any fractures and evidence of displacement. The presence of fractured teeth or teeth in the fracture line should be noted as well. Coronal images of the mandible are then viewed to reveal any evidence of subcondylar fracture, as seen in Fig. 5-4. If a fracture is questionable, remember to look at the contralateral side, because the mandible is symmetrical. If any portion of the mandible is not seen on imaging, repeat imaging should be considered. Bilateral fractures of the mandible can often occur in blunt trauma and can indicate the direction of the impact force. For example, a high-energy strike from a right-handed assailant to the left side of the mandible often results in a left-sided angle or parasymphyseal fracture. Transmission of the force across the mandible can result in a contralateral (right) subcondylar fracture.

The fracture on the impact side is often referred to as the *primary fracture;* the fracture caused by transmission and torsion on the opposite side is referred to as the *secondary fracture.*

When any mandible fracture is noted, particular attention must be given to the contralateral side.

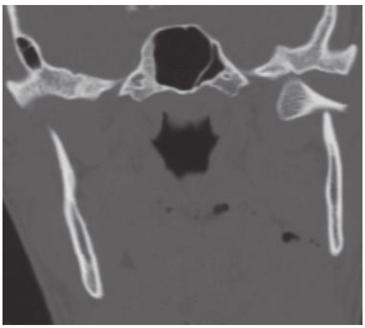

Fig. 5-4 Subcondylar mandible fracture seen on coronal CT. The subcondylar region of the mandible is well visualized on coronal cuts. Notice that the proximal fragment is displaced medially by the lateral pterygoid muscle.

Zygomaticomaxillary Complex

The zygomaticomaxillary complex (ZMC) is often incorrectly described as a tripod, but it is a tetrapod supported by four buttresses: the lateral orbital rim, infraorbital rim, zygomatic arch, and zygomaticomaxillary buttress. The zygoma has two articulations with the cranium and two with the maxilla. It forms the lateral orbital wall (the base of the tetrapod) and a majority of the orbital floor. Evaluation of ZMC fractures requires thorough evaluation in the axial and coronal planes, as demonstrated in Fig. 5-5. Axial imaging permits evaluation of the following articulations: zygomaticomaxillary, zygomaticotemporal, and zygomaticofrontal. Fractures at these three articulations have led to the term *tripod fracture,* but one must remember the posterior relationship of the zygoma with the sphenoid bone. The degree of comminution as well as rotation (medial and lateral) and projection (anterior and posterior) should be noted. The initial head CT scan in a trauma patient to detect intracranial injury often extends inferiorly to the zygomaticofrontal suture. If a fracture is seen at the zygomaticofrontal suture or along the zygomatic arch, there is a high likelihood that a ZMC fracture is present. Further studies, such as a dedicated CMF CT scan, will be needed to completely visualize the area.

Orbital floor integrity and possible inferior rectus muscle entrapment is evaluated by reviewing the CT images in the coronal plane. Sagittal views further allow assessment of a floor fracture in the anteroposterior dimension. On a coronal image, if the inferior rectus muscle appears flattened in its correct position, the

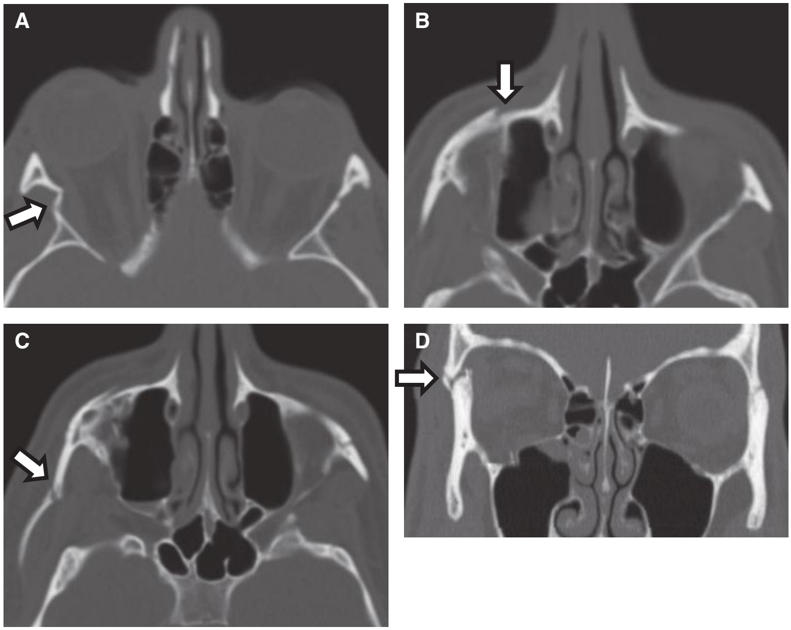

Fig. 5-5 **A,** Zygomaticomaxillary complex fracture as seen with axial CT. The zygoma is a tetrapod and articulates with the frontal, sphenoid, maxillary, and temporal bones. Fracture of the zygomaticosphenoid suture *(arrow)* leads to angulation of the lateral orbital wall and increased orbital volume. **B,** Fracture of the zygomaticomaxillary suture *(arrow).* The degree of displacement and rotation of the zygoma is noted. The pull of the masseter muscle on the zygoma leads to this rotational deformity. **C,** Fracture of the zygomatic arch. Notice the degree of comminution and displacement of the zygomatic arch *(arrow),* which is responsible for establishing the width of the face. **D,** Fracture of the zygomaticofrontal suture. An axial head CT scan, performed to evaluate for intracranial injury, can show a fracture at the zygomaticofrontal suture. A dedicated CMF CT scan should then be obtained, as was done here, to further delineate the fracture *(arrow)* in the coronal plane.

fascial sling of the globe likely remains intact, as seen in Fig. 5-6, *A* and *B.* However, if the inferior rectus appears rounded and inferiorly displaced, there is a high likelihood that the muscle and periorbital tissue have prolapsed into the orbital floor defect, as seen in Fig. 5-6, *C* and *D.* Diagnosis of orbital floor fractures in children is more challenging, because the displaced portion of orbital floor tends to spring back to its anatomic location, trapping the inferior rectus muscle in the maxillary sinus, as seen in Fig. 5-7. Bone alignment in these pediatric "trapdoor" orbital floor fractures appear normal, and the diagnosis can easily be missed if one is not conscious of the location of the inferior rectus muscle in relation to the orbital floor and the clinical scenario.

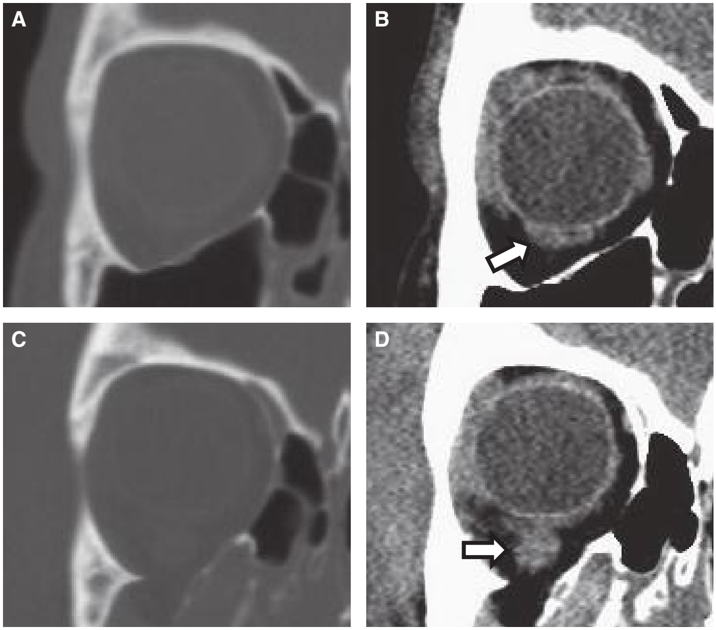

Fig. 5-6 **A,** Coronal CT image showing normal inferior rectus anatomy in a bone window, and **B,** in a soft tissue window. The inferior rectus muscle *(arrow)* appears flattened in its correct position. This indicates that the fascial sling of the globe remains intact. The extraocular muscles are best appreciated by viewing the CT scan in a soft tissue window such as a brain window (which is shown in **A**). **C,** Coronal CT image showing orbital floor fracture with inferior rectus entrapment in a bone window, and **D,** in a soft tissue window. The inferior rectus *(arrow)* appears round and inferiorly displaced. This indicates disruption of the fascial sling of the globe. The rectus muscle and periorbita have prolapsed into the defect of the orbital floor fracture.

Fig. 5-7 Coronal CT image showing pediatric orbital floor trapdoor fracture with entrapped inferior rectus muscle. The orbital floor in children tends to spring back to its anatomic location, trapping the inferior rectus muscle in the maxillary sinus. The orbital floor often appears normal, and thus the diagnosis can be easily missed. Notice the position of the entrapped inferior rectus muscle *(left arrow)* compared with the contralateral inferior rectus muscle *(right arrow).*

LeFort Fractures

Fracture patterns involving separation of all or a portion of the maxilla from the skull base, as seen in Fig. 5-8, were initially described by René Le Fort in 1901. For this separation to occur, the junction of the posterior maxilla and the pterygoid plate must be disrupted. Recognition of a LeFort fracture is often noted by initial identification of a fracture of the pterygoid plate or posterior wall of the maxillary sinus on axial CT images. The facial buttresses are then inspected to determine the type of LeFort fracture. Fractures through the inferior portions of the medial and lateral maxillary buttresses create a LeFort I segment and indicate that the tooth-bearing maxilla is separated from the midface. In a LeFort II fracture, the entire maxilla and nasal complex moves in relation to the

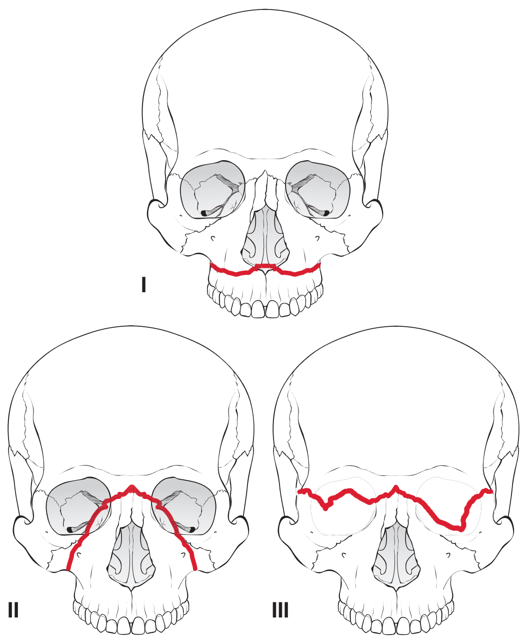

Fig. 5-8 LeFort midface fractures. LeFort fractures involve separation of all or a portion of the maxilla from the skull base. A LeFort I fracture traverses horizontally across the inferior portion of the maxilla from the piriform aperture to the pterygomaxillary suture. LeFort II fractures involve separation of the maxilla and nasal complex as a unit from the cranial base. LeFort III fractures involve complete craniofacial dissociation, with the fracture line extending through the zygomatic arch, the superior lateral maxillary buttress, and the superior medial maxillary buttress.

skull base. These fractures involve the zygomaticomaxillary and frontomaxillary sutures and are called *pyramidal fractures.* The fracture extends through the nasofrontal junction along the medial orbital walls, through the inferior orbital rim at the zygomaticomaxillary suture, and then posteriorly through the pterygoid plates. When the zygomatic arch, the superior lateral maxillary buttress, and the superior medial maxillary buttress are fractured, a LeFort III is diagnosed, with resultant craniofacial disjunction. LeFort III fractures typically consist of fractures through the pterygoid plates at a high level.

Panfacial Fractures

Panfacial fracture is a poorly defined term with no single accepted definition across different specialties. At our institution, panfacial fractures are defined as fracture patterns that involve at least three of the four axial segments of the facial skeleton: frontal, upper midface, lower midface, and mandible. Facial fractures have traditionally been described with anatomic terminology that reflects common craniofacial fracture patterns. Classification and reporting of facial fractures becomes ambiguous when multiple complex fractures share common fracture lines. Redundancy is minimized by describing multiple complex fractures according to a hierarchical system. Table 5-1 provides the hierarchy of complex facial fractures that we use at our institution. The second (lower-order) complex fracture is best described by simply listing the component fractures (simple or complex) that are not accounted for in the higher-order complex fracture.[5]

Table 5-1 Hierarchical System for Describing Complex Fractures, According to the Duke Classification System

When complex fractures include elements of multiple fractures, redundancy is minimized by first describing the highest order (lowest numbered) complex fracture, and then describing the remaining fractures that are necessary to fully describe the patient's remaining fracture components.

Order 1	LeFort I
Order 2	LeFort II
Order 3	LeFort III
	Zygomaticomaxillary complex
Order 4	Nasoorbital ethmoid
Order 5	All simple fractures

POSTOPERATIVE IMAGING

The use of routine postoperative imaging is highly variable among institutions and countries. Panoramic tomography for mandible fractures and plain radiography for midface fractures are commonly performed in Europe. At our institution, we routinely obtain postoperative imaging studies before a patient is discharged to establish a baseline sense of fracture reduction and hardware position. Therefore we obtain postoperative panoramic tomography films for all patients with mandible fractures, and plain films (Caldwell projection, Waters projection, and so on) for all patients with midface fractures. If a patient then returns to the clinic with complaints that indicate possible malunion or hardware failure, new imaging studies are obtained and compared with the baseline studies. Patients who have undergone repair of frontal sinus fractures should be followed on an annual basis, because mucoceles have been reported to develop up to 40 years after the initial operation. Some surgeons recommend a 1-year follow-up CT; any new development of symptoms always warrant a repeat study.

CONCLUSION

Radiographic imaging forms the cornerstone of facial fracture diagnosis as well as preoperative planning. A thorough history and physical examination should be performed before evaluating the radiographic imaging studies, because the history and physical examination direct the physician to look for specific fractures and fracture patterns. Confirming that the correct imaging studies have been obtained and that they are of adequate quality is of utmost importance to ensure timely and accurate diagnosis of facial fractures. The CT scan is the imaging modality of choice for facial fractures, including mandible fractures. It is best to review the facial CT images in a systematic fashion every time so that all anatomy of the face is examined, not just the abnormal anatomy. Each specific fracture pattern (LeFort, ZMC, and so on) comprises other solitary fractures, which are best viewed in a specific orientation (for example, an orbital floor fracture is best seen on a coronal reformat). Three-dimensional CT is useful for assessing the degree of comminution and displacement when complex or panfacial fractures are present. For panfacial fractures, a hierarchical system of reporting is recommended to communicate effectively with other surgeons and radiologists.

Pearls

- *CT imaging of a facial trauma patient is not a replacement for a thorough history and physical examination.*
- *The surgeon should evaluate the imaging studies personally to ensure that the entire area in question can be visualized and that the coronal and sagittal reformats are done to better characterize certain fractures.*
- *The status of the nasofrontal recess in frontal sinus fractures is ascertained by examining the coronal cuts.*
- *The surgeon should look for splaying of the medial vertical maxillary buttress, which looks like an inverted Y in an NOE fracture.*
- *CT scans can often indicate the direction of force with nasal fractures, but these fractures are often diagnosed from the physical examination.*
- *CT is more effective than panoramic tomography for diagnosing mandible fractures.*
- *A contralateral subcondylar fracture should be suspected when a parasymphyseal mandible fracture is seen.*
- *Evaluation of the orbital floor is best done with coronal and sagittal cuts.*
- *The zygomaticomaxillary complex is a tetrapod or quadripod with four articulations; therefore the term* tripod fracture *should be abandoned.*
- *LeForte fractures, by definition, must involve the pterygoid plate.*

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6 Internal Fixation Principles

Josef G. Hadeed, Jeffrey R. Marcus

Background

Fractures of the craniofacial skeleton may result from a variety of deformational forces. The common end result of these forces is fracture of the bone from an overload of mechanical forces. A proper understanding of bone healing and a fundamental knowledge of principles of internal fixation are paramount in the management of fractures of the craniomaxillofacial skeleton. Without this, restoration of form and function is not possible.

FRACTURE HEALING

There are three major phases that bone undergoes during the healing process:

1. The first stage, or *inflammatory phase,* occurs immediately after the bone is fractured and lasts several days. During this stage, the endosteal and periosteal blood supply to the fracture site is disrupted. Because of the force required to fracture bone, the surrounding soft tissues are frequently injured. There is an influx of proinflammatory cells, including macrophages, platelets, and polymorphonuclear leukocytes into the area. A hematoma ultimately forms at the fracture site (Fig. 6-1).
2. The second, or *reparative stage,* is characterized by callus formation and bone deposition. Multipotential mesenchymal cells invade the hematoma. Chondroblasts and osteoblasts derived from periosteal cells are deposited into the fracture site, and eventually unite with the same cells derived from the other side of the fracture. In doing so, a fracture callus is formed. Hyaline cartilage and woven bone bridge the fracture gap. These are gradually replaced with lamellar bone by the processes of bony substitution and endochondral ossification. This occurs soon after the collagen matrix becomes mineralized. Osteoblasts lay down lamellar bone on the surface of the matrix. Eventually the cells of the callus are replaced by trabecular bone, which restores most of the original strength of the bone.
3. In the third, or *remodeling stage,* osteoclasts resorb the trabecular bone. Compact bone is then deposited by osteoblasts. Gradually, the original strength and shape of the bone is replicated by this process.

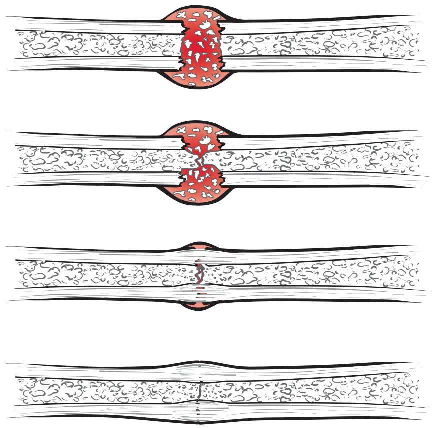

Fig. 6-1 The stages of bone healing. (Modified from Greenberg A, Prein J, eds. Craniomaxillofacial Reconstructive and Corrective Bone Surgery: Principles of Internal Fixation Using the AO/ASIF Technique. New York: Springer-Verlag, 2002.)

There are two mechanisms by which bone heals: direct and indirect. In direct bone healing, or primary osseous healing, precise anatomic alignment and stable fixation of the fracture fragments permit direct formation of bone across the fracture. There is no callus formation, because the external callus that would normally be formed is replaced by the presence of an implant. This is in contrast to indirect bone healing, in which there is resorption of the bone ends and subsequent callus formation.

Mechanical factors support the ideal environment for reliable fracture healing, thus allowing restoration of function of the injured part. In turn, biologic factors depend on the presence and ability of cells to participate in the healing process. Both factors must be present for successful bone healing to occur, and each is affected by the other.

The primary goal of fracture treatment is to restore function of the skeletal part. To this end, adequate reestablishment of proper anatomic shape is paramount. Perhaps nowhere else in the body is this more important than in the craniofacial skeleton. A slight discrepancy in the mandible, for example, may result in a malocclusion that is unacceptable to the patient and the surgeon. Furthermore, the aesthetic appearance of the face is largely determined by the underlying skeleton. Failure to address an orbital floor fracture and potential subsequent enophthalmos can result in functional and aesthetic problems for the patient. Thus proper anatomic reduction of the fractured skeletal part is important to reestablish both form and function.

The nature of the injury itself, as well as individual patient factors and conditions, help the surgeon determine whether to approach a fracture by closed or open methods. The indications for open reduction and fixation vary according to the specific fracture. Some general concepts are more broadly applicable to perhaps all but fractures of the mandibular condyles, which merit special considerations. Fractures that are nondisplaced and closed can often be managed with conservative methods. Many isolated fractures with moderate displacement, such as those of the zygoma, may be treated with closed reduction alone. More-complex fractures, including those with significant displacement, are best treated with open reduction of the fragments and internal fixation (Box 6-1).

Some patients with fractures present after a significant delay; in such cases, closed reduction of a displaced fracture is less likely to be stable when 3 to 5 days have passed since the fracture, and beyond this time, displaced fractures will likely require internal fixation. When several weeks have passed, indirect healing is in process, fracture segments are more difficult to mobilize, and open exposure will certainly be needed. There are additional socioeconomic factors to be considered in the decision-making process of whether to treat a fracture conservatively or with open methods. These should not, however, supersede the goals of treatment: restoration of form and function, relief of pain, and avoidance of late sequelae.

Box 6-1 Indications for Internal Fixation of Craniomaxillofacial Fractures

There are several recognized indications for internal fixation of craniomaxillofacial fractures:

- Multiple or comminuted fractures
- Panfacial fractures
- Fractures with a gap or segmental bone loss
- Open fractures
- Midface dislocation
- Atrophic mandible fractures in geriatric patients
- Infected fractures
- Malunion or nonunion

Principles of Stabilization

There are two methods of fracture fixation, each differing in their method of stabilization and the amount of stability achieved. The first method, splinting, aims to decrease the mobility of the fracture fragments. However, it does not completely eliminate motion at the fracture line. The degree of motion reduction achieved depends on the inherent characteristics of the splint being used. Splints can be external, internal, or transcutaneous. External splints are not in immediate contact with bone, and their forces are not transmitted directly to bone. Internal and transcutaneous devices are in direct contact with bone; thus they provide greater motion reduction between the fracture fragments. The other method of fixation is compression, which eliminates movement at the fracture site. Compression acts by forcing two surfaces together—each bone against the other, or an implant to the surface of the bone. By producing friction at the interface between the two surfaces, motion is eliminated if the frictional forces exceed those of the shear or torque applied to the fracture site. Additionally, the increase in preload resulting from the compression resists motion from opposing forces.

ANATOMIC CONSIDERATIONS

There are several things that should be taken into account when deciding on implants in the craniofacial skeleton. Both the thickness of the cortical bone as well as the overlying soft tissue envelope should be considered. In general, areas with thicker cortical bone are suitable for miniplates, whereas areas with thinner cortical bone are best treated with microplates.

MATERIALS USED FOR FIXATION

The main devices used for skeletal fixation are plates and screws. They differ in shape, size, thickness, and composition to allow custom application at each site of the craniofacial skeleton. These characteristics are vital for addressing the differing biomechanical loads found at various locations on the face. Knowledge of the basic terminology of screws and plates is necessary to understand the fundamentals of fracture fixation (Box 6-2 and Fig. 6-2).

The two main types of screws are *cortical* and *cancellous* (Fig. 6-3). The cortical screw is the primary type used in craniomaxillofacial fixation. The basic components of the screw are the head and the shaft. The head of the screw comes in a variety of configurations, depending on the manufacturer. The shaft of the screw contains the threads.

Box 6-2 Basic Terminology of Screws

Pitch: The distance between the threads
Lead: The distance the screw advances with one revolution
Core diameter: The diameter of the inner shaft of the screw
Outer diameter: The diameter of the screw including the threads

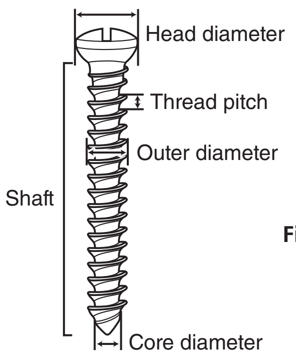

Fig. 6-2 Basic configuration of a screw.

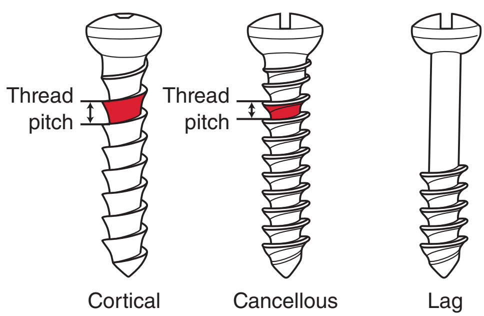

Fig. 6-3 Types of screws.

It is also important to distinguish between pretapped and self-tapping screws. These are differentiated by the method in which they are inserted into the bone. Tapping the bone threads is required before inserting a pretapped screw. These screws are blunt-tipped and form threads as they are passed into the bone. With a self-tapping screw, a hole is drilled within the bone and the screw is then inserted. The screw itself is fluted at the end and is thread-cutting as it passes through the drill hole.

A more recent advance is the self-drilling, self-tapping screw. It is not necessary to drill a hole within the bone before placing the screw. It is thought to act by compressing, rather than cutting, the cancellous bone around the screw threads. The retentive strength of these screws is therefore superior to self-tapping screws in cancellous bone, although in thin bone the two are equivalent. The use of self-drilling screws is quite user dependent. Because they require significant force to insert, they are best suited for placement in sturdy, stabilized bone (such as cranial bone in a frontal sinus repair). The use of self-drilling screws in unstable, thin, or comminuted bone is not advisable.

Lag Screw and the Lag Technique

A *lag* screw is used to obtain compression between two bony segments. The threads on the screw are inclined. When the screw is inserted into the bone, the threads do not purchase the proximal fragment. Instead, the screw glides through the proximal portion and, as it crosses the fracture line, it purchases the distal fragment and converts the torsional force applied into a compressive force. The two bone fragments are secured to each other in such a manner that no microscopic movement occurs between them. Sometimes a fully threaded cortical screw is used to achieve interfragmentary compression. The proximal cortex must be overdrilled to the width of the outside diameter of the screw for this to happen.

The standard technique first calls for the drilling of the outer or gliding hole. The drill bit diameter must be equal to the outer diameter of the screw. Next, a drill sleeve with an outer diameter equal to that of the gliding hole is placed within the hole. The inner diameter of the sleeve is equal to the root diameter of the lag screw. A hole is subsequently drilled into the opposite cortex. The drill holes of the two fragments are thus lined up, and the differing diameters allow placement of the lag screw and compression in the direction of its placement.

It is imperative during placement of the lag screw that the drill holes be made perpendicular to the plane of the fracture. If the drill holes are not precisely placed, the fragments will be subject to shearing forces, which can disrupt the compression acting to hold the fragments together. In such instances, a percutaneous approach may be necessary to achieve proper alignment.

In some instances, the threads might be stripped as the screw is inserted into the bone. When this happens, most craniomaxillofacial fixation kits contain "emergency" or "rescue" screws. These screws are slightly larger than the initial

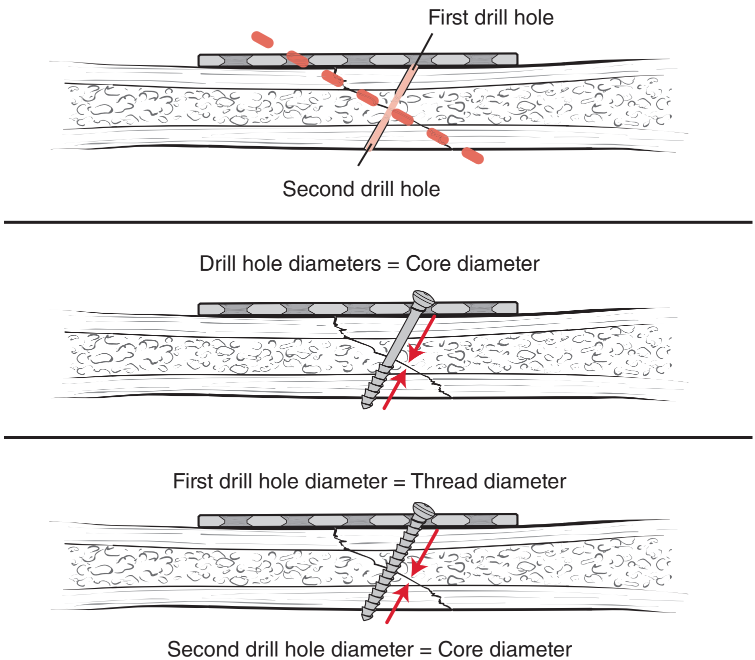

Fig. 6-4 Lag screw placed across a fracture line to gain compression.

screw, usually with an outer diameter equal to the core diameter of the first screw. This permits rescue of the screw hole (Fig. 6-4).

Plates

When a plate is applied across a fracture site, it secures the fracture and prevents rotational forces from acting on the segment. By reducing motion in three dimensions, it allows the bone to be held stable and thus facilitates healing by primary union. As with screws, there are several styles and configurations of plates available.

A conventional plating system works by having the plate lie in intimate contact with the bone by precise contouring. As the screw is tightened into the hole, it compresses the plate against the bone, thus achieving stability. Eventually, the cortex of the bone that lies adjacent to the plate will resorb. However, if the plate is not intimately associated with the bone or there are host factors associated with compromised healing, the cortex will resorb before bone healing, and the end result will be unstable fixation.

Locking plate and screw systems circumvent the need for precise adaptation of the plate to the bone. The stability of the system is gained by the screw "locking" into the plate while the shaft of the screw secures the bone.

Two separate philosophies exist with regard to the fixation of mandibular fractures. The AO/ASIF (Arbeitsgemeinschaftfür Osteosynthesefragen; Association for the Study of Internal Fixation) philosophy proclaims that complete rigidity and compression of the bone fragments without interfragmentary mobility is necessary to achieve primary bone healing during active use of the mandible.[1] Compression plating is depicted in Fig. 6-5. As described previously, compression acts by forcing two surfaces together; in this case, offset screwheads drive the segments of bone together as the screw is tightened and seated. By producing friction at the interface between the two surfaces, motion is eliminated if the frictional forces exceed those of the shear or torque applied to the fracture site. The other philosophy, as presented by Champy et al[2] and Michelet et al,[3] advocates the use of miniplates and monocortical fixation, without offset screws and their associated compression.[4] With this technique, complete immobilization of the bone fragments is not necessary, based on the concept of the ideal lines of osteosynthesis and neutralization of forces.

The principle associated with the Champy technique is identifying the line of tension at the fracture site. The plate is applied across the fracture line without compression, thereby allowing it to bear large loads of tension. Another advantage is that only monocortical screws are necessary, because compression is unnecessary. The plates are small and the complication rate associated with them is low. Although initially advocated by Champy for mandibular fractures, their use has been extended to treating all areas of the facial skeleton.

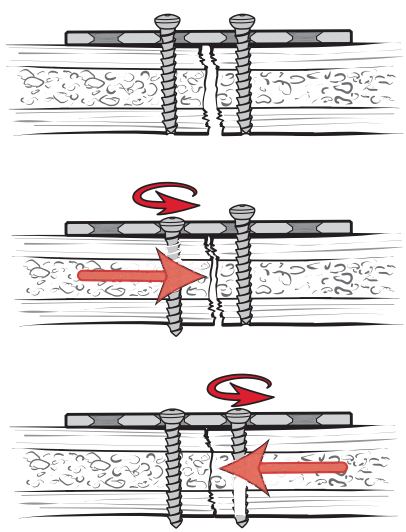

Fig. 6-5 Compression plate. (Modified from: Prein J, ed. Manual of Internal Fixation in the Craniofacial Skeleton. Berlin: Springer-Verlag, 1998.)

One concern with the use of metal plates is the interference they may produce if a patient requires imaging postoperatively with either a CT scan or an MRI. However, it has been shown that titanium plates and screws produce limited artifacts in either imaging modality.[5,6] Furthermore, the size of the plate does not influence the amount of distortion.

Biodegradable Products

The use of titanium plates and screws is well accepted for the treatment of fractures of the craniomaxillofacial region. There is a certain subset of patients, however, who will require removal of the hardware. Common causes for removal of implants include pain, infection, loose plates or screws, palpable or prominent hardware, thermal sensitivity, and wound dehiscence. Additionally, there are some concerns that the use of rigid fixation in pediatric patients can adversely affect skeletal growth. As a result of these concerns, biodegradable products were developed for use in certain patients with facial fractures.

Biodegradable products must be strong enough to stabilize fractures to allow healing, and their biocompatible profile must allow quick resorption so they do not invoke a foreign-body response. Recent advances in the biomechanical properties of plates and screws have made the use of biodegradable products more common. The products are usually polymers and copolymers of lactic acid, glycolic acid, or mixtures of L- and D-lactides.

The primary advantage, of course, is that, because they are bioresorbable, the need to remove them because of infection or palpability is much less. The disadvantages of bioresorbable materials include the fact that they require a heating source to facilitate bending, they tend to be larger and weaker than titanium, and predrilling and/or pretapping is necessary, because the screws are not self-tapping. There are some recent products that allow fixation of resorbable plating by means of an ultrasonic driven pin or rivet. This allows applications in thinner bone, such as the maxilla, where tapping would be challenging. Bioresorbable fixation is less suited to use in severely comminuted fractures, fractures with severe displacement, or areas requiring significant load-bearing.

Despite these disadvantages, there are several situations in which the use of bioabsorbable materials should be considered. These products have been used most extensively in craniofacial procedures in pediatric patients in whom the facial skeleton is still growing and developing.

Certain considerations must be taken into account when using biodegradable plates and screws. Potential complications include a foreign body reaction, soft tissue swelling, and osteolysis.

COMPLICATIONS

As with surgery in any area of the body, certain complications can occur with osteosynthesis of the craniomaxillofacial region. Although rare in general, the more common complications include infection of either the soft tissue or bone, delayed union, malocclusion, or injury to surrounding structures. Certain factors that have been found to contribute to the development of these complications are delayed treatment, fracture instability, and insufficient antibiotic treatment. Surgical technique and the method of fixation can also contribute to the development of complications.

A recent meta-analysis that specifically evaluated fixation systems in mandibular fractures found lower complication rates in systems using noncompression plates than in systems with compression plates.[7] By extension, monocortical systems also had a lower complication rate compared with bicortical placement. Additionally, single-plate placement was more advantageous than multiple-plate fixation.

Pearls

- *The primary goal of fracture treatment is to provide function of the skeletal part; both mechanical and biologic factors play a role in successful fracture healing.*
- *Not all craniofacial fractures require fixation; however, there are several recognized indications for operative intervention.*
- *Both the thickness of the cortical bone and the overlying soft tissue envelope should be considered when choosing an implant for fixation.*
- *A lag screw converts a torsional force to a compressive force, thereby securing the bone fragments to each other and prohibiting microscopic movement between the fragments.*
- *The principle associated with the Champy technique is identifying the line of tension at the fracture site. The plate is applied across the fracture line without compression, thereby allowing it to bear large loads of tension.*
- *Biodegradable products should be considered for pediatric patients in whom the skeleton is still growing.*

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7 Intermaxillary Fixation Techniques

Jeffrey R. Marcus, Mark D. Walsh

Background

Intermaxillary fixation (IMF), or mandibulomaxillary fixation (MMF), is the concept of providing stabilization to the jaws by binding the upper and lower dental occlusal arches to one another. The most important goal in the treatment of any fracture of the maxilla or mandible is to reestablish the patient's preinjury dental occlusion.[1] Intermaxillary fixation allows the surgeon to set and secure proper occlusion. For some fractures, reduction and stabilization with IMF provides adequate treatment without internal fixation and is maintained long enough to allow the fracture (or fractures) to heal. For many (if not most) jaw fractures, IMF is a crucial step in the process of open reduction and internal fixation (ORIF). It is critical to understand that success and failure in fracture treatment are defined by occlusal outcome. An apparent anatomic reduction can result in occlusal imperfection if proper steps are not taken to ensure correct occlusion first. Over time, many methods have been employed to provide IMF, and we review these in this chapter. The "first and last" principle for IMF is emphasized for cases treated by ORIF: intermaxillary fixation is applied first to secure occlusion; it is released last to check occlusion. The decision to resecure IMF after the final check is addressed.

PRINCIPLES OF INTERMAXILLARY FIXATION

Before beginning this discussion, the reader should review Chapter 4 on dental occlusion, because a working knowledge of occlusion is needed to accomplish the goal of intermaxillary fixation; occlusion is *set* before IMF is *secured.*[1-3]

Implications of Fracture Location

Fractures of either jaw can occur between tooth roots or distal (posterior) to the dental arch (Fig. 7-1). An example of a fracture behind the mandibular dental arch is an angle fracture; for the maxilla, a LeFort I fracture. The arch form remains intact, and congruent malocclusion occurs in these injuries as the entire arch shifts. Fractures between teeth create separate segments of the dental arch; one or both segments may be mobile. An example is a parasymphyseal mandibular fracture. Located between the canine and the first bicuspid, each segment may splay outward, resulting in bilateral buccal crossbites. In the maxilla, a longitudinal palatal fracture splits the maxilla into two pieces. When fractures occur between teeth, the application of IMF is challenging because of segmental mobility. As long as one arch is intact, the segments of the opposing arch can be brought into occlusion by finding the proper fit with the intact arch. IMF is most challenging when both the mandibular and maxillary arches are segmented, because neither arch provides a template.

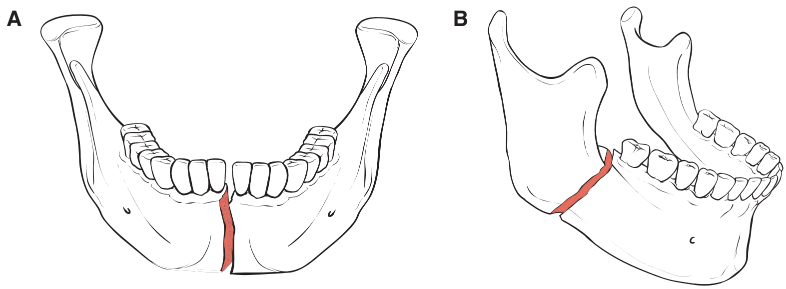

Fig. 7-1 Examples of fracture locations relative to the dental arch. **A,** A true symphyseal fracture occurs between the central incisors. **B,** A fracture at the mandibular angle is posterior to the dental arch. The entire arch shifts as a single unit.

IMF as Treatment Versus IMF as an Adjunct

Before the introduction of miniplates and microplates to provide fixation after open reduction, IMF alone was the only means to treat jaw fractures. In some cases, IMF may still be favored as the primary treatment modality without internal fixation.[4-6] To align the dental arch and normalize occlusion, closed reduction of the fracture is necessary and therefore is a component of the IMF process. Conceptually, this is similar to the closed treatment of a long bone fracture: when a fracture is nondisplaced, it can be immobilized for a period of time while the fracture heals. If it is displaced, the fracture is reduced before immobilization. When a fracture occurs between teeth, manual reduction of the two segments is often necessary. If the fracture is not between teeth, placing the arches into occlusion with IMF passively provides reduction at the fracture site. Intermaxillary fixation immobilizes the jaws and maintains the occlusal relationship; it is held for a period of time to allow the fractures to heal. The problems encountered in the past with IMF treatment alone were that (1) fracture reduction was functional but not necessarily anatomic, potentially leading to nonunion or malunion, and (2) the need for prolonged immobilization can result in trismus and even ankylosis of the temporomandibular joint. Additional difficulties associated with immobilization include risks to the airway, poor nutrition, poor hygiene, phonation difficulties, insomnia, social inconvenience, patient discomfort, and work loss.

Today a large percentage of maxillary and mandibular fractures are treated with ORIF. The indications specifically for ORIF are detailed in Chapters 6 and 16. ORIF provides anatomic reduction and secure fixation at the fracture site, limiting the reliance on prolonged intermaxillary fixation. However, IMF is still required to establish an occlusal relationship. Without securing occlusion, it is possible to perform a seemingly anatomic reduction and still find that the occlusion is unsatisfactory, because minute discrepancies can equate to significant disturbances in intercuspation.

IMF is performed as the first step in every case. When internal fixation is complete, the IMF is released, and occlusion is checked again. If occlusion has not been maintained, fixation may need to be revised.

Rigid Versus Elastic Intermaxillary Fixation

A variety of techniques allow application of IMF. Most rely on a combination of wire, screw, or apparatus to be applied to the maxilla and mandible independently, and then secured to one another. (The methods are described in detail later in this chapter.) The most common method currently used employs the Erich arch bar, which is wired to the dentition of each arch separately (Fig. 7-2, *A*). Opposing tabs on each arch bar allow the surgeon to apply a wire loop at two or more sites to bind the jaws together in proper occlusion. The snug wire loops provide effective immobilization; this is called *rigid IMF* (Fig. 7-2, *B*). Rigid IMF is needed for fractures being treated by IMF alone. Some micromovement occurs at the fracture site, but, when stable, the construct allows fracture healing after formation of an initial callus. The opposing arch bars also allow the application of elastic bands to draw the arches together into occlusion; this is called *elastic IMF* (Fig. 7-2, *C*). The strength

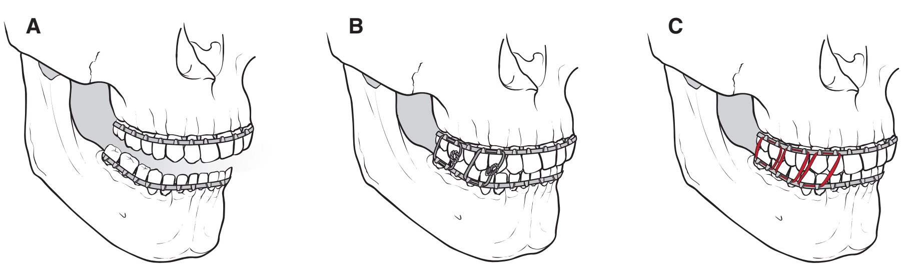

Fig. 7-2 Erich arch bars. **A,** An arch bar is applied independently to the maxillary and mandibular teeth with 25-gauge wire. **B,** Rigid IMF. Proper occlusion is determined and then set by wiring the arch bars together. **C,** Elastic IMF. Elastic bands may be used in a variety of configurations to guide the teeth into occlusion. The more bands applied, the tighter the IMF will be.

of elastic IMF depends on the number of bands used. If one elastic band is used per side, the tension gently guides the arches together (guiding elastics). In contrast, if three or four bands are used per side, the effect is similar to rigid IMF.

In patients treated primarily with IMF, elastic IMF may be useful after a period of rigid IMF. For example, with mandibular condyle fractures, it is initially advantageous to have a period of rigid IMF to allow for early fracture healing. Once tenderness at the fracture site has subsided (indicating effective early healing), transition to elastic IMF allows the patient more dietary freedom while still providing occlusal guidance. The number of elastic bands may be decreased gradually to avoid abrupt transitions. It is important to note, in this example, that range of motion is permitted at the TMJ to address concerns about the development of trismus or ankylosis.

In patients treated with ORIF, occlusion should be set and secured initially with rigid IMF according to the "first and last" principle. After fixation has been applied, the IMF wire loops are cut and occlusion is checked. At this point, it must be determined whether further immobilization is necessary. If the surgeon's judgment is that rigid IMF is needed to ensure the occlusal outcome, IMF may be reapplied. However, in most cases, elastic IMF provides adequate occlusal assistance and negates the potential risks of rigid IMF.

IMF Safety

Rigid IMF should be solid and secure. However, patients should be instructed on the means to release IMF. Wire cutters should always accompany the patient from the operating room to the recovery area and floor and should be sent home with the patient for emergent use. Elastic IMF is more easily removed. The patient should be instructed on placement and replacement of the elastic bands. The most common reason for IMF release is nausea and/or emesis. For this reason, postoperative care regimens should always include an antiemetic prophylactically.

Duration of Treatment With Intermaxillary Fixation

One issue that lacks consensus in the treatment of mandibular/maxillary fractures is the length of time required for maintenance of IMF. Among those treated with IMF alone, the duration of treatment and security of immobilization must be sufficient to allow fracture healing. Inadequate treatment durations can lead to nonunion, malunion, and malocclusion, whereas prolonged treatment can lead to trismus or ankylosis. There is no algorithmic approach to the judgment of the surgeon, but there are a number of factors that can influence the decision. Among these are patient age, comorbidities, and compliance. Younger patients with fewer comorbidities who are compliant with treatment will heal faster and require a shorter period of rigid IMF. As noted previously, functional healing can be determined when pain and point tenderness have subsided. At this time, rigid fixation may be changed to elastic fixation. Every attempt should be made to avoid rigid IMF for longer than 3 weeks.

In our practice, most patients are treated with ORIF. Primary IMF treatment is reserved for situations in which the need for *rigid* IMF duration is not likely to exceed 3 weeks. This could include isolated condylar injuries, pediatric fractures, or nondisplaced (or minimally displaced) isolated fractures in young patients who seem likely to comply with treatment needs. Rigid IMF is rarely maintained for longer than 2 to 3 weeks. Elastic IMF is then continued, decreasing gradually to one elastic band per side, until 6 weeks have elapsed.

In patients who have been treated with ORIF, IMF sets and secures occlusion before rigid fixation is used. Movement at the fracture site is minimized by plating, and prolonged immobilization with rigid IMF is more detrimental than helpful. The use of two or three elastic bands per side, gradually stepped down over 6 weeks, provides a better risk-benefit profile (Fig. 7-3).

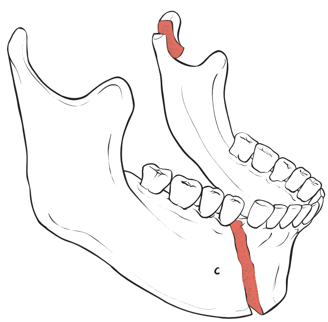

Fig. 7-3 Mandibular body and contralateral condylar fractures. ORIF of the body fracture is needed to permit early range of motion for the condyle. Arch bars are applied, and IMF is placed. The body fracture is plated, IMF is released, checked, then reapplied. Two weeks of rigid IMF allows for early healing and comfort, followed by 4 weeks of guiding elastic IMF.

HISTORICAL PERSPECTIVE AND MODERN PRACTICE

Among the early IMF methods were those in which metallic wires were placed around one or more (adjacent) teeth at their bases and were then twisted down securely to the teeth.[1] When a wire is passed around a tooth (or teeth) at the base in such a way, it may be called a *circumdental wire ligature* (CW) (Fig. 7-4). Multiple CWs can be placed along the span of the dental arch in a series, or the wire may be fashioned so that a single continuous strand securely incorporates multiple teeth along the arch. In whatever manner this is accomplished, both upper and lower arches are treated the same way, then the jaws are secured to one another by placing wire loops or elastic bands around the CWs of the opposing jaws, thus accomplishing IMF.

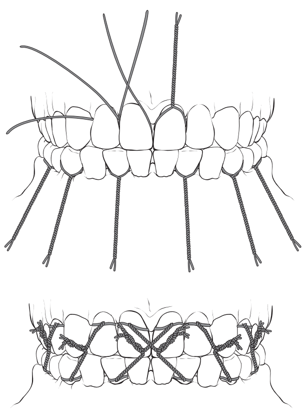

Fig. 7-4 Early use of circumdental wires. (From Rowe NL, Williams JL. Maxillofacial Injuries, vol 1. Edinburgh, Scotland: Churchill Livingstone, 1985.)

Robert Ivy[7] was one of the American fathers of plastic surgery; he practiced at the University of Pennsylvania and introduced a useful method of circumdental wire ligature in 1914. *Ivy loops* incorporate two teeth securely and provide an ingenious means for securing intermaxillary fixation (Fig. 7-5). If both dental arches are intact, IMF can be achieved with Ivy loops alone by placing one Ivy loop per quadrant so that the maxillary and mandibular loops are directly in line with one another. A wire is then placed through the eyelets on each side as a vertical loop (while holding occlusion), and IMF is completed. Ivy loops are still useful today, and can also play a role in challenging cases when other methods are difficult to adapt.

The concept of the arch bar (or arch wire) was established in the early 1900s. Currently, arch bars are the most frequently employed technique for IMF. The concept involves the use of a linear metal bar or wire that can be adapted and

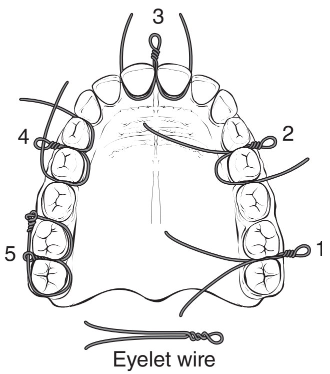

Fig. 7-5 Ivy loops. *1,* The two strands are passed through an interspace. *2,* Each end is then brought out to the buccal side through the two neighboring interspaces. *3,* The strands are pulled so that only the wire loop protrudes between the teeth. *4,* One strand is passed through the loop. *5,* The wire is tightened. (From Rowe NL, Williams JL. Maxillofacial Injuries, vol 1. Edinburgh, Scotland: Churchill Livingstone, 1985.)

secured to the dental arch form. The arch bar generally has a number of hooks/tabs facing in a single direction. As previously depicted, the arch bars and their corresponding hooks are placed in opposing directions for the upper and lower jaws so that wire loops or elastic bands can securely affix the jaws together (see Fig. 7-2). Arch bars provide several advantages:

1. Arch bars are secured to multiple teeth along the dental arch, and thus have good overall stability.
2. Arch bars may be used for monomaxillary fixation. For example, in dento-alveolar fractures, the injured tooth or segment of teeth may be secured to the arch bar and to the surrounding teeth.
3. They have inherent rigidity and therefore maintain reduction of the fracture at the level of the alveolar ridge when fractures occur between teeth. This concept is known as a *tension band,* because it prevents an opening gap at this level, such as when plating the lower border of a mandible fracture (Fig. 7-6).

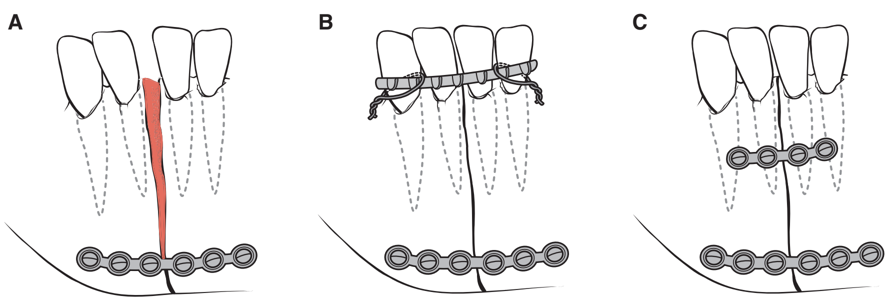

Fig. 7-6 Tension band concept. **A,** When a fracture occurs between teeth, plating at the lower border alone permits a gap at the upper border. **B** and **C,** A tension band refers to an arch bar, wire, or plate placed near the upper border to prevent the gap.

Despite the widespread use of arch bars, they have numerous drawbacks for IMF. Placing them is time consuming, taking 30 to 60 minutes in experienced hands. Removal can be challenging as well as protracted. The use of multiple wire ligatures can result in prick injuries to the surgeon. Wire ligatures may cause injury to the dental papillae or gingiva directly or through ischemia as the wires are tightened.

An IMF technique has evolved over the past 20 years in which bone screws are placed at the level of the gingiva between tooth roots. Projection of these screws is external to the gingiva or mucosa (Fig. 7-7). Two or more IMF screws are placed into each of the upper and lower jaws, typically one per quadrant. A wire loop is then either wrapped around the head of two opposing screws, or, as is more commonly done now, placed through a tiny hole through each of the two opposing screw heads to provide IMF. There are several advantages of IMF screws compared with arch bars:

1. Placement is relatively simple and requires little time.
2. IMF screws can be applied with the use of a local anesthetic.
3. Removal is easy and does not generally require more than a local anesthetic.
4. The risk to the surgeon is dramatically reduced.
5. The potential for injury to the teeth, dental papillae, and gingiva is reduced.
6. Dental hygiene is easier.

Because of these advantages, IMF screws have become increasingly popular. However, IMF screws are not suitable for many of the situations in which they are currently being employed. They have several limitations that outweigh the potential

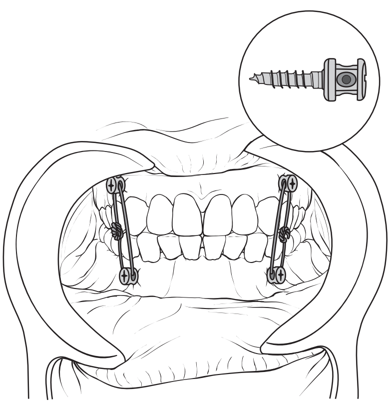

Fig. 7-7 IMF screws allow rapid intermaxillary fixation but are not appropriate for all patients. The surgeon must understand the limitations of all IMF techniques.

benefits. IMF screws do not provide stability to the dental arch, nor full IMF along the entire arch. Placement of the screws in alveolar bone is associated with a risk of injury to the dental roots or to the inferior alveolar or mental nerve. Wires are applied to opposing screws, and the direction or angle of the wire is only determined by the placement of the screws. In contrast, with arch bars the direction can be selected from among the tabs present over the length of the arch bar.

The placement and maintenance of elastic bands using IMF screws can be unreliable, particularly if gingiva or mucosa is elevated over the screw heads.

Finally, IMF screws provide no tension band effect. We do not use IMF screws when fractures occur between teeth or when the posttreatment regimen requires the use of elastic IMF (such as with condylar injuries).

TECHNIQUES

Application of Erich Arch Bars

Erich arch bars are the most common prefabricated arch bars commercially available. They are inexpensive and are made from a relatively soft material that can be adapted to the dental arch. Each bar has a number of tab projections. The bar is situated so that the tabs face upward for the maxilla and downward for the mandible. The bar is measured by determining the length of one quadrant from the first molar to the dental midline. The tabs are counted to determine the total length needed for the complete arch bar. After the bar is cut, it is placed along the full arch to check that the length is accurate. Arch bars are secured to the teeth using 24- to 26-gauge circumdental wires. Typically, three or four circumdental wires are used per quadrant to secure the arch bar. There are two common methods for applying the arch bar. In one technique, the wire ligatures are applied one at a time with the arch bar in place, working from mesial (anterior) to distal (posterior). Alternatively, the wires can all be placed and held with hemostats before applying the arch bars and tightening them in each quadrant. Again, they are tightened from mesial to distal.

After the arch bars have been applied, optimal occlusion is determined and held as wire loops are placed and tightened to secure IMF. In contrast to individual wires, traction is not applied while tightening IMF wire loops.

Wire Application Guidelines

Regardless of the technique preferred, there are several guidelines:

- Wires should be placed through the interdental space, avoiding injury to the dental papillae or gingiva if possible.
- Wires should be tightened in a clockwise direction as a matter of consistency. This will be appreciated when they are removed later.
- While twisting, apply traction to seat the ligature at the base of the tooth tightly. Traction is directed so that the twist lies at either the upper edge of the maxillary arch bar or at the lower edge of the mandibular arch bar.
- The central and lateral incisors should be avoided if possible; their conical root shape predisposes them to extrusion as the wires are tightened.
- After tightening all wires, the twists should be cut at 1 cm and then turned clockwise to form a small loop that will not rub against the buccal mucosa.
- If the fracture occurred between teeth with displacement, it is helpful to place a bridle wire first. This is a circumdental wire that incorporates one or two teeth on either side of the fracture. When this is tightened, reduction is maintained at the level of the alveolus. The arch bars can then be applied as described.

Application of IMF Screws

IMF screws are used most commonly for nonsegmental injuries (fractures not occurring between teeth).[1] The number of screws placed can vary according to the judgment of the surgeon, but typically one screw is placed per quadrant. One wire loop per side is then passed through the opposing maxillary and mandibular screws and tightened to achieve IMF while occlusion is held.

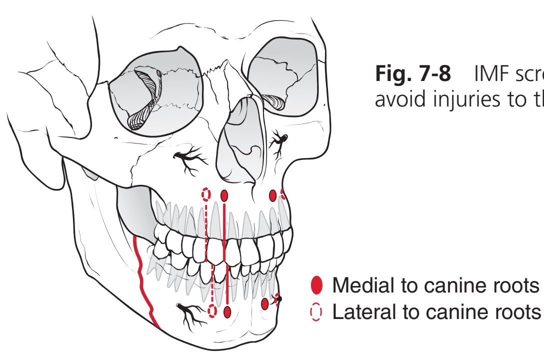

Fig. 7-8 IMF screws are placed between tooth roots to avoid injuries to the dental roots or mental nerves.

IMF Screw Guidelines

- Screws must be placed between dental roots (Fig. 7-8).
- In the mandible, the mental nerve should be avoided. The interspace between the canine and first bicuspid provides a safe location.
- The screw should be placed through gingiva close to, but not at, the mucosal interface. A small nick may be made with a needle point cautery to allow the screw to seat on bone without intervening gingiva.
- If IMF screws become draped or covered with soft tissue, removal is more difficult, and elastic bands may be difficult to apply.
- IMF screws may vary in length. For the maxilla, an 8 mm screw is adequate. For the mandible, a longer screw (12 to 15 mm) allows more complete purchase of bone.

Application of Gunning Splints in Edentulous Patients

Edentulous patients present a particular challenge. If the patient has dentures, the process can be aided by incorporating the dentures themselves into the IMF construct. The technique, called the *Gunning splint,* relies on the surgeon's ability to secure the denture to the occlusal arch. In doing so, any fracture is reduced; the denture then acts as a splint that stabilizes the fracture. The methods for securing the Gunning splint to the maxilla or mandible can vary.[2,3,8,9] For the maxilla, the denture may be wired anteriorly to the piriform aperture; posteriorly, wires may be passed above the alveolar ridge and then through either a groove or drill hole in the denture. Some surgeons also use a palatal screw (or screws) placed through the denture into the hard palate. When there is adequate bone along the alveolar ridge, screws may possibly be placed through the denture into alveolar bone. Fixation of the denture to the mandible is somewhat more straightforward. Typically the denture is secured with circummandibular wires.

Once the Gunning splint or splints have been applied, proper occlusion is acquired. The question then becomes how best to secure IMF. If the surgeon has access to a dental technician or prosthodontist, it is ideal to have multiple surgical fixation hooks bonded to the dental appliances before surgery (Fig. 7-9). If this is not feasible, then the IMF screws discussed previously may be placed in the dentures (Fig. 7-10). If the patient has one denture, then the native dental arch should be treated routinely (with arch bars or IMF screws).

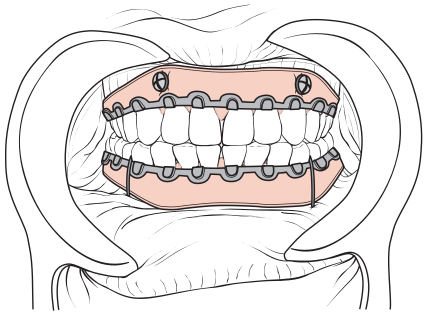

Fig. 7-9 Gunning splints. Upper and lower dentures can be preoperatively fashioned with arch bars by a technician, then secured with a combination of screws and circummandibular wires. IMF is then secured.

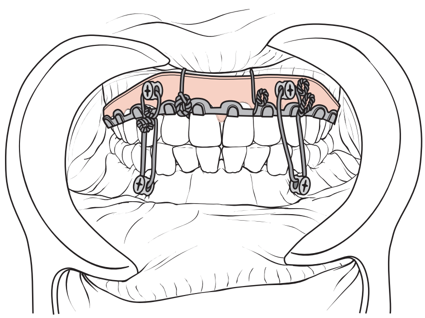

Fig. 7-10 Gunning splints. In this example, a maxillary denture is secured using a screw in the hard palate and wires through the piriform aperture. IMF screws are placed into the dentures and native mandible to secure IMF.

IMF for Treatment of Pediatric Mandibular Fractures

All types of mandibular fractures may occur among children. Dental development and the associated risk to developing structures are the main challenges in determining the method of treatment. Fractures can occur during the periods of deciduous dentition, early mixed dentition, and late mixed dentition. In early childhood, the conditions are not favorable for internal fixation because of the presence of tooth buds and the thin, weak, intervening bone. The inferior border, which is a desirable site for placement of fixation implants, may still contain tooth buds at its inferiormost extent. The inferior alveolar nerve is also more at risk among children. For these reasons, treatment in the deciduous and early mixed dentition stage should be conservative; internal fixation is avoided. Fig. 7-11 presents an algorithmic approach, as described by Smartt, Low, and Bartlett.[10] If plating is done at the inferior border, we believe it should be under the following conditions:

1. The procedure should be avoided in patients younger than 7 years of age.
2. Only monocortical screws should be used.
3. Radiographs should show enough safe clearance at the inferior border.

In patients older than 12 years of age who have mixed dentition, the surgeon may choose to apply internal fixation. This section relates primarily to the age group in deciduous and early mixed dentition.

In children with nondisplaced mandibular fractures who show no evidence of malocclusion, conservative treatment can include soft diet, pain management, and proper hygiene. For those with malocclusion, intermaxillary fixation is necessary.

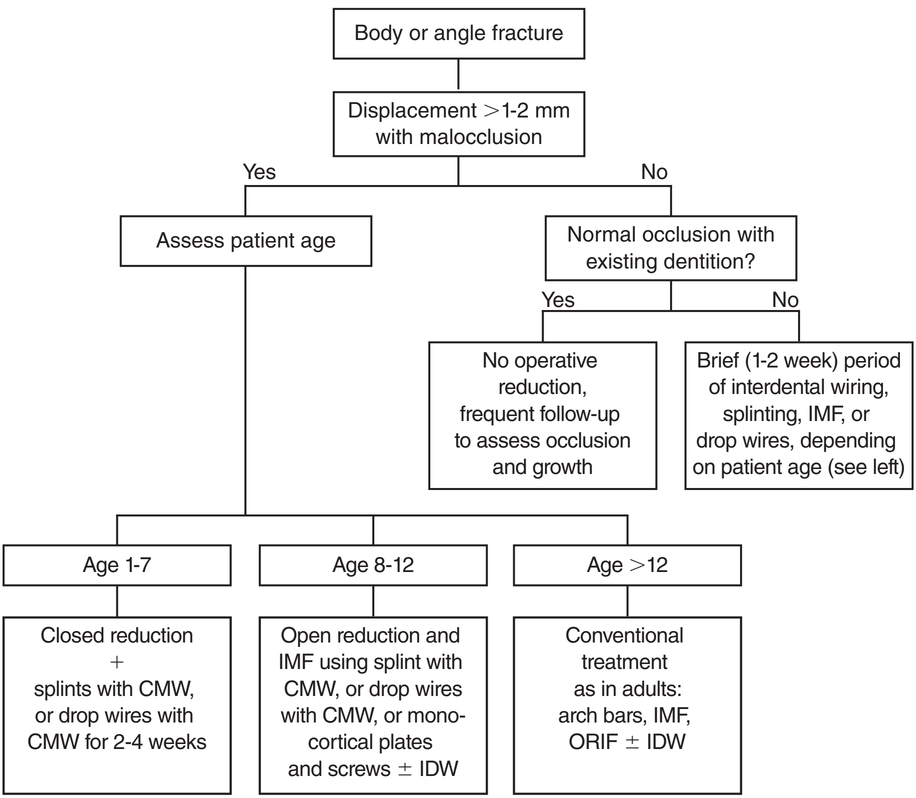

Fig. 7-11 Algorithm for the management of body and angle fractures. (*CMW,* Circummandibular wires; *IDW,* interdental wiring; *IMF,* intermaxillary fixation; *ORIF,* open reduction and internal fixation.) (From Smartt JM Jr, Low DW, Bartlett SP. The pediatric mandible: II. Management of traumatic injury or fracture. Plast Reconstr Surg 116:28-41, 2005.)

The two most common techniques mentioned in this chapter—arch bars and IMF screws—are not applicable among this subset of patients. Arch bars rely on circumdental ligatures to affix the bar to the teeth; these wires cannot be placed around deciduous teeth because of the risk of avulsion. IMF screws create a significant risk to underlying tooth buds and the inferior alveolar nerve. Furthermore, the bone is not solid enough to allow stable placement.

Application of IMF in children requires the use of wiring techniques, with or without an acrylic occlusal splint (Fig. 7-12). When fractures occur posterior to the dentition (such as an angle or condyle fracture), an occlusal splint is not imperative. When fractures occur between teeth (parasymphyseal), an occlusal splint stabilizes the arch form along the occlusal plane.

To fabricate an occlusal splint, dental impressions are taken. In some cases, this is performed with the patient under anesthesia for comfort. Dental casts are made from impressions; the models are cut at the fracture site to mimic the injury and allow optimal alignment of the segments. The model surgery is completed, and an acrylic splint is created. In the operating room, the fractures are reduced. The

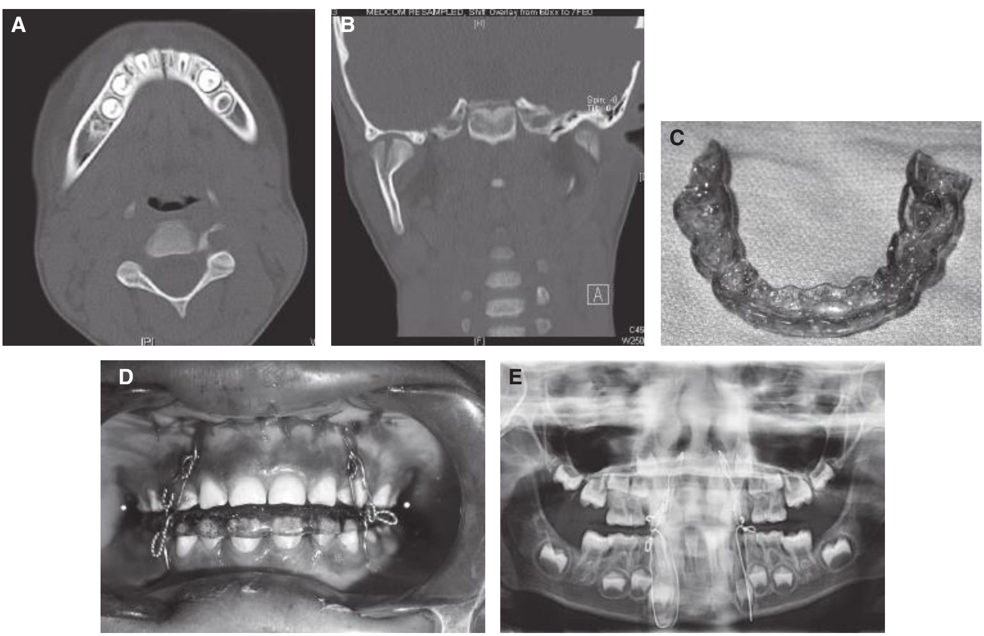

Fig. 7-12 Pediatric mandible fracture at the symphysis and condyle with malocclusion. **A** and **B,** CT images of the fractures. **C,** Impressions are taken, models are made, model surgery is performed, and an occlusal splint is made. **D,** Piriform drop wires are placed, and the splint is secured to the mandible with circummandibular wires. Wire loops then connect the drop wires and the splint to secure IMF. **E,** Panorex image demonstrating the wiring technique.

splint is placed, and the segments are fitted into it. The splint is then held in place with circummandibular wires.

Through the upper buccal sulcus, drop wires are placed at the piriform aperture on each side. Wire loops can then be passed through the drop wires above and the circummandibular wires (or the splint) below to establish IMF. When IMF is later released by cutting the wire loops and removing the piriform drop wires, the occlusal splint will remain wired to the mandible. The splint can be left on at the surgeon's discretion, providing stability to the fracture while allowing free movement and range of motion at the TMJ. If an occlusal splint is not used, the steps are still the same: piriform drop wires are linked to circummandibular wires.

Pearls

- *Selected fractures may be treated with IMF alone, but conservative treatment may have greater risks than ORIF, depending on the case.*
- *Prolonged IMF should be avoided to minimize the risk for trismus.*
- *Fractures occurring between teeth require stabilization at the level of the occlusal plane to prevent separation—the tension band effect.*
- *IMF can be applied with wire for rigid IMF, or with elastic bands for elastic IMF.*
- *Following ORIF, the patient may be placed into either rigid or elastic IMF at the surgeon's discretion. If rigid IMF is used, it should be released within 2 to 3 weeks in most cases and replaced with elastic IMF to permit range of motion while providing occlusal guidance.*
- *At our center, the protocol period for IMF time is 6 weeks in either elastic IMF or in a combination of rigid and elastic IMF.*
- *Arch bars provide a tension band effect and can accommodate a variety of wire or elastic placements and vectors. Arch bars may be used for any fracture.*
- *IMF screws may be placed and/or removed relatively quickly. They are most useful in fractures that do* not *occur between teeth, because they provide no stability along the upper border.*
- *All patients with IMF should be provided with a means to release fixation in the event of emesis. Wire cutters should accompany patients home. Antiemetics should be used during and after surgery.*
- *Edentulous patients and children with deciduous or early mixed dentition require special consideration for IMF.*

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8 Local Anesthetics

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Background

Local anesthetics constitute a class of drugs that temporarily block nerve conduction by reversibly binding to and inactivating neuronal sodium channels. Without the influx of sodium ions, the depolarization threshold is not reached, and action potentials are halted.

Local anesthetics can be injected locally into tissue to produce a field block, *around peripheral nerves to produce a specific* dermatome block, *around nerve plexuses to produce a* major conductive block, *or into the spinal or epidural space to produce extensive* neuroaxial blockade. *Venous infusion of local anesthetic with tourniquet isolation to prevent systemic circulation (the* Bier block*) is possible in the extremities.*[1]

ANESTHETIC AGENTS

Mechanism of Action

To induce anesthesia, a local anesthetic agent must cross the epineurium, perineurium, and endoneurium to reach the neuron cell membrane. The epineurium and endoneurium are rather freely permeable, whereas the permeability of the perineurium differs by region. The perineurium of peripheral nerves is relatively impermeable, thus requiring much higher doses of anesthetic (approaching 50 times higher) compared with what is required for spinal anesthesia.[1]

As the concentration of local anesthetic increases around a nerve, autonomic transmission is blocked first, followed by sensory transmission, and then motor nerve transmission.[1]

Classification of Anesthetic Agents

Local anesthetics are divided into two groups based on their chemical structure: the amino amides and the amino esters. The first local anesthetic used in clinical practice was cocaine, an amino ester derived from the leaves of the *Erythroxylum coca* plant. Cocaine remains the only naturally occurring local anesthetic to be used in clinical practice, although numerous derivatives have been synthesized. Table 8-1 lists some of the more commonly used anesthetics and their properties.

Table 8-1 Commonly Used Anesthetic Agents

Anesthetic	Formulation (%)	Onset* (min)
Cocaine	4	1-10
Lidocaine (Xylocaine)	1	<2
	1, with 1:100,000 epinephrine	<2
	2	<2
Bupivacaine (Marcaine)	0.25	5
	0.25, with 1:100,000 epinephrine	0.5
	0.5	5
Ropivacaine (Naropin)	0.2	1-15
	0.5	1-15
Procaine (Novocaine)	1	2-5
	2	2-5

*Onset and duration depend on the method of application (such as infiltration, topical administration, and so on). These values are approximations only.

Amino Amide

Amino amide anesthetics have in common an amide linkage between a benzene ring and a hydrocarbon chain ending in a tertiary amine. The benzene ring confers lipid solubility for penetration of nerve membranes, and the tertiary amine attached to the hydrocarbon chain makes these local anesthetics water soluble. Amide anesthetics are metabolized by the liver. Examples of amide anesthetics are lidocaine, bupivacaine, mepivacaine, prilocaine, and ropivacaine.

Amino Ester

Amino ester anesthetics have an ester linkage in place of the amide linkage. They are metabolized by *plasma cholinesterases,* which yield metabolites (such as PABA) with slightly higher allergenic potential. Examples of ester anesthetics are cocaine, procaine, chloroprocaine, tetracaine, and benzocaine.

Approximate Duration* (hr)	Maximum Dosage (mg/kg)	Maximum Volume (ml/kg)	Comments
0.5	2	0.05	Ester
0.5-1.5	4	0.4	Amide
1.5-3	7	0.7	
1-1.5	4	0.2	
3-5	2	0.8	Amide
5-8	3	1.2	
4-6	2	0.4	
8-13	2.5	1.25	Amide
8-13	2.5	0.5	
0.25-0.5	7	0.7	Ester
0.5-1	7	0.35	

Pharmacokinetic Characteristics

Potency

Potency is related to *lipid solubility:* The more lipophilic an anesthetic agent, the more quickly it penetrates the neuronal membrane to effect a block. The onset of action is also related to the pKa of the anesthetic and the proportion of the drug that remains in the unchanged base form. An agent with a lower pKa (for example, lidocaine, with a pKa of 7.6) will have a faster onset than an agent with a higher pKa (for example, bupivacaine, with a pKa of 8.1).[2,3]

Duration of Action

Duration of action depends on the degree of *protein binding:* highly protein-bound drugs (such as bupivacaine, 95% protein-bound) are long-acting, whereas less protein-bound drugs (such as procaine, 6% protein-bound) are short-acting.

Duration of action is also affected by systemic absorption, which in turn depends on vascular clearance from the field of infiltration. All anesthetics other than cocaine are *vasodilatory* when administered at clinical doses. (Cocaine is uniquely vasoconstrictive, making it useful in intranasal surgery.) Vasodilation results in systemic absorption of the anesthetic, therefore decreasing its duration of action. The addition of epinephrine to an anesthetic counters the vasodilatory effect. Because less anesthetic is absorbed systemically, the addition of epinephrine prolongs the duration of locoregional anesthesia and allows a greater dose to be used without incurring systemic toxicity. Commercial concentrations of 1:100,000 and 1:200,000 epinephrine are available. High doses of epinephrine may lead to tissue necrosis or rebound hyperemia and bleeding.[4]

Toxicity

Toxicity of local anesthetics results from absorption into the bloodstream or from inadvertent direct intravascular injection. Toxicity manifests first in the more sensitive central nervous system, followed by the cardiovascular system.

Central Nervous System

As the plasma concentration of local anesthetic rises, symptoms progress from restlessness to complaints of tinnitus. Slurred speech, seizures, and unconsciousness follow. Halting the seizures by administering benzodiazepine or thiopental and maintaining the airway are immediate treatment measures. If the seizure persists, the trachea must be intubated with a cuffed endotracheal tube to guard against pulmonary aspiration of stomach contents.

Cardiovascular System

With increasingly elevated plasma levels of local anesthetics, progression to hypotension, increased P-R intervals, bradycardia, and cardiac arrest may occur. Bupivacaine is more cardiotoxic than other local anesthetics. It has a direct effect on ventricular muscle, and because it is more lipid soluble than lidocaine, it binds tightly to sodium channels (it is called the fast-in, slow-out local anesthetic).

Patients who have received an inadvertent intravascular injection of bupivacaine have experienced profound hypotension, ventricular tachycardia and fibrillation, and complete atrioventricular heart block that is extremely refractory to treatment.

Calculation of the upper limit dose before injection is imperative. The recommended maximum dose of lidocaine without epinephrine is 3 to 5 mg/kg or 5 to 7 mg/kg with epinephrine. The toxic dose of bupivacaine is approximately 3 mg/kg.

Maximum dose and volume calculation: It is helpful to remember that for any drug or solution, 1% = 1 g/100 ml = 10 mg/ml. For a 50 kg (110 pound) person, the toxic dose of bupivacaine is approximately 3 mg/kg × 50 kg = 150 mg. A 0.5% solution of bupivacaine equals 5 mg/ml. Therefore, the maximum volume that can be infiltrated before reaching a potentially toxic dose can be calculated at 150 mg ÷ 5 mg/ml = 30 ml. For lidocaine without epinephrine in the same patient, the calculation is 5 mg/kg × 50 kg = 250 mg upper limit dose; for a 1% solution, the upper limit volume is 250 mg ÷ 10 mg/ml = 25 ml.

COMPOUNDING AND USEFUL ADJUNCTS

Mixing various anesthetics, a process called *compounding,* allows one to achieve the onset of action of a fast-onset anesthetic (such as lidocaine) with the duration of action of a long-lasting anesthetic (such as bupivacaine). The toxicity of a mixture is typically no greater than that of its components.[1,5] Toxicity results from inadvertent intravascular injection or overdosage and may include CNS manifestations (such as seizures or respiratory depression) and cardiovascular effects (such as hypotension, bradycardia, and arrhythmias).

Other medications may serve as valuable adjuncts to local anesthetics. Examples include premedication of mucosal surfaces or skin with viscous lidocaine or topical lidocaine (such as EMLA, LMX4, Betacaine) before local infiltration, administration of systemic opioids or anxiolytics (such as benzodiazepines), conscious sedation (such as ketamine), or general anesthesia.

LOCOREGIONAL BLOCKADE IN THE HEAD AND NECK

Cutaneous innervation to the head, face, and neck is provided by the *trigeminal nerve* (CN V, the fifth cranial nerve) and cervical nerves (Figs. 8-1 through 8-3 and Table 8-2). Several locoregional blocks may be used, as required by the procedure. Selected blockades are described below by region to be anesthetized. Depending on the specific neurologic anatomy, a particular regional block may anesthetize neighboring regions.

> One should always draw back on the syringe to avoid inadvertent intravascular injection, and injection should be gentle, never forceful, particularly in the periorbital region.

Text continued p. 113

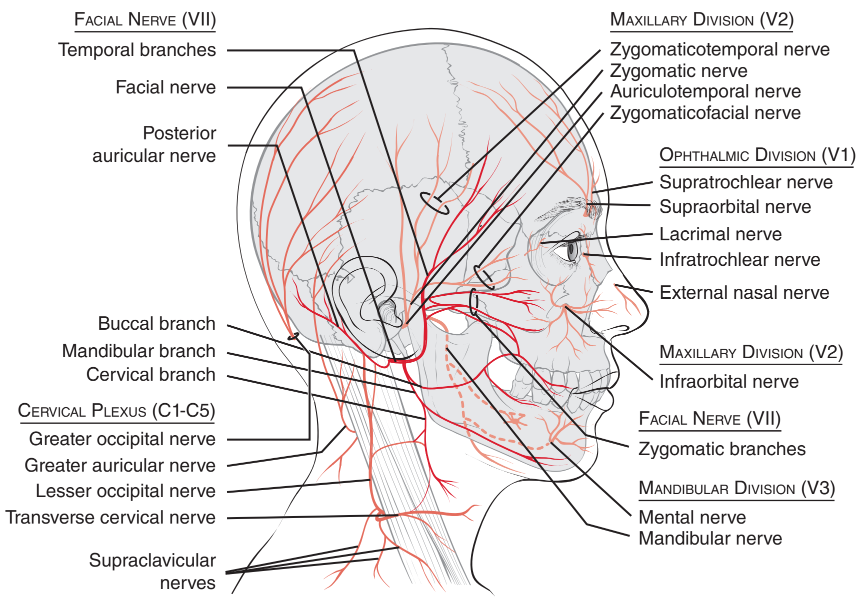


Fig. 8-1 Cutaneous innervation of the scalp, face, and neck.

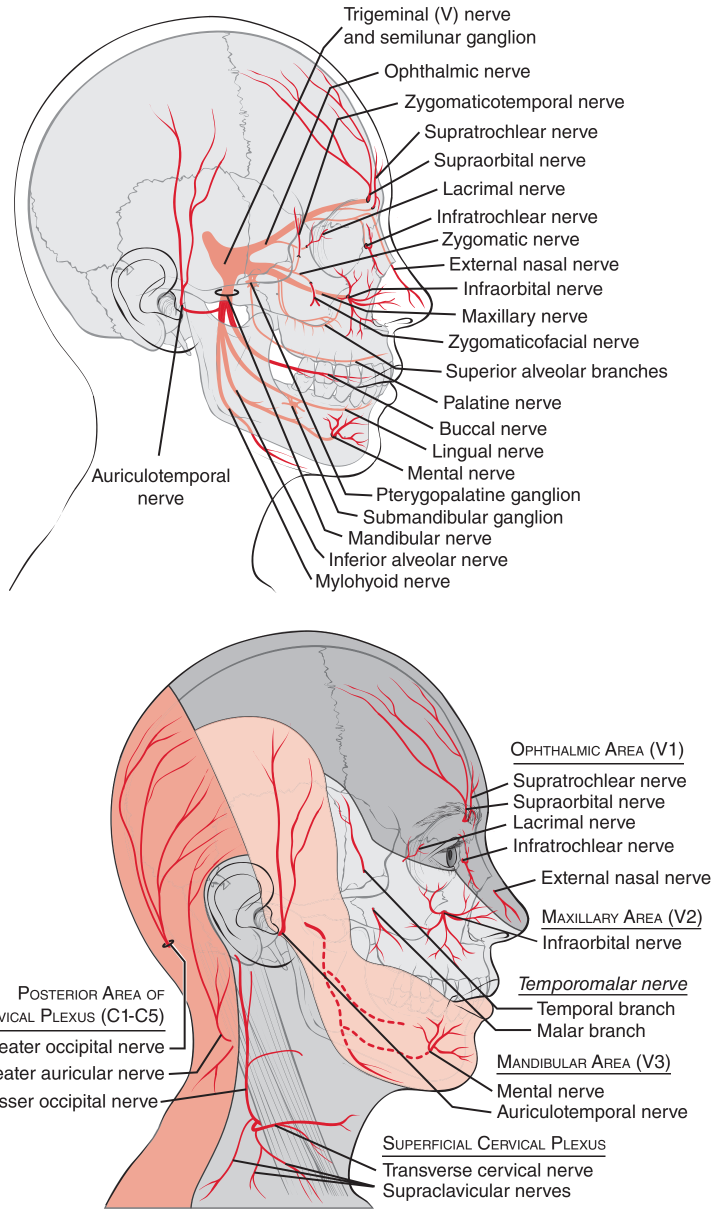


Fig. 8-2 Divisions and dermatomal innervation of the trigeminal nerve (CN V).

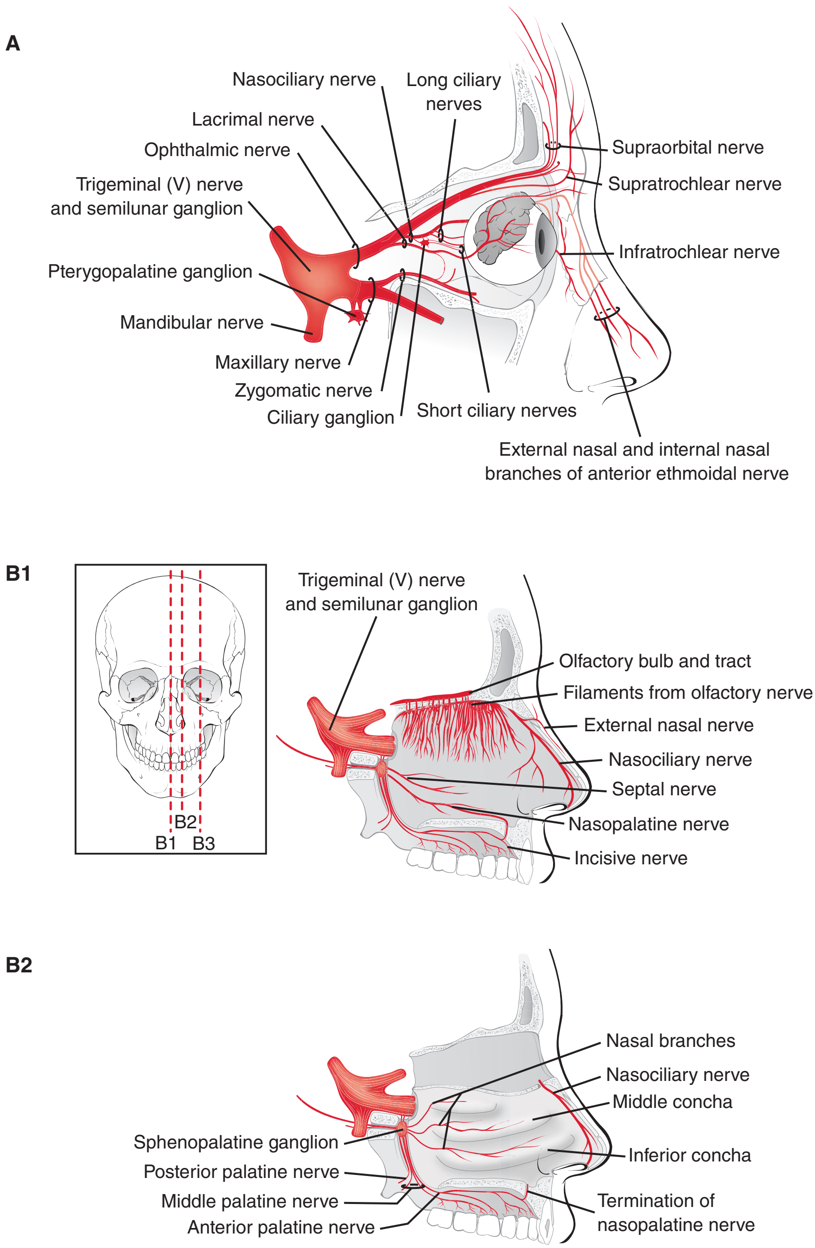
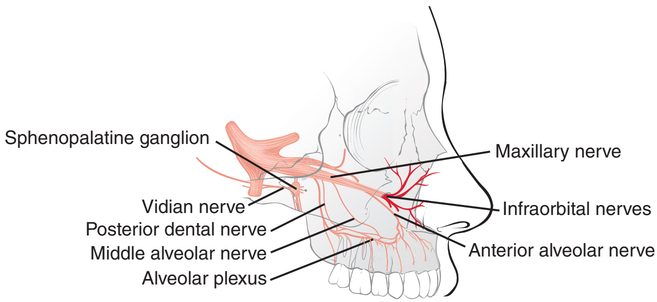


Fig. 8-3 Anatomy of the, **A,** ophthalmic division (V1), **B,** maxillary division (V2) and, **C,** mandibular division (V3).

B3



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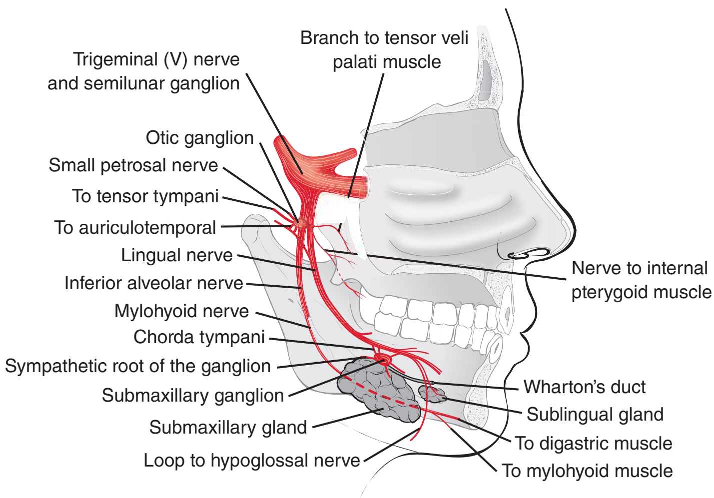

Fig. 8-3, cont'd

Table 8-2 Cutaneous Innervation of the Head and Neck

Block	Nerve(s) Being Blocked	Region Anesthetized
Ophthalmic division (V1)	• Frontal	
	– Supraorbital – Supratrochlear	Forehead and anterior scalp from the eyebrows to the vertex
	• Nasociliary	
	– Infratrochlear	Medial eyelids and conjunctiva, superolateral nose
	– Anterior ethmoidal – Posterior ethmoidal	Nasal septum and the lateral wall of the nasal cavity
	– External nasal nerves	Nasal dorsum and lateral surface to the nasal tip, nasal septum
	• Lacrimal	Superolateral aspect of upper eyelid
Maxillary division (V2)	• Inferior palpebral	Lower eyelid
	• Infraorbital	Lower eyelid, lateral nose, columella
	• Zygomatic	
	– Zygomaticotemporal	Temporal scalp
	– Zygomaticofacial	Malar eminence
	• Nasopalatine nerves	Palate, nasal septum, nasal mucosa and sinuses, maxillary dentition
	• Greater/lesser palatine nerves	
	• Superior alveolar nerves	
	• Superior labial	Upper lip
Mandibular division (V3)	• Mandibular • Inferior alveolar	Lower jaw, gingiva, mandibular dentition
	• Auriculotemporal	Preauricular skin, ear (tragus, crus helicis)
	• Lingual	Anterior two thirds of tongue
	• Mental	Lower lip, labial commissures, chin
Cervical plexus (C1-C5)	• Greater and lesser occipital nerves	Posterior scalp, occiput
	• Great auricular	Ear, mastoid
	• Transverse cervical	Anterior neck
	• Supraclavicular nerves	Clavicle, shoulder

Forehead and Frontoparietal Scalp

Both the supraorbital and supratrochlear nerves are terminal divisions of the ophthalmic branch (V1) of the trigeminal nerve (CN V) and emerge from the orbit to provide sensory innervation to the forehead. The *supraorbital nerve* emerges from the supraorbital foramen, which can be palpated along the upper border of the orbit, approximately 2.5 cm lateral to the midline of the face. The *supratrochlear nerve* lies more medially, at the angle formed by the eyebrow and the nasal spine.

Blockade of these nerves is accomplished by inserting the needle just inferior to the lateral third of the eyebrow; 1 ml of local anesthetic is infiltrated as the needle is advanced medially along the superior orbital margin. Just medial to the supraorbital notch, which can be palpated, an additional 2 or 3 ml of anesthetic is injected, advancing medially to touch the nasal bones.[6]

Eyelids

The upper eyelid is innervated medially by the *infratrochlear nerve* and laterally by the *lacrimal nerve.* The infratrochlear nerve is also anesthetized during the supratrochlear–supraorbital nerve blockade just described. Alternatively, it can be targeted directly by a 2 or 3 ml infiltration 1 cm medial to the supraorbital notch. The lacrimal nerve may be anesthetized by infiltrating 1 ml of local anesthetic superior to the lateral canthus tendon.[6]

The lower eyelid is innervated by the *inferior palpebral* and *infraorbital nerves.* The infraorbital nerve may be approached using an intrabuccal approach: the nondominant hand is used to retract the upper lip, and the needle is directed into the canine fossa toward the palpated infraorbital foramen. Alternatively, the nerve may be anesthetized using a percutaneous nasolabial approach: the needle is inserted between the upper nasolabial groove and the alar rim, which should lie directly inferior to the medial limbus of the iris, approximately 7 mm inferior to the inferior orbital rim. The needle is advanced until it enters the infraorbital foramen. Typically, 1 or 2 ml of anesthetic is used.

Nose and Nasal Mucosa

The skin of the nose is innervated predominantly by the *external (dorsal) nasal nerve,* a continuation of the nasociliary branch of V1. The nerve innervates the nasal dorsum, lateral surface, ala, and tip. Blockade of this nerve is accomplished by injecting 1 or 2 ml of local anesthetic (per side) approximately 7 mm lateral to the midline of the nasal bones. This technique should be employed before any local infiltration of the nasal tip, which is otherwise quite painful.

The lateral nasal sidewall, including ala and columella, is innervated by the *infraorbital nerve,* which is blocked according to the method previously described for the lower eyelid.

Sensation to the superior portions of the septum and lateral wall of the nasal cavity is supplied by the *nasociliary–anterior ethmoidal nerve,* a terminal branch of V1. The inferior and posterior portions of the septum and the lateral wall of the nasal cavity are innervated by branches arising from the sphenopalatine ganglion. These terminal branches lay superficially just beneath the nasal mucosa and can be anesthetized by direct topical application of a local anesthetic, such as cocaine. They may also be anesthetized during regional blockade of the supraorbital/supratrochlear/infratrochlear nerves, described previously.

Cheek and Temporal Scalp

The zygomatic nerve, a branch of V2, bifurcates into the zygomaticotemporal and zygomaticofacial nerves to supply the temporal scalp and malar eminence, respectively. The *zygomaticotemporal nerve* blockade is accomplished by inserting the needle behind the lateral orbital and advancing to approximately 1 cm inferior to the lateral canthus. The *zygomaticofacial nerve* is blocked where it exits through a foramen in the zygoma less than 1 cm inferolateral to the junction of the inferior and lateral orbital rims.[6]

To anesthetize the bulk of the cheek and preauricular skin, the *mandibular nerve* (V3) must be blocked at the base of the skull: The sigmoid notch between the mandibular coronoid process and condyle is located by palpation approximately 2 cm anterior to the tragus. A long spinal needle is inserted through the notch and directed perpendicularly to a depth of approximately 3 cm, when it hits the pterygoid plate. Drawing back on the syringe will avoid intravascular injection. Typically, 3 to 5 ml of anesthetic is used.[6]

Ear

The tragus and crus helicis are innervated by the *auriculotemporal nerve,* whereas the external auditory meatus is innervated by *Arnold's auricular branch* of the vagus nerve. The remainder of the ear and postauricular skin is innervated by the *great auricular nerve* of the cervical plexus.

Blockade of the auriculotemporal nerve is accomplished by infiltrating 1 ml of anesthetic anterior and superior to the external auditory meatus. Blockade of the great auricular nerve is accomplished by infiltrating 2 ml of anesthetic over the sternocleidomastoid muscle approximately 7 cm inferior to the external auditory meatus.[6]

Lower Lip and Chin

The *mental nerve* is the terminal continuation of the inferior alveolar nerve of V3 as it exits the mental foramen, which is generally below the second bicuspid. Blockade is accomplished by intraoral injection of 1 ml of local anesthetic submucosally in the gingivobuccal sulcus beneath the second lower bicuspid. This anesthetizes the lower lip to the level of the labiomental fold.

To fully anesthetize the chin pad, either an inferior alveolar nerve blockade or the *mental plus* block described by Zide and Swift[6] may be employed. For the latter, the lower lip is retracted outward, and the needle is inserted in the anterior gingivobuccal sulcus inferior to the lower central incisors. The needle is advanced to below the level of the inferior border of the mandible, and an additional 1 ml of anesthetic is injected.

At times, full anesthesia of the chin requires blockade of the *transverse cervical nerve* of the cervical plexus. This is anesthetized by local infiltration anterior to the sternocleidomastoid muscle.

Pearls

- *Lidocaine and bupivacaine are two of the more commonly used local anesthetics, and it is imperative to know their maximum doses. The recommended maximum dose of lidocaine without epinephrine is 3 to 5 mg/kg or 5 to 7 mg/kg with epinephrine. The toxic dose of bupivacaine is approximately 3 mg/kg. For any agent, a 1% solution is equivalent to a concentration of 10 mg/ml.*
- *For some procedures, local infiltration is sufficient. For others, the patient may be more comfortable if a regional nerve block is employed. Certain anatomic areas require that multiple nerves be anesthetized to achieve full effect.*

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9 Airway Management: Anesthetic and Perioperative Considerations

Richard Turley, Liana Puscas

Background

A craniomaxillofacial (CMF) trauma patient presents unique perioperative issues and challenges for first responders, emergency physicians, the CMF surgeon, the anesthesiologist, and the rest of the health care team. The foremost challenge is airway management, which is the primary topic of discussion in this chapter. Pertinent airway anatomy, the approach to airway evaluation, airway management options, and the effects of various fracture patterns on airway management are reviewed. Positioning in the operating room, postoperative care, potential complications, and follow-up issues unique to CMF patients are also discussed.

REGIONAL ANATOMY

The upper airway is anatomically and physiologically complex; it includes the nasal passages, oral cavity, pharynx, larynx, and trachea (Fig. 9-1). The key to evaluating and managing patients with CMF and potentially compromised airways is having a thorough understanding of the normal airway and the ways in which CMF injuries

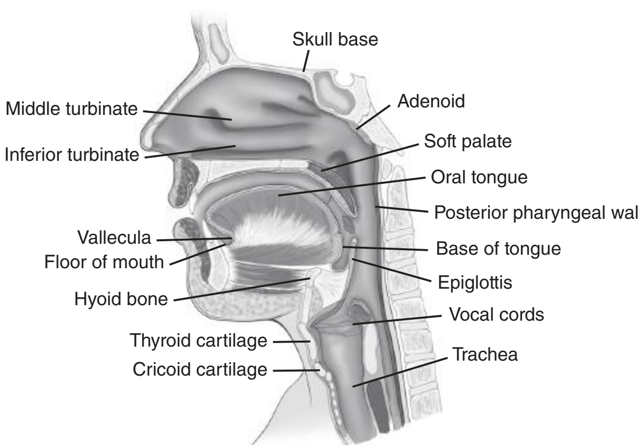

Fig. 9-1 Sagittal view of the upper airway.

can alter the airway. By definition, nearly all CMF injuries involve the airway to some extent and can thus lead to potential compromise.[1]

APPROACH TO AIRWAY EVALUATION

Because *airway* is the A in the ABC evaluation of any trauma patient, airway evaluation and management begins from the moment that the first responders arrive at the scene of injury. The CMF surgeon is usually consulted well after initial stabilization; however, regardless of when the patient is first evaluated, the airway should be the initial focus. A systematic approach is begun with a general assessment, which can be accomplished by an observant consultant within the first few seconds of entering the patient's room. The patient's respiratory rate and effort, position (sitting or supine), and voice, as well as the presence or absence of stridor, stertor, cyanosis, vomiting, drooling, or bleeding are all noted. The patient's mental status, including the level of alertness and cooperation, anxiety, agitation, and possible intoxication, are also noted, because these can all affect how much airway compromise the patient will tolerate, along with the urgency and the method necessary to secure the airway. For example, a severely intoxicated patient may have decreased airway protection reflexes but will tolerate full examination, whereas an anxious child with significant pain may maintain his or her airway without difficulty but may not allow full examination. Because many CMF trauma patients present with full stomachs and may be combative because of traumatic brain injury or have altered mental status as a result of intoxication, it is important to treat nausea aggressively. Vomiting can lead to aspiration, especially in a supine patient wearing a C-spine collar.[1-3]

Following a general evaluation, each portion of the airway should be systematically evaluated as part of the standard CMF examination. The examiner should assess the nasal cavity, taking note of bleeding and obstruction from clots, nasal and septal fractures, or a septal hematoma. The oral cavity examination should include checks for lacerations, hematomas, ecchymosis, edema, decreased tongue mobility, trismus, and compromised patency of the oral cavity. If trismus is present, it is important to determine whether it is caused by pain alone and will thus improve after sedation, allowing oral intubation, or whether the restriction is the result of posttraumatic anatomic change that will not improve with sedation. The floor of the mouth should be palpated, because a submental hematoma can lead to retropulsion of the tongue base, resulting in compromise of the oropharyngeal airway.

The laryngeal landmarks—hyoid, thyroid notch, cricoid, and proximal trachea—should be palpated. Significant laryngeal tenderness, hoarseness, lacerations, crepitus, swelling, or ecchymosis of the neck are all signs of a potential laryngotracheal injury, which, although very rare, can cause precipitous airway compromise. The CMF surgeon should therefore maintain a high index of suspicion for laryngeal fractures when evaluating all CMF trauma patients with any of these neck findings. Verschueren et al[4] found that more than 95% of patients with laryngotracheal injuries had concomitant CMF injuries. Stable patients with these symptoms should undergo airway evaluation with a flexible fiberoptic scope; unstable patients, when there is concern for laryngeal injury, should undergo an emergent awake tracheostomy.[4]

Included in the initial evaluation is a cervical spine assessment. If the patient already has a C-spine collar in place, the anterior portion should be carefully removed to fully examine the neck while maintaining in-line stabilization. If the patient's cervical spine has already been clinically cleared, the CMF surgeon should verify that this has been documented. If the cervical spine has not yet been cleared, the CMF surgeon should consult with the trauma and/or spine team regarding how and when the cervical spine will be evaluated.

After the initial evaluation is complete, it is critical to keep in mind that maintaining airway patency is a dynamic process, and patients may develop progressive obstruction from posttraumatic swelling, bleeding, or changes in mental status. All CMF trauma patients should be serially evaluated, and those who are at high risk for developing airway compromise should either have their airway definitively secured or be observed in a unit that can provide frequent airway monitoring. One study found that 16% of mortalities in inpatient trauma patients are caused by failure to intubate, secure, or protect the airway.[1]

AIRWAY MANAGEMENT OPTIONS

Determining the best method for airway management requires collaboration among the emergency department and the anesthesia and surgical teams. This is especially important in the preoperative period. Before starting the anesthetic, the surgeon and the anesthesia provider should discuss the patient's other medical comorbidities and injuries, the CMF injury pattern, the surgical exposure issues, and any potential difficulties in securing the airway. Based on all of these factors, an airway plan should be formalized, including backup options in case the initial plan is unsuccessful. In the emergent setting or in a patient with a known difficult or tenuous airway, the most experienced providers available should perform the airway procedures.[2] Although the anesthesia team is usually responsible for obtaining the airway, the surgical team should be present in the room during intubation (and extubation) to give assistance if needed, especially in case a surgical procedure is needed to obtain the airway. Another reason for the surgeon, especially a surgeon in training, to participate in obtaining the airway is to gain experience and improve his or her skills. These are valuable skills that can be useful in emergency situations when more experienced airway providers may not be available, and the CMF surgeon may need to take the primary role in securing the airway.

Preparation

Before using any airway techniques, all blood and secretions in the oral and nasal cavities should be suctioned and foreign bodies and loose teeth removed. Epistaxis and facial bleeding should be controlled with packing or direct pressure. In the nonemergent setting, all airway equipment should be checked to ensure that it is functioning and should be laid out in a stepwise fashion so that it is easily accessible. For airways that are known to be difficult, advanced equipment, including fiberoptic scopes, fast-track laryngeal mask airways (LMAs), and a tracheostomy kit, should all be in the room.

Oxygen by Nasal Cannula or Face Mask

Occasionally, oxygen can be administered through a nasal cannula or mask for patients undergoing mild sedation for repair of soft tissue injuries. If electrocautery is used, a nonvolatile preparation solution should be used, and tenting of the surgical drapes should be avoided to prevent an airway fire.

Laryngeal Mask

An LMA can be placed blindly; it allows ventilation and oxygenation but does not completely prevent aspiration. It should therefore be thought of as an oropharyngeal rather than a definitive airway, but it can often be used to bridge an unstable patient until more advanced equipment can be obtained.[3] Fast-track LMAs allow placement of a standard oral endotracheal tube (ETT) through the LMA, either blindly or with fiberoptic guidance; this can be helpful in facilitating intubation of a patient with a difficult airway.

Oral Intubation

In an acute trauma patient, rapid-sequence induction is performed by giving simultaneous sedation and neuromuscular blockade while maintaining cricoid pressure. This allows rapid establishment of the airway while decreasing the risk of aspiration.[3] A variety of laryngoscope blades and videolaryngoscopes are available that can be useful with difficult airways. Cook catheters or bougies can be placed in the airway initially if there is significant laryngeal edema, and the endotracheal tube can then be placed over the catheter using a Seldinger technique. Once the ETT is in place, the surgeon should ensure that it is adequately secured so that it will not be dislodged with surgical manipulation. Per usual protocol, the position of the tube is verified by listening to breath sounds, checking carbon dioxide tracing, observing bilateral chest rise, and so on. If intermaxillary fixation (IMF) will be included in the procedure, a reinforced tube can be placed in a retromolar position to keep the ETT out of the surgical field. In this case, the surgeon needs to be aware of how deep the tube is placed and take care not to extubate the patient when manipulating the tube during the operative repair. Lee et al[5] described a method of securing the retromolar ETT by suturing it to the last molar or to a tooth adjacent to a gap in the dentition from a missing tooth. If IMF screws can be used, they may be preferable, because securing the ETT to the teeth in this manner can interfere with placement of arch bars (Fig. 9-2).

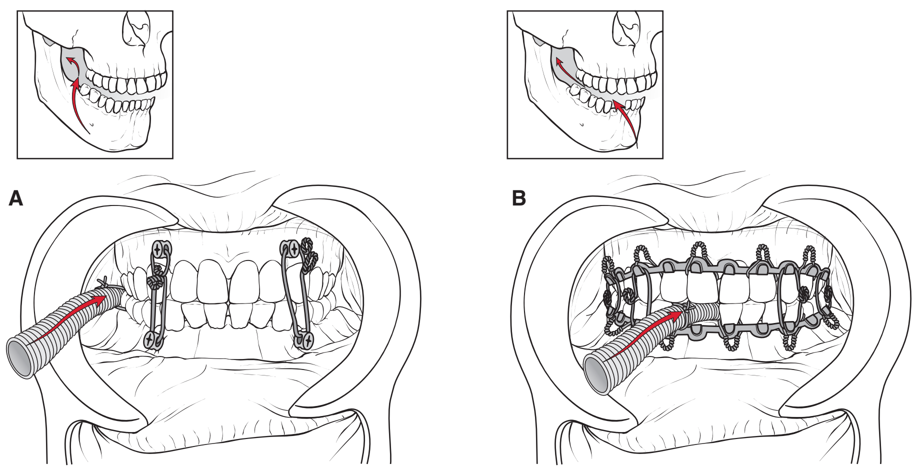

Fig. 9-2 Methods of alternative endotracheal tube placement when nasal intubation is not possible. **A,** In retromolar placement, the tube is passed behind the last molar and secured with a wire to the tooth. Some compression of the tube may occur when IMF is applied, making this technique less favorable. **B,** In "gap" placement, the tube is placed in a gap between teeth if one is present. The tube is secured with wire to the mandibular teeth.

Nasal Intubation

Nasal intubation can be done with a standard endotracheal tube or a nasal RAE tube, which is longer and has a bend to allow it to be secured to the forehead more easily. Before placing the ETT, the nose should be decongested with oxymetazoline (Afrin) or a similar agent, and the nasal passage should be dilated with progressively larger nasal trumpets. This decreases the risk of epistaxis, which can greatly complicate intubation and extubation. While the nose is prepared, the ETT is softened by soaking it in warm saline solution. The tube is then lubricated and gently passed through the nasal cavity into the oropharynx, and a McGill forceps is used to advance the tube into the airway while direct laryngoscopy is performed. Care must be taken to avoid damaging the cuff when grasping the tube with McGill forceps. Once the tube is in the appropriate position, we prefer to secure the tube to the membranous nasal septum with a 2-0 silk suture. The suture is passed from the side with the ETT through the membranous septum, then through a small piece of prep sponge (to prevent undue pressure on the septum), then back through the septum. The suture is then tied, looped around the ETT and tied again. A second suture is used to secure the ETT at the forehead. This is done by placing a prep sponge between the ETT and the forehead and then passing the suture through the sponge, then the skin, and back through the sponge. It is then looped around the ETT, and the same process is repeated on the other side and tied tightly. This secures the tube while minimizing the risk of pressure necrosis (Fig. 9-3).

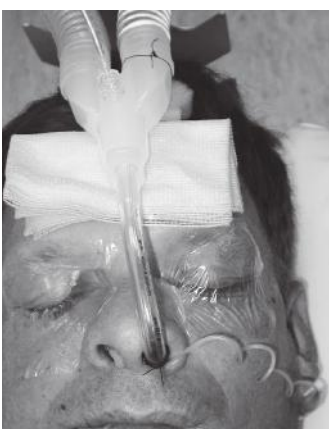

Fig. 9-3 Nasal intubation is the preferred method in most facial trauma procedures. A nasal RAE tube is used so that the bend allows the circuit to pass superiorly over the patient's head. The ETT is secured at two sites. First, the tube is secured with a single 2-0 silk suture through the membranous septum. A small piece of foam opposite the side with the tube prevents the suture from pulling through the septum. The second suture is placed at the hairline to secure the circuit so that there is no pressure on the ala.

Awake Fiberoptic Intubation

Fiberoptic intubation of an awake patient may be necessary when oral intubation is not possible because of the presence of trismus, soft tissue edema of the airway, or injuries that may make it difficult to use mask ventilation (as is usually done before an attempted oral intubation). Awake fiberoptic intubation can be done either orally or nasally. Managing the patient's anxiety during the procedure is paramount for its successful execution; the airway team should explain each step before and during the procedure to keep the patient calm and cooperative. The patient's airway is topically anesthetized by spraying 4% lidocaine in the nose and pharynx and having the patient then gargle this solution several times. The nose is decongested and dilated, and the ETT is prepared as previously described. The ETT is passed over the fiberoptic scope, the nasal and oral passages are suctioned clear, and the scope is carefully passed through either the mouth or nose until the larynx is visualized. The larynx is carefully touched with the scope, and if this causes coughing, indicating inadequate topical anesthesia, lidocaine is sprayed on the larynx and vocal folds through the port in the scope. The scope is then passed between the vocal folds to the distal trachea. The ETT is then advanced over the scope in a Seldinger fashion, and the position of the distal end of the ETT relative to the carina is assessed with the scope. Once the tube is appropriately positioned, the patient is sedated, and the tube is secured, as described previously. All of the sedating medications should be in-line before starting the intubation, because once the tube is in place, the patient may become agitated, and rapid sedation may be necessary to prevent self-extubation.

Cricothyroidotomy

Cricothyroidotomy is an emergency procedure, used only when other ventilation methods (such as intubation or bag mask) have failed, and there is not sufficient time to perform a tracheotomy. The cricothyroid membrane is palpated 1 to 2 cm inferior to the thyroid notch. A horizontal incision is made through the skin and extended deeply through the membrane itself until the airway is entered. A clamp is then used to spread the cricoid and thyroid cartilages apart. If instrumentation is not available, the handle of the scalpel can be inserted in the wound and turned 90 degrees. A tracheostomy tube or ETT is then inserted in the airway and secured in place until the patient is stabilized and a formal tracheotomy can be performed.

Tracheostomy

Indications for a tracheostomy include upper airway obstruction, airway diversion for or after facial fracture repair, pulmonary toilet, long-term mechanical ventilation, neurologic injury, laryngotracheal injury, and extensive facial fractures.[6] Tracheostomy has been shown to improve patient comfort, provide better pulmonary toilet, reduce the length of ventilation and ICU stay, and decrease the risk of glottic and subglottic stenosis (compared with prolonged intubation for more than 10 to 14 days).[6] Many multiorgan trauma patients with facial fractures meet one or more indications for tracheostomy. Performing tracheostomy during the same anesthetic, just before facial fracture repair, not only prevents the patient from receiving multiple anesthetics but can also facilitate surgical exposure for the facial fracture repair. Holmgren et al[6] found that more than 1 in 10 patients with facial fractures undergo tracheostomy, of which nearly a third are performed for reasons other than the CMF trauma itself. This highlights the importance of reviewing the patient's concomitant medical problems and traumatic injuries before scheduling CMF repair. There are a variety of approaches to performing tracheostomy, including percutaneous and various open approaches. The pros and cons of each are well documented in the literature and are not discussed here.

> If an airway method other than a tracheostomy is used during facial trauma surgery, the neck should always be prepped so that an emergent tracheostomy can be performed in case the tube is dislodged and cannot be replaced.

Submental Intubation

Although we do not have experience with submental intubation, there is significant discussion in the literature regarding this technique for airway diversion during CMF repairs that require IMF and an unobstructed surgical field. Proponents of submental intubation report that, in some situations, it can provide a secure airway while avoiding some of the complications of tracheostomy and nasotracheal intubation; however, it has several drawbacks, and its use must be tailored to the individual situation.[7]

FRACTURE PATTERNS

Many cases of facial trauma involve direct injury or alteration of the airway; however, even in injuries that do not directly affect the airway, operative repair usually requires the surgeon to "work around the airway"; that is, the endotracheal or tracheostomy tube. Each main fracture pattern requires a unique approach to maintain a secure airway while allowing adequate exposure of the operative site to repair the injury.

Soft Tissue

Soft tissue injuries can create significant bleeding that can result in aspiration and respiratory compromise. Initial management should include nasal packing for brisk epistaxis or soft tissue injury in the perinasal area that results in blood draining into the nasal airway. Before packs are placed, the nose should be gently suctioned, ideally under direct visualization, to remove all clots. Placing nasal packs in a nose already filled with clots often pushes the clots into the oropharynx, which may result in aspiration. Also, if packs are placed, the surgeon should keep in mind that the patient must now rely completely on the oral airway alone, which may not be sufficient for some patients, depending on their injuries. Oral or facial bleeding that is draining into the mouth should be quickly stopped. Massive injury may require intubation to prevent aspiration and allow the surgeon to stop the bleeding in a controlled manner. Soft tissue injury often results in significant swelling that progresses over the first 1 to 3 days after injury, and this may lead to airway obstruction. When soft tissue repair requiring electrocautery is done with the patient under sedation, the surgeon should use a nonalcohol-based preparation solution and avoid tenting drapes over the nasal cannula and face mask oxygen, since these can predispose to fire.

Nasal/Septal

Nasal or septal injuries can result in significant epistaxis, which should be controlled quickly, as discussed earlier. Isolated nasal fractures can be repaired in the operating room using standard oral intubation with a throat pack to prevent aspiration of blood.

Upper Midface

The upper midface includes orbital, nasoorbital ethmoid, zygomaticomaxillary complex (ZMC), and frontal sinus fractures. If these fractures are isolated or occur in conjunction with one another, the airway can be secured with standard oral intubation and a throat pack. Because taping an ETT to the oral commissure can sometimes pull the soft tissues of the face to one side and distort the normal facial symmetry, we recommend using an oral RAE tube taped to the midline mandible. For example, when repairing a ZMC fracture, the surgeon needs to compare the malar eminences with each other for symmetry to ensure that reduction is adequate. If the ETT is pulling the facial tissues to one side, it may be more difficult to evaluate the reduction.

Skull Base

Original versions of advanced trauma life support (ATLS) protocols stated that placement of nasogastric tubes, nasal trumpets, or nasotracheal tubes in a patient with potential or confirmed anterior skull base fractures is contraindicated because of reports of intracranial injury from these measures. However, Perry and Morris,[2] in their review of ATLS and facial trauma, stated that the risk of this type of injury is very low if these devices are placed by an experienced provider. The advent of fiberoptic flexible scopes has made it possible to place a nasal trumpet or ETT under direct visual guidance, thus further decreasing the risk of injury to the fractured skull base.

Lower Midface

The lower midface includes LeFort I and palate fractures, which require establishment of occlusion with IMF as part of the fracture reduction and/or stabilization. For an isolated LeFort I fracture, a nasotracheal tube may be acceptable; however, we often use an orotracheal tube and place it in the retromolar position or in a gap in the dentition, if present. Either method still requires the surgeon to work around the airway in the operative field. When these fractures are combined with nasal fractures, a nasotracheal tube usually inhibits surgical exposure and is not an ideal option. Although we do not have experience with submental intubation, this method is reported to be ideal for this fracture pattern.[7]

Mandible

The airway in isolated mandibular fractures is most easily managed with a nasotracheal tube. Comminuted extensive fractures of the mandible and panfacial fractures often require a tracheostomy, because they require prolonged IMF, and their repair often results in extensive soft tissue edema of the oral cavity, resulting in airway obstruction that may prevent extubation for several days.[6]

Laryngotracheal

The most appropriate method of laryngotracheal treatment depends on the extent of the injury. Patients with nondisplaced fractures and stable airways should be evaluated with flexible fiberoptic laryngoscopy. If there is no airway compromise, these mild injuries can be treated with close observation, humidified air, and elevating the head of the bed. If there are signs of mucosal laceration, these patients should be evaluated with dedicated CT scans and direct laryngoscopy in the operating room. Patients presenting with unstable airways and signs of laryngotracheal injury should undergo an emergent awake tracheotomy using local anesthesia, followed by direct laryngoscopy and radiographic evaluation. Oral intubation should be avoided because of the risk of false passage if there is laryngotracheal separation. Displaced fractures require open reduction and internal fixation, and in the case of endolaryngeal injury, a laryngofissure approach is used to repair the laryngeal structures and place a stent, if needed. This repair should be done in the first 24 to 48 hours after the injury, before or at the same time as operative repair of facial fractures.[4]

Penetrating CMF and Neck Trauma

With severe injuries, a tracheostomy is often required. Vascular injury is common and requires urgent evaluation and management according to established guidelines. Injury to the aerodigestive tract, although less common, can have devastating complications if not repaired expeditiously.

POSITIONING

The patient should be positioned to maximize the surgeon's access to the site of repair. In the emergency department, adequate light, nursing assistance, and a table of adjustable height for instruments and supplies greatly facilitates the surgical repair. An awake patient must be sufficiently cooperative so that he or she can be appropriately positioned by the surgeon. A patient who is combative or intoxicated must be restrained (physically or pharmacologically) to at least allow examination and cleaning of the wounds. If the patient remains uncooperative, occasionally repair must be delayed a few hours until the patient is sufficiently lucid or sober to cooperate.

In the operating room, the patient's head is placed at the end of the table, and the table is usually turned 90 or 180 degrees to allow the surgeon full access to the head. The entire face is prepared and kept in the field to allow the surgeon to evaluate the reduction of fractures by examining their symmetry with contralateral structures. The neck is also prepped in case a tracheostomy is required, but it is usually covered with a towel during the procedure. If the patient has a known cervical spine injury or an uncleared cervical spine, the neck is maintained in an in-line, neutral position. This can usually be accomplished by keeping the posterior half of the C-spine collar in place and putting towels, intravenous fluid bags, or sandbags on either side. Although these methods do not completely immobilize the neck, they serve as a reminder to the surgeon not to manipulate the neck. The patient's eyes should be taped closed, or corneal guards with ophthalmic ointment should be used to prevent accidental corneal abrasion.

POSTOPERATIVE CARE

If the airway is deemed to be adequate, the patient can be extubated immediately. If mild to moderate airway edema is suspected, then treating with steroids for 12 to 24 hours before extubation may improve the chance of successful extubation.[8] If the patient requires a tracheostomy, it is our practice to change the tracheostomy tube for the first time at 3 to 7 days after surgery to ensure that the tract is healing appropriately and that the tube can be safely changed thereafter by respiratory therapy and/or nursing staff. Further routine tracheostomy care, downsizing, and decannulation can often be facilitated by respiratory therapy staff; however, if the CMF trauma dictates any change from the facility's standard protocols, this should be communicated to all members of the health care team.

Patients who are kept in IMF should be treated aggressively to prevent nausea and should have wire cutters at their bedside so that the wires can be cut in the event of vomiting. Patients going home with IMF in place should be given wire cutters to take home and receive thorough education regarding how to cut their wires if they become nauseated or vomit.

Alcohol abuse is common among CMF trauma patients and therefore appropriate monitoring and treatment of alcohol withdrawal is essential in the perioperative setting.

COMPLICATIONS

Airway fires are always a risk when using electrocautery in the presence of oxygen and a fuel source. All three are often in close proximity during CMF surgery. If a fire starts in the ETT, the patient should be immediately extubated, the oral cavity flooded with water, the airway quickly suctioned, and direct laryngoscopy and bronchoscopy performed to evaluate the extent of injury and to reestablish the airway.

There is an increased risk of losing the airway intraoperatively because of CMF injuries themselves and the need to manipulate the airway to gain surgical access. It is therefore wise to prep the neck in case the need for a surgical airway arises. Airway edema and subsequent obstruction can occur in the immediate postoperative period or in a delayed fashion. If signs of obstruction develop, the airway must be rapidly evaluated and secured.

IMF increases the risk of aspiration, and thus all IMF patients should be aggressively treated for nausea and have wire cutters at the bedside and at home, as previously discussed.

Pressure necrosis of the nose can occur with nasotracheal tubes (and nasogastric tubes), especially if they are left in place for an extended period. One study found that pressure ulcers could form after as little as 8 hours of nasal intubation.[9] Our previously described method of securing nasotracheal tubes decreases this risk; the small sponge piece prevents overtightening of the suture in the columella, and the bend in the nasal RAE tube decreases the amount of contact between the ETT and the nasal ala. If there is still some contact and prolonged intubation is expected, the nasal skin can be protected with a DuoDERM dressing.[9]

RECOMMENDED FOLLOW-UP

Tracheostomy patients should follow up with the airway surgeon as an outpatient for downsizing and decannulation, if this has not already occurred on an inpatient basis. Swallowing difficulties are common in tracheotomized as well as decannulated patients and should be fully investigated, because this may represent a complication.

Pearls

- Airway *is the A in the ABCs of trauma management and is always the highest priority for any patient.*
- *Regardless of training background (otolaryngology, plastic surgery, oral and maxillofacial surgery), all CMF surgeons should be comfortable with airway evaluation and placement of an emergency surgical airway.*
- *If a patient develops airway compromise or intubation is predicted to be difficult, it is better to get help sooner rather than later.*
- *The surgeon should collaborate with the anesthesia team. This includes forming a preoperative plan, establishing and securing the airway, positioning, safe extubation, and other considerations.*
- *The patient's other injuries and medical comorbidities should be considered when formulating the airway and surgical plan.*
- *An inexperienced surgeon should practice airway management skills in nonemergent situations (routine tracheostomies, oral and nasal intubations, fiberoptic intubations) so that when faced with an emergent airway obstruction, he or she will be comfortable evaluating and securing the airway with the most appropriate method.*
- *Before beginning any airway or CMF procedure, it is important to ensure that the patient is correctly positioned and that all necessary supplies are available (including suction).*
- *A healthy respect for the airway must always be maintained, never underestimating the rapidity with which airway status can deteriorate.*

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10 Surgical Exposure

Jonathan A. Zelken, Eduardo D. Rodriguez

Background

Trauma and congenital and acquired disease of the facial skeleton are commonly encountered in academic and community settings. Missed or inadequately repaired injuries can lead to deformity, functional impairment, infection, and pain. A thorough workup, including imaging, may indicate the need for operative repair. During surgery, respect for plastic surgical principles and the use of preexisting wounds to access the facial skeleton will optimize the result.

FRONTAL BONE AND UPPER FACE

Coronal Approach

When injury to the upper face, nose, zygomatic arch, and brow requires extensive reconstruction beyond the realm of less-invasive approaches, the coronal approach should be considered. A well-placed incision behind the hairline may yield an excellent cosmetic outcome.

Shaving the hair is not necessary and has not been shown to reduce infection rates. Alternative strategies include twisting small locks of hair and securing them with rubber bands or applying generous amounts of bacitracin ointment or petrolatum jelly (Vaseline) as a pomade and parting the hair around the markings. A line 5 cm posterior to the hairline is often described for the marking. Incisions closer to the hairline should be avoided, because a visible scar and thin band of hair anterior to the scar may result. In balding men the marking may need to be even more posterior.

Incision of skin proceeds through the galea to the subgaleal fascial plane (Fig. 10-1, *A*). Dissection proceeds toward the facial skeleton. Lateral dissection over the temporalis fascia aids excursion of the anterior flap. If tension persists, a preauricular extension to the tragus or earlobe should be considered. Once the subgaleal flap is elevated two fingerbreadths superior to the supraorbital rim, the supratemporal line is palpated laterally. An incision through the pericranium is made just medial to the superior temporal line from one side to the other, then dissection proceeds subperiosteally (Fig. 10-1, *B*). Alternatively, a large trapdoor flap of pericranium can be raised, which allows subperiosteal dissection and provides a vascularized flap of dependable tissue for sinus reconstruction.

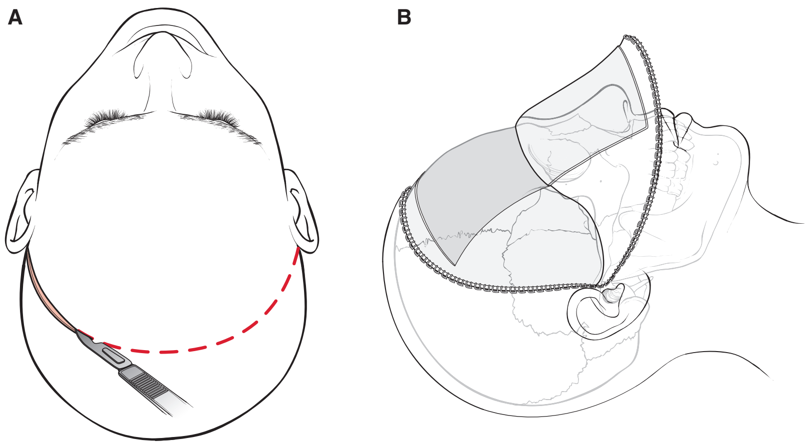


Fig. 10-1 **A,** Incision for the coronal approach to the midface and orbit. **B,** The coronal approach is shown. Use of hemostatic clips may be helpful but is controversial.

Subperiosteal dissection continues to the orbital rim and root of the zygoma. Special care should be taken not to disrupt or incise the superficial fat pad. The supraorbital vessels can be mobilized by removing a bridge of bone along the orbital rim and delivering the contents inferiorly.

Parallel midline incisions of periosteum reduce tension on the supraorbital neurovascular bundles, with retraction of the anterior flap allowing deep orbital extension and exposure to the nasal tip. Canthotomy and neurovascular ligation may be considered if intact structures compromise exposure. If deeper dissection into the temporal fossa is required, the entire temporalis muscle may be elevated subperiosteally en bloc. Dissection of the masseter off the zygoma anteriorly and the mandible laterally will expose the temporomandibular joint.

Closure of the coronal incision involves reapproximation of as many soft tissue layers as feasible with absorbable suture. Inadequate resuspension of fasciae may result in drooping and a suboptimal cosmetic result after extensive dissection. Some surgeons prefer *oversuspension* of the incised superficial temporalis fascia to a point 1 or 2 cm above the superior flap to prevent iatrogenic injury to the facial nerve. Drain exit sites should be placed in hair-bearing areas.

ORBIT

Numerous techniques have been described to allow access to the orbit. Supraorbital and upper eyelid approaches enable access to the superior orbit; transconjunctival and transcutaneous lower eyelid approaches enable access to the inferior orbit and maxilla. (An eyebrow incision would minimize the risk to neurovascular structures, but might result in visible scarring and alopecia.) Extended modifications of the transconjunctival and transcutaneous lower eyelid approaches allow access to the lateral orbital wall and zygoma.

Upper Eyelid Approach

The upper eyelid approach to the lateral orbital rim allows direct exposure and is cosmetically favorable, but it requires an understanding of the upper eyelid anatomy. The levator aponeurosis inserts into the orbicularis oculi of the upper lid and blends with the orbital septum 10 or 15 mm from the eyelid margin. The Müller muscle inserts on the superior aspect of the upper tarsal plate. With proper technique, exposure of the superolateral orbital rim should not disrupt these structures.

The globe should be protected with a tarsorrhaphy suture. The skin marking is either the upper or lower margin of the standard blepharoplasty and should follow lines of relaxed skin tension. The incision is placed through skin and the orbicularis oculi, avoiding creation of subcutaneous flaps (Fig. 10-2). This will optimize the blood supply and improve the cosmetic result.

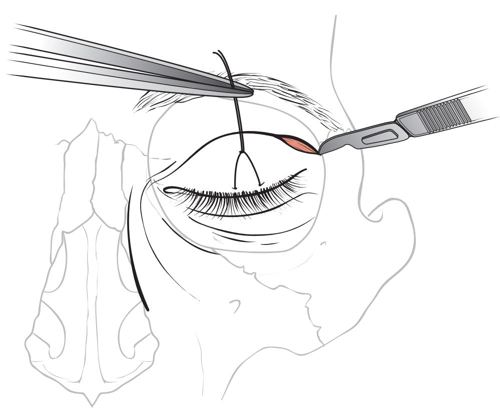


Fig. 10-2 The upper eyelid approach incision and Frost (tarsorrhaphy) suture in place.

Continuing through the periosteum, the incision follows sharply along the orbital rim in the proximity of the injury. Care must be taken when dissecting the periosteum off the lateral wall to avoid injuring or herniating the lacrimal gland. The gland can be preserved if the periosteum is not breached. After repair of the injured structures, the surgeon performs a layered closure of the periosteum, orbicularis oculi, and skin.

Transconjunctival Approach to the Lower Orbit

The transconjunctival approach to the inferior orbit will not leave a visible scar and obviates the need for skin and muscle dissection (Fig. 10-3, *A*). However, there is an increased risk of entropion. The approach can proceed preseptally or retroseptally (Fig. 10-3, *B*). The incision can be extended superomedially behind the lacrimal duct and laterally through skin. Medial dissection through the transcaruncular approach allows access to the medial orbital wall and can be combined with the retroseptal approach.[2] The transconjunctival approach can be extended laterally, providing access to the lateral orbital wall.

The globe should be protected with a corneal shield, and a vasoconstrictor should be injected under the conjunctiva. Two or three traction sutures are placed in the lower eyelid 5 mm inferior to the margin and including the tarsal plate.

Lateral canthotomy and cantholysis of the inferior limb of the lateral canthal tendon afford exposure of lateral orbital structures, when needed. These incisions generally precede the transconjunctival incision. Through the canthotomy incision, blunt-tipped scissors are used to develop the subconjunctival plane and then incise the conjunctiva at the approximate midpoint between the tarsal plate and inferior fornix.

Dissection proceeds retroseptally or preseptally. Retroseptal dissection allows direct access to the periosteum, and we prefer this approach at our institution (see Fig. 10-3, *B*). Orbital contents are retracted, and sharp dissection or electrocautery proceeds through the periosteum just posterior to the orbital rim. Preseptal dissection begins through the conjunctiva just below the inferior lower tarsal margin and continues through the lower lid retractors and orbital septum. The suborbicularis plane is developed, and dissection proceeds to the periosteum at the anterior aspect of the orbital rim.

The periosteum does not need to be closed if circumstances warrant expediency. If applicable, the limbs of the canthotomy are tagged for subsequent canthopexy. The transconjunctival incision can be closed with running chromic sutures, and a canthopexy is performed with simple interrupted sutures.

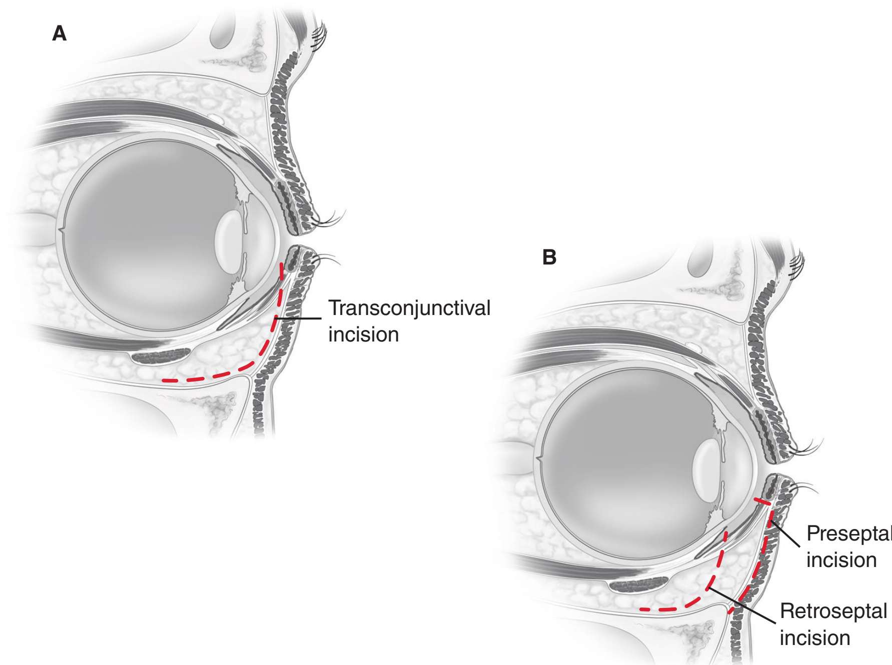


Fig. 10-3 A, Sagittal view of the level of the transconjunctival lower eyelid approach. **B,** In the transconjunctival approach, the exposure may be performed anterior to the septum (preseptal) or through the septum (retroseptal approach).

Transcutaneous Approach to the Inferior Orbit

The transcutaneous approach to the infraorbital rim is based on external incisions of the lower eyelid. Two approaches are currently widely accepted: *subtarsal* and *subciliary.* The infraorbital approach through the cheek-eyelid junction has been found to yield a poor cosmetic result and is mentioned for historical purposes only[4] (Fig. 10-4).

A loose tarsorrhaphy suture is placed. The *subciliary* marking is made just inferior to the lower eyelash line. This incision is well-hidden and can be extended 10 to 15 mm laterally to expose lateral orbital structures along Langer's lines. *Skin-only* dissection involves separation of skin from underlying muscular and subcutaneous tissue until the orbital rim is reached (Fig. 10-4, *B*). This may lead to buttonholing or discoloration of overlying skin. A deeper approach involves incision of skin and pretarsal muscles, dissecting down along the orbital septum and to the orbital rim. This may lead to ectropion or entropion. The *step method* involves skin-only dissection followed by suborbicularis dissection after 5 mm of subcutaneous dissection (see Fig. 10-4, *B*).

The *subtarsal* marking is made at a level just below the lower tarsus in the subtarsal fold, following lines of relaxed skin tension and continuing laterally to just beyond the lateral orbital rim (Fig. 10-4, *C*). Lateral extension provides limited access to lateral orbital rim, similar to an extended subciliary incision. Incision through both skin and muscle precedes suborbicularis dissection. Careful division of bridging muscle fibers between the tarsal and septal portion of orbicularis will expose periosteum. Incision and subperiosteal dissection reveals the inferior orbit and superior maxilla.

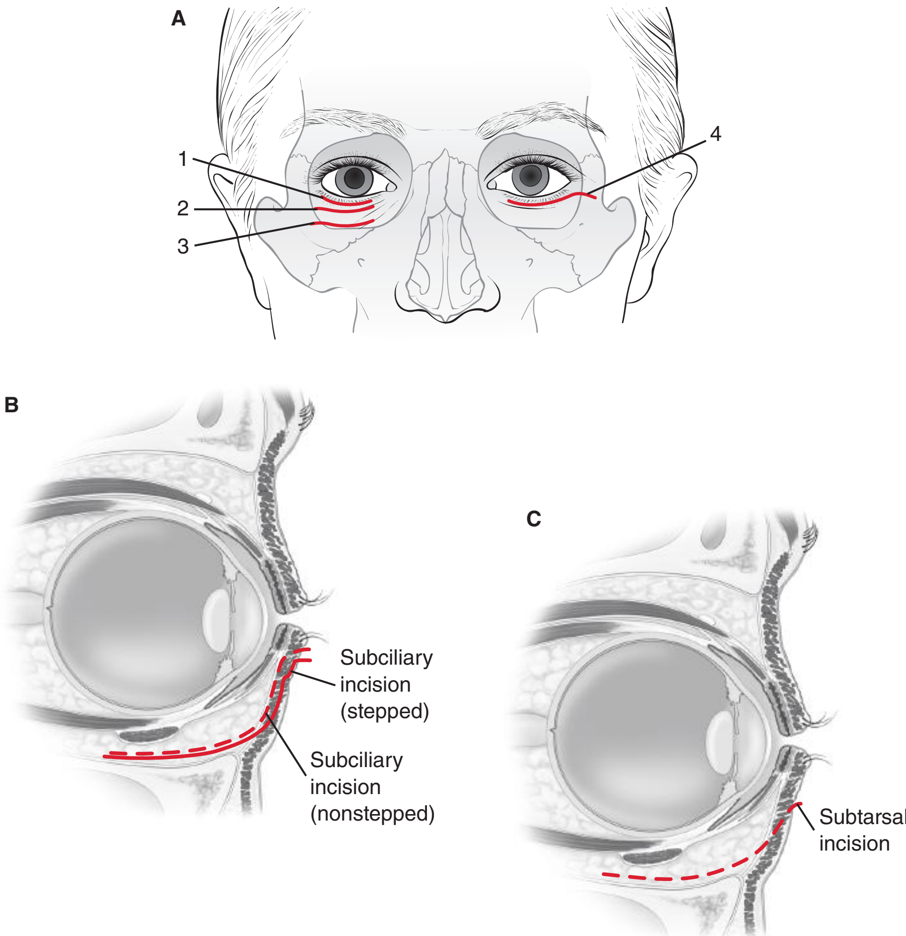


Fig. 10-4 **A,** Transconjunctival approaches to the inferior orbit: *1,* subciliary; *2,* subtarsal; *3,* infraorbital; and *4,* extended subciliary. NOTE: The infraorbital approach is not recommended. **B,** Sagittal view of the level of the subciliary lower eyelid approach. **C,** Sagittal view of the level of the subtarsal lower eyelid approach. (*A* modified from AO North America. Review of surgical approaches to the cranial skeleton, 2010. Available at *www.aona.org.*)

MIDFACE AND ZYGOMATIC ARCH

Gillies Approach to Zygomatic Fractures

Isolated zygomatic fractures may not warrant an extensive approach. A well-concealed incision two fingerbreadths superior to the zygoma and posterior to the hairline may significantly reduce or eliminate risk to the facial nerve (Fig. 10-5). An incision is made through the skin and superficial temporal fascia, then through the temporalis fascia proper. Dissection using a periosteal elevator continues deep to the temporalis fascia and the deep layer of the temporalis fascia until the zygoma is palpated. Using a bimanual technique, one hand is used to palpate the zygomatic fragment while the other reduces the displaced fragment. (See Chapter 18 for further discussion of zygomaticomaxillary fractures.)

Fig. 10-5 Incision for the Gillies approach to zygomatic fractures.

Maxillary Vestibular Approach

Access to the maxilla is achievable with no visible scar through the maxillary vestibular approach. Transoral surgery provides excellent access to the facial skeleton with relatively low risk, if performed correctly. The most important structure to avoid in the midface and maxilla is the infraorbital neurovascular bundle, which lies 1 cm inferior to the infraorbital rim. Respect for the muscles of facial expression that carpet the maxilla, and the buccal fat pads laterally, will optimize the cosmetic and functional result.

After a vasoconstrictor is infiltrated, the incision is placed 3 to 5 mm labial to the mucogingival junction, beginning at the midline and continuing posteriorly as necessary (Fig. 10-6). Posterior dissection should not continue beyond the first molar to avoid buccal fat pad injury. The incision should extend deep to bone.

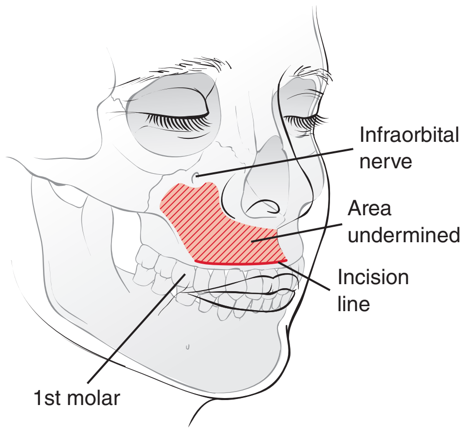


Fig. 10-6 Extensive exposure can be achieved with the maxillary vestibular intraoral approach.

The incision proceeds superiorly in the subperiosteal plane, then medially along the piriform aperture, and posteriorly behind the zygomaticomaxillary buttress. Medial dissection warrants careful dissection of the mucosa from the nasal spine. Deep dissection into the nasal cavity should not proceed until the inferior and lateral edges of the aperture are released. Posterior dissection may entail sharp division of the masseter along the inferior edge of the zygomatic arch. Keeping zygomatic periosteum intact will prevent buccal fat pad herniation.

Closure proceeds with a series of three steps to ensure adequate repair of the muscular layer and to optimize aesthetic results. Simple closure of the mucosa may result in alar base widening, decreased projection of the nasal tip, and inversion of the upper lip. To combat these sequelae, two or more cinch sutures are placed around the transverse nasalis muscles lateral to the alae and tightened, and the mucosa is closed in a V-Y fashion.

Midfacial Degloving

Midfacial degloving may be thought of as an extensive maxillary vestibular dissection *plus* endonasal transection to allow the midfacial soft tissue to be lifted free from the underlying skeleton.

The nasal vibrissae are shaved with a scalpel and the nasal cavity is cleansed; nasal packing is added, and a vasoconstrictor is infiltrated submucosally and subcutaneously. The nasal skeleton is exposed with a circumferential endonasal incision, intercartilaginous incisions laterally, and division of the caudalmost septum medially (Fig. 10-7).

Dissection should proceed deep through the mucosa, submucosa, and perichondrium. Subperichondrial division of the lower lateral cartilages from the upper lateral cartilages will facilitate facial degloving, with only the septal cartilage, upper lateral cartilages, and nasal mucosa left behind. If additional exposure is warranted, nasal bone, maxillary, and LeFort osteotomies can expose deeper structures.

Closure is the same as with the maxillary vestibular approach, and the endonasal incisions are closed with absorbable sutures. External nasal splinting and nasal trumpets may facilitate healing.

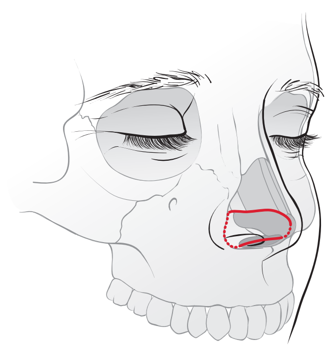


Fig. 10-7 Incision for midfacial degloving.

Weber-Ferguson Approach

When additional exposure is needed, the transoral approach can be extended transcutaneously along the aesthetic subunits of the midface and lower eyelid. This is generally appropriate when dealing with tumors and panfacial trauma. With the transoral approach, the infraorbital nerve anatomy may be spared or sacrificed, depending on exposure requirements. The end branches of the lacrimal branch of the trigeminal nerve may be encountered laterally about the zygoma and should be protected.

Surgical incision begins through the midline lip; the cutaneous-vermilion border must be well marked. The incision is carried around the base of the columella and 1 or 2 mm lateral to the alar base, continuing cephalad along the cheek-nose junction (Fig. 10-8). The incision can proceed to the upper eyelid with or without a canthotomy to expose ethmoidal and medial orbital structures. Alternatively, the incision may continue along the lower eyelid if the injury is limited to the maxilla. Additional options include subtarsal or infraorbital dissection, as described earlier. Intraoral extension may follow the course of the maxillary vestibular approach, as previously described, or along the cervical margins of the teeth. In edentulous patients, the incision is along the alveolar ridge.

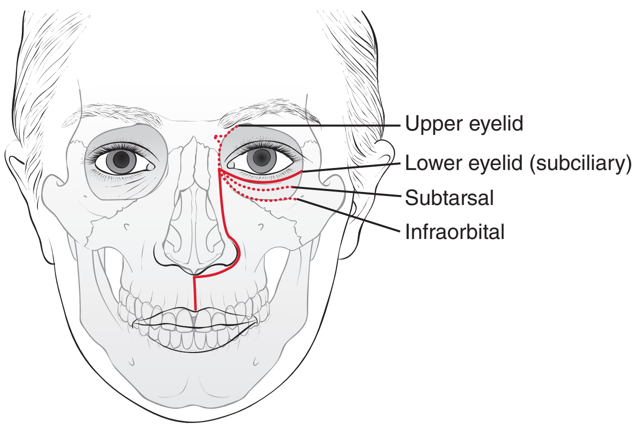


Fig. 10-8 Incisions for the Weber-Ferguson approach.

The flap can be raised subperiosteally or supraperiosteally. Defects resulting from soft tissue resection and oroantral communication can be addressed with a split-thickness skin graft. When bony support is missing, suspension sutures are used. Failure to adequately resuspend midfacial soft tissue can result in ectropion, drooping, and widened scars.

Oral mucosa is closed in the manner previously described. An alar cinch suture is used when the entire piriform region is released. When alveolar bone is excised, redundant mucosa is excised, and buccal mucosa is elevated and advanced to palatal mucosa.

MANDIBLE AND TEMPOROMANDIBULAR JOINT

The mandible can be approached intraorally or transcutaneously. The facial nerve is at risk for injury during transcutaneous approaches to the mandible.

Mandibular Vestibular Approach

The vestibular approach provides excellent exposure of much of the body and ramus and allows real-time assessment of dental occlusion. Exposure may be limited along the lower border at the angle and ramus. Care must be exercised to avoid injury to the mental nerve.

This site is infiltrated with a vasoconstrictor and an incision is made through lower lip mucosa only, leaving a 1 to 1.5 cm rind of mucosa attached to the gingiva from canine to canine. At the level of the canine, the incision should take a superior path to avoid injury to the mental nerve (Fig. 10-9). Over the body and posterior mandible, the incision should lie 5 mm inferior to the mucogingival junction. Anteriorly, mentalis muscles are cut sharply, leaving enough tissue behind to hold the sutures at closure. Over the external oblique ridge posteriorly, the incision should continue through the buccinator and buccopharyngeal fascia down to the periosteum. The incision should not pass superior to the occlusal plane to avoid injury to the buccal artery, nerve, and fat pad.

In anterior approaches, the mentalis is stripped subperiosteally. Dissection proceeds along the body, with careful circumferential freeing of the periosteum around the mental nerve. To mobilize the mental nerves, periosteum can be incised parallel to the mental nerve fibers. Subperiosteal dissection can continue posteriorly along the body of the mandible to the angle and ascending ramus, stripping buccinator attachments laterally and temporalis attachments superiorly near the coronoid process.

Posterior soft tissue can be closed in a single layer with a running absorbable suture, capturing mucosa, facial muscles, and periosteum in a single pass. The suture is tied at the level of the cuspids. Mentalis muscles are reapproximated using slowly resorbing suture. At this point the lip should be in anatomic position with respect to the mandible, and mucosal closure is performed with running resorbable suture.

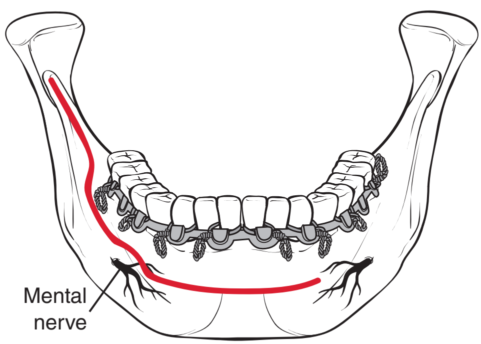


Fig. 10-9 Marking for the mandibular vestibular approach. Note the proximity of the mental nerve.

Submandibular Approach

Transcutaneous access to the mandible is preferred in disease of the mandibular ramus and posterior body region, where transoral access is limited. With this approach, the mandibular angle, ramus, condyle, and temporomandibular joint can be exposed.

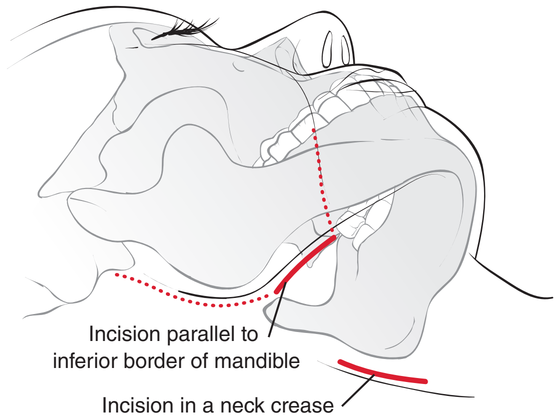
The incision is made either 2 cm inferior and parallel to the inferior border of the mandible or in an inconspicuous neck crease nearby (Fig. 10-10, *A*). The incision can be extended as far anterior as the lower lip following the mentolabial crease, and posterior to the mastoid. If necessary, bilateral submandibular incisions can be connected at the midline to facilitate complete exposure of the mandible.

A vasoconstrictor is infiltrated, and skin and fat are incised to the level of the platysma. Subcutaneous flaps are raised superiorly and inferiorly. Careful dissection of the platysma reveals the deep cervical fascia and submandibular salivary gland just beneath it. The superficial layer of deep cervical fascia is divided at the level of the incision, 1 to 2 cm inferior to the mandibular border. Fascia is undermined, with special care taken to avoid the nearby facial artery and vein, and the marginal mandibular branch of the facial nerve (Fig. 10-10, *B*). The facial vessels may be ligated if necessary. Nerve branches must be protected when encountered.

Once vital structures are controlled and protected, deep dissection continues until the periosteum is encountered. Posteriorly, the pterygomasseteric sling will overlie the mandible; this should be incised over the inferior border of the mandible, where the sling is most avascular. A periosteal elevator can be used to strip the masseter from the ramus laterally. The mental nerve must be avoided when dissecting anteriorly.

Closure of the pterygomassteric sling with interrupted resorbable suture precedes platysmal closure with a running resorbable suture. Finally, overlying skin is closed in layers.

A



B

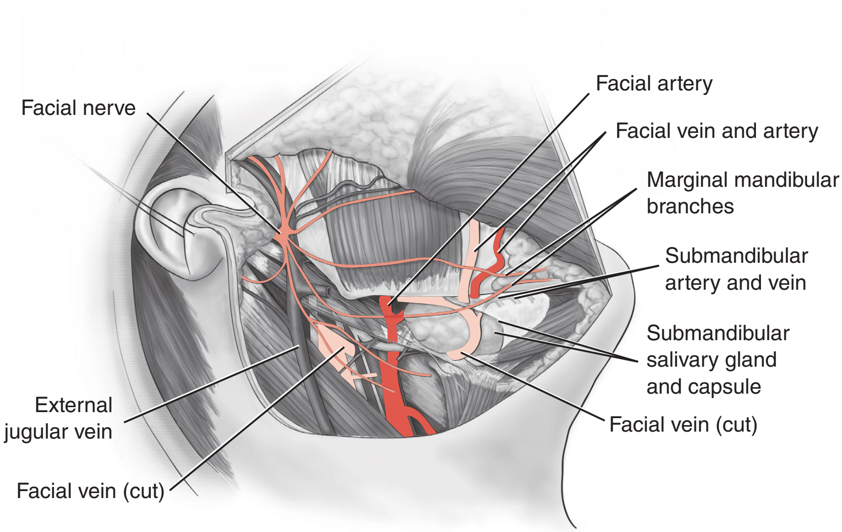


Fig. 10-10 **A,** Incision for the submandibular approach. **B,** Anatomy of the lower mandible and angle regions.

Retromandibular Approach

For injuries involving the ramus, neck, or head of the mandible, the retromandibular approach provides easier and more direct access than the submandibular approach. Special care must be taken to avoid the superior and inferior divisions of the facial nerve and retromandibular vein. We will describe two variations of this approach.

One approach is the posterior version of the submandibular approach. The skin is marked 2 cm behind the border of the ramus (Fig. 10-11, *A*). The parotid capsule is encountered, and the gland is separated from the sternocleidomastoid. This protects intraglandular facial nerve structures, in theory, by separating them from the line of fire. However, the ramus is not directly exposed.

An alternative approach occurs over the posterior border of the ramus below the earlobe, courses inferiorly toward the mandibular angle, and deep through the substance of the parotid to the mandible (Fig. 10-11, *B*). Careful dissection reveals the SMAS, platysma, and parotid capsule. The parotid capsule is breached and glandular tissue is bluntly divided with a hemostat, parallel to the anatomic course of the facial nerve branches. Dissection continues until the pterygomasseteric sling is reached. The sling is divided along the rim of the mandible as far superior and inferior as possible. Care should be taken to preserve the retromandibular

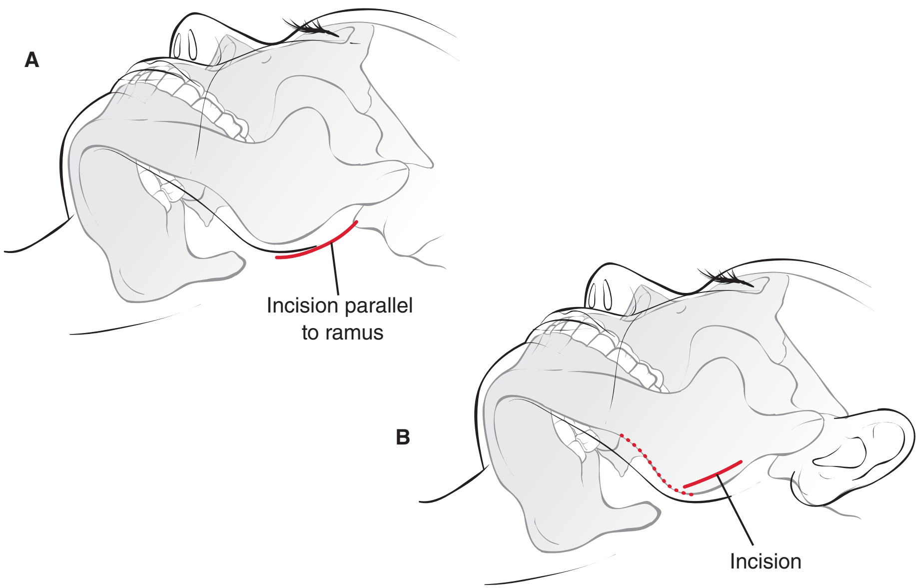


Fig. 10-11 **A,** and **B,** Two incision options for the retromandibular approach.

vein, which lies just posteromedial to the ramus border. Submasseteric dissection proceeds using a periosteal or Freer elevator.

Closure begins with reapproximation of the pterygomasseteric sling. The parotid capsule is sealed with a slowly resorbing running horizontal mattress suture through the SMAS, platysma, and parotid capsule as a single layer. This will help prevent fistula formation. Subcutaneous tissue and skin are closed in layers.

Face-Lift Approach

Also known as the *rhytidectomy approach,* the face-lift approach provides a superior cosmetic result compared with the retromandibular approach. The greater auricular nerve, which provides sensation to the skin overlying the anterior ear, parotid, and mastoid processes, is at risk of injury.

After infiltration of a vasoconstrictor, skin and subcutaneous tissue are dissected starting just superior to the zygomatic arch, coursing through a natural crease just anterior to the pinna, around the lobe, and just lateral to the mastoid-pinna crease, then back up to the hairline, following it posteriorly for several centimeters (Fig. 10-12). A face-lift flap is elevated in this plane. Anterior and inferior retraction of the skin flap exposes thin soft tissue coverage of the mandibular ramus. The remainder of the dissection is the same as in the retromandibular approach.

Closure should include a drain to avoid formation of a hematoma or seroma. The appropriate placement for the drain exit site is posterior, concealed behind the hairline. Skin and subcutaneous tissues are closed in layers.

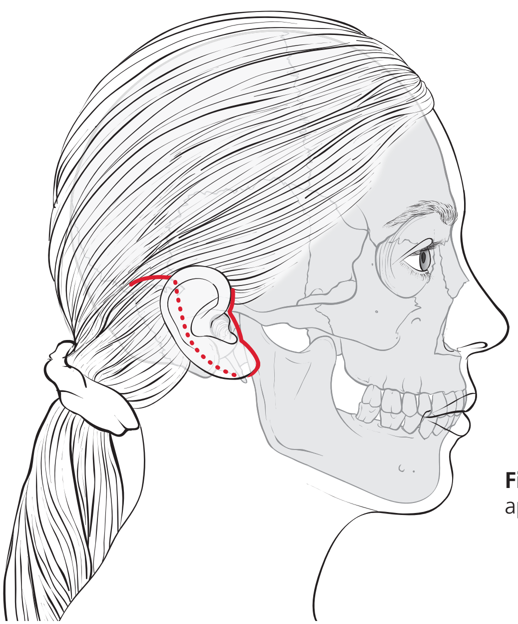


Fig. 10-12 Incision for the face-lift approach.

Preauricular Approach to the Temporomandibular Joint

The temporomandibular joint (TMJ) can be exposed through preauricular and postauricular approaches. The postauricular approach, which involves transection of the external auditory meatus, will not be described in this book. An abbreviated review of the anatomy of the TMJ and its surrounding structures should elucidate potential risks of this approach (Fig. 10-13, *A*). For example, the pole of the parotid gland lies directly atop the capsule of the TMJ, and the superficial temporal vessels and auriculotemporal nerve are at risk of injury. The auriculotemporal nerve is in such close proximity to the joint capsule that injury is quite common, albeit avoidable.

The surgical approach to the TMJ is through a natural fold of the skin found at the facial-helical junction from the lobe to the top of the helix (Fig. 10-13, *B*). Local infiltration of vasoconstrictor precedes incision through skin, fat, and temporoparietal fascia until the superficial layer of temporalis fascia is exposed. Using an elevator or scissors, a 1 to 2 cm flap is raised anteriorly above the zygomatic arch. Scissors are used to expose the cartilaginous external auditory meatus posteriorly.

The superficial layer of temporalis fascia is then incised obliquely above the zygomatic arch, and the periosteum is elevated. The periosteal elevator must then be shifted as far posterior as possible, abutting the external auditory canal, and a vertical incision through this flap is made over the elevator, protecting the underlying tissue. Retraction of this flap exposes the TMJ capsule.

Capsulotomy is facilitated by injecting the superior joint space and distracting the mandible inferiorly. Using scissors or a scalpel, the capsule is incised or cut millimeters below the zygomatic arch, exposing the superior joint space. The disk can be grasped and retracted to optimize exposure. Exposure to the inferior joint space is provided by incision and release of the articular disk–lateral capsule attachments.

Closure entails reattachment of incised capsule and disk using slowly resorbing running suture. Zygomatic periosteum can be used to reinforce or perform the superior capsulorrhaphy. The preauricular skin incision is closed in layers; no intervening tissue reapproximation is necessary.

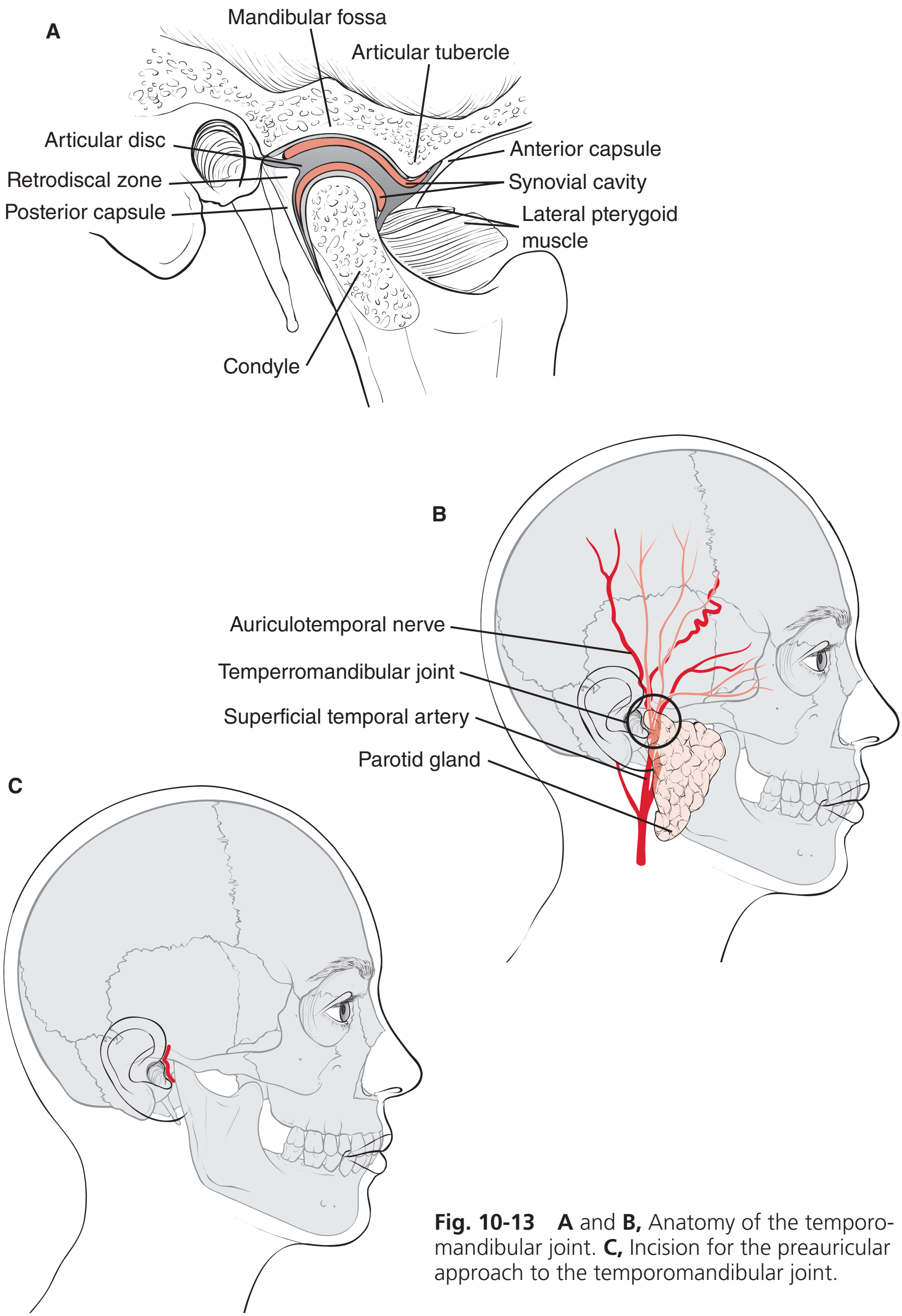


Fig. 10-13 **A** and **B,** Anatomy of the temporomandibular joint. **C,** Incision for the preauricular approach to the temporomandibular joint.

Pearls

Frontal Bone and Upper Face

- *The coronal approach is less desirable in patients with male pattern baldness.*
- *Keloid-prone patients should be forewarned that scarring may occur.*
- *Small interlocking zigzag incisions often help to conceal scars.*
- *Hatch marks at the midline using a marking pen and at lateral equidistant sites should be used to reapproximate flaps.*
- *Blood vessels run superficial to the SMAS-temporoparietal layer and the facial nerve deep to it.*[7]
- *The scalp is extensively vascular. Hemostatic techniques include infiltration with a vasoconstrictor, use of compressive clips along the flap edges, or running a locking nylon suture alongside the incision.*
- *Special care should be taken to orient the incision parallel to the hair follicles.*

Orbit

- *An eyebrow incision minimizes the risk to neurovascular structures but may result in visible scarring and alopecia.*
- *The upper eyelid or upper blepharoplasty approach requires careful dissection to avoid injury to the lacrimal gland.*
- *The transconjunctival approach provides a hidden scar in the conjunctiva and requires less dissection; however, it requires greater surgical precision, and any complications can be difficult to correct.*
- *Transcutaneous and transconjunctival approaches can both be modified to gain access to the lateral orbital wall.*
- *Care must be taken to avoid injury to the lacrimal drainage system and Horner muscle during medial exposure and transcaruncular dissection.*
- *Preseptal transconjunctival dissection is more challenging than retroseptal dissection but does not disrupt intraorbital tissue and preserves periorbital fat.*
- *Endoscopic assistance may facilitate visualization of the medial wall, including anterior and posterior ethmoidal vessels.*

Midface and Zygomatic Arch

- *A coronal incision will provide greater access and visualization than the Gillies approach in severely displaced or comminuted zygomatic fractures.*
- *When the maxillary vestibular approach is used, caution is required during posterior extension to avoid violating the buccal fat pad because of the resultant fat prolapse, which obscures the surgical field.*
- *Additional exposure afforded by midface degloving and the Weber-Ferguson approach is not considered a mainstay treatment.*
- *The addition of the nasal incision in facial degloving creates a risk of nasal vestibule stenosis and asymmetry caused by scar contracture.*

Mandible and the Temporomandibular Joint[5]

- *The facial nerve is a critical structure that is at risk for injury during transcutaneous approaches to the mandible.*
- *The buccal and marginal mandibular branches of CN VII may be encountered during transcutaneous approaches to the mandible, and care should be taken to dissect within the void between these branches.*
- *Posterior to the facial artery, the marginal mandibular branch of the facial nerve may lie superior (most commonly) or inferior to the inferior border of the mandible. Anterior to the facial artery, nerve branches are more likely to run superior to the mandibular border.*
- *Ligation of the facial artery and vein, when necessary, is feasible because of the extensive collateral network in the face.*

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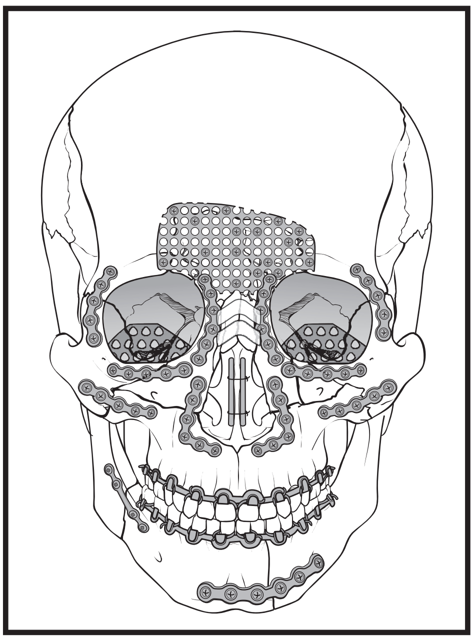
Part Two

Regional Management



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11 Skin and Soft Tissue Injury

Jason D. Toranto, Howard Levinson

Background

Perhaps the most common reason for a surgery consultation in facial trauma is laceration management. This is a basic element of trauma repair, and it must be practiced at the highest level. Many other soft tissue injuries also may be recognized and managed in the emergency department. There are a few diagnostic and therapeutic maneuvers that must be mastered to appropriately manage these injuries.

EVALUATION

In the initial encounter with a craniomaxillofacial (CMF) trauma patient, there are a host of potential injuries that require evaluation; these include bony, nervous, ocular, dental, and soft tissue injuries. All patients require a thorough CMF evaluation to address these areas, but the scope of this chapter is limited to the primary management of facial soft tissue injury.

Although evaluation of facial trauma injury, as with all traumatic injuries, starts with the ABCs of airway, breathing, and circulation, subsequent management is determined by the diagnosis. For soft tissue injuries, there are two important questions that dictate the interventions that are necessary: What structures are involved, and how extensive is the damage?

Most traumatic injuries of the soft tissue can be managed in the emergency department. Nevertheless, for massive hemorrhage, extensive soft tissue loss, or trauma to specific anatomic regions—the medial/lateral canthal tendon (or tendons), lacrimal system, facial nerve, and parotid duct—the operating room may be a more appropriate setting. Those that can be diagnosed and managed outside of the operative theater will be discussed in this chapter.

Determine the diagnosis by identifying the injured structures and the extent of injury; these factors dictate subsequent management.

BASIC MANAGEMENT OF SOFT TISSUE INJURIES

In general, complex reconstruction is not performed in the management of acute facial trauma. The goal in primary management is preservation of viable tissue and the most accurate reapproximation of injured tissues, without sacrifice of any possibly viable tissue. Late reconstruction or revision may require complex soft tissue flaps. However, these measures are preferably reserved for secondary treatment, allowing potential salvage and healing of all preserved tissues. We will discuss the general approach to laceration and abrasion management in children and adults as well as the management of complex soft tissue injuries by anatomic region.

Abrasions

The majority of abrasions (Fig. 11-1) are minor and involve a partial denuding of the skin that will heal well after appropriate local wound care, including:

1. Removal of foreign bodies
2. Thorough cleansing
3. Application of ointment (to keep the wound moist to optimize epithelialization)

In hirsute areas, the hair must be trimmed before the site is cleansed and ointment applied. Clippers rather than a razor should be used to remove hair.[1] Antimicrobial ointment has not been shown to be more effective than petrolatum ointment

Fig. 11-1 Scalp abrasion ("road rash") is treated through cleansing, hair removal, and the application of ointment. The wound should be washed frequently with mild soap and water.

alone; however, the antibiotic will cause transient hyperemia in a small percentage of patients.[2,3]

Major scalp abrasions merit specific mention: scalp abrasions will heal extremely quickly if the hair of the affected region is shaved and the surrounding hair is kept off the abraded area. The surface of the abrasion will be exudative, and this material will coalesce with the hair to create a cast, which will retain bacteria and impair epithelialization. Preserving the patient's hair in this situation is a significant disservice. After treatment, it is critical that patients be instructed to cleanse the area at least three times a day with mild soap and water.

Trim hair, remove foreign bodies, cleanse the wound, apply ointment, and instruct the patient to clean the area with mild soap and water three times a day.

Lacerations and Suturing

Most lacerations are minor, so any resultant hemorrhage is controlled by the clotting cascade. In large bleeding lacerations, immediate application of direct pressure is the first step. This will suffice unless a major vessel has been transected, there is a significant scalp wound, or the patient has a bleeding diathesis from congenital disease or medications. (See p. 163 for details on management of scalp hemorrhage.)

The injured area of the face is often quite sensitive, so analgesia is an important preliminary consideration in laceration repair. A combination of systemic analgesia (such as morphine or fentanyl) and local analgesia is most effective. Lidocaine with epinephrine can be used universally in the face. Numerous studies have demonstrated that epinephrine does not cause infarction of distal structures.[4-6]

In managing specific lacerations, whether intraoral or extraoral, a field block may be used to numb the affected area by infiltrating a perimeter around the injury. Alternatively, the entire face can be anesthetized through appropriate selection of regional blocks. Zide and Swift[7] have delineated the anatomy of the sensory nerves of the face and the blocking techniques for each. The most common two nerve blocks for treatment of facial injuries are infraorbital and mental. An infraorbital block will anesthetize the ipsilateral cheek and upper lip as well as the posterior maxillary dentition; a mental nerve block will anesthetize the ipsilateral lower lip and chin. Once adequate analgesia has been obtained, repairing a laceration becomes algorithmic (Fig. 11-2).

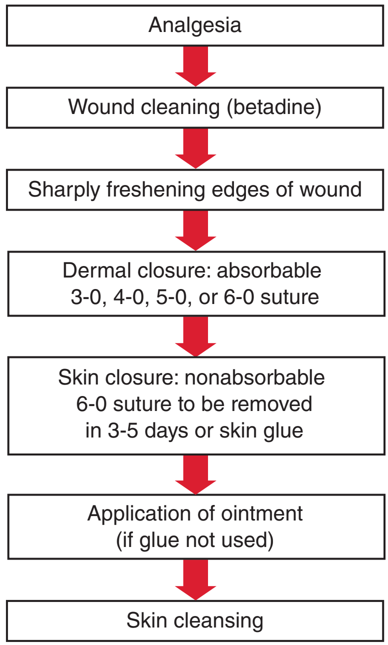

Fig. 11-2 Facial laceration repair is algorithmic. Each of these steps should be followed in order each time a laceration is repaired.

It is important to choose the right suture for a given purpose. When considering suture material, it is easiest to think of them in two categories: absorbable and nonabsorbable. Full-thickness lacerations are generally closed in two layers: one deep, buried layer, and one surface or superficial layer. Absorbable sutures are often buried, whereas nonabsorbable sutures are placed on the surface and frequently are removed in 3 to 5 days. Absorbable sutures initiate an inflammatory response that leads to their degradation. In general, the more vigorous the inflammatory response, the faster the suture will absorb, and the worse the scar will appear. Plain gut and chromic sutures incite a significant inflammatory response (and are therefore rarely used for deep layer closure), whereas PDS, Vicryl, and Monocryl do not cause such a response. These sutures are frequently used for deep dermal closures of the face and will degrade, in the order listed, from slowest to fastest. Plain gut, chromic gut, and Vicryl are often used to suture the lip and nasal mucosa.

Nonabsorbable sutures are either polypropylene or nylon. Silk is infrequently used for controlling bleeding vessels in the deep subcutaneous tissue, because it is black and may be seen through the skin.[8] Table 11-1 summarizes suture materials and their characteristics.

TABLE 11-1 SUTURE MATERIAL AND THEIR CHARACTERISTICS

Suture Material	Absorbable	Time to Full Absorption	Maintains Tensile Strength	Where to Use
Monocryl*	Yes	91-119 days	Up to 3 weeks	Subcuticular, dermis
Vicryl*	Yes	56-70 days	3-4 weeks	Dermis, mucosa
PDS*	Yes	6 months	Up to 6 weeks	Subcuticular, dermis
Fast gut	Yes	<70 days	5-7 days	Pediatric epithelium†
Plain gut	Yes	70 days	7-10 days	Mucosa
Nylon	No	N/A	N/A	Epithelium†
Polypropylene	No	N/A	N/A	Epithelium†
Silk	No	N/A	N/A	Deep subcutaneous

*Ethicon, Somerville, NJ.
†Epithelium means the suture is usually used as a running or interrupted skin suture and not buried.
Data from Lai SY, Becker DG, Edlich RF. Sutures and needles. (Accessed at *http://emedicine.medscape.com/article/884838-overview*.)

A fine suture such as a 5-0 or 6-0 Prolene on a small cutting needle is preferred when suturing most lacerations. Sutures come on a variety of needles—cutting, reverse cutting, taper, and Keith—but in general, one should make every attempt to use (reverse) cutting needles when closing the epithelium/subcuticular layer. It is also important to find appropriate-sized instruments to use with these small needles. Larger needle drivers will warp the needles when they are cinched down, so the curved needle will instead become S shaped. Smaller instruments also give better tactile feedback, which improves precision during closure.

Adequate analgesia is obtained, and two-layer closure is performed with optimal materials for laceration repair.

Pediatric Lacerations

Lacerations in children are handled in the same fashion as discussed previously, with two differences: analgesia and suture material. In many pediatric patients, systemic analgesia with ketamine will be necessary to perform the repair.[9,10] A papoose board and a local analgesic can also be used. If these options are not available or the laceration will take a significant amount of time to repair, operative anesthesia will be required. Suture removal can be quite traumatic for children, so a two-layer skin closure is performed using a 5-0 or 6-0 absorbable suture such as Vicryl for the dermis, followed by 5-0 or 6-0 fast-absorbing gut or skin glue for skin closure. Failure to place a deep layer can result in dehiscence because of the limited and brief strength of fast-absorbing gut or skin glue.

> For pediatric patients, the use of ketamine may be necessary for analgesia; fast-absorbing gut suture is appropriate for skin closure.

Bite Wounds

Dog, cat, and human bite wounds are commonly found on the face and are managed in similar fashion to other lacerations, with certain points of emphasis:

- Appropriate antibiosis
- Tetanus/rabies prophylaxis
- Aggressive debridement
- Primary versus delayed closure

Bite wounds from other animals will not be covered in this chapter. *Pasteurella multocida, Eikenella corrodens, Staphylococcus* species, and *Streptococcus* species are frequently seen in bite wounds, and the antibiotic chosen must address these pathogens. An extended-spectrum penicillin such as amoxicillin clavulanate (Augmentin) is an ideal choice, because it provides coverage for these bacteria. Prophylactic coverage for tetanus (and rabies, if appropriate) needs to be administered. The wound should be copiously irrigated and aggressively debrided. This is the central tenet to the management of any mammalian bite wound. Determining whether the wound is amenable to primary or delayed closure involves examining multiple factors:

- The extent of devitalized tissue to be debrided
- The level of contamination of the wound
- The amount of time that has passed since the bite occurred

REGIONAL SPECIFICS

Scalp

Hemorrhaging from the scalp can be quite troublesome, because the strong, fibrous, unyielding nature of the scalp prevents vessels from contracting, so they continue to bleed. Hemorrhagic shock can develop from a scalp laceration alone. If a patient with a scalp wound is hypotensive during initial evaluation, active hemorrhaging may not be seen, but subsequent resuscitative efforts may uncover a significant pathology. In such an instance, the wound is whipstitched with a 2-0 or 3-0 polypropylene or nylon suture until the equipment and assistance is in place for definitive management. Some institutions use staples for this maneuver. Concomitant fluid resuscitation is critical for a hemorrhagic scalp wound.

Although hair-clipping is essential for a scalp abrasion, it does not have to be done for a simple laceration, although many prefer to do this for ease of repair. A heavy ointment (such as Surgilube) can be used to “grease” the hair out of the way. To close a wound in the hair-bearing region, skin staples are substituted for a subcuticular stitch or glue.

An additional complicating factor in scalp lacerations is the relative immobility of the scalp because of its dense, fibrous attachments. The scalp can be readily mobilized in the emergency department by dissecting through the galea into the loose areolar tissue just above the periosteum (Fig. 11-3). The wound can then be extensively undermined in an avascular plane, which will often afford the mobility necessary for wound closure. The galea needs to be reapproximated with a strong,

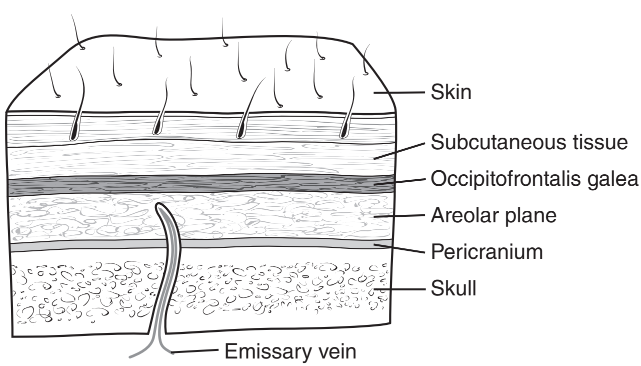

Fig. 11-3 The scalp layers as seen on sagittal section. The loose areolar tissue plane below the galea allows mobilization of the scalp.

absorbable suture such as 2-0 or 3-0 Vicryl, followed by a standard two-layer skin closure. A Penrose or closed-suction drain in the subcutaneous or subgaleal layer may be used after extensive undermining to avoid development of a hematoma.

> Scalp hemorrhage is controlled, using staples in the hirsute areas, and the scalp is mobilized, if necessary.

Eyelid

The management of eyelid trauma involves consideration of these six anatomic structures and their subsequent reconstruction:

1. Skin
2. Orbicularis oculi
3. Tarsus
4. Conjunctiva
5. Canaliculus
6. Canthal tendons

Any injuries to this area in which an injury to the globe is clinically suspected or there are changes in vision necessitate an ophthalmologic evaluation.

Repairing eyelid lacerations in the emergency department should, in general, be limited to those that can be closed linearly or those that can be readily converted to a wedge resection and closed. Injuries are closed from deep to superficial, beginning at the conjunctiva, which is repaired with buried fast-absorbing 6-0 gut suture. The suture should be tied so the knot rests on the deep surface of the lid rather than on the corneal side. If a tarsal injury is present, then the very first step is the placement of a suture along the "gray line" (ciliary margin). Upward traction can be applied to the suture to allow trimming of the margins and closure. The tarsal plate itself can be reapproximated with 5-0 or 6-0 Monocryl. The orbicularis oculi muscle is sutured with 5-0 Vicryl when the laceration is vertical to the eyelid margin. Lacerations parallel to the lid margin do not require muscular reapproximation.[11] The skin is closed in running fashion with 6-0 polypropylene or fast-absorbing gut. It is critical that during the closure the ciliary margin be aligned properly. Even the slightest discrepancy can often be perceptible.

The conjunctiva can readily sustain injury or desiccate, especially in those who are critically ill. Should the potential for conjunctival exposure or irritation be noted, the two best interventions are lubrication or placing a tarsorrhaphy stitch. The latter is performed by placing a full-thickness horizontal mattress 4-0 or 5-0 silk suture at the gray line at the level of the lateral limbus.

The lacrimal system comprises the superior and inferior puncta and canaliculi, lacrimal sac, and lacrimal duct (Fig. 11-4). The Jones test is performed to determine whether there is an injury to this system and, if so, whether it is within the upper system (puncta through the common canaliculus) or lower system (sac and duct).[12] A drop of fluorescein dye is placed in the conjunctival cul-de-sac, and

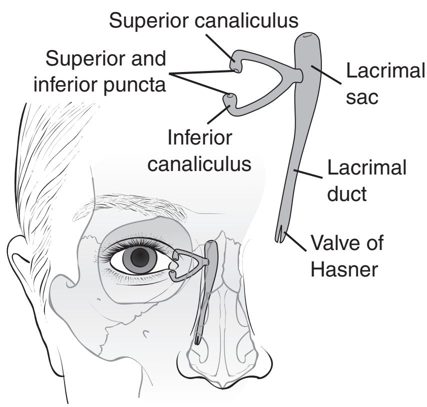

Fig. 11-4 The lacrimal system is made up of superior and inferior canaliculi that eventually coalesce into the common canaliculus. This empties into the lacrimal sac, which drains into the nose through the lacrimal duct. The upper system is composed of the superior/inferior puncta through the common canaliculus, and the lower system consists of the lacrimal sac and duct.

5 minutes later the nose is examined (Fig. 11-5, *A*). Fluorescein present in the nose indicates patency of the system. Conversely, the absence of fluorescein in the nose suggests injury or obstruction of the system, and the second part of the test must be performed (Fig. 11-5, *B*). The lacrimal sac is cannulated with a 25-gauge angiocatheter and irrigated with saline solution (Fig. 11-5, *C*). The fluid in the nose is collected and examined. The absence of fluorescein in the fluid indicates an injury to the upper system, whereas the presence of fluorescein indicates an injury to the lower system. Another method for testing the integrity of the cana-

A

B

C

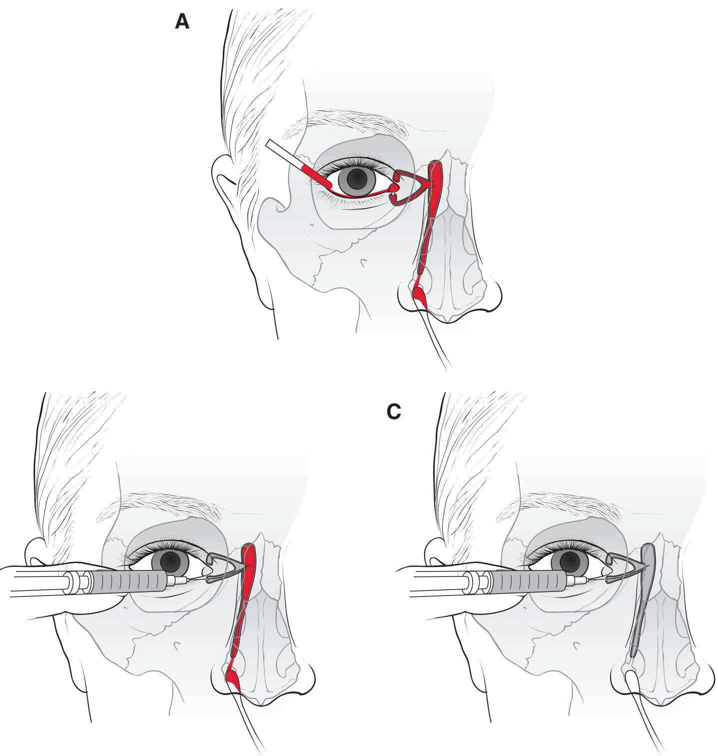

Fig. 11-5 Jones test. **A,** A drop of fluorescein dye is placed in the conjunctival cul-de-sac and the nose is examined for the presence of dye. **B,** If no dye is seen, a 25-gauge angiocatheter is used to intubate the inferior lacrimal papilla to the lacrimal sac. **C,** The sac is flushed with 2 to 3 ml of saline, and the flush in the nose is evaluated for the presence of dye. If dye is present, the injury is in the lower system. If no dye is present, the injury is in the upper system.

licular system is to intubate the system as above with a 25-gauge angiocatheter and feel for a “hard” or “soft” stop (Fig. 11-6). An incomplete injury will heal if the surrounding soft tissues are well reapproximated. Complete injuries require intubation of the lacrimal system with Guibor silicone stents over 0.064 cm diameter stainless steel probes and repair of the soft tissues overlying the injured duct.[11,13] The ductal tissue is not repaired—only the surrounding soft tissues. The stents are removed 2 to 6 months after the repair, and the Jones test is repeated to ensure patency.

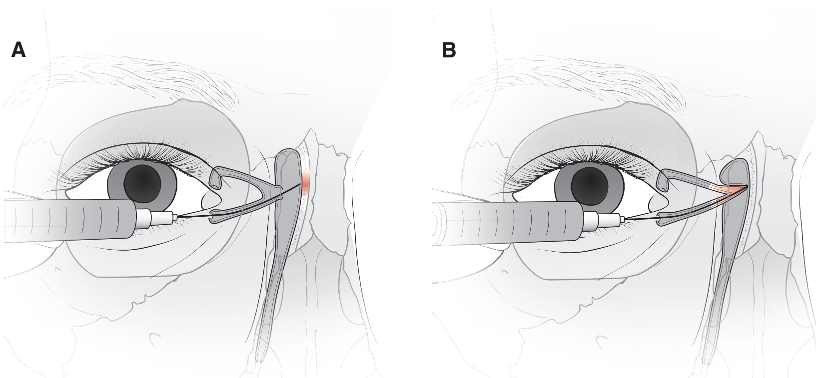

Fig. 11-6 **A,** A 25-gauge angiocatheter is used to intubate the inferior lacrimal papilla and is slowly advanced medially. If there is no injury, the catheter tip will contact bone (“hard stop”). **B,** If there is an injury, tissues will prevent the advancement of the catheter (“soft stop”).

In devastating injuries to the medial and lateral eyelids, the canthal tendons are often involved. These need to be reconstructed through canthopexy. This can be problematic medially if the native structures have been devastated, and a transnasal wire is used to perform the canthopexy.

For eyelid trauma, an ophthalmology consult is requested, lacerations are repaired from deep to superficial, the ciliary margin is carefully aligned, and the surgeon determines whether the canalicular system is injured. Conjunctival desiccation must be prevented.

Ear

The management of ear trauma is unique in these three respects:

1. Cartilaginous reapproximation
2. Chondritis prophylaxis
3. Analgesia

The potential for exposed cartilage makes the repair of ear lacerations more involved than many other lacerations. Partial-thickness injuries are repaired as with any other laceration; however, for full-thickness lacerations, the cartilage is reapproximated first, followed by skin closure. Because of the nature of cartilage and the potential devastating effects of chondritis, cleansing and debridement of this wound must be thorough. The edges of the cartilage should be sharply freshened and subsequently reapproximated with 5-0 clear nylon or 5-0 PDS or Monocryl. The skin is closed in standard fashion.

If the soft tissue loss leaves exposed cartilage that cannot be readily closed in the emergency department and the operative intervention will be delayed by at least 24 hours, mafenide acetate (Sulfamylon cream) should be applied on the exposed cartilage. In patients with sulfa allergies, silver sulfadiazine is used. If definitive coverage will be obtained in less than 24 hours, the wound can be dressed wet to dry, although mafenide acetate is preferable.

Because of the numerous nerves that innervate the ear—the greater auricular, lesser occipital, auricular branch of the vagus nerve, and auriculotemporal—a field block is the most effective technique for anesthetizing the entire ear (Fig. 11-7). This can be supplemented with or supplanted by local infiltration.

A field block is used for anesthesia, the cartilage is reapproximated with 5-0 clear nylon or 5-0 PDS or Monocryl, and exposed cartilage is dressed with mafenide acetate.

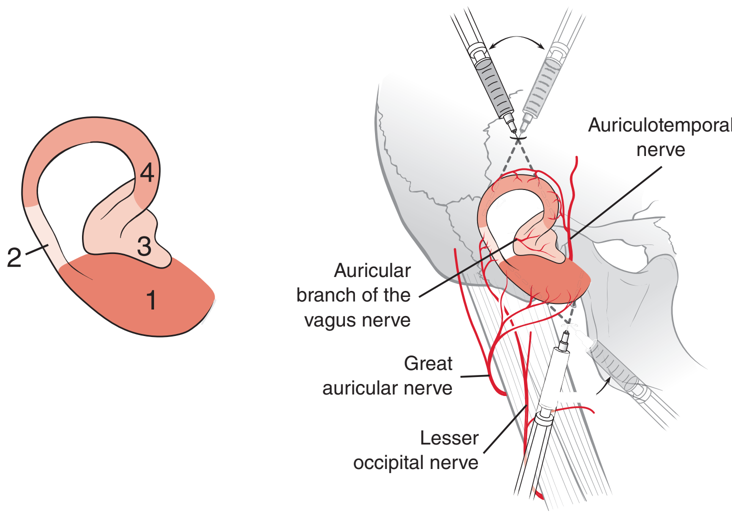

Fig. 11-7 There are four nerves that provide most of the sensation to the ear: the great auricular nerve *(1),* the lesser occipital nerve *(2),* the auricular branch of the vagus nerve *(3),* and the auriculotemporal nerve *(4).* A field block will affect all of these nerves and provide dense analgesia.

Nose

Most nasal lacerations are simple wounds that can be repaired either linearly or by converting the injury to a wedge excision, followed by closure. As with the eyelid, injuries through the skin, cartilage, and mucosa are repaired in layers. The management of major nasal trauma, including nasal fractures, is discussed in Chapter 13. As previously discussed, soft tissue defects of the nose are not repaired in the primary setting using skin or soft tissue flaps. These valuable resources must be preserved for potential secondary revision under more controlled settings. Even when a certain degree of anatomic distortion is anticipated with primary closure, this should be accepted rather than sacrificing reconstructive options. In certain cases of skin loss without cartilage exposure, a skin graft can be used to repair the defect temporarily.

During the evaluation of nasal trauma, one must look for the presence of a septal hematoma. If present, this must be incised and drained. A septal splint should be applied, consisting of Silastic sheets (or equivalent) on either side of the septum, sewn in place with a 3-0 nylon U stitch to prevent re-formation. This buttress is removed in 3 to 5 days.

> Repair of nasal lacerations is similar to that for the eyelid. The surgeon should evaluate for a septal hematoma.

Lip

The lip is a relatively straightforward structure to repair; however, the repair must be meticulous, because small misalignments are readily noticeable. A full-thickness injury to the lip requires a three-layer closure: mucosa, orbicularis oris, and skin. The orbicularis oris muscle should be repaired with 4-0 or 5-0 absorbable suture, such as Vicryl. The mucosa is closed with 4-0 plain gut suture until one reaches the vermilion (the red line or wet-dry junction), at which point 5-0 or 6-0 polypropylene or fast-absorbing gut is used.

At the skin-vermilion border, a single 6-0 polypropylene suture is placed with the utmost care to ensure precise alignment. The key to an aesthetic lip closure is lining up the vermilion-cutaneous junction (the white roll). This is best performed by closely examining the laceration under loupe magnification, determining the location of the white roll on either side of the defect, and marking these two points with a surgical marker. Lip closure then involves placing a suture that aligns these two points perfectly. The most common mistake is infiltrating the lip before placing the marks, which complicates an otherwise simple maneuver. The marks can be placed and then a local anesthetic infiltrated, but the ability to make subtle adjustments after the injection of the local anesthetic might be limited. To avoid this issue entirely, an infraorbital nerve block for the upper lip or a mental nerve block for the lower lip can be performed. This affords dense analgesia without anatomic disruption. Zide and Swift[7] have described how to perform these blocks.

> A full-thickness lip injury is repaired in three layers. The vermilion-cutaneous junction should be perfectly aligned.

Parotid Region

The parotid region is the danger zone of the face. The presence of Stenson's duct and the facial nerve make therapeutic interventions potentially precarious. Only sutures, not monopolar cautery, should be used in this region. A thorough facial nerve examination must be performed before any intervention is initiated. The zygomatic and buccal branches of the facial nerve share numerous connections, even distant to the parotid region. The marginal mandibular and frontal branches do not have extensive arborization and are therefore more adversely affected when injured. Table 11-2 lists the branches of the facial nerve and their respective functions. Facial nerve injury necessitates operative intervention.

Table 11-2 Facial Nerve Branches and Their Respective Functions

Each must be tested separately as a part of the traumatic craniofacial examination to ensure functionality.

Facial Nerve Branch	Unique Function
Temporal	Forehead elevation
Zygomatic	Eyelid closure
Buccal	Elevation of upper lip
Marginal mandibular	Depression of lower lip
Cervical	Platysma contraction

Fig. 11-8 demonstrates how to diagnose an injury to Stenson's duct. A ductal injury should be repaired in the operating room by identifying either end of the injured duct, placing a 22-gauge Silastic stent across the injury, and reapproximating the injured duct with an 8-0 nylon suture. The end of the catheter is sewed in place intraorally and removed after 2 to 3 weeks.[14]

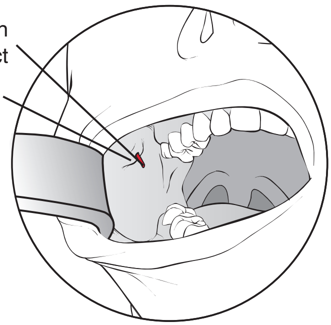

Fig. 11-8 To determine whether there is a parotid duct injury, a 22-gauge Silastic tube is used to intubate the duct by locating the papilla in the buccal mucosa opposite the second maxillary molar. The tube is advanced into the duct, and the base of the laceration is inspected for the presence of the tube. Saline is injected into the tube to test for leakage into the wound. Methylene blue has been used for this, but if there is a leak, the discoloration of the tissues can make surgical dissection more difficult.

The facial nerve and Stenson's duct are evaluated and repaired in the operating room.

CPT CODING FOR WOUND CLOSURE

Classification and coding of wound closure is addressed in the Appendix, p. 176.

LONG-TERM CARE

The best aesthetic outcome takes not only surgical excellence at the time of laceration repair but also involved long-term scar management by the patient. Patients should be counseled that they should:

1. Perform routine scar massage
2. Prevent scab formation and open wound desiccation
3. Wear sunscreen

Scar massage will help to soften the scar. Silicone-based products may be helpful in reducing scar formation. Moisture can be maintained by applying cocoa butter, petrolatum, or an equivalent moisturizer. Sunscreen prevents permanent pigment changes that can occur with sun exposure. If patients are unhappy with their scars, scar revision is an option after a year has passed.

Scar massage, moisturizers, and sunscreen provide the best aesthetic outcome.

CONCLUSION

Most facial lacerations are relatively straightforward to manage, but it is important to develop good techniques and habits to achieve the best results. Following the principles outlined previously, good results can be achieved on a routine basis.

Pearls

- *Perform a full facial-trauma examination during evaluation to determine the injured structures and the severity of the injury.*
- *Abrasions: Cleanliness is paramount. Remove all foreign bodies, trim hair, and cleanse the wound.*
- *Lacerations: Select appropriate instruments and suture to perform the best two-layer closure possible.*
- *Pediatric lacerations: A papoose or ketamine may be necessary. Fast-absorbing gut is the suture of choice for skin closure.*
- *Scalp: Ensure hemorrhage control and remember to use staples in hirsute areas.*
- *Eyelid: Always carefully align the ciliary margin during repair. Obtain an ophthalmology consultation if there is any possibility of ocular trauma.*
- *Ear: Exposed cartilage should be treated with mafenide acetate (or silver sulfadiazine as an alternative).*
- *Nose: Evaluate for a septal hematoma.*
- *Lip: Make sure the vermillion-cutaneous junction is perfectly aligned.*
- *Parotid region: Evaluate the facial nerve and Stenson's duct. Both are critical structures, and significant trauma to either requires operative intervention.*
- *Moisturizers, scar massage, and sunscreen yield the best long-term clinical outcome.*

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Appendix

Current Procedural Terminology (CPT) Coding

CPT coding for repair of facial lacerations is based on three principles: anatomic depth, complexity, and length. The length is determined by adding up the length of every laceration of the same complexity within the same anatomic region or site repaired to determine the total length repaired. Full-thickness repairs of the eyelid and lip have separate codes that are not listed in the table on the following pages. Each laceration will be debrided before closure, but this is not always coded. According to the AMA's terminology manual[1]:

> *Debridement is considered a separate procedure only when gross contamination requires prolonged cleansing, when appreciable amounts of devitalized or contaminated tissue are removed, or when debridement is carried out separately without immediate primary closure.*

The appropriate debridement code is determined by the anatomic depth of the wound and ranges from partial thickness of skin all the way to involving bone (see the table). The AMA manual further specifies[1]:

> *The complexity of wound closure may be classified as simple, intermediate, or complex. Simple repair is used when the wound is superficial; e.g., involving primarily epidermis or dermis, or subcutaneous tissues without significant involvement of deeper structures, and requiring simple one layer closure. Intermediate repair includes the repair of wounds that require layered closure of one or more of the deeper layers of subcutaneous tissue and superficial (nonmuscle) fascia, in addition to the skin (epidermal and dermal) closure. Single-layer closure of heavily contaminated wounds that have required extensive cleaning or removal of particulate matter also constitutes intermediate repair. Complex repair includes the repair of wounds requiring more than layered closure, viz., scar revision, debridement (e.g., traumatic lacerations or avulsions), extensive undermining, stents, or retention sutures. Necessary preparation includes creation of a defect for repairs (e.g., excision of a scar requiring complex repair) or the debridement of complicated lacerations or avulsions.*

For the length of the laceration repair, the code is determined by the cumulative sum of the lengths of all the repairs performed. For example, a 3 cm laceration repair on the forehead and a 2 cm laceration repair on the cheek are coded as a 5 cm laceration. Of note, this additive principle only applies to lacerations of identical complexity and anatomic site. Lacerations of varying anatomic sites and complexity should be coded as separate laceration repairs.

CPT Codes for Debridement and Facial Laceration Repair

Simple Repair	CPT	Complex Repair	CPT
Scalp		***Scalp***	
2.5 cm or less	12001	For less than 1.0 cm, use simple/ intermediate code	—
2.6 to 7.5 cm	12002	1.1 to 2.5 cm	13120
7.6 to 12.5 cm	12004	2.6 to 7.5 cm	13121
12.6 to 20.0 cm	12005	Each additional 5 cm (in addition to code for primary procedure)	13122
20.0 to 30.0 cm	12006		
Over 30.0 cm	12007		
Face, Ears, Eyelids, Nose, Lips, or Mucous Membranes		***Forehead, cheeks, chin, mouth***	
2.5 cm or less	12011	For less than 1.0 cm, use simple/ intermediate code	—
2.6 to 5.0 cm	12013	1.1 to 2.5 cm	13131
5.1 to 7.5 cm	12014	2.6 to 7.5 cm	13132
7.6 to 12.5 cm	12015	Each additional 5 cm (in addition to code for primary procedure)	13133
12.6 to 20.0 cm	12016		
20.1 to 30.0 cm	12017	***Eyelids, Nose, Ears, and/or Lips***	
Over 30.0 cm	12018	1.0 cm or less	13150
		1.1 to 2.5 cm	13151
		2.6 to 7.5 cm	13152
		Each additional 5 cm (in addition to code for primary procedure)	13153

Intermediate Repair (Layer Closure)	CPT	Intermediate Repair Layer Closure)	CPT
Scalp		***Face, Ears, Eyelids, Nose, Lips, or Mucous Membranes***	
2.5 cm or less	12031	2.5 cm or less	12051
2.6 to 7.5 cm	12032	2.6 to 5.0 cm	12052
7.6 to 12.5 cm	12034	5.1 to 7.5 cm	12053
12.6 to 20.0 cm	12035	7.6 to 12.5 cm	12054
20.0 to 30.0 cm	12036	12.6 to 20.0 cm	12055
Over 30.0 cm	12037	20.1 to 30.0 cm	12056
		Over 30.0 cm	12057

Debridement	CPT
Skin and subcutaneous tissue, 20 cm^2 or less	11042
Skin and subcutaneous tissue, each additional 20 cm^2	11045 (use with 11042)
Muscle and/or fascia (includes epidermis, dermis, and subcutaneous tissue, if performed), 20 cm^2 or less	11043
Muscle and/or fascia (includes epidermis, dermis, and subcutaneous tissue, if performed), each additional 20 cm^2	11046 (use with 11043)
Bone (includes epidermis, dermis, and subcutaneous tissue, muscle and/or fascia, if performed), 20 cm^2 or less	11044
Bone (includes epidermis, dermis, and subcutaneous tissue, muscle and/or fascia, if performed), each additional 20 cm^2	11047 (use with 11044)

Modified from the American Medical Association. Current Procedural Terminology 2011. Chicago: The Association, 2010.

Reference

1. The American Medical Association. Current Procedural Terminology 2011. Chicago: The Association, 2010.

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12 Frontal Sinus Fractures

Mark D. Walsh, Jeffrey R. Marcus

Background

Approximately 5% to 12% of facial fractures are of the frontal sinus.[1] The frontal bone is relatively strong in relation to other facial bones, requiring 800 to 2200 pounds of force to cause a fracture[2]; consequently, a frontal sinus fracture results from a high-energy impact. When a diagnosis of a frontal sinus fracture is made, other facial fractures should carefully be ruled out. There are potentially significant adverse sequelae of untreated frontal sinus fractures, which provide the basis for therapeutic intervention. The primary indications for operative intervention include restoring forehead contour, accessing a dural tear for repair, and definitively managing a traumatically obstructed nasofrontal duct to prevent the future development of a mucocele.

REGIONAL ANATOMY

The calvarial bones begin to form in the eighth to ninth week of gestation, and subsequent pneumatization of the frontal sinus begins at 16 weeks' gestation. Most of the pneumatization occurs between the ages of 12 and 16, with some additional pneumatization continuing until around age 40 (Fig. 12-1). Therefore frontal sinus fractures are rare in the pediatric population, instead, frontal bone skull fractures and fractures of the supraorbital rim are more common in this group.

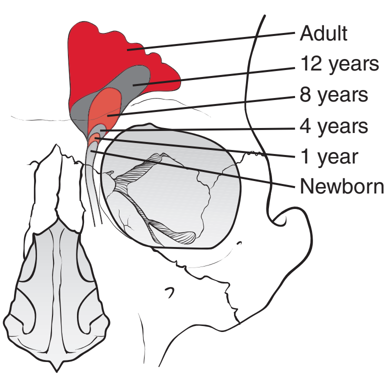

Fig. 12-1 Progressive increase in size of the frontal sinus with growth and development. Significant aeration does not occur until adolescence.

Up to 20% of patients of all ages may have underdevelopment, asymmetrical development, or no development of the frontal sinuses.[3]

Drainage of the frontal sinuses occurs through the nasofrontal ducts, or recesses. The term *duct* implies a narrow passage, whereas *recess* is more accurate, reflecting the wider, funnel-shaped configuration of this space. The recesses open inferiorly and medially and drain near the middle meatus (Fig. 12-2). The frontal sinuses are lined with mucosa. The mucosal surface incorporates invaginations in the inner table, called the *pits of Breschet.* Mucus secreted by the mucosal surfaces undergoes intrinsic recirculation through the frontal sinus with subsequent drainage through the nasofrontal recess (Fig. 12-3). Fractures of the frontal sinus or the nasoorbital ethmoid complex can lead to obstruction of this drainage. Obstruction results in sinus congestion, and prolonged obstruction can lead to formation of a mucocele (see Fig. 12-3).

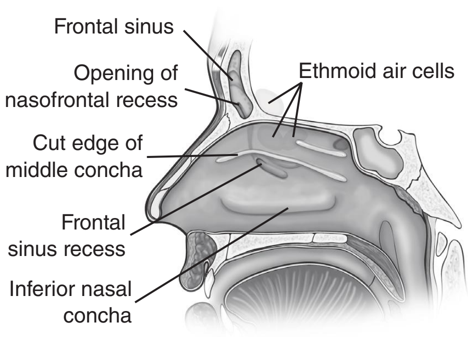

Fig. 12-2 Sagittal view showing the relationship between the frontal sinus and the nasofrontal recess, which drains into the middle meatus. Notice also the relationship between the frontal sinus and the ethmoid air cells.

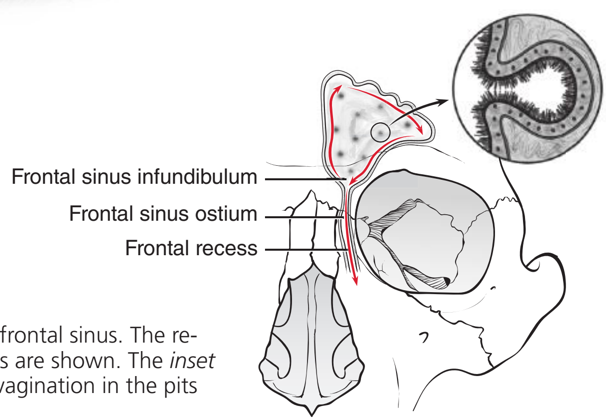

Fig. 12-3 Coronal view of the frontal sinus. The recirculation and drainage patterns are shown. The *inset* is a close-up view of mucosal invagination in the pits of Breschet.

DIAGNOSIS

A frontal sinus fracture is diagnosed through clinical and radiologic examination. Clinical examination may reveal a visible contour irregularity or a palpable step-off area. Lacerations may be present overlying the fracture. If the patient describes or has evidence of nasal discharge, a CSF leak must be ruled out. A CSF leak is confirmed by the laboratory when beta-2 transferrin is identified in the fluid.

More detailed information can be obtained through radiographic examination. Frequently with a trauma injury an initial head CT scan will have been performed to rule out intracranial injury. A frontal sinus fracture should be apparent based on this initial head CT scan. However, because frontal sinus fractures are often caused by high-energy impacts, and a standard head CT scan generally stops at the orbits, a more complete craniomaxillofacial CT scan with 1.5 mm axial slices should be considered (see Chapter 5). Both axial and sagittal views should be obtained. A review of the films from the vertex of the skull to the lower orbits should be standard for clinicians evaluating the frontal sinus region. Salient features to note include whether the anterior table, posterior table, or both tables of the sinus are fractured. Additionally, the region of the nasofrontal recess should be examined carefully to determine whether the recess appears patent or obstructed. The severity of the fracture and the degree of comminution and/or depression should also be assessed. A typical classification is shown in Fig. 12-4.

> Plain films do not add any diagnostic information to CT scanning; however, for operative planning, a 1:1 ratio frontal view may be useful as a template for entering the frontal sinus.[4]

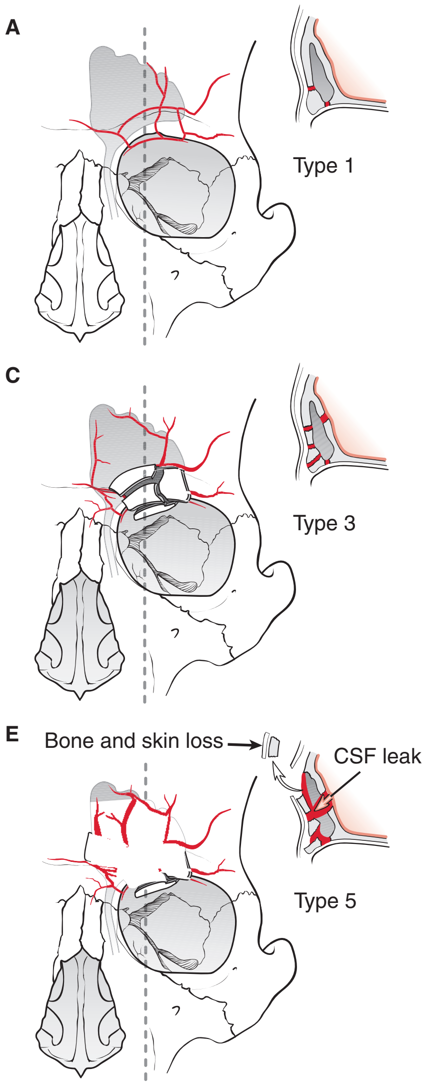

Fig. 12-4 Classification of frontal sinus fractures. **A,** Type 1, minimally displaced anterior table fracture. **B,** Type 2, significantly comminuted or depressed anterior table fracture. **C,** Type 3, anterior and posterior table comminuted fracture. **D,** Type 4, comminuted anterior and posterior table fracture with dural injury. **E,** Type 5, tissue/bone loss in association with comminuted anterior and posterior table fracture and dural injury.

SURGICAL REPAIR

After comprehensive clinical and radiologic examinations, the surgeon decides whether surgical intervention is appropriate. Isolated nondisplaced fractures of the anterior table generally do not warrant surgery. The same is true for fractures of this nature that extend along the supraorbital rims. The approach to the frontal sinuses requires a coronal incision in most cases (rarely, a laceration may be used to address an anterior table displacement). A depressed fracture, evidence of nasofrontal recess obstruction, or a persistent CSF leak is an indication for operative repair.

Fig. 12-5 presents useful algorithms based on anterior or posterior table injury. The appropriate surgical intervention is based on which tables are fractured, as well as the patency of the nasofrontal recess. In short, fractures with significant displacement of the anterior table that cause visible deformity require operative reduction. If there is evidence of obstruction of the nasofrontal recess on CT

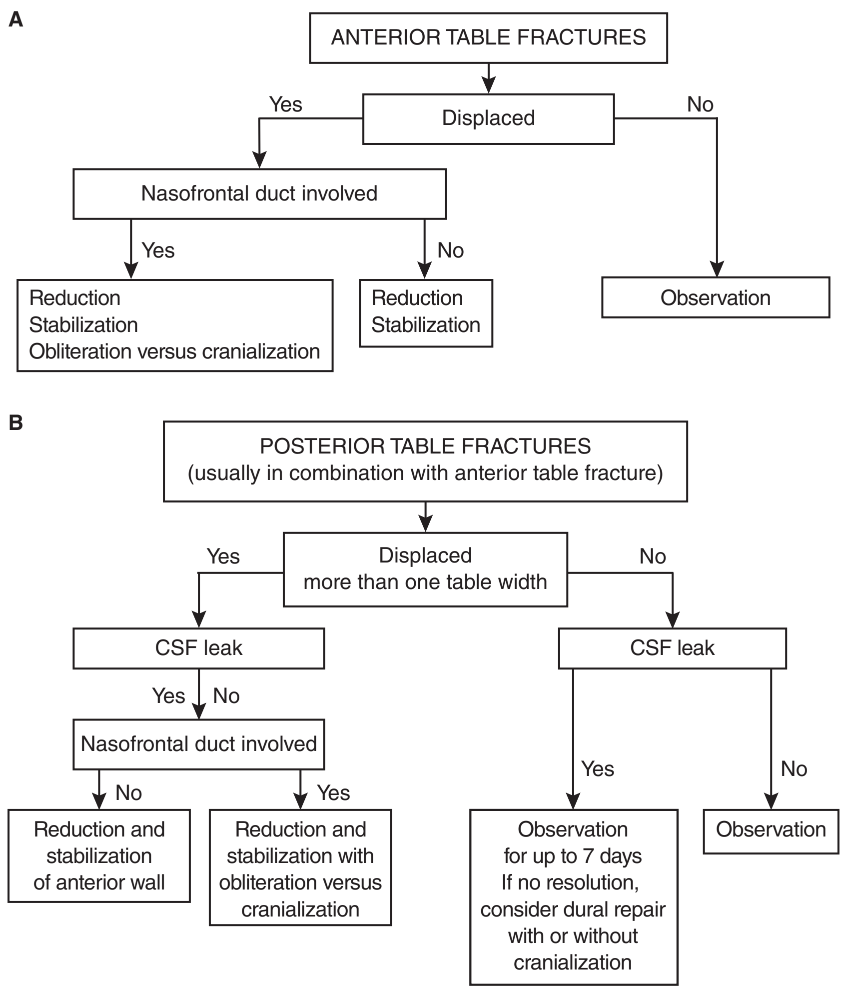

Fig. 12-5 Algorithm for management of **A,** anterior and, **B,** posterior table fractures. (From Joshi AS, Preciado DA, Byrne P, et al. Plastic surgery for frontal sinus fractures. Medscape Reference, 2008. Available at *http://emedicine.medscape.com/article/1283338.*)

scans, the sinus should be obliterated following mucosal stripping of the sinus and obliteration of the nasofrontal recess itself. There are numerous obliteration methods (described later). If the patency of the recesses is in question, they may be examined intraoperatively. Methylene blue or fluorescein may be instilled in the sinus, and recess patency is confirmed when dye is identified in the nose. Clinicians should have a low threshold for obliterating the recesses, because it is associated with a decreased risk of complications.

With posterior table involvement, patients need to be evaluated for a CSF leak. If the anterior table is not displaced, a CSF leak may be observed conservatively for up to a week. If the CSF leak persists or operative intervention is required to repair the anterior table, then dural repair should be considered, along with cranialization and obliteration of the nasofrontal recesses.

There are two main approaches to the frontal sinus: an anterior approach, by means of an incision or through an existing laceration, or a coronal approach. A coronal approach is preferred for cosmetic reasons, but in older patients with prominent forehead rhytids or in patients with large lacerations, a direct approach may be appropriate for adequate exposure. Endoscopic repair of frontal sinus fractures has been described as well. Practically and currently, the endoscopic approach is limited to simple anterior table fractures, but it does have the advantage of being less invasive and is associated with decreased recovery time.

Surgical intervention is often performed to address nasofrontal recess obstruction. When a coronal incision is employed, options for frontal sinus and nasofrontal recess obliteration must be considered. Many clinicians use a galea-frontalis flap or a pericranial flap to assist with obliteration. These flaps must be planned when performing the initial dissection for exposure.

After exposure of the fracture, anterior table fragments should be removed with the orientation preserved. The remainder of the anterior table should be removed as necessary to facilitate stripping of all mucosal surfaces. A 3 to 5 mm diamond burr allows complete removal of mucosal elements without risking abrupt penetration of the remaining thin bone, as could potentially occur using a cutting burr. All inner surfaces of the frontal sinus are abraded to remove traces of mucosa in the pits of Breschet. If mucosa is left behind, it has the potential to continue to secrete mucus that would have no route for drainage. A mucocele or mucopyocele is a possible sequela of retained mucosa and may not be evident for several years after the repair.

The posterior table is then examined. Extensive comminution or a CSF leak requires removal of the posterior table bone and repair of the dura, as necessary. The brain is subsequently allowed to prolapse forward and fill the sinus; this is called *cranialization.*

After removing the entire posterior table for cranialization, any sharp osseous prominences are removed as well. Over time, the brain will expand into the space; in the short term, however, this region will likely appear as epidural fluid on postoperative imaging. Whether performing obliteration or cranialization, the nasofrontal recess must be plugged. The goal is to provide the most reliable barrier between the nose and anterior fossa; therefore it is preferable to use vascularized tissue, such as a pericranial flap with or without bone grafts (typically obtained from the posterior table). Many other materials have been described to plug the recess, including muscle, fat, fascia, and bone chips. However, caution should be exercised when using nonvascularized tissue to obliterate the nasofrontal recess.

Finally, the anterior table fragments should be reassembled and replaced with plate and screw fixation. With large fragments, it may be possible to use several microplates (1.0 to 1.2 mm) or low-profile neurosurgical plates to replace the fragments. In our practice, however, a smoother restoration of contour has been achieved by routinely incorporating the comminuted fragments on a back table to a single, thin, titanium mesh. The fragments are labeled with marking pencil as they are initially removed. A drawing is made indicating the orientation of these fragments. The fragments are then assembled on the titanium mesh by placing a series of 1.0 mm screws. The titanium construct is then trimmed to allow only the necessary overlap peripherally to secure the construct. Before reconstruction of the anterior table, the pericranial or galeal flaps must be draped to their final position, with care taken to avoid disturbing them. Many authors use fibrin glue sealant as an adjunct to the obliteration of the frontal recess, and this can also help stabilize the vascularized tissue flap. A space should be provided anteriorly (a longitudinal space of 2 to 3 mm) to provide passage of the flap into the anterior fossa.

POSTOPERATIVE CARE

Initial postoperative management is not significantly different from that for other facial fractures. Patients should have their head elevated for 24 to 48 hours to minimize edema. Ice or cold packs may also be used to diminish swelling. Patients should be clearly advised against blowing the nose for 4 to 6 weeks, although saline mist irrigation with passive drainage is permissible to clear the nasal passages. If there was posterior table involvement or a dural repair was performed, the patient should be observed for evidence of a CSF leak. If a dural repair was performed, drains are typically not advisable. However, if no injury to the dura was noted, a single closed suction drain may be placed. Strenuous activity should be kept to a minimum for the first 1 to 2 weeks. Patients should refrain from engaging in contact sports and avoid situations that place them at risk for additional craniofacial trauma for at least 6 to 8 weeks after repair.

CONSEQUENCES OF INJURY AND COMPLICATIONS

Problems associated with frontal sinus fracture and repair can be categorized as early or late. The injuries themselves may lead to problems, regardless of treatment. Early sequelae may be transient; pain and sensory changes of the forehead should resolve within a few weeks. A more significant early complication is a CSF leak. Most of these leaks resolve spontaneously; persistent leaks may need to be treated with lumbar drainage and/or reexploration. Antibiotics should be administered while a drain is in place. Meningitis is a rare complication, occurring in approximately 6% of cases.[4] Patients with fevers, neck pain, or mental status changes should be evaluated expeditiously to rule out meningitis.

Late complications generally result from the development of a mucocele. Slow-growing mucoceles may present as late as 10 years after injury. They are locally destructive, lead to bony erosion, and cause intracerebral mass effects. These lesions can involve the brain, sinuses, and orbits. Contour deformities and frontal bone osteomyelitis are also late sequelae of frontal sinus fractures. Therefore the follow-up of patients with frontal sinus fractures should include both early and long-term visits. Initially patients are seen 1 or 2 weeks after repair, then 4 to 6 weeks later. At these visits, symptoms of headache and/or sinus congestion should be improving. Any evidence of infection should prompt repeat imaging. The patient should again be seen at 6 months and 1 year after injury, and thereafter at the judgment of the treating surgeon. A CT scan should be considered at the 1-year follow-up visit.

Pearls

- *The frontal sinus is a bilateral structure, separated by a thin, osseous septum. In most cases, both sides are involved. Occasionally, unilateral injuries can occur and may be treated on the affected side only.*
- *Fractures can involve the posterior table in isolation, with or without a CSF leak. In most cases these can be managed conservatively with resolution of the CSF leak.*
- *Coronal and sagittal CT views are useful for observing the full course of the nasofrontal recess to determine its patency.*
- *Complete removal of all mucosal elements must be done during cranialization or obliteration of the frontal sinuses to avoid late formation of a mucocele.*
- *Vascularized tissue is the most reliable means for obliterating the frontal sinus (pericranial flap or galea-frontalis). When using such anterior-based flaps, one must allow a space at the caudal aspect of the reconstructed anterior table through which the flap can pass without being compressed.*
- *Titanium mesh, rather than multiple plates, provides a construct or anterior table reconstruction that is quite stable and relatively smooth.*
- *Late follow-up, including reimaging, should be performed for cases treated either operatively or nonoperatively, because a mucocele may form in either instance.*

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13 Nasal and Septal Injuries

Halton Wolfgang Beumer, Liana Puscas

Background

Given the nose's projection from the face, it is unsurprising that nasal bone fractures account for nearly half of all facial fractures. Furthermore, most nasal bone fractures are associated with septal injury. Understanding the anatomy and being able to recognize injuries early are key to successful functional and cosmetic outcomes. Learning the proper techniques for managing these injuries, particularly those treated at the bedside, lessens patient discomfort and reduces the likelihood of complications.

REGIONAL ANATOMY

Osseous and cartilaginous structures provide structure and function to the nose (Fig. 13-1). The bony vault is composed of a set of paired nasal bones that are abutted by the maxilla laterally and the frontal bone superiorly. Their junctions compose the nasomaxillary and nasofrontal sutures lines, respectively. The paired upper lateral cartilages attach to the caudal aspect of the nasal bones and form the superior portion of the cartilaginous vault. Inferior to these are the paired lower lateral cartilages, further subdivided into the lateral and medial crura.

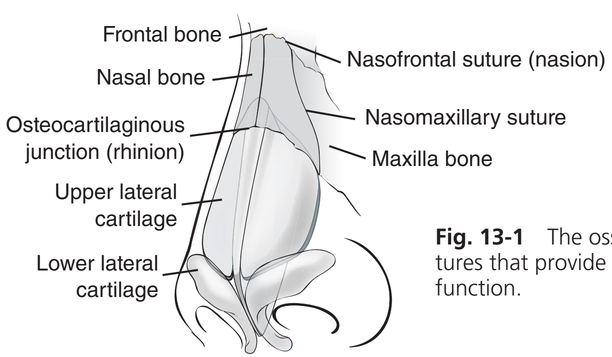

Fig. 13-1 The osseous and cartilaginous structures that provide the nose its structure and function.

The nasal septum is composed of osseous and cartilaginous structures as well (Fig. 13-2). The septum divides the nasal cavity in two. Anteriorly, the septum is composed of the quadrangular cartilage. Posteriorly, the septum is composed of two bones: superiorly, the perpendicular plate of the ethmoid bone, and, inferiorly, the vomer. The whole septum rests on a bony ridge of the maxilla called the *maxillary crest.* Superiorly, the septum separates the lower and upper lateral cartilages and, posteriorly, it integrates into the skull base at the cribriform plate.

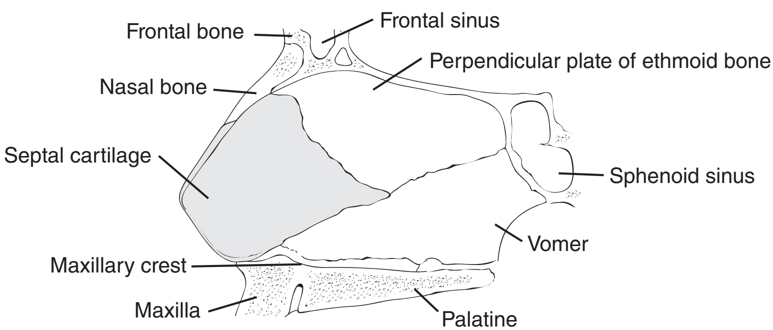

Fig. 13-2 Sagittal view of the osseous and cartilaginous structures of the septum and surrounding anatomy.

Relevant surface anatomy is important when describing the appearance of the nose (Fig. 13-3). The *rhinion* marks the osteocartilaginous junction between the upper lateral cartilages and the nasal bones. The *nasion* overlies the nasofrontal suture line and marks a depression just above the nasal bridge. The *nasal bridge* refers to the bony dorsum. The *glabella* refers to the raised region between the eyebrows, above the nasion.

Sensory innervation to the nose is supplied by the first (supratrochlear, infratrochlear, anterior ethmoidal) and second (infraorbital) branches of the trigeminal nerve (Fig. 13-4).

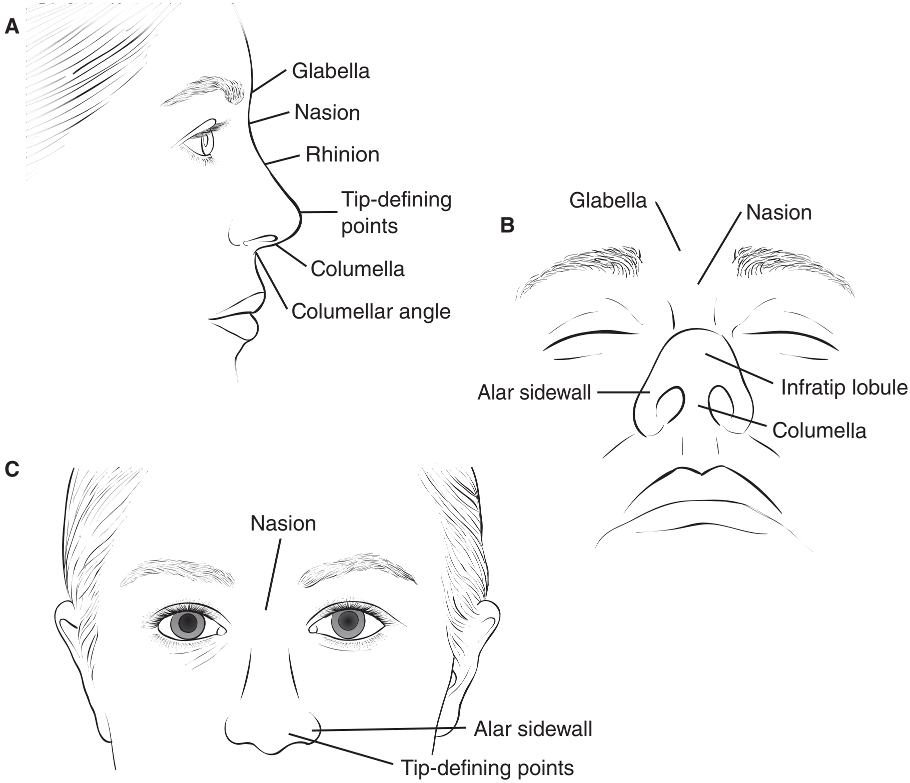

Fig. 13-3 Nasal surface anatomy. **A,** Lateral. **B,** Basal. **C,** Frontal.

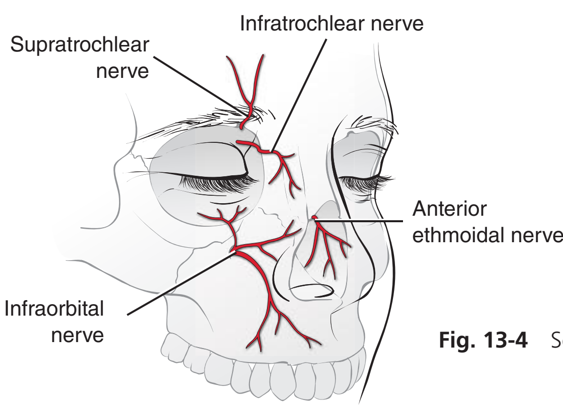

Fig. 13-4 Sensory innervation of the nose.

PHYSICAL EXAMINATION

The nose is the most prominent point on the face. Unsurprisingly, it is the most common bony facial injury.[1-3] Isolated nasal bone fractures can usually be identified on clinical examination. Early evaluation before the onset of significant edema is helpful; this is usually within the first 2 to 3 hours. If significant swelling has already set in, waiting several days with the patient's head elevated and intermittent applications of ice may be beneficial. Minimal swelling can be temporarily reduced at the bedside by applying uniform gentle pressure over the nasal dorsum.

On inspection, findings that suggest nasal bone or cartilage injury include deviation, asymmetry, depression, edema, overlying laceration, epistaxis, and periorbital ecchymosis. On palpation, bony crepitus, focal tenderness, step-offs, loss of support, and freely mobile bony segments are suggestive of injury.

The internal nose should then be carefully evaluated. Septal injuries are identified on anterior rhinoscopy as well as by external examination of the nose. However, septal deviation may or may not represent an acute injury, because septal deviation is a common finding in patients with no history of nasal trauma.[4] Clues that the injury is acute include a freely mobile septum, mucosal lacerations, or a septal hematoma. In an acute injury, anterior rhinoscopy may be difficult because of epistaxis and mucosal edema. The use of topical decongestants such as oxymetazoline or diluted epinephrine and suctioning may significantly improve visualization.

Often significant swelling is associated with nasal bone fractures, making obvious nasal deformities more subtle. A maxillofacial CT scan is the imaging modality of choice to identify fractures and other concomitant injuries (such as orbital floor fractures). Plain nasal radiographs can often identify that a fracture is present, but they do not provide information about displacement, which is the key factor in whether reduction is indicated. Clinical examination provides the most useful information. When imaging is thought to be necessary, CT should be considered.

Not uncommonly, patients presenting with nasal injuries have a history of prior nasal trauma.[3] Particularly in intubated patients or those who cannot provide a clear history, one must consider that the injury is not acute. A lack of edema, periorbital ecchymosis, bony crepitus, evidence of epistaxis, and fresh lacerations, as well as a CT scan that reveals no sinus opacification, are all clues that a fracture or asymmetry is old. The presence of well-healed scars on the septum or nasal dorsum, along with a bony fracture on CT scan, without any soft tissue changes are also indications that an asymmetry is long standing. If possible, patients or family members should be queried as to the patient's preinjury appearance, nasal function (prior nasal obstruction) and prior surgeries. Preinjury photos, if available, are helpful. Nevertheless, a thorough history of the mechanism of trauma may give insight as to what injuries one should suspect.

FRACTURE PATTERNS

Bony, Cartilaginous, and Mixed Injuries

The paired nasal bones, attached semirigid upper lateral cartilages, and the nasal septum compose the framework of the nose to which the overlying skin and the mobile lower lateral cartilages are attached. Both cartilaginous and bony components are susceptible to fracture. There is no established classification for nasal bone fractures; nevertheless, injuries to the nose can be grouped into bony, cartilaginous, and mixed injuries.

Fractures can be predicted based on the mechanism of injury. Forces delivered laterally or obliquely (a hook punch) versus those delivered anteriorly (an impact against a steering wheel) result in different patterns of injury, as do high- versus low-velocity insults. Typically, a low-velocity lateral force results in a unilateral, depressed nasal bone fracture. Higher forces may result in contralateral lateralization of the nasal bone. Bowed or C-shaped deformities resulting from a lateral blow to the nose are often associated with septal injury. Disarticulation of the cartilaginous septum from the bony septum or the maxillary crest may result in significant septal deviation, which may in turn affect the appearance of the nasal dorsum.

A high-velocity frontal force may typically result in more comminuted nasal bone fractures with telescoping or AP compression of the bony and cartilaginous structures.[4] This may happen with or without septal fractures. High-energy trauma may result in nasoorbitoethmoid (NOE) fractures (see Chapter 19).

SURGICAL INDICATIONS

Septal hematoma, nasal deformity, and nasal obstruction are the three key indications for intervention. Treating septal hematomas is critical, because sequelae can be significant (such as saddle nose deformity). Patients involved in aggressive physical activities (such as boxing and martial arts) require honest discussion regarding the likelihood of reinjury and the extent of intervention to correct current deformities.

TREATMENT GOALS

The immediate goals of treatment are to address facial edema, resolve epistaxis, and treat septal hematomas. Reducing facial edema with ice and elevation can lead to better visualization of the extent of injury and therefore a more accurate repair. Control of epistaxis is necessary for adequate inspection of the nose. This is usually achieved with vasoconstrictor sprays (such as oxymetazoline and phenylephrine) and bilateral external pressure over the cartilaginous nose. If epistaxis does not resolve within 15 minutes, nasal packing may be necessary.

For a septal hematoma, treatment is necessary to prevent septal deterioration or infection, which can lead to perforation and/or saddle nose deformity. Nasal bone and septal fractures are addressed to restore the preinjury external appearance and to correct nasal obstruction.

EXPOSURE

Most nasal bone injuries are reduced in a closed fashion. For extensive injuries or complex revisions, open and closed septorhinoplasty techniques can be employed. Details of this are beyond this scope of this chapter. Typically, overlying lacerations or the usual open rhinoplasty skin incisions allow excellent exposure of all aspects of the nose.

OPERATIVE SEQUENCE

Nasal and septal injuries should be repaired as soon as possible, but a delay of up to 14 days is acceptable to allow resolution of edema. However, best results are usually obtained within 7 days of injury.[1] Septal hematomas must be treated within hours of diagnosis to prevent sequelae.

Nasal Fractures

Most nasal bone fractures can be reduced using a closed technique. This can usually be accomplished at the bedside. The key is applying proper topical and local anesthesia. In most cases, closed reductions (either at the bedside or in the operating room) are effective, safe, and successful. The literature suggests that 60% to 90% of these injuries are treated with good outcomes.[3,5] Some patients, including children, will not tolerate reduction under local anesthesia. These cases can be treated in the operating room with conscious sedation or a general anesthetic. Ultimately, the decision to undergo open surgical correction versus closed reduction is made on an individual basis. Open approaches are typically reserved for severe cases. Epistaxis immediately after a closed nasal reduction is very common and usually stops spontaneously after a few minutes.[1] Topical vasoconstrictive sprays may help speed the resolution.

Closed Reduction

Topical intranasal anesthesia and vasoconstriction are accomplished by applying pledgets soaked with 0.025% oxymetazoline (Afrin) and 1% tetracaine within the nasal cavities bilaterally. Alternatively, 1:50,000 epinephrine or 1:10 0.25% phenylephrine can be used instead of oxymetazoline, and 2% to 4% lidocaine can be used instead of tetracaine. The pledgets should be placed under direct visualization in the nasal vault between the septum and turbinates and at the base of the septum. Correct placement is important and is greatly aided by use of a headlight and a nasal speculum. At least 10 to 15 minutes should be allowed for adequate vasoconstriction and anesthesia.

While the pledgets are in place, local anesthesia should be administered. Bilateral infraorbital nerve blocks can be performed by administering 1 to 3 ml of 1% lidocaine with 1:100,000 epinephrine at the infraorbital foramina. The infraorbital foramen is located in the midpupillary line within 15 mm of the inferior orbital rim. For the intraoral approach, one finger is left over the foramen, then the cheek is retracted, and a syringe with a 27-gauge needle is guided from the buccal-gingival sulcus, adjacent to the first maxillary premolar, along the anterior maxilla to the infraorbital foramen. The needle is usually advanced 1.5 to 2.5 cm. After aspiration to ensure that the needle is not within a vessel, 1 to 3 ml of local anesthetic is administered. Care should be taken to avoid advancing the needle too far into the orbit or into the foramen. A transdermal injection can also be performed by injecting directly over the infraorbital foramen after cleansing the skin.

Supraorbital nerve blocks should also be performed. The supraorbital foramen is located approximately 2 to 3 cm lateral to the midline along the superior orbital rim. The notch just lateral to the foramen can usually be palpated. The skin overlying this is cleaned with povidone-iodine (Betadine) or alcohol solution, and a 27-gauge needle is used to inject 1 to 3 ml of 1% lidocaine with 1:100,000 epinephrine just superior to the notch. Again, aspiration is done before injection, and care is taken to avoid injecting into the foramen or the orbit.

If lidocaine is used, the nerve blocks usually take 4 to 6 minutes to take effect. In addition, a field block directly overlying the nasal bone can be administered by injecting 0.5 ml of 1% lidocaine with 1:100,000 epinephrine bilaterally. Care must be taken to avoid overinjecting, causing effacement of the bony architecture. If effacement occurs, gentle pressure is used, and after 10 to 15 minutes the swelling will subside.

After the anesthetic has taken effect, the pledgets are removed. A Goldman or Boise elevator can be used to perform the closed reduction. First, the elevator is placed along the nose externally to measure the distance from the alar rim to the nasion or medial canthus (Fig. 13-5). The thumb and/or forefinger are placed to set the safe length along the retractor. Once in this position, they remain in place to prevent introducing the elevator too far, leading to skull-base injuries. The elevator is introduced into the nasal cavity in the side with the concave deformity, along the septum under the nasal bones. The opposite hand is placed over the fracture site to bimanually guide the fragments back into proper alignment as the elevator is used to elevate and lateralize the concavity. Depending on the fracture, the pressure applied to reduce the fracture will be variable in its intensity. If reduction is not successful, placement of the elevator in the contralateral nasal cavity may be necessary, and the maneuver with bimanual pressure is repeated. Depending on the degree of displacement and the time elapsed since injury, it may take some force to reposition the nasal bone fragments correctly. If the distal segment of fractured nasal bone is displaced inferiorly and posteriorly (telescoped) under the proximal segment of the nasal bone (as seen in force applied in the anterior-posterior direction), often this can be corrected using a single hook to retrieve the segment. This type of injury is often associated with mucosal tears, which allows access for placement of the hook.

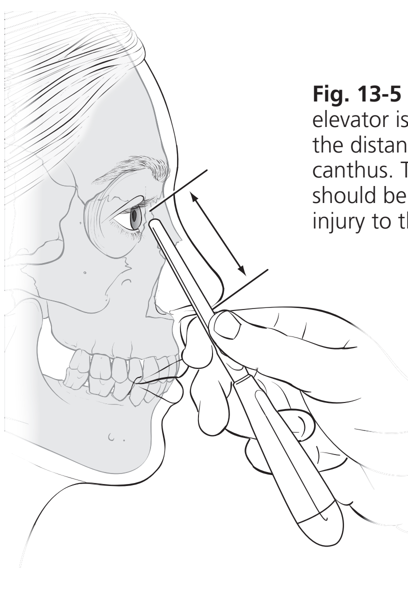

Fig. 13-5 Before a closed reduction is performed, an elevator is placed along the nose externally to measure the distance from the alar rim to the nasion or medial canthus. This is the maximum distance the elevator should be placed within the nasal cavity to prevent injury to the skull base.

Cartilaginous and Septal Injuries

If a septal hematoma was noted on the initial examination, this should be addressed before reduction of the nasal bone.[1] Septal hematomas are drained by making a unilateral, horizontal mucosal incision along the base of the hematoma. Clots can be evacuated with suctioning. The incision is left open to allow continued drainage. If bilateral incisions are necessary, they should not directly oppose each other, because this may lead to septal perforation.

Septal injuries can be divided into anterior cartilaginous and posterior bony fractures. Unless significant, posterior injuries usually do not contribute to nasal obstruction, nor do they affect the external appearance of the nose. Anterior cartilaginous injuries, on the other hand, are more likely to contribute to nasal obstruction and may also affect the external appearance of the nose.

Closed Reduction

To correct septal dislocations, Ash forceps or a Goldman elevator can be used to gently reposition the septum to its original state (Fig. 13-6). Anteriorly, the septum should lie between the medial crura of the lower lateral cartilages. If it is significantly displaced, a 4-0 chromic suture can be placed through the anterior cartilaginous septum to secure it between the medial crura. Intranasal septal Silastic splints should be placed, along with Merocel packs or petrolatum gauze bilaterally to hold the septum in place for 5 to 7 days. If inflatable nasal packing is used, care should be taken to not overinflate the packing, because this can result in pressure necrosis of the mucoperichondrial flaps, ultimately exposing cartilage and

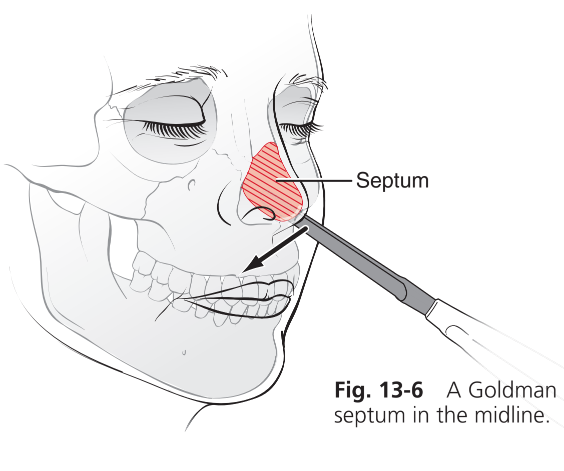

Fig. 13-6 A Goldman elevator is used to reposition the septum in the midline.

risking septal perforation. While nasal packs are in place, it is important to place the patient on gram-positive antibiotic coverage to prevent toxic shock syndrome.

Merocel packs are also useful for supporting comminuted or unstable nasal bone fractures from within the nasal cavity. Inverted Doyle splints can also be used. Once nasal bone fractures and septal injuries have been addressed, a dorsal splint (such as the Denver Splint or a Thermasplint) should be applied to protect the reduction for 5 to 7 days.

Displaced upper lateral cartilages will usually be corrected with reduction of the displaced segment (or segments) of the nasal bones. If this is not the case, avulsion of the cartilage from the bone should be suspected. Usually this is not immediately apparent because of edema. Consequently, this is usually identified later and corrected in a secondary surgery with spreader grafting, cartilage overlay grafting, or other techniques.

Open Reduction

In a high-velocity injury resulting in complex nasal bone injuries (severe deviation, significant lacerations, tissue avulsion, acute saddling of the nose, open compound injuries, severe comminution of bones), closed reduction may not be adequate to restore the original contour of the nose. In such a case, or in cases in which other facial injuries need to be surgically addressed, an open approach is the preferred option. Open septorhinoplasty or a coronal approach offers the best exposure, unless there is an overlying laceration. Miniplates and screws can be used to anchor free segments at the nasofrontal suture line and nasal process of the maxilla. This provides a stable framework on which to further reduce and secure distal bony fragments as needed. If the upper lateral cartilages have been avulsed, they can be reapproximated to the nasal bone margins by drilling small holes in the nasal bones and using 5-0 clear nylon to secure the cartilage in place. Open septoplasty can be performed as needed to address septal injuries. Overall, the goal is to correct nasal injuries sequentially from proximal to distal.

POSTOPERATIVE CARE

Splints and packing, if used, should remain in place for 5 to 7 days.[1,5] Patients are advised to avoid any additional trauma to their faces, because this will likely result in dislocation of the reduction. In patients who have nasal packing, gram-positive antibiotic coverage with cephalexin, amoxicillin, or a similar agent should be prescribed for as long as the packs are to remain in place to prevent toxic shock syndrome. Appropriate pain medications are prescribed. NSAIDs, ice, and elevation can be used to reduce inflammation and swelling. In patients without packing, oxymetazoline nasal spray is useful to have on hand to treat unforeseen epistaxis. However, patients should be warned about the development of rhinitis medicamentosa with prolonged use (more than 3 days). Nasal saline sprays (every 2 hours) and irrigation (two to three times daily) should be prescribed, especially if septal splints, septal hematoma, or intranasal mucosal lacerations are factors. Patients are seen back in the clinic 5 to 7 days after reduction for removal of dorsal splints and nasal packing. At this follow-up visit, swelling has usually subsided enough to reevaluate for external nasal deformity. If significant deformity or septal deviation persists, the surgeon and patient can discuss secondary operative management.

CONSEQUENCES OF INJURY AND COMPLICATIONS

Consenting patients should clearly understand the complications inherent in nasal trauma and the complications that may arise when the injury is repaired. Inadequate or no reduction of bony or cartilaginous injuries may result in persistent nasal deformity, nasal obstruction, and/or septal deformity. Inadequately drained septal hematomas may result in septal abscess, septal perforation, and/or saddle nose deformity. Excessive packing may also result in mucoperichondrial necrosis and septal perforation. The instrumentation used for reducing the nasal bone fractures carries the risk of causing skull-base (that is, cribriform plate) fractures and consequent CSF leaks. There is also a risk of orbital injury. Orbital and skull-base injuries during reduction are highly unlikely if care is taken to measure the elevator before introducing it into the nasal cavity. Instrumentation may also cause mucosal lacerations and epistaxis, although this is usually minor and is easily addressed with topical vasoconstrictors in patients who are not coagulopathic. Orbital injuries may also result when performing nerve blocks.

RECOMMENDED FOLLOW-UP

Patients should return for a follow-up visit 5 to 7 days after their intervention for removal of splints, packing, and sutures, as needed. If patients still have significant edema, it may be difficult to assess the adequacy of the reduction. They may continue to experience some nasal obstruction as well. These patients should be seen back in 2 to 3 weeks for reevaluation.

Patients who are satisfied with their appearance and are experiencing no significant nasal obstructive symptoms may be seen back on an as-needed basis. Postoperative radiographs are not necessary. For patients who are not happy with the cosmetic appearance of the nose or who are still experiencing nasal obstruction, a secondary septorhinoplasty 6 to 12 months later may be necessary. In these cases, a facial CT scan before revision surgery may be of value.

Pearls

- *A history of prior nasal trauma or surgeries is very important. Preinjury photographs, if available, are helpful.*
- *A thorough physical examination is essential so that septal injuries are not overlooked.*
- *The elevator must be measured before reducing fractures to prevent orbital or skull-base injuries.*
- *Splints and packing are important, especially after septal manipulation.*
- *While nasal packing is in place, patients need to receive a course of gram-positive prophylactic antibiotic therapy.*
- *Good local anesthesia is vital when performing closed reductions at the bedside or in the office.*
- *If imaging is thought to be necessary, a facial CT scan is the imaging modality of choice. Plain film radiographs are insufficient for evaluation.*
- *Suction equipment should be immediately on hand to help with any epistaxis.*

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14 Orbital Fractures

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Background

Orbital fractures can occur in isolation or in combination with other facial injuries or fracture complexes. Although much of the discussion in this chapter focuses on isolated orbital floor or wall injuries, it provides detailed clarification to complement and complete the discussions found in associated chapters. Orbital fracture *is a broad term, because there are numerous patterns of injury and a wide range of severity. The word* orbit *refers to the space formed by the osseous structures that surround it. Orbital fractures can involve any of these surrounding structures, and the significance of an orbital injury is related to its effect on the space or the contents of the space. Not only is there variation, depending on the type of injury and the association with other facial fractures, but there is also some debate among surgeons with regard to indications, timing, and techniques of fracture repair. There are differences of opinion regarding the choice of incision, approach, reconstructive materials, and wound closure.*

REGIONAL ANATOMY

The bony orbit is shaped like a pyramid, with a quadrangular base composed of seven individual bones of variable thickness: the zygoma, ethmoid, frontal, maxilla, lacrimal, palatine, and greater and lesser wings of the sphenoid (Fig. 14-1). The bony orbit can be conceptualized as having anterior, middle, and posterior thirds.

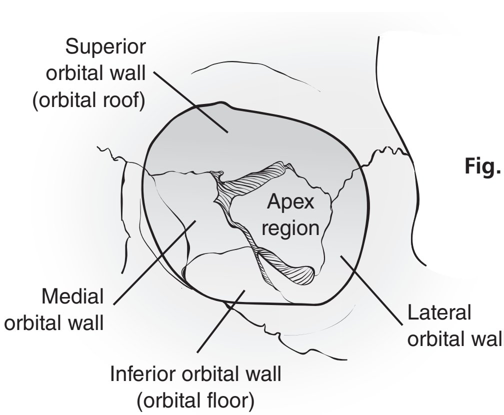

Fig. 14-1 Anatomy of the bony orbit.

The anterior third is a circumferential and stable orbital rim composed of supraorbital, nasoethmoidal, and zygomatic sections. The middle third defines the orbital cavity and is far thinner, making it prone to fracture as it absorbs forces transmitted through the rim. It is made up of the roof, floor, and medial and lateral walls. The posterior third of the bony orbit is the thickest section and is relatively protected from fracture. It houses the superior and inferior orbital fissures and optic foramen.

The orbital cavity is defined by superior, inferior, medial, and lateral walls. The superior wall, or *roof,* is thin yet protected by a strong superior rim formed predominantly by the frontal bone. The inferior wall, or *floor,* is defined by the zygoma and maxillary roof. The lacrimal bone and lamina papyracea of the ethmoid compose the medial orbital wall. The thicker frontal and zygomatic bones and the greater wing of the sphenoid form the lateral wall.

The supraorbital nerve exits the frontal bone through the supraorbital foramen. The greater wing of the sphenoid houses the superior orbital fissure, through which pass several nerves (as discussed later). The infraorbital nerve travels along or through the orbital floor, exiting the maxilla just below the infraorbital rim via the infraorbital foramen.

Cranial nerves III, IV, and VI, as well as the ophthalmic division of the trigeminal nerve, traverse the superior orbital fissure. The infraorbital division of the maxillary segment of the trigeminal nerve and the zygomaticofacial nerve pass through the inferior orbital fissure, also located in the posterior third of the orbit. The optic foramen can be found in the superior and medial aspect of the orbit, approximately 45 mm from the orbital rim. It houses the optic nerve and the ophthalmic artery.

The orbit receives its blood supply through branches of the internal and external carotid arteries and their anastomoses. The internal carotid artery gives off the ophthalmic artery, which supplies the eyelid, nasal dorsum, and forehead. The ophthalmic artery branches into the supraorbital, supratrochlear, infratrochlear, anterior and posterior ethmoid, medial and lateral palpebral, and marginal arteries. The anterior and posterior ethmoid arteries anastomose with the external carotid artery; hence embolization procedures and injections of external carotid branches can inadvertently result in blindness. The external carotid artery gives rise to the internal maxillary artery, which emerges as the infraorbital artery in the pterygopalatine fossa before passing through the infraorbital fissure into the orbit. It continues anteriorly through the infraorbital groove and canal to emerge below the inferior orbital margin to supply the lower eyelid. The superficial temporal artery, just before crossing the zygomatic arch, gives off the transverse facial artery to supply the lateral canthal area.

The eyelids consist of three lamellae: anterior (skin and orbicularis oculi muscle), middle (orbital septum), and posterior (conjunctiva, capsulopalpebral fascia, medial and lateral canthal tendons, and tarsal plate). In the anterior lamella, the orbicularis oculi is the primary lid constrictor, containing pretarsal, preseptal, and orbital fibers. The middle lamella contains the orbital septum, which forms a membrane spanning to the periosteum of the orbital rim and separates the orbital contents from surrounding periorbita. In the posterior lamella, Müller's muscle and the levator palpebrae superioris serve as the upper eyelid retractors, whereas the capsulopalpebral fascia serves the lower lid. The tarsal plates are dense, cartilaginous structures that provide vertical support to the eyelids. Along the medial and lateral margins of the palpebral fissure, the tarsal plates become confluent with their respective canthal tendons.

Ligamentous support of the globe consists of medial and lateral canthal ligaments as well as check ligaments. The lateral canthal tendon is formed by the confluence of the upper and lower crura and Whitnall's ligament, which merge to create the lateral retinaculum. This inserts onto Whitnall's tubercle of the lateral orbit. The nasoethmoidal region of the medial orbital rim contains the attachments for the levator palpebrae superioris to the medial canthus and Lockwood's ligament (the lower lid analog of Whitnall's ligament) to the superior aspect of the lacrimal fossa, respectively. The lacrimal gland is a bilobed structure situated in the lacrimal fossa of the superolateral orbit. The smaller palpebral lobe empties into the upper lateral half of the superior fornix. The main orbital lobe sends ducts through the palpebral lobe for drainage. Tears pass from the palpebral fissure through the lacrimal ducts and canaliculi via the puncta lacrimali. The canaliculi merge as a common canaliculus to empty into the lacrimal sac, which is situated within the bony lacrimal fossa just posterior to the insertion of the medial canthal tendon.

FRACTURE PATTERNS

Orbital Floor

The orbital floor is most susceptible to injury in the adult population and is commonly fractured in craniofacial trauma. Two main mechanisms have been proposed to explain the cause of floor fractures. The *hydraulic mechanism* attributes fractures to the direct transmission of pressure from the intraorbital contents and globe to the orbital floor. In contrast, the *buckling mechanism* credits osseous conduction, or indirect transmission, of force to the orbital rim as the cause of fracture. The orbital floor is thin, and the presence of the infraorbital foramen and groove make this site susceptible to fracture from forces applied to the midface. In addition, the contour of the orbital floor changes from concave just behind the infraorbital rim to convex closer toward the apex. Both factors may account for the high frequency of fractures seen in the orbital floor.

A pure blowout fracture involves the internal orbital walls without fracture of the orbital rims. On examination, diplopia and enophthalmos are frequently evident. Diplopia is most often the result of edema but can result from incarceration of the inferior oblique or inferior rectus muscles, Lockwood's ligament, Tenon's capsule, or periorbital fat within the fracture line, any of which may lead to restricted ocular movement. Similarly, direct damage to the extraocular muscles or their innervations, hematoma, or edema can also lead to diplopia.

Orbital floor fractures can occur in combination with zygomaticomaxillary complex (ZMC) or LeFort fractures, each differing in terms of severity and presenting with distinct sequelae. Isolated orbital floor injuries have been demonstrated on CT scan to result in orbital expansion, whereas those occurring in association with ZMC fractures can result in a decreased orbital volume.[1]

Medial Wall

Composed of the lacrimal bone and lamina papyracea of the ethmoid, the medial orbital wall occupies a vertical position with a slightly lateral slant. Anteriorly, it houses the lacrimal sac between the frontal process of the maxilla (anterior lacrimal crest) and the lacrimal bone (posterior lacrimal crest). A fracture in this anterior third (the medial rim) is typically classified as a nasoorbital ethmoid fracture, whereas a fracture of the weak lamina papyracea connotes a pure medial wall injury. Because the medial wall separates the orbit from the ethmoid sinus, epistaxis and orbital emphysema are commonly seen with floor fractures that involve the medial wall.

Lateral Wall

The lateral orbital wall is formed primarily by the orbital surface of the zygomatic bone and the greater wing of the sphenoid bone. The sphenoid portion of the lateral orbit is separated from the roof of the orbit by the superior orbital fissure and from the floor by the inferior orbital fissure. Isolated fractures of the lateral wall are the least common of all orbital fractures, because the frontal and zygomatic bones are thick and offer support. However, fractures of the ZMC are common and always involve the lateral wall through articulations with the zygoma and greater wing of the sphenoid.

Orbital Roof

Roof fractures, although rare in the adult population, are the most common orbital fractures seen in children less than 7 years of age. Possible reasons include incomplete pneumatization of the frontal sinus as well as the proportionately larger sized cranium in the pediatric population. After age 7, the orbital floor becomes the most prevalent fracture site, because sinus pneumatization, as well as facial development, redirects traumatic forces. Incidence of concomitant involvement of the zygomatic complex (50%), nasoethmoidal region (32%), and frontal sinus (28%) are notable, and thus identification of an orbital fracture on imaging should trigger careful analysis to rule out common associated fracture patterns.[2] Fig. 14-2 shows the commonly observed fracture patterns.

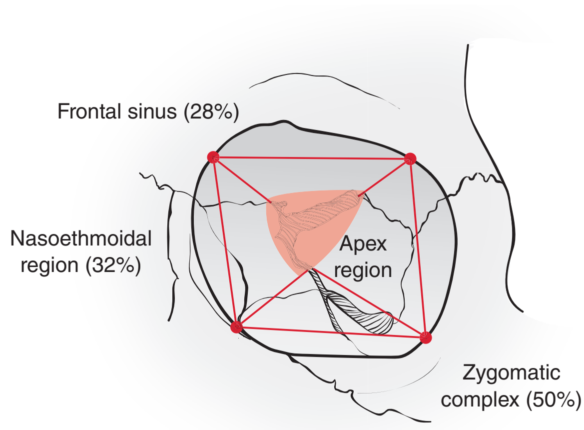

Fig. 14-2 Common orbital fracture patterns.

SURGICAL INDICATIONS

Surgical repair of orbital fractures can be classified as emergent, urgent, or delayed. Indications for repairing orbital fractures include significant structural defects confirmed by imaging, extraocular muscle entrapment, deteriorating visual acuity, persistent diplopia in central gaze, and distorted globe position (early enophthalmos or vertical dystopia). Such fractures are repaired with some urgency within 2 weeks of the injury. If a patient has sustained significant periorbital trauma, an examination by an ophthalmologist should be performed preoperatively and postoperatively to determine the presence of globe injury. This should include an examination of the anterior chamber to rule out a hyphema, and of the cornea to rule out the presence of an abrasion. A bright-light examination with dilation of the pupil should be conducted for full inspection of the retina to rule out detachment.

Findings on Imaging

A CT scan with both bone and soft tissue windows is the standard imaging modality for diagnosis of orbital fractures. Thin cuts (1.0 to 1.5 mm) in the coronal and axial planes are preferable; coronal sections reveal information regarding the status of the orbital floor, roof, and medial wall, as well as visualization of the extraocular muscles. Orbital volume can also be calculated, with most surgeons operating to prevent the development of late enophthalmos for either floor defects of 40% to 50% of the floor area or a 20% change in orbital volume.[1,3] Sagittal reformations can demonstrate the proximity of injury to the orbital apex and floor inclination, especially when prosthetic floor reconstruction is being planned. Sagittal cuts can clarify the AP position of the injury. Posterior injuries allow the globe to settle both down and posteriorly, resulting in enophthalmos and/or vertical dystopia. Relative to anterior injuries, a given change in volume posteriorly will be less well tolerated.

Visual Acuity and Visual Field Testing

Rates of associated ocular and neurologic injury have been reported as high as 33% and 57%, respectively, in the setting of orbital fracture.[2] Diplopia can result from muscle or ligament entrapment and should be evaluated. It can be primary (in the central visual field) or secondary (on extreme peripheral gaze), yet it is most commonly observed with upward gaze. Long-term follow-up of untreated orbital blowout fractures has demonstrated that if present on initial presentation, diplopia resolves in over half of patients within 2 weeks of injury, and in almost 75% of patients overall.[4] Several tests have been applied to assess vision, globe mobility, and position. The forced-duction test is a means for differentiating entrapment of the ligaments of the inferior rectus muscle from weakness, contusion, or paralysis. The test is performed by first instilling a few drops of local anesthetic into the conjunctival sac. The insertion of the inferior rectus onto the globe lies at a point approximately 7 to 10 mm from the limbus; it is grasped and the globe is gently rotated into all cardinal directions of gaze with the patient's head held straight and facing forward. A normal examination result demonstrates unhindered extraocular motion.

> Duction testing may give spurious results in the first week after injury because of the presence of edema or hematoma and thus should be repeated if results are abnormal or inconclusive, and following any surgical intervention.

Globe Position

Enophthalmos is a disturbance of the anterior-posterior position of the globe, or the difference between the anterior corneal surface and the lateral orbital rim. It occurs when there has been an increase in orbital volume. Fractures with enophthalmos on initial presentation tend to involve the medial wall as well as the orbital floor. On examination, an exaggerated superior sulcus above the upper lid and pseudoptosis (no change in distance between the inferior lid margin and pupil) are evident. The Hertel exophthalmometer uses the lateral orbital rim as a reference point to measure the degree of enophthalmos in relation to the normal contralateral orbit, and thus its measurement will be inaccurate when the rim is displaced or significant posttraumatic edema is present. Enophthalmos or dystopia may only become apparent after 1 or 2 weeks when edema has resolved; thus a follow-up examination is crucial. A difference between the eyes of more than 3 mm is considered significant displacement. When the lateral orbital rim has been displaced, a Naugle exophthalmometer is preferred, because its reference structure is not the lateral orbital rim, but rather the frontal and infraorbital structures.

Emergency Treatment

There are situations in which emergent operative intervention is indicated. Most indications are based on pending partial or complete loss of vision from direct or indirect trauma to the optic nerve.

Retrobulbar Hematoma

Operative exploration is indicated for increased intraocular pressure and presence of an acute space-occupying lesion, which can compromise neurovascular structures and lead to vision loss within 1 hour of onset. The classic presentation of retrobulbar hematoma includes proptosis, pain, and CN III palsy with a progressive decrease in visual acuity. Emergent decompression is indicated with findings of a tense, proptotic globe. Access is obtained through a transcutaneous, transseptal incision (Fig. 14-3). A transconjunctival pressure release—with or without a lateral canthotomy—is performed, followed by an inferior cantholysis. The presence of an associated carotid–cavernous sinus fistula, presenting as a pulsating exophthalmos, can be ruled out with imaging.

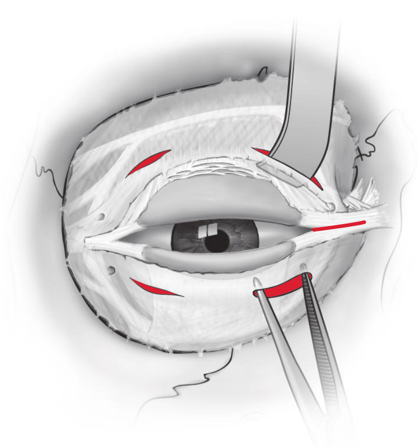

Fig. 14-3 Emergent drainage of a retrobulbar hematoma. A transconjunctival pressure release, with or without a lateral canthotomy, is performed, followed by an inferior cantholysis.

Traumatic Optic Neuropathy

Although an uncommon cause of blindness secondary to orbital fracture, direct trauma to the optic nerve or optic nerve ischemia from compression in the posterior third of the orbit has been reported. Operative reduction itself can also lead to blindness by similar mechanisms, again demonstrating the importance of preoperative ophthalmologic examination. In traumatic optic neuropathy, the spectrum of findings can range from decreased color perception to total vision loss. In patients with posttraumatic blindness, a high-resolution CT scan can suggest the cause by demonstrating optic nerve swelling or fracture within the bony canal. A patient with complete vision loss (absence of light perception) that occurred at the moment of injury is unlikely to recover vision. A patient with progressive loss of visual acuity has a relatively better chance for recovery with appropriate treatment. The use of high-dose steroids[5] has been suggested to be beneficial in all cases presenting with traumatic optic neuropathy; treatment consists of an intravenous loading dose of 30 mg/kg of methylprednisolone, followed 2 hours later by 15 mg/kg every 6 hours.[6] Surgical nerve decompression is reserved for patients with at least some light perception on presentation.

Superior Orbital Fissure and Orbital Apex Syndromes

Superior orbital fissure syndrome results from fracture line extension into the superior orbital fissure and subsequent injury to cranial nerves III, IV, VI, and the ophthalmic branch of the trigeminal nerve. Symptoms include ophthalmoplegia, ptosis of the upper lid, proptosis, a fixed and dilated pupil, loss of corneal reflex, and sensory loss in the distribution of V_1.*Orbital apex syndrome* results from ischemic optic neuropathy caused by fracture extension into the optic foramen or retrobulbar hematoma. It is similar to superior orbital fissure syndrome, with the distinction that the optic nerve is involved in orbital apex syndrome. A swinging light source moving from one pupil to the other can detect whether a relative afferent pupillary defect is present and can be performed in even an unconscious patient. This test is used to detect optic nerve impingement at the orbital apex; an abnormal result reveals no indirect light reaction of the unaffected eye (Marcus Gunn pupil). Visual evoked potential testing can be employed to confirm unclear results. If it occurs postoperatively, an emergent CT scan is performed, followed by operative exploration.

Trapdoor Phenomenon

In pediatric patients, there is a subset of orbital fractures that require emergent repair; that is, repair within the first 24 to 36 hours after injury. A *trapdoor fracture* refers to an orbital floor fracture that, because of elastic recoil, results in entrapment of orbital contents and the inferior rectus muscle (Fig. 14-4). The recoil occurs as a result of the relatively thick periosteum in children. Examination demonstrates impaired ocular muscle function, pain on attempted range of motion, and possible bradycardia, nausea, and/or syncope resulting from the oculocardiac reflex mediated through the parasympathetic pathway. The recoiled floor often appears uninjured on CT scan but should demonstrate the entrapped muscle. This ischemic insult to the muscle can progress to necrosis. Improved muscle function has been demonstrated with earlier surgical correction.

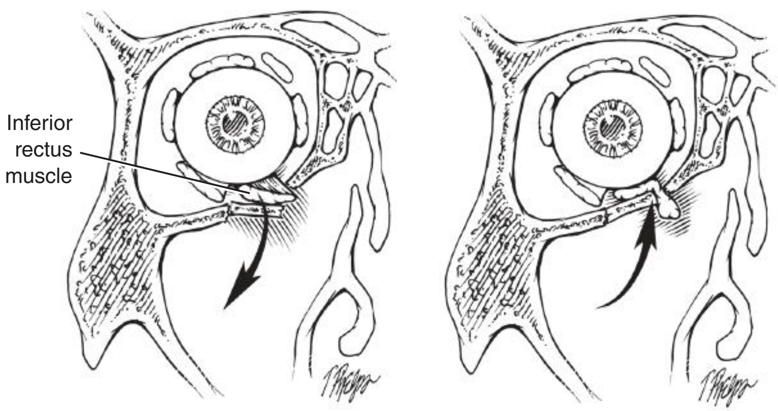

Fig. 14-4 Trapdoor deformity. The recoiled floor often appears uninjured because of the elasticity of the bony structures, as in this greenstick fracture, yet the inferior rectus muscle remains entrapped and susceptible to ischemic insult.

Symptomatic Orbital Emphysema

Although a common finding with orbital floor and medial wall fractures, *orbital emphysema* rarely presents with clinical symptoms and usually requires no intervention. However, there are instances in which intraorbital air raises intraorbital pressure and leads to central retinal artery occlusion. Indications for needle aspiration of the air include rising intraocular pressure associated with visual deterioration, pain, and ocular motility impairment. In addition, the patient should be instructed to avoid nose-blowing during the acute pressure increase.

Contraindications to Operative Repair

Observation alone is usually adequate for nondisplaced fractures without disturbance of eye motility. However, if the patient's condition prohibits operative intervention, observation may also be necessary in an acute setting. Severe ocular trauma may also necessitate a delay of bony orbital repair. Such ophthalmologic emergencies include rupture of the globe, hyphema (hemorrhage into the anterior chamber), and retinal detachment. Ocular injury is a contraindication to early surgical intervention, because orbital manipulation increases the risk of secondary bleeding into the anterior chamber and the development of acute closed-angle glaucoma. For a globe injury, communication with the ophthalmologist is necessary to develop a consensus plan for the timing of repairs. In addition, orbital fracture in a patient's only seeing eye remains a relative contraindication to operative reduction and fixation. Secondary deformities that result can be challenging to correct. Secondary or revision surgery is required to treat residual deformity, loss of facial shape, inadequate projection, enophthalmos, exophthalmos (rare), orbital dystopia, traumatic telecanthus, and soft tissue deformity.

TREATMENT GOALS

Surgery is performed to treat symptoms and restore appearance. For orbital rim reconstruction, fractured fragments are first aligned with regard to adjacent intact, stable structures. The goal of orbital reconstruction is to restore anatomy in all three dimensions. This begins by addressing the most reliable reference structures on the side with the least comminution. Multiple portions of the orbit are often fractured, and thus stabilization of both the rim and internal orbital walls must be achieved. The accuracy of the reduction is increased with simultaneous exposure of multiple segments for alignment.

EXPOSURE

Surgical access to the entire orbit is not possible through any single incision. Many incisional techniques have been described for access to the craniofacial skeleton for traumatic fracture repair. There are three basic approaches through the lower eyelid to give access to the inferior, lower medial, and lateral aspects of the orbital cavity: subciliary, subtarsal, and transconjunctival approaches (Fig. 14-5). Each is associated with a distinct set of complications.

> The decision between transcutaneous and transconjunctival incisions reflects a balance between a need for adequate exposure and a desire for an aesthetically acceptable incision. A proper understanding of each incisional technique requires an appreciation of the relevant anatomy and the risk of associated complications.

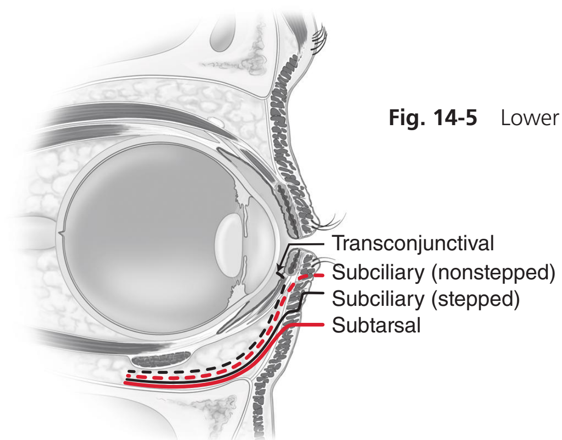

Fig. 14-5 Lower eyelid approaches.

Subciliary Approach

The subciliary approach was first described for use in orbital trauma by Converse in 1944. It was described as an incision several millimeters below the lash line. There are two main variations of this approach: the *skin-only flap* approach and the *skin-muscle flap* approach. The skin-only flap approach involves dissection just below the skin and superficial to the orbicularis oculi muscle to the level of the infraorbital rim. It has been associated with skin necrosis and a high rate of ectropion. The stepped technique is a variation in which the skin flap is elevated for 4 to 5 mm before splitting the muscle along its fibers, then continuing in the preseptal (submuscular) plane. It is said to be associated with less scar inversion and a lower incidence of ectropion. By dissecting inferiorly for several millimeters, it avoids the pretarsal portion of the orbicularis oculi, which provides lower lid support. Loss of pretarsal orbicularis activity predisposes to ectropion. In comparison, the skin-muscle flap approach divides the skin and the orbicularis oculi muscle at the same level, with the dissection then proceeding in the preseptal plane deep to the orbicularis oculi to the level of the infraorbital rim.

Subtarsal Approach

The subtarsal approach, popularized by Converse in the 1960s, offers direct access to the infraorbital rim with minimal risk of retraction. The appropriate subtarsal wrinkle is infiltrated with local anesthetic. An incision is then made along a natural crease parallel to the ciliary margin at a level just below the tarsal plate. Dissection is carried through the orbicularis oculi in the direction of its muscle fibers, and the orbital septum is exposed down to the infraorbital rim in a preseptal plane. After the orbital rim is identified, an incision is made from the facial side of the rim through the periosteum and above the infraorbital nerve. A stepped technique can also be used. Following osteosynthesis, the periosteum and skin are reapproximated. The subtarsal approach preserves the innervation of the pretarsal orbicularis oculi and thus potentially lowers the risk of scleral show and ectropion. It is a valid option for older patients with pronounced wrinkling and skin laxity; however, it is not an aesthetic choice for younger patients.

Transconjunctival Approach

The transconjunctival approach was introduced by Bourquet in 1924 for use in lower eyelid blepharoplasty; it was reported by Tessier in the 1970s, and Converse extrapolated its use to facial trauma. The transconjunctival approach gained popularity because of the inconspicuous incision and the decreased risk of ectropion, and its application has increased over the past 10 years. It allows rapid access to the inferior orbital rim and floor, provides adequate exposure for fracture visualization, and eliminates external postoperative scars. A lateral canthotomy can be added for additional exposure if desired.

The incision site is infiltrated with local anesthetic. A series of traction sutures are placed through the lid margin (gray line) to aid in eversion. The incision is carried out at the conjunctiva 5 mm below the level of the tarsus and directed lateral to medial. Dissection is performed using spreading scissors in a preseptal dissection plane between the orbicularis oculi and orbital septum. Blunt dissection with a cotton-tipped applicator is also a useful means to define the plane.

Dissection is continued to the infraorbital rim, where the arcus marginalis will be visualized. The arcus is a thick band of white periosteum along the infraorbital rim. The periosteum is incised, and a leading edge is elevated and continued onto the floor. An elevator is placed into the defect using an upward sweeping motion to elevate the prolapsed periorbita. Dissection is directed superiorly.

Regarding closure, some surgeons state that closure in traumatically disrupted soft tissue planes may lead to an increase in postoperative eyelid malposition, and thus they do not reapproximate the tissue. The transconjunctival approach can be complicated by entropion, particularly if reapproximation incorporates wide bites of the conjunctiva. To avoid conjunctival retraction while also limiting the risk of entropion, we choose to carefully place two inverted fast-absorbing gut sutures with small tissue bites to reapproximate only the conjunctiva.

Superior Orbital Exposure

Exposure to the superior orbit can be achieved through the brow, lateral limb upper blepharoplasty, canthal detachment with lower eyelid incision, and coronal approaches. The incision is made in a supratarsal upper lid skin crease (at least 10 mm above the upper lid margin). If only the lateral aspect of the superior orbit requires exposure, the incision can be limited to extend from the midpupil level to the lateral orbital rim. A skin-orbicularis flap is then raised, with care taken to avoid incising the underlying levator aponeurosis and orbital septum. (Fig. 14-6). The periosteum is then incised, and the fracture is exposed. For supraorbital rim fractures, one must be conscious of the supraorbital foramen/fissure to avoid injury to the supraorbital nerve.

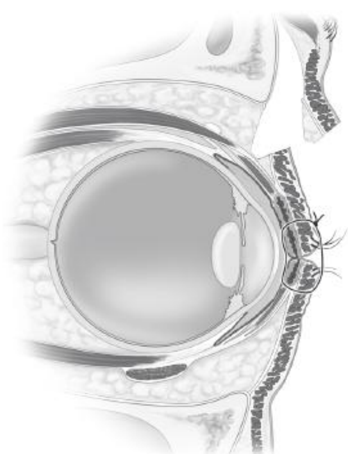

Fig. 14-6 Upper eyelid approach. A sagittal section through the orbit demonstrates the plane of dissection between the orbicularis oculi muscle and the levator palpebrae superioris.

OPERATIVE TIMING AND SEQUENCE

Initially, swelling may limit the ability to perform meticulous exposure and to retract the orbital contents. In nonemergent cases, a delay of 1 to 3 days may therefore be beneficial. Most orbital fractures should be repaired within 2 weeks. Beyond this time, the thin orbital bones become brittle because of the initial osteoclastic response of normal healing. This can lead to further propagation of the fracture during exposure.

In isolated orbital floor injuries, exposure is performed using one of the aforementioned techniques. The orbital contents are elevated circumferentially from the defect in the orbital floor. Ideally, a stable shelf will be present surrounding the defect on which a reconstructive implant or graft can rest. Dissection for implant placement should proceed a bit superiorly, rather than directly posteriorly, to avoid placing implants into the maxillary sinus, because the orbital floor is set on a superior incline. The posterior shelf must be defined to support the implant or graft. If the defect extends far posteriorly, the shelf may be difficult to identify. By placing a blunt Freer elevator in the maxillary sinus and "walking" it up the posterior wall of the sinus, the shelf is easily defined.

When fractures of the orbital rims occur (such as in panfacial trauma or ZMC injury), the orbital exposure is often performed early to allow more careful dissection of the delicate structures. However, fractures of the orbital walls or floor are generally the last fractures to be plated or repaired following restoration of the buttresses. For the orbital rims, a variety of titanium microplates and miniplates are available for fixation. Low-profile plates (1.0 to 1.3 mm) are recommended to prevent plate prominence and palpability. Plates should be fixed with at least two screws in each fracture fragment[7] (Fig. 14-7).

In some cases, large fragments of the orbital floor or walls may remain stable after reduction. However, comminution frequently results in bone defects that must be reconstituted using some form of implant. The main material distinction is between a graft and an alloplastic implant. Among grafts, options include autogenous grafts, allografts, and xenografts; of these, autogenous grafts are most common and are taken from either the iliac crest or split calvarium. Many authors think that autogenous bone is preferable for large orbital defects abutting the ethmoid or maxillary sinuses, because alloplastic materials can pose a risk of late infection.

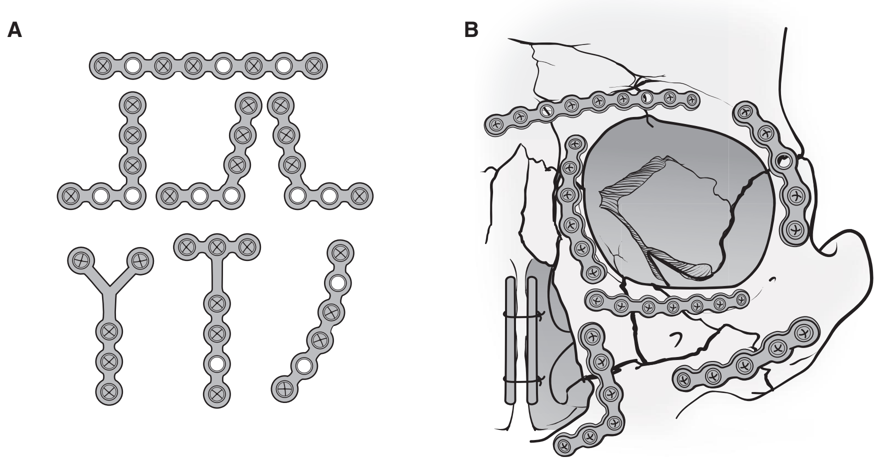

Fig. 14-7 **A,** Orbital plate options. For the orbital rims, a variety of titanium microplates and miniplates are available for fixation. Low-profile plates (1.0 to 1.3 mm) are recommended to prevent plate prominence and palpability. **B,** Plates should be fixed with at least two screws in each fracture fragment.

Depending on the size and location of the defect, alloplastic implants of various materials, sizes, and shapes are available. There remains a lack of evidence to definitively support the ideal choice for an orbital implant. The options include nonresorbable or resorbable alloplastic materials and composites. Table 14-1 lists the advantages and disadvantages of available implant options. In general, orbital implants should be cut to the minimum size required, fixed with the minimum fixation points required, and contoured to fit the defect. In general, the implant should be fixed if possible behind the internal orbital rim with a screw to prevent migration. Implants are positioned on an incline to reach the posterior shelf of intact bone. The anterior-posterior position of globe should be evaluated after the implant is positioned to ensure correct placement. A narrow elevator can be placed beneath the implant after it has been secured to confirm that its posterior border lies above the posterior shelf.

TABLE 14-1 COMPARISON OF MATERIALS FOR ORBITAL RECONSTRUCTION

Implant Type	Advantages	Disadvantages
Calvarial bone graft	Low cost Radiopaque Maximal biocompatibility Ease of dissection off periorbita in secondary reconstructions	Donor site (harvest time, pain, scar, possible surgical complications) Remodels; possible contour and dimensional changes Difficult to shape to patient's anatomy Less drainage from the orbit (versus titanium mesh)
Titanium	Availability Stability Ease in contouring Adequate in large three-wall fractures (the prebent plate is limited to medial wall and orbital wall fractures only) Radiopaque Allows fluid dissipation and tissue incorporation No donor site needed	Cost No long-term safety data for use in children
Porous polyethylene (PPE)	Availability Ease in contouring Smooth edges (versus titanium) Allows tissue ingrowth	Not radiopaque Nonrigid if thin wafer; thick wafer may cause dystopia Allows less drainage from orbit (versus titanium mesh)
Thermoplastic	Availability Ease in handling/contourability Smooth surface and smooth edges (versus titanium)	Not radiopaque Degradation of material with possible contour loss Sterile infection/inflammatory response Nonperforated variant allows less drainage from orbit (versus titanium mesh)
Preformed orbital implant	Radiopaque Smooth surface Minimal or no contouring necessary	Cost

At the conclusion of any orbital reconstruction, a forced-duction test should be performed to ensure free mobility of the globe. Soft tissues are then reapproximated, depending on the type of exposure. Lid support is the final step of the procedure to avoid lid retraction (ectropion or entropion). Support of the lower lid can be achieved through lateral canthoplasty or canthopexy, and a variety of techniques may be used. We most frequently employ a lateral retinacular suspension in which the inferior limb of the lateral canthus is secured using an undyed 4-0 or 5-0 braided permanent suture to the inner aspect of the orbit at the level of Whitnall's tubercle. A Frost suture is then placed using 5-0 silk along the gray line of the lid and secured to the forehead with adhesive tape. It is left in place for 3 to 5 days.

POSTOPERATIVE CARE

An assessment of gross vision should be performed after the patient has awakened from anesthesia. Postoperative care consists of elevating the head of the bed and using ice packs as needed to control edema. Nose-blowing should be avoided for at least 10 days after orbital fracture repair to prevent orbital emphysema. Frost sutures remain in place 3 to 5 days, and the patient should be reassessed often to confirm that the sutures are in place and the cornea is adequately protected. Ophthalmic ointment may be used to ensure adequate lubrication, although conjunctival irritation with prolonged use has been reported. Some surgeons implement extraocular range of motion exercises postoperatively. Visual acuity should be carefully monitored in all orbital trauma patients, and a prompt CT scan should be performed if any deterioration is noted.

Postoperative imaging should be repeated at the surgeon's discretion to evaluate implant position and the accuracy of the stabilization, as well as to detect any neurologic or visual abnormalities. No clear data exist to suggest a benefit to perioperative antibiotics. Similarly, although preoperative administration of intravenous steroids has been suggested to decrease swelling and allow better assessment of postoperative globe position, their definitive role in the postoperative period has not yet been established. One suggested regimen recommends dexamethasone 20 mg intravenously on initial presentation, followed by 10 mg every 8 hours for three doses total, after which steroids are discontinued.[8] NSAIDs should be avoided in the first postoperative week. Nasal decongestants can be prescribed if symptoms warrant. Finally, for a minimum of 6 weeks after trauma, patients should avoid airline travel, scuba diving, and other environments that expose them to changes in air pressure to prevent air embolization.

CONSEQUENCES OF INJURY AND COMPLICATIONS

Orbital injuries themselves are associated with a number of possible problematic sequelae regardless of treatment. Visual changes or visual loss have already been discussed. There are also a number of known complications that can occur in attempting to repair these injuries, related primarily to exposure and/or fixation.

Lower lid malposition is a common complication after treatment of orbital fracture. Ectropion, or eversion of the eyelid margin away from the globe, is typically of a cicatricial, paralytic, and/or mechanical nature after orbital trauma, with an overall reported incidence of 5%. It is seen more frequently with transcutaneous approaches to the orbital floor, notably with the subciliary incision. Cicatricial ectropion results from vertical shortening of the anterior lamella from the lid being tethered to the orbital rim. Postoperative placement of a Frost suture can hinder its development. Management ranges from conservative measures, such as corneal lubrication, taping, and massage, to surgical scar release for symptomatic problems that persist without gradual improvement. Less common complications and their reported incidences include lower lid edema (1% to 4%), hypertrophic scars (1% to 2%), entropion (1%), lower lid retraction, and scleral show.[9]

Persistent diplopia following surgical repair may result from persistent or recurrent soft tissue incarceration or implant adhesions. Forced-duction testing should be performed to rule out a mechanical cause, and if test results are normal, conservative management and close follow-up should be performed for up to 6 months, because diplopia resulting from neurapraxia is common. However, diplopia that persists beyond this 6-month observation period warrants surgical reexploration. Persistent enophthalmos is caused by increased orbital volume, which can be secondary to inadequate surgical restoration of orbital volume, extraocular muscle contracture and fibrosis, fat atrophy, and ligamentous injury. The interval between injury and surgical repair is a risk factor for the development of late enophthalmos, since delay in repair beyond the 2-week window has been associated with a greater than threefold increase in the incidence of late enophthalmos.[10] The use of alloplastic implant materials is also associated with a unique set of complications: implant malposition, infection, and extrusion can occur late and may mandate implant removal.

RECOMMENDED FOLLOW-UP

Close follow-up is recommended for fractures treated surgically as well as those treated nonsurgically. Before the patient is discharged, gross vision is assessed. Within 1 week, the patient should be seen for reevaluation and removal of the Frost suture. Any early evidence of lower lid retraction is aggressively treated with massage. Tape may be applied to the lateral aspect of the lower lid and retracted superolaterally to support the lower lid to the temple. Clinical signs of visual acuity deterioration or mental status changes at any point should be investigated. Patients should be seen 3 or 4 weeks after the injury or repair to examine vision, lid position, and globe position. Follow-up imaging is performed at the discretion of the treating surgeon. In isolated orbital injuries, a final follow-up visit may be conducted 6 to 8 weeks after the injury or repair if there are no ongoing concerns. A long-term follow-up visit is recommended at 6 to 12 months.

Pearls

- *Enophthalmos is difficult to detect in the acute stage because of edema.*
- *The position of a floor defect is important; for a given defect size, posterior orbital floor injury is more likely to lead to enophthalmos and/or vertical dystopia. Sagittal views should be obtained to evaluate the AP dimension of the defect.*
- *The surgeon must anticipate and promptly treat trapdoor deformities in pediatric patients.*
- *The superior inclination of the orbital floor requires that dissection proceed superiorly, rather than directly posteriorly, to avoid placing implants into the maxillary sinus.*
- *If the surgeon encounters difficulty finding the posterior ledge, a Freer elevator can be walked up the back wall of the maxillary sinus.*
- *Duction tests should be performed before and after dissection as well as after implant fixation; the results are compared with those from the preoperative examination to ensure freedom of the extraocular muscles and ligaments.*
- *New postoperative or worsening visual and cranial nerve abnormalities should prompt an urgent workup.*

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15 Maxilla: LeFort Fracture Patterns

Scott T. Hollenbeck, Detlev Erdmann

Background

Maxillary fractures may result in significant disturbances of midface anatomy and function. In patients with midface fractures, physical examination may reveal periorbital ecchymosis, epistaxis, dental trauma, and malocclusion, as well as altered facial height, width, and projection. Anatomic changes associated with maxillary fractures and poorly performed repairs may lead to important functional changes in occlusion, nasal airflow, and ocular alignment. A thorough understanding of nonoperative and operative strategies is necessary for proper management.

REGIONAL ANATOMY

The maxilla constitutes the middle third of the face and is formed from two pyramid-shaped bones containing the hollowed space of the maxillary sinus. These paired bones support the maxillary dentition, contribute to the formation of the hard palate, define the floor and lateral wall of the nasal cavity, and form part of the inferior rim, lateral rim, and floor of the orbit. The alveolar process of the maxilla supports eight teeth per side in an adult; the canine roots are the longest and most prominent. At the superior aspect of the maxilla there is a thickening of the bone along the infraorbital rim. The medial extension of the maxilla is the frontal process, which articulates superiorly with the frontal bone, medially with the nasal bone, and posteriorly with the lacrimal bone. The nasolacrimal canal and medial canthal tendon are closely associated with the maxillary frontal process and may be disrupted by fractures through this region. The superior portion of the maxilla forms the anterior and medial aspect of the orbital floor. Laterally, the maxilla articulates with the zygomatic bone to form the lateral orbital wall.

The maxilla and surrounding bones make up a system of buttresses that provide support to the face. Facial bones are thin in many locations, but the buttresses are thicker, which gives them their mechanical advantages. Fixation depends on the inherent stability of bone, so during fixation the surgeon should apply plating preferentially along the buttress lines. These include the nasofrontal, orbital, zygomatic arch, and medial and lateral maxillary buttresses (Fig. 15-1). The term *medial maxillary buttress* is synonymous with *piriform rim* or *nasomaxillary buttress.* The *lateral maxillary buttress* is often referred to as the *zygomaticomaxillary buttress.* In this chapter we use the terms *medial and lateral maxillary buttresses.*

The midface is highly vascularized, partly as a result of the abundant blood supply of the external carotid artery. The largest branch of the external carotid artery is the maxillary artery, which lies within the pterygopalatine fossa and terminates as the sphenopalatine artery, descending palatine artery, infraorbital artery, posterior superior alveolar artery, and buccal artery. The maxillary nerve (V2) is one of three branches of cranial nerve V. Its function is to provide sensation to the maxillary teeth, nasal cavity, sinuses, and skin of the midface. An important branch of V2 is the infraorbital nerve, which travels within the maxillary bone through the infraorbital canal along the floor of the orbit and exits through the infraorbital foramen. The infraorbital foramen is located approximately 5 to 10 mm below the infraorbital rim in line with the medial limbus of the pupil and also contains the infraorbital artery and vein. During intraoral exposure, it is important to consider the expressive muscles of the midface that could be disrupted: the zygomaticus major and minor, levator labii superioris, levator labii superioris alaeque nasi, levator anguli oris, depressor septi, and nasalis.

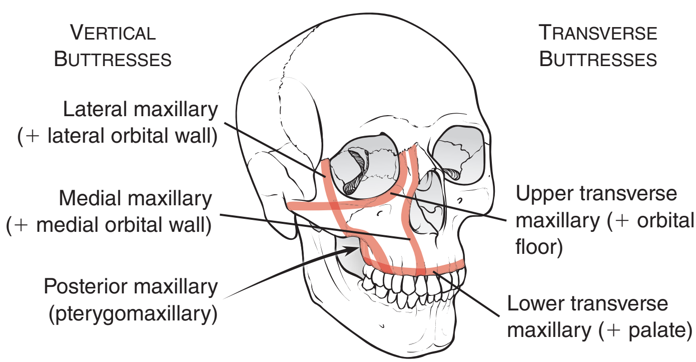

Fig. 15-1 The buttress system of the face. Within the maxilla, the medial and lateral maxillary buttresses are critical for bony alignment and stabilization. The orbital rim, nasofrontal process, and zygomatic arch make up the remaining maxillary buttresses.

FRACTURE PATTERNS

The most common cause of fractures of the maxilla is frontal or lateral impact. The maxilla and surrounding bones dissipate forces in a manner that protects the globe and brain from injury as a result of alternating areas of strength and weakness. This anatomic property leads to common fracture patterns. Maxillary fractures are routinely described using the LeFort classification system. These fractures may be bilateral or asymmetrical and often include other associated facial fractures. LeFort fractures typically involve the pterygoid plates; however, repair of these posterior buttresses is not commonly performed. In describing complex fractures (which often include maxillary components), redundancy is minimized by first naming the lowest-level LeFort pattern, then adding the remaining fractures to fully describe the fracture components.

LeFort I

The classic LeFort I fracture extends horizontally across the base of the maxillary sinus and floor of the piriform aperture to effectively separate the lower maxilla from the rest of the face. For the maxilla to be mobile, the fracture must extend through the medial and lateral maxillary buttresses bilaterally, as well as the pterygoid plates posteriorly (Fig. 15-2, *A*). A unilateral injury can occur, but significant displacement is less likely, because the contralateral side provides stability in these cases.

LeFort II

The classic LeFort II pattern is known as the *pyramidal fracture.* The fracture line extends through one lateral maxillary buttress across the maxilla, through the infraorbital rim and orbital floor, the medial orbital wall, and through the nasal bones and nasofrontal junction (Fig. 15-2, *B*). Nasal involvement may be relatively low or high and may involve bones or cartilage. Furthermore, ethmoid involvement is common with these fractures and may be associated with disruption of the lacrimal system.

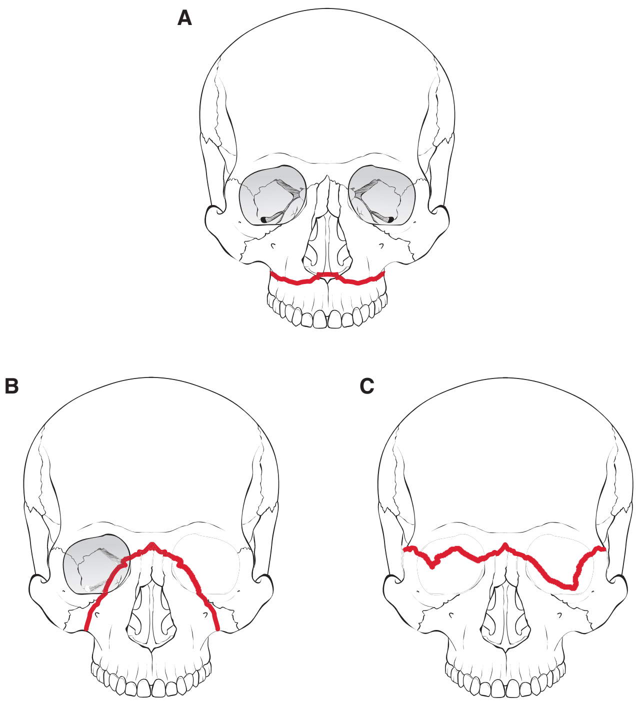

Fig. 15-2 LeFort fracture patterns. **A,** LeFort I fractures extend horizontally across the base of the maxillary sinus and floor of the piriform aperture to effectively separate the lower maxilla from the rest of the face. **B,** The LeFort II fracture line extends through one lateral maxillary buttress across the maxilla, through the infraorbital rim and orbital floor, the medial orbital wall, and through the nasal bones and nasofrontal junction. **C,** LeFort III fractures traverse the lateral and medial orbital walls, the nasofrontal region, and the zygomatic arches.

LeFort III

The classic LeFort III fracture is also known as *craniofacial disjunction.* These fractures traverse the lateral and medial orbital walls, the nasofrontal region, and the zygomatic arches (Fig. 15-2, *C*). Associated fractures are common with this pattern and make repair more complex.

Split Palate

Sagittal fractures of the maxilla result in a *split palate.* These fractures may accompany and complicate a LeFort fracture or may occur in isolation. For palatal fractures, numerous patterns have been observed and should be described with particular attention to alveolar or dental involvement. A sagittal injury of the maxilla can result in widening of the maxillary dental arch, with resultant bilateral buccal crossbites.

SURGICAL INDICATIONS

Emergent management of maxillary fractures may be indicated for control of bleeding or airway stabilization, and for fractures associated with extensive soft tissue destruction. Usually, maxillary fracture management is done in combination with systemic trauma evaluation. The timing of operative intervention is dictated by concomitant injuries. The most important goal of operative management of maxillary fractures is to reestablish occlusion. For high-energy maxillary fractures, the surgeon should consider the patency and stability of the airway. Displaced fractures associated with extensive swelling or bleeding may impair nasal and oral airflow. Likewise, tooth fragments, dentures, other foreign bodies, and secretions may obstruct the airway, so the presence of these objects must be assessed.

Malocclusion and instability (mobility) of the maxilla are the two most important clinical findings and are the basis for operative intervention.

Occlusion should be carefully evaluated. Often pain or swelling may influence a patient's ability to bring the teeth into occlusion. When this is the case, passive manual motion can assist the patient to determine whether he or she can achieve proper occlusion. Instability can be determined by grasping the incisors and gently rocking the maxillary arch. A LeFort fracture can be impacted superiorly, leading to an anterior open bite as the molars make contact first. Midface fractures can also be associated with posterior and inferior displacement of the maxilla. This is related to the pull of the pterygoid musculature and results in an elongated and retruded face. Because of the downward and posterior displacement of the maxillary dentition, an anterior open bite with class III malocclusion may occur. Additionally, LeFort II and III fractures may be associated with fractures of the middle or anterior cranial fossa. In these circumstances, the presence of a CSF leak should be evaluated. Clinical examination and radiographic studies remain the best ways to evaluate patients with midface fractures. For maxillary fractures, computed tomography with axial, coronal, sagittal, and three-dimensional reformation is used to determine the need for treatment. On CT the fracture pattern should be apparent when each of the buttresses is evaluated, with an awareness that unilateral or asymmetrical injuries can occur. For example, a patient can have a LeFort I fracture on one side and a LeFort II on the contralateral side. Nearly all patients with LeFort fractures have maxillary sinus fluid present.

TREATMENT GOALS

The most common facial skeletal abnormalities that occur after a midface fracture include lack of projection, increased facial width, enophthalmos, and malocclusion. Thus the goals of LeFort fracture treatment are to restore midface height and projection, reestablish preoperative occlusion, and restore orbital and nasal structure. Many LeFort fracture patterns are asymmetrical, and operative plans should identify stable structures on each side that can serve as anchoring points for rigid fixation. Although an untreated LeFort fracture will result in an elongated face, treated fractures have a tendency to result in reduced facial height. Thus anatomic reduction with restoration of the maxillary buttress system is critical to restoring proper facial height. Anteriorly, this involves the medial and lateral maxillary buttresses. Posterior maxillary height is established by placing the patient into intermaxillary fixation with the stable or reconstructed mandible. When a mandibular fracture occurs concurrently, it should be reduced and stabilized before stabilization of the LeFort fracture. For palatal fractures, the goals of treatment are to correct malocclusion and reestablish the maxillary arch width.

An edentulous patient with a minimally displaced LeFort fracture may be managed nonoperatively. Following fracture healing, new dentures can be made to correct for the new configuration of the maxilla. For significantly displaced fractures, dental splints are required to achieve intermaxillary fixation. This may be combined with open reduction and internal fixation to reestablish the maxillary buttress system.

LeFort II and III fractures involve the orbit, so an ocular examination and assessment of visual acuity are essential to planning surgical treatment. Orbital fractures that affect globe position and create diplopia must be addressed in the LeFort fracture operative strategy. LeFort III fractures also involve the lateral orbital wall and often include additional fractures of the zygoma. Likewise, LeFort II and III fracture patterns involve the nasoethmoidal region. In some instances the frontal process of the maxilla, which carries the medial canthal tendon, is disrupted. This finding is characteristic of a nasoorbital ethmoid fracture and should be addressed as part of the treatment plan for the LeFort fracture. Failure to treat these fractures will result in a widened interorbital and intercanthal distance.

Maxillary fractures that include the palate may lead to palatal widening and malocclusion. Operative goals include reduction and restoration of normal palatal width. Disparate alveolar segments should be reduced and stabilized to prevent segmental malocclusion. Dental trauma frequently accompanies maxillary fractures and should be addressed in conjunction with the LeFort fracture.

Airway Considerations

Intermaxillary fixation is required in all cases to establish proper occlusion. Oral intubation in these cases is difficult; the endotracheal tube needs to be passed behind the molars (retromolar) to allow the teeth to be brought into occlusion. This may cause compression of the tube or prevent the establishment of optimal occlusion. Nasotracheal intubation is the preferred method.

Advanced Trauma Life Support guidelines caution against the use of *blind* nasal intubation in an acute stabilization when a LeFort fracture is suspected. However, at the time of fracture repair, nasotracheal intubation (or oral-nasal ETT exchange) may be performed under controlled conditions by a skilled anesthesiologist using fiberoptic guidance.

If there is a known fracture of the cribriform/cranial base, a tracheostomy is the safest method that allows treatment goals to be achieved. For patients with extensive concomitant injuries for which prolonged intubation is expected (such as pulmonary contusions and intraabdominal injury), a tracheostomy should be considered.

EXPOSURE

A reconstructive plan that reestablishes facial width is central to the design of the surgical exposure. The type of surgical exposure needed for maxillary fractures depends on the location of stable cranial and peripherally based landmarks. With a proper approach, stable buttress alignment and fracture fixation can occur in a stepwise manner. For less-complex fractures, such as an isolated LeFort I fracture, anterior approaches may suffice. For more-complex fractures, establishing osteosynthesis may require more superior and posterior facial exposure to define stable landmarks. In general, most maxillary fractures can be approached using the following methods.

Coronal

The coronal approach is helpful when access to the cranium and upper facial skeleton is required. This may be necessary when repair of LeFort II and III fractures requires stabilization of the nasofrontal or orbital regions. The supraorbital nerve should be identified and preserved and may require mobilization to access the lower portion of the upper face. Thorough knowledge of the anatomy of the frontal branch of the facial nerve is essential to avoid injury to this structure. The incision should be placed in the hair-bearing region with oblique cuts in the direction of the hair follicles to limit alopecia.

Intraoral

The sublabial or upper gingivobuccal sulcus approach readily exposes the midface from the maxillary dentition to the inferior portion of the nasal bones and zygoma. LeFort I and II fracture patterns usually require this approach. Care must be taken to identify and avoid injury to the infraorbital nerve during dissection. Infection is uncommon and can be minimized with good oral hygiene at the time of operation and in the postoperative period.

Periorbital

There are several eyelid approaches that are useful when exposure of specific periorbital regions is needed. These include the transconjunctival, subciliary, and brow incisions. Each of these approaches may be used to access the inferior and lateral aspect of the orbital rim. Of these three, the brow incision provides the best exposure to the zygomaticofrontal suture. However, poor scar formation and brow alopecia may complicate this approach. An alternative to accessing the upper lateral orbit is the upper eyelid blepharoplasty approach, which tends to result in an improved cosmetic result compared with the brow incision.

With all exposures it is important to consider repositioning of the soft tissues. Reapproximation of the periosteum and fascia as well as the muscle layers incised is critical to preventing soft tissue abnormalities. With time, injured soft tissue will develop internal fibrosis, and malpositioning at that point is difficult to correct.

OPERATIVE SEQUENCE

Intermaxillary fixation (IMF) remains the mainstay of treatment for maxillary fractures and should be applied as soon as possible. Ideally, arch bars should be placed on upper and lower dentition and linked with wires or elastic. LeFort fractures often occur in combination with other facial fractures and are not uncommonly asymmetrical. Thus the surgical approach needs to be tailored to integrate known stable structures for fixation to known unstable structures. Moreover, most maxillary fractures are comminuted because of the thin nature of the bone over the surface of the maxilla and frequently occur with other associated bony injuries including zygoma, frontal, or mandible fractures. Although much maxillary bone is thin, the buttresses are relatively solid. The medial and lateral maxillary buttresses contain compact solid bone suitable for fixation with plates and screws. Plating should be done along the buttresses rather than intervening thin bone. Miniplates (1.5 to 1.7 mm) can be used to span comminuted areas from solid bone to solid bone. Overall, intermaxillary fixation allows for stabilization of the lower midface to the more rigid mandible in the correct occlusal plane. Likewise, the upper midface can be stabilized to the orbital rim and zygoma in LeFort I and II fractures.

LeFort I

Treatment of LeFort I fractures starts with application of IMF. This may be done with either arch bars or dental splints (for edentulous patients). Once the occlusal relationship is reestablished, osteosynthesis sites are exposed. The medial and lateral maxillary buttresses must be assessed for proper alignment. If they will not align, further disimpaction and mobilization of the maxilla may be needed (Fig. 15-3). The reduction is then held in position while a template is made for plate selection. In general, plates should be used so that two screws can be placed on either side of the fracture line. Before plate fixation, occlusion is reconfirmed. Each screw hole is drilled sequentially. Proper screw length can be determined with a depth gauge. In general, for maxillary bone, screws 4 to 7 mm long are used. Reduction and fixation are completed for the remaining buttresses. When bone gaps of 5 to 10 mm exist, bone grafts may be needed to improve long-term stabilization.

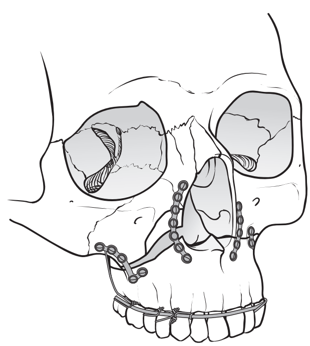

Fig. 15-3 Rigid fixation of a LeFort I fracture pattern. Occlusion is checked before applying rigid fixation. The medial and lateral maxillary buttresses provide stable bone for plate fixation.

LeFort II

Treatment of LeFort II fractures starts with application of IMF to reestablish occlusion as described previously. The lower midface may be approached through an intraoral incision. The need for a coronal approach is dictated by the presence or absence of other fractures that require fixation. In particular, if a frontal sinus fracture requires treatment, coronal exposure allows fixation at the nasofrontal fracture. In the absence of another indication for coronal exposure, the nasofrontal fracture may not be plated. The inferior orbital rim must be exposed, and this can be accomplished through a periorbital incision. Once the maxillary and periorbital buttresses have been visualized, the fractures may be reduced. If a coronal approach is being performed, depressed or comminuted nasal bones need to be addressed. In these circumstances, the fragments can be stabilized to the frontal bone at the nasal root with plate fixation. The lateral buttress and infraorbital rim can then be treated with miniplate fixation (1.5 to 1.7 mm). Large bone gaps (5 to 10 mm) may warrant a bone graft.

LeFort III

LeFort III fractures are first addressed with application of IMF, in a similar fashion to LeFort I and II fractures. If proper occlusion cannot be set, fracture disimpaction may be required before IMF. When a LeFort III fracture occurs with minimal comminution and displacement, a limited approach may be possible. In these cases, the zygomaticofrontal fracture line may be treated with miniplates through a brow or upper eyelid incision. The lateral orbital wall can serve as a reference point for proper reduction. Following this, the remaining fractures may be treated as outlined previously. For complex LeFort III fractures, such as those with multiple displaced or comminuted regions, maximal exposure is required. A coronal approach allows exposure to the nasal root, zygomatic arch, and orbit. The intraoral approach allows exposure of the maxillary buttresses. With proper occlusion established, the nasofrontal area is fixed to prevent rotation of the midface. Next, the zygoma is fixed at the arch, zygomaticofrontal suture, and infraorbital rim using the zygomaticomaxillary relationship as a guide to reduction. Finally, the maxillary buttresses and associated fractures are repaired as outlined previously. As in LeFort I and II fractures, when large bone gaps exist (5 to 10 mm), a bone graft should be considered.

Alveolar segment fractures can often be addressed with arch bar wire fixation. Likewise, palatal fractures lead to lower midface widening and malocclusion and must be addressed when they accompany LeFort fractures. The intact or reconstructed mandible can serve as a guide point for alveolar or palatal fracture alignment. A palatal flap can be elevated to expose the palatal fracture site, which can be fixed with miniplates. Alternatively, a dental splint made preoperatively from models can be used to maintain the arch width.

POSTOPERATIVE CARE

Following maxillary fracture repair, facial edema may complicate airway patency and should be considered in the context of extubation versus tracheostomy. Once airway independence is established, care should shift toward maintaining fracture fixation, preventing infection, and enteral nutrition.

The intraoral hardware used for IMF remains the primary source of frustration for patients following maxillary fracture repair. While in the hospital, the patient should be instructed in proper care and maintenance of the hardware. The patient should be asked whether there are any areas of tenderness or irritation caused by contact with intraoral hardware. If so, the wires may be adjusted or covered with wax to prevent sores from developing. Arch bar care includes the use of chlorhexidine mouthwash three times daily to prevent bacteria buildup on hardware and at suture lines. In the immediate postoperative period, the patient should be placed on an antiemetic regimen on a scheduled basis.

The bony maxilla normally heals by 6 to 8 weeks; however, highly comminuted fractures may require longer. The timing of release of intermaxillary fixation is determined by the stability of the fixation, the degree of fracture comminution, and the presence of associated fractures. In general, rigid (wire) IMF is kept in place for 1 to 3 weeks. Intermaxillary wires are then removed and replaced with one or two elastic bands per side for a total of 6 weeks of treatment. During this time, close observation is needed to assess occlusion. If an occlusal deformity begins to develop, the patient should be placed back into rigid IMF to prevent malunion. If no occlusal deformity develops during this time, the arch bars may be removed after a total of 6 weeks. During this 6-week period of IMF (rigid plus elastic), the patient should remain on a pureed or soft diet.

In general, immediate postoperative radiographs are not necessary. For maxillary fractures, the best indicator of adequate reduction is intraoperative assessment of occlusion. However, a postoperative CT scan may be helpful in identifying malocclusion or hardware failure and may be indicated in certain cases or during the later postoperative period.

CONSEQUENCES OF INJURY AND COMPLICATIONS

The most immediate complications following maxillary fracture involve airway compromise and hemorrhage control. Patients with high-energy injuries are often evaluated at a trauma center. A team approach is needed for acute injuries when airway compromise and significant bleeding occur. The surgeon caring for facial fractures should be available to assist with patient management in the acute setting. High-energy injuries that result in maxillary fractures are often associated with severe facial soft tissue swelling that may obstruct or obscure the nasopharynx and/or oropharynx. This is the most urgent potential complication and should be evaluated immediately. Patients with airway compromise or impending compromise should have a definitive airway established with nasal, oral, or tracheal intubation. Once this is done, workup and management can proceed.

Bleeding associated with maxillary fractures may be a result of superficial or deep vessel damage. In the acute setting, nasal packing or ligation of visible bleeding vessels can be performed. For a deep hemorrhage that is not controlled by packing, manual reduction of the fracture with IMF may be needed. A hemorrhage that continues despite these maneuvers requires angiographic embolization or direct ligation of the external carotid artery. In these instances, bleeding may be from the posterior superior alveolar artery.

Subacute complications following maxillary fractures tend to involve the surrounding structures, which may be disrupted or injured from bony fragments of the fracture and the associated high energy of the trauma. These problems may persist as chronic complications if not optimally addressed early in treatment. Nonunion or malunion remain the most common long-term complications and may require further surgical intervention.

As with all surgeries, infectious complications may occur early or late. Infection following a maxillary fracture is less common than following mandibular fractures. Infectious complications may result in hardware failure or exposure. If this occurs, the plate must be removed. Hardware removal following maxillary fracture (although less common) occurs in less than 1% to 21% of cases and is most commonly caused by infection at the hardware site, leading to failure or exposure. The use of prophylactic antibiotics in the perioperative period has been shown to reduce the rate of infectious complications in maxillofacial injuries; however, long-term suppressive antibiotics are not indicated.

LeFort fractures may extend through the skull base at the cribriform plate, producing a CSF leak. In these instances there may be concern for the risk of meningitis. Generally, prophylactic antibiotics may be used to reduce this risk; however, the efficacy has not been clearly proven, and this measure may select out drug-resistant bacteria if used for long periods. CSF leaks should be managed in conjunction with neurosurgical assessment and may require CSF drainage.

The lacrimal duct lies between the lacrimal bone and the frontal process of the maxilla and may become obstructed as a result of maxillary fracture. If this occurs, dacryocystitis or orbital cellulitis may result, and external drainage will be necessary. Additionally, the nasolacrimal duct may be transected as it traverses the maxilla toward the inferior meatus. If the nasolacrimal duct remains obstructed or otherwise nonfunctional following fracture reduction, a dacryocystorhinostomy is indicated.

Blindness, although uncommon following a maxillary fracture, may occur from swelling within the optic canal. Diplopia may complicate maxillary fractures with a significant orbital component. Initially this is usually the result of extraocular muscle contusion; however, diplopia may signal muscle entrapment, and this should be determined with a forced-duction test. Persistent postoperative diplopia may indicate globe displacement or extraocular muscle dysfunction. The displaced globe may not lie at its proper level following treatment of the orbital fracture. In general, displacement must exceed 5 to 10 mm to account for diplopia.

Nonunion and malunion of maxillary fractures may occur with either a delay or with improper fracture management. Following rigid fixation, nonunion or malunion of a maxillary fracture usually represents failure to provide adequate IMF and/or (open) reduction and rigid fixation. Treatment requires secondary exposure of all fractures, and reduction may not be possible without an osteotomy. Disimpaction and repositioning should occur and may require bone grafts, followed by a period of rigid or elastic IMF.

RECOMMENDED FOLLOW-UP

Patients with LeFort fractures require close postoperative monitoring during fracture healing to evaluate the occlusal relationship. Adjustments in IMF can prevent malunion from occurring. Once bony healing has occurred, follow-up should primarily center on restoring normal function of surrounding structures. This may include secondary procedures to address dental, ocular, or lacrimal system abnormalities, all of which should be checked at each postoperative follow-up. Once no such problems are noted and the patient is able to open his or her mouth 30 to 40 mm at the incisors and close into proper occlusion, he or she can be discharged. In our institution, patients are followed intermittently for 3 to 6 months before final discharge.

Pearls

- *The maxilla provides support for dentition, contributes to the formation of the hard palate, defines the floor and lateral wall of the nasal cavity, and defines part of the inferior rim, lateral rim, and floor of the orbit.*
- *Maxillary fractures are described using the LeFort classification system. These fractures may be bilateral or asymmetrical and often include other facial bone fractures.*
- *Most common bony abnormalities associated with midface fractures include lack of projection, increased facial width, enophthalmos, and malocclusion.*
- *The goals of LeFort fracture treatment are to restore midface height and projection, reestablish preoperative occlusion, and restore orbital and nasal structure.*
- *The type of surgical exposure needed for maxillary fractures depends on the location of stable cranial and peripherally based landmarks. Stable buttress alignment and fracture fixation should occur in a stepwise manner.*
- *Intermaxillary fixation remains the mainstay of treatment for maxillary fractures and should be applied as soon as possible. Maxillary bone is thin, except for the buttresses. Fixation should be placed carefully to only rely on buttress bone for placement of at least two screws on each side of the fracture.*
- *Early postoperative care centers on management of soft tissue edema, maintenance of intraoral hardware, and strategies for proper feeding.*
- *Close follow-up and assessment of intermaxillary fixation is needed during fracture healing to prevent malunion and occlusal deformities.*
- *Long-term follow-up centers on ocular, dental, and lacrimal function as well as assessment of facial height and width restoration. If trismus occurs, physical therapy should be initiated.*
- *Secondary procedures may be required to address persistent diplopia, malunion, or lacrimal dysfunction.*

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16 Mandible Fractures

J. Alex Kelamis, Eduardo D. Rodriguez

Background

Mandible fractures are frequently encountered in both adult and pediatric patients. The physical, emotional, and social consequences of these injuries can be profound. Often, patients will experience further problems in addition to the initial fracture injury. Proper diagnosis, management, and postoperative care can help prevent many of the undesirable side effects that these patients encounter, as well as speed recovery, decrease loss of productivity, and reduce costs for the patient.

A thorough knowledge of the anatomy and mechanics of the normal mandible is essential for comprehending the anatomy and mechanics of the injured mandible. This helps a surgeon build a foundation for the diagnosis and management of mandible fractures. The causes of these fractures are many, and the multiple factors involved with the numerous fracture patterns can be overwhelming. However, it is possible to make sense of these injuries. Each fracture pattern is associated with likely mechanisms of injury, as well as specific physical examination and radiographic findings. Although it may be easy to identify many fractures by physical examination and radiographic imaging, it is important to keep in mind the types of fractures that often appear together.

Some fractures are so profound that they may distract the physician from other more subtle fractures. Failing to recognize all fractures will almost certainly lead to failed treatment, regardless of the methods used to address the known fractures.

Although some injuries can be adequately managed with noninvasive measures, such as a soft no-chew diet or various types of closed reduction, many others require open reduction and internal fixation. There are numerous surgical options, but attention to the principles of exposure and operative technique ensure that a patient receives adequate treatment.

Each aspect of a mandible fracture is directly dependent on other aspects, and a thorough appreciation of one will reinforce the surgeon's understanding of others. Building on this foundation is paramount so that we can provide prompt, comprehensive, and effective care for our patients.

REGIONAL ANATOMY

The mandible is the second most commonly fractured facial bone, but it is also the strongest facial bone, suggesting that it is involved more frequently in high-energy injuries. The mandible consists of two hemimandibles fused at the midline. In terms of anatomy and function, each hemimandible consists of vertical and horizontal buttresses that allow the directional transmission of forces. The horizontal buttresses consist of the body and parasymphysis. The vertical components consist of the condyle, coronoid process, and ramus, which unite at the sigmoid notch (Fig. 16-1). The angle serves as the junction of the vertical and horizontal components.

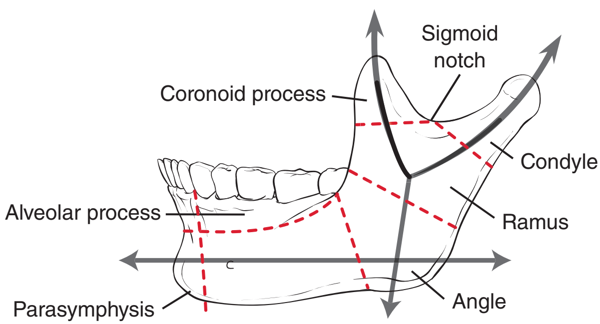

Fig. 16-1 Vertical and horizontal components of the mandible.

On the buccal surface, a faint median ridge at the midline of the mandible marks the symphysis (Fig. 16-2). The symphysis divides near the inferior border, creating a triangle enclosing the mental protuberance. The base of this triangle is depressed at the center and raised at the ends, forming bilateral mental tubercles. The oblique line runs from each mental tubercle in a posterior and superior path, aiming just posterior to the third molar, where it blends into the anterior border of the ramus. The triangularis muscle attaches to the anterior half of the oblique line, with the quadratus labii inferioris muscle attachment superior and the platysma attachment inferior. The mental foramen is located below the second premolar approximately halfway between the superior and inferior borders; it allows passage of the mental neurovascular bundle. There is an incisive fossa on either side of the symphysis just below the lower incisors that serves as the origin for the mentalis and as the partial origin for the orbicularis oris muscle. On the lingual surface, the genioglossi muscles originate at the inferior border of the symphysis from bilateral mental spines, with a second pair of spines, or ridge, inferior to these, marking the origin of the geniohyoid muscles. Immediately below this on either side is the anterior margin of the mylohyoid line, which, like the oblique line, runs in a posterior and superior fashion toward the inferior margin of the third molar. This line is the origin for the mylohyoideus muscle.

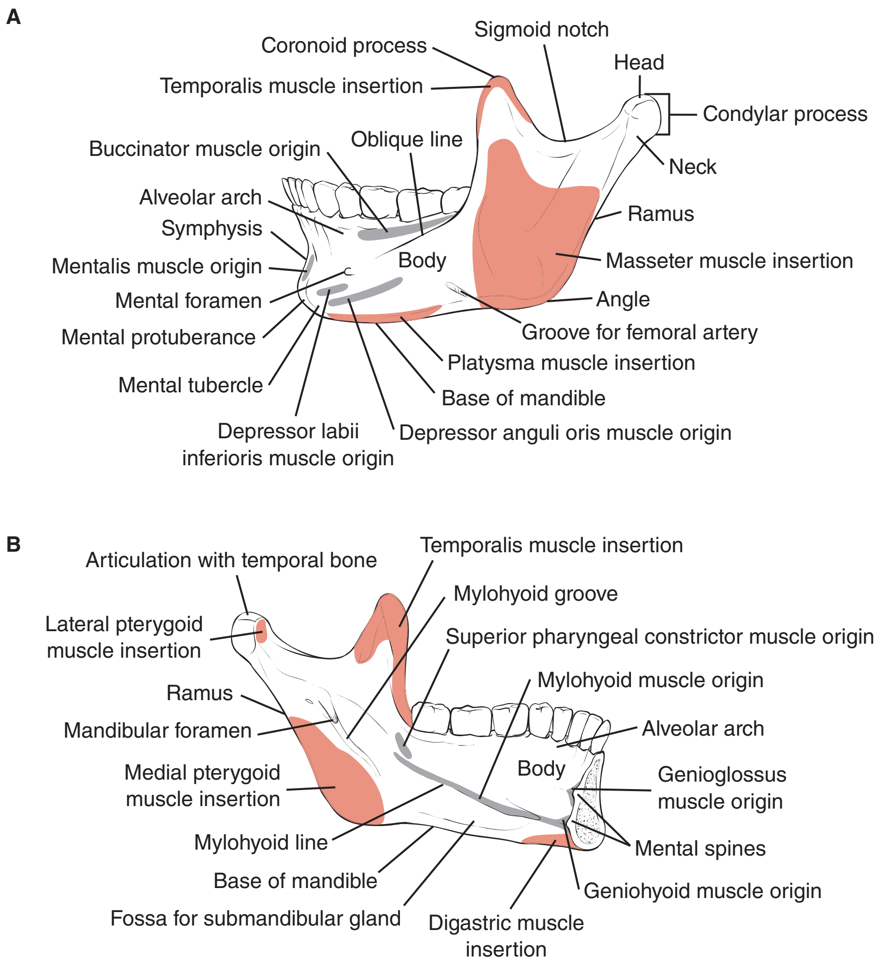

Fig. 16-2 **A,** External and, **B,** internal anatomy of the mandible.

The mandibular foramen is approximately 2 cm inferior to the sigmoid notch and allows passage of the inferior alveolar neurovascular bundle into the mandibular canal. A bony prominence at the site of the mandibular foramen known as the *lingula* serves as a surgical landmark for the nerve at this site of entry. Just proximal to the mandibular canal, the inferior alveolar artery and nerve give off their respective mylohyoid branches, which then run along the internal surface of the mandible in the mandibular groove.

Two groups of muscles impart movement to the mandible: the muscles of mastication (temporalis, masseter, lateral pterygoid, and medial pterygoid) and the suprahyoid muscles (digastric, mylohyoid, and geniohyoid). Although the stylohyoid muscles are technically part of the suprahyoid muscles, they do not attach to the mandible and therefore impart no direct movement for the mandible. All muscles of mastication are innervated by branches of the trigeminal mandibular nerve. The temporalis muscle is innervated by the deep temporal branches of the mandibular nerve; this muscle elevates the mandible. In addition, its posterior fibers aid in retrusion of the mandible. The masseter is innervated on its deep surface by the masseteric nerve; it elevates the mandible, along with slight concomitant protrusion. Its deep fibers also aid in retrusion. The lateral pterygoid muscle is innervated on the deep surface by the lateral pterygoid nerve and consists of superior and inferior heads. Together, the heads both protrude and depress the mandible. When acting alternately, they produce a grinding side-to-side movement of the mandible. The medial pterygoid muscle is innervated by the medial pterygoid nerve and consists of a deep and a superficial head. Together, the heads help elevate and protrude the mandible. When acting alternately, they produce a grinding side-to-side movement. When acting alone, they are capable of protruding the ipsilateral side of the mandible. The suprahyoid muscles elevate the hyoid and the floor of the mouth and, with the exception of the stylohyoid muscles, allow slight depression of the mandible. The digastric muscle is formed by anterior and posterior bellies. The anterior belly is innervated by the mylohyoid branch of the trigeminal nerve and attaches to the digastric fossa of the mandible. The posterior belly is innervated by the facial nerve and attaches to the mastoid notch. The mylohyoid muscle is innervated by the mylohyoid nerve of the trigeminal nerve. The stylohyoid muscle is innervated by the facial nerve. The geniohyoid is innervated by the hypoglossal nerve from C1.

The superior border of the mandible, or alveolar ridge, is wider at the posterior aspect, whereas the inferior border of the mandible is wider at the anterior aspect. The buccinator muscle originates along the superior border below the first, second, and third molars and inserts into the angle of the mouth.[1]

FRACTURE PATTERNS

An understanding of fracture patterns requires a thorough knowledge of anatomy, biomechanics, and causes of fracture. Fractures are more likely to occur in areas of weakness, such as unicortical areas of the angle and condylar neck, at the foramina, and along long tooth roots, such as the canines. Unifocal mandible fractures do occur, with the angle being most common, but most patients with mandible fractures (approximately 60%) have multifocal fractures. There is usually only one area of comminution signifying the area of impact.

> The fracture as seen on radiographic examination should be described as *complete* or *incomplete, displaced* or *nondisplaced, simple* or *comminuted, transverse* or *oblique.* It is important to note any greenstick component in pediatric patients.[2]

The site of mandible fracture depends on the mechanism of injury, not on age or the inherent characteristics of the mandible, such as the absence of teeth. Studies differ on the most common fracture site. Multiple studies agree that the most commonly fractured anatomic regions are the parasymphysis, angle, body, and subcondylar regions. However, false conclusions may be drawn from figures of regional fracture percentages, because most mandible fractures are multifocal. Taking the mechanism of injury into account, fractures of the angle and body may be the most common, with parasymphyseal fractures a close second, as discussed later. The percentage of fractures at each location for the general population is shown in Fig. 16-3. True midline symphyseal fractures occur in less than 1% of fractures; therefore the term *parasymphyseal* is used throughout the remainder

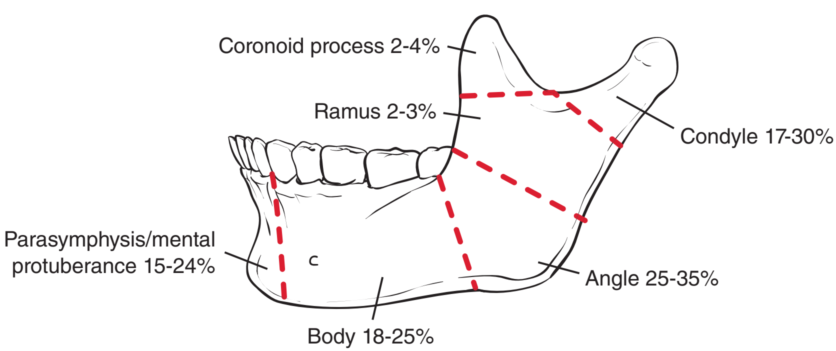

Fig. 16-3 Regional occurrence of mandible fractures.

of this chapter to indicate symphyseal/parasymphyseal fractures, emphasizing the low likelihood of true symphyseal fractures, whereas *true parasymphyseal* refers to a strict parasymphyseal location.

Patients with injuries associated with violence (assault) are statistically more likely to receive a forceful lateral blow to the mandible and are therefore most likely to have angle and body fractures. If the impact is of high velocity, these fractures can be unifocal. Another common fracture pattern involves angle or body fractures frequently seen concomitantly with contralateral true parasymphyseal fractures. This pattern also results from lateral blows to the angle or posterior body. When the angle or posterior body is struck, there is usually a lateral horizontal force that fractures the angle or posterior body and continues to force the anterior fragment medially. This causes the mandible to flex—most pronounced at the contralateral parasymphysis. The contralateral parasymphysis is subsequently fractured for several reasons. It is a relatively weak area because of the long tooth roots of the canine and the mental foramen. Also, it lies along a pronounced curvature that is relatively distal from the impact area of the angle or body. The impact on the angle/body (force) combined with the distance to the contralateral parasymphysis (length) creates considerable torque that acts on the contralateral parasymphysis, creating a second fracture.

It is worth noting that the force in this example is not oriented along the horizontal or vertical vectors of the mandible. Forces oriented perpendicular to the horizontal and vertical vectors create fractures with relative ease because of the lack of dissipation throughout the mandible. This helps explain why regional parasymphyseal fractures are so common, even though the most common mandible fractures are caused by violent injuries at the angle or body. A violent blow to the angle or body can result in a unifocal fracture (high velocity) or can include an additional parasymphyseal fracture.

Automobile accidents account for a large percentage of mandible fractures and are the second most common cause after violent assault. Victims of automobile accidents commonly have primary parasymphyseal fractures and are statistically less likely to have primary angle or body fractures. These patients are also likely to have condylar and subcondylar fractures. The likelihood of fracture increases if the patient was not wearing a seatbelt and if airbags did not deploy. The differences in mechanism of injury can clearly explain the findings.

During an automobile accident, a person's chin will likely receive a posteriorly directed force, such as occurs when striking the steering wheel or dashboard, which explains the high rate of parasymphyseal fractures.

Patients who receive a posterosuperior impact to the chin, such as from an automobile accident or a fall forward, striking their chin on the ground, often present with a primary parasymphyseal fracture and a contralateral condylar neck fracture. Examination usually reveals a contralateral open bite with deviation to the ipsilateral side of the condylar fracture on opening of the mandible. If the condylar neck fractures are bilateral, examination will reveal an anterior open bite caused by premature contact of the posterior molars from vertical collapse of the mandible. The fractures usually occur at the condylar necks because of the horizontal and vertical force vectors in the mandible. A force applied to the chin travels posterior and superior along relatively thick, strong bone. However, when it encounters the condylar neck, all of the force is compressed to a small cross-sectional surface area. If the stress reaches the critical point, fracture occurs.

Another possible presentation is a patient with a primary parasymphyseal fracture and an ipsilateral angle fracture. This occurs when a strong posterior force on the parasymphysis travels parallel along the body to the angle. When the force reaches the angle, the bone can be fractured because of the complex structure of the body and ramus intersecting at the angle. Patients who have primary parasymphyseal fractures are at the highest risk of having concomitant multifocal fractures. The physician examining a patient with a parasymphyseal fracture should be alerted to the possibility of contralateral subcondylar or ipsilateral angle fractures.[3]

The location and orientation of a fracture, along with the forceful pulling of the mandibular musculature, lends directly to the concept of a *stable* versus an *unstable* fracture, sometimes referred to as *favorable* versus *unfavorable.* Vertical stability means that muscle contraction across the fracture leads to vertical compression, whereas vertical instability leads to vertical distraction (that is, fracture fragments shift cephalad or caudally). Horizontal stability means that muscle contraction across a fracture leads to horizontal compression, whereas horizontal instability leads to horizontal distraction (that is, fracture fragments will shift medially or laterally). This is best illustrated with fractures of the posterior body and angle, as seen in Fig. 16-4.

In Fig. 16-4, *A,* the fracture line is oriented in a posterior-superior to anterior-inferior fashion. The masseter muscle pulls to elevate the posterior fracture fragment. This moves the posterior fragment into contact with the anterior fragment and vertically compresses them together. However, if the fracture line orientation runs from anterior-superior to posterior-inferior (Fig. 16-4, *B*), contraction of the masseter muscle elevates the posterior fragment in a direction roughly parallel to the fracture line leading to vertical distraction. Fractures extending in an anterior-lateral to posterior-medial direction (Fig. 16-4, *C*) result in a horizontally stable fracture pattern. The medial pull of the medial pterygoid muscle pulls the angle and ramus into the oblique surface of the anterior fracture fragment. A fracture extending from the anterior-medial to posterior-lateral aspect results in a horizontally unstable fracture pattern (Fig. 16-4, *D*). Here the medial pterygoid muscle pulls the angle and ramus medially, distracting them from the fracture.

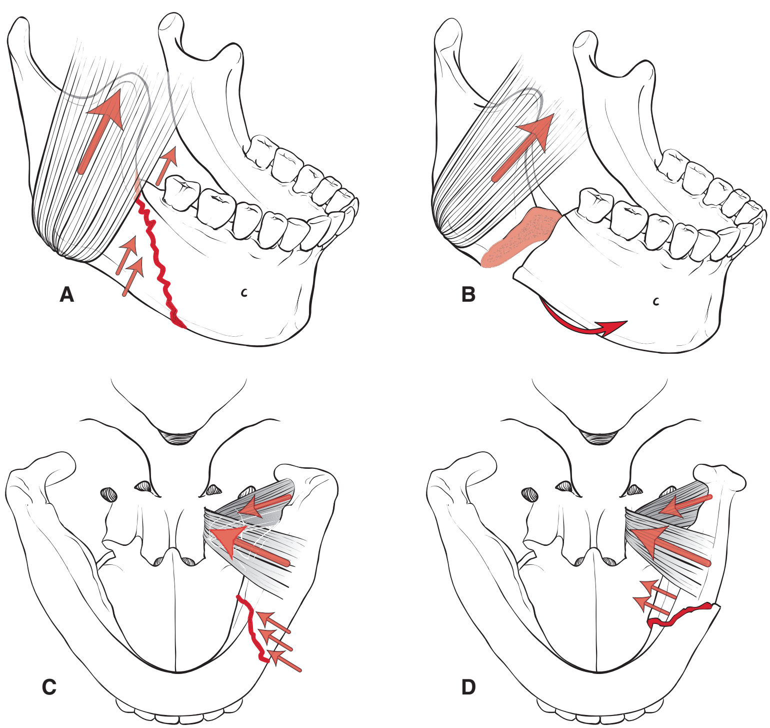

Fig. 16-4 **A,** Vertically favorable. **B,** Vertically unfavorable. **C,** Horizontally stable. **D,** Horizontally unstable.

This concept can be applied to symphyseal, parasymphyseal, subcondylar, and condylar fractures in the same fashion. Most ramus fractures are vertically favorable, whereas most angle fractures are vertically unfavorable (they extend posterior-inferior). Because of the downward pull of the suprahyoid muscles on the anterior mandible, most symphyseal and parasymphyseal fractures tend to be vertically unfavorable (with a downward distraction of one fragment). High condylar fractures also tend to be horizontally unstable because of the medial pull of the condylar head by the lateral pterygoid muscle.[4] The concept of stability becomes important when determining methods for immobilization and fixation, as discussed later.

DIAGNOSTIC STUDIES

The examiner must be capable of giving a thorough description of the injury to effectively communicate its nature and severity and expedite appropriate treatment. A full history should be obtained from the patient or from witnesses. The mechanism of injury, force of impact, duration of impact (impulse), and direction of impact should be determined. This helps the physician not only to understand the facial trauma but also to recognize other polytrauma that may be present, including cervical spine and closed head injuries. The physical examination should follow the consistent approach described in Chapter 3.

The following aspects of the routine examination may raise suspicion of a mandibular injury when positive findings are noted:

- Intraoral and extraoral bony palpation
- Assessment of lacerations, including involvement of the gingiva or floor of the mouth, and dental examination
- Evaluation of occlusion
- Bimanual manipulation of the mandible to assess for fracture mobility
- Active range of motion examination, including maximal opening, protrusion, and retraction, recording any deviations, crossbites, or premature contact anteriorly or posteriorly

Careful and meticulous neurosensory assessment and documentation is essential and may be performed first. Any inferior alveolar nerve deficit should prompt the physician to suspect a fracture involving the inferior alveolar canal. After the neurosensory examination, infiltration of regional and/or local anesthesia may be performed to offer comfort to the patient for the remainder of the examination, which, if performed properly, can be quite painful.

The regional location of each fracture is determined by radiography and should include imaging in at least two planes. Computed tomography is the benchmark evaluative tool and is easily obtained, but plain films can be invaluable.

The utility of plain films for diagnosing mandible fractures can be underestimated. Facial trauma surgeons should still have expertise in diagnosis by plain film radiography. Plain films are a useful study for most mandible fractures and should include panoramic and posteroanterior views.

Townes views are obtained if condylar fractures are suspected. If the surgeon's institution is not equipped to perform panoramic views, a mandibular series can be obtained which includes a posteroanterior view, Townes, bilateral oblique, lateral, and submentovertex views. For computed tomography, orders should always include axial and coronal views with three-dimensional reconstruction.[5]

INDICATIONS

The appropriate surgical intervention depends largely on the location and nature of the fracture. Options range from a soft, no-chew diet only with no reduction or fixation to open reduction with internal fixation (ORIF) or, in extremely contaminated open fractures, external fixation. It is advisable to perform definitive surgical fixation as soon as possible. This limits the amount of soft tissue edema, hematoma formation, and fibrin adhesions, which can limit exposure. However, there is no evidence of any direct relationship between time to surgery and the occurrence of postsurgical complications. A normal occlusal relationship is the most important fundamental goal when treating a mandible fracture.

Regardless of the technique used, it must provide stabilization for the fracture fragments to heal without distraction or nonunion. It must be able to withstand the forces of musculature for the full duration of treatment. Although any reduction and fixation technique may be stable at first, if poorly devised, it will allow wires, screws, teeth, or plates to loosen, thus impairing reduction and fixation, and lead to complications.

The mandible should be viewed as a system. Consideration must be given not only to each individual fracture but also to the effects that each fracture has on the other fractures. When this is done successfully, the surgeon is able to determine the best operation for the patient.[6]

Fractures with no displacement, a stable fracture line orientation, and normal preinjury occlusion can be appropriately treated with a soft, no-chew diet and careful follow-up. The patient's compliance must be assessed if this method is employed. These patients may have better pain control if a closed reduction method is employed, and this should be taken into consideration with the patient's desire.

Nondisplaced greenstick fractures, minimally displaced condylar and subcondylar fractures, coronoid fractures, and any other fracture with minimal displacement can be treated by closed reduction through the use of intermaxillary fixation (IMF) with Erich arch bars, Ivy loops, or intermaxillary fixation screws. Poor dentition and periodontal disease precludes the use of these closed reduction techniques. For an edentulous patient, closed reduction can be achieved with Gunning splints, lingual splints, the use of the patient's dentures, or with circummandibular wiring. Regardless of the type of closed reduction used, the fracture fragments must remain stable with proper reduction throughout the full course of treatment.[7] The sequence of application for each type of closed reduction treatment is beyond the scope of this chapter but should be reviewed in Chapter 7.

Most mandibular fractures are best treated by ORIF. These include most symphyseal, parasymphyseal, and angle fractures (because of their inherently unstable fracture pattern); body and ramus fractures; displaced fractures in edentulous patients; an atrophic mandible; unstable fractures or those with rotation or angulation; comminuted fractures; multifocal fractures; foreign bodies; fractures with an unstable midface; the presence of concomitant head trauma; a noncompliant patient; failure to achieve preinjury occlusion; failure to properly reduce and stabilize by closed reduction; and patient choice. In multifocal fractures, each fracture must be assessed and treated with an understanding of how it affects the other fractures; one cannot simply treat each fracture in isolation. For example, in a parasymphyseal fracture with a contralateral condylar neck fracture, the fragment between the two fractures is unstable at both ends. If one fails to adequately stabilize the condylar neck, any fixation of the parasymphyseal fracture will be compromised, regardless of thoroughness and attention to detail.[1] This concept and the indications for IMF after ORIF are discussed in further detail later in this chapter.

Fractures that are open, comminuted, and heavily contaminated are at high risk for infection and are best treated by external fixation. After healing has occurred, revision with bone grafts and soft tissue reconstruction can be carried out as indicated.[8]

EXPOSURE

The proper surgical exposure depends largely on the location of the fracture, whether there is comminution or multiple fractures, and the surgeon's ability. Research has failed to show a difference in infection rates between intraoral and extraoral approaches. Most fractures can be approached intraorally.

For noncomminuted symphyseal, parasymphyseal, and body fractures, a vestibular incision can be made with care to avoid injury of the branches of the mental nerve. If the fractures are isolated, the incision can be even smaller to accommodate a single 2.0 mm miniplate placed at the superior border of the fracture. This is known as the *Champy technique* and is discussed further on p. 16.14.

The Champy technique can also be used for noncomminuted isolated angle fractures. A vestibular incision can be made and a single 2.0 mm miniplate can be placed at the superior border of the fracture along the oblique line to provide a functionally stable fixation. Another option is to place a second 2.0 mm miniplate at the inferior border or just below the first miniplate. It is often difficult to adequately expose the angle to provide room to place a second inferior plate and secure the screws. To accommodate this, transbuccal trochar instrumentation is used. Using this method, several small stab incisions are made through the skin directly overlying the second plate. Once the plate is in place, the screws are placed through the stab incisions.

A transfacial approach is appropriate for comminuted ramus fractures, comminuted angle fractures, gunshot wounds, condylar fractures, fractures of an atrophic mandible, and any fracture that cannot be adequately exposed and treated using a transoral approach.[6]

The Risdon approach is useful for complicated angle and ramus fractures, such as comminuted cases. Its drawback is that the marginal mandibular nerve is at risk of injury. An incision is made 2 cm inferior to the inferior border of the mandible. Dissection is carried through the superficial cervical fascia. The platysma is sharply incised to expose the superficial layer of the deep cervical fascia. The marginal mandibular nerve is deep to this fascial layer. The dissection is carried to the bony surface, using a nerve stimulator where the pterygomasseteric sling is incised to expose the bone.

A retromandibular approach can be used to access the ramus and subcondylar region. A 0.5 cm incision is made below the earlobe and carried inferiorly for 3 cm along the posterior border of the mandible. Dissection is carried through the platysma and superficial muscular aponeurotic system and parotid capsule.

The marginal mandibular nerve and cervical branch of the facial nerve may be encountered at this point. The pterygomasseteric sling is incised and periosteal stripping is performed to access the bony surface. For approaches to the condyle, see Chapter 17.

OPERATIVE SEQUENCE

Terminology

Several terms need to be defined to have a better understanding of the operative sequence.

Rigid internal fixation Ellis and Miles[6] described *rigid internal fixation* as the application of hardware that is able to withstand any movement across the fracture site under normal functional forces. It is synonymous with a *load-bearing structure* and allows bony healing to occur without the formation of a callus. Examples include the use of locking and nonlocking compression plates, multiple plates at the fracture site, and multiple lag screws. Rigid internal fixation is required for comminuted fractures, atrophic mandibles, and those with missing bone fragments. Here, the compression plate bridges the fracture site completely, and the native bone shares no functional force loads.

Functionally stable fixation *Functionally stable fixation* involves the application of hardware that allows minimal movement to occur across the fracture site under normal functional forces. It is synonymous with a *load-sharing structure.* Bony healing occurs with the formation of a bony callus. Examples of this include a single miniplate/Champy technique. Functionally stable fixation requires that there is no comminution or bony defect, because the native bone shares functional force loads.

Postoperative IMF may or may not be required with both fixation techniques. Rigid IMF involves wire loops that prevent any movement. Elastic IMF involves one or more elastic loops on each side that allow movement but guide the patient into occlusion. If several elastic bands are used per side, this can be analogous to rigid IMF. If rigid IMF is used in combination with a functionally stable fixation, it may allow bony union to occur without a bony callus. Postoperative rigid IMF is not required if appropriate fixation is applied to the fracture. However, guiding elastic IMF may be desirable.

Tension banding *Tension banding* refers to the concept of applying stabilization along the superior border of a fracture, particularly in the setting of symphyseal, parasymphyseal, body, and angle fractures. Where the compression or fracture plate is secured to the inferior border of the mandible, it may not prevent splaying of the superior border of the fracture site under normal functional forces. To prevent this superior splaying, some form of a tension band can be used. The tension band effect can be achieved with an arch bar applied across the dentition involved in the fracture, by circumdental wiring such as an Ivy loop, or by application of a single 2.0 mm miniplate with monocortical screws along the superior border. When a fracture plate is used as a tension band, it is placed just inferior to the root apices. Its location and monocortical design prevent injury to the root apices. In mandibular angle injuries, the fracture is located posterior to the dentition; therefore the use of arch bars or wiring does not provide a tension band for these fractures.

Champy technique The *Champy technique* involves the use of a single monocortical miniplate and is most commonly employed for noncomminuted angle fractures. The plate is usually placed along the external oblique ridge and extends anteriorly to the buccal surface of the mandible. Regardless of where a miniplate is used, it should have a minimum of two screws per side of the fracture (Fig. 16-5). Although angle fractures are frequently unstable in orientation, the location of the miniplate is biomechanically favorable, because it opposes the muscle forces.

There are several advantages to this technique. First, it requires less exposure to the fracture site. Because less exposure is needed, there is less periosteal stripping and a less compromised blood supply to the bone. Second, because less exposure is needed, it can often be done without the need of a transfacial approach. Less hardware also, in principle, decreases the risk of hardware exposure and hardware infection. Disadvantages to the Champy technique include the possibility of instability at the fracture site. Its monocortical design limits the use of bicortical screw stability. However, research has shown that angle fractures treated with the Champy technique are not at greater risk of instability. Although there has been controversy regarding this technique in the past, it is gaining wider acceptance. Postoperative IMF may be used in addition to the Champy technique. However, many surgeons have reported a high success rate in the treatment of angle fractures with a single miniplate without the use of postoperative IMF. When more stabilization is desired, a second miniplate may be placed along the inferior border of the angle (Fig. 16-6). Bicortical screws may be used if placed below the inferior alveolar canal. This technique requires the use of transbuccal trochar instrumentation to place the screws, because perpendicular access to the inferior border cannot be obtained through an intraoral approach. The screws are placed by making several small stab incisions in the skin.

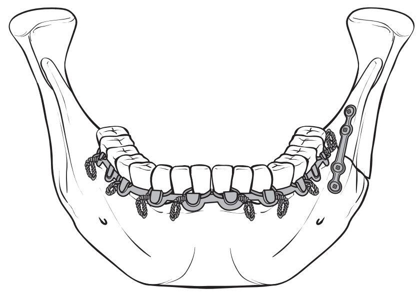

Fig. 16-5 Plating of an angle fracture with the Champy technique. The fracture is reduced and a 4-hole monocortical miniplate is placed along the external oblique ridge posteriorly with extension onto the buccal surface anteriorly.

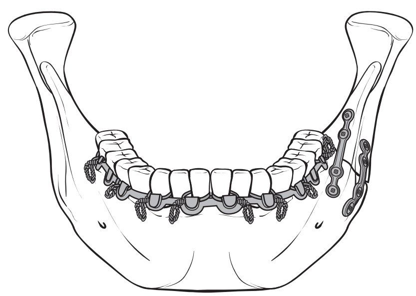

Fig. 16-6 Plating of an angle fracture with the addition of a second miniplate using the Champy technique. A second 4-hole monocortical miniplate is placed along the inferior border of the mandible through an intraoral approach and secured with transbuccal trochar instrumentation.

Technique

> The most important principle in treating mandible fractures is restoration of pre-injury occlusion. The second most important principle is achieving proper anatomic alignment with normal function.

The patient should be questioned about the alignment of the teeth—how the alignment feels compared with how it normally feels. Any dental moldings that were made before the injury should be obtained; however, few patients will have these.

To facilitate ORIF, IMF is secured initially to restore preinjury occlusion. Once this is done, ORIF is performed. The purpose of this is twofold. First, preinjury occlusion helps bring the bony fragments toward their natural alignment and makes fixation easier. The act of placing the patient into IMF entails closed reduction to align the dental arches. When the fracture line occurs between teeth, manual reduction is often needed. Second, the ultimate goal is to have a bony structure that allows proper occlusion. Proper occlusion is more important than perfect bony alignment. The bones should be made to accommodate occlusion, not vice versa.

At the end of successful ORIF, the IMF is removed. The reduction is inspected carefully. If the reduction is found to not hold the preinjury occlusion, the surgeon must start over. If preinjury occlusion is maintained, IMF is reapplied with wires or elastic bands, if necessary. This will ensure that the IMF and ORIF are working synergistically.

The current trend at Johns Hopkins and Duke University is to limit the use of postoperative IMF by discontinuing it once functional healing has occurred. Functional healing implies no instability of the healing fracture under normal mandible stress. This is easily assessed by firmly palpating the fracture site. If the patient experiences worsening pain during palpation, then functional healing has not yet occurred. Prolonged IMF risks include airway difficulty, poor nutrition and hygiene, difficulty speaking, discomfort, social inconvenience, and difficulty regaining full functional range of motion. The use of elastic IMF postoperatively after functional healing allows guidance of the occlusion and improved comfort, and it facilitates range of motion.

With regard to locking versus nonlocking screws, we tend to favor the use of locking screws when possible. The concern is that nonlocking screws may cause periosteal pressure necrosis, leading to plate instability. When any plate is placed, the plate must be molded to the contour of the mandible before it is secured. A plate must never be molded to the contour of the mandible by pressing the plate against the mandible and attempting to bend it to fit the mirrored contour. This only causes further fracture distraction and compromises the periosteal surface of the mandible. Large compression plates take considerably more time to bend and mold.

> There is still much controversy in regard to removing teeth during ORIF. Ellis advocates leaving involved teeth in the fracture line unless they are grossly mobile, nonviable, infected, or limiting reduction. Third molars are an exception and may be removed if needed. However, removal of the third molars converts a closed fracture to an open fracture, and this must be considered.

Isolated fractures of the symphysis, parasymphysis, and body can be approached through a vestibular incision. The periosteal envelope of the mental nerve branches is carefully dissected and retracted to avoid injury. IMF is placed and bone clamps are applied by drilling holes in the outer cortices to accommodate the breaks. The bones are then reduced further. Care should be taken at this point to inspect posterior occlusion. Compression of the anterior fracture may cause widening of the posterior mandible, and this should be addressed before applying any hardware. If dentition is adequate, a single four-hole 2.0 mm miniplate may be applied anywhere below the root apices, followed by IMF to provide a functionally stable fixation (Fig. 16-7). If the fracture extends through the mental foramen, the miniplate may be placed superior to the foramen. This negates the need for extensive mental nerve mobilization. If dentition is poor or the fracture is unstable or comminuted, a larger bicortical compression plate can be placed at the inferior border of the fracture. The use of a tension band in this circumstance is advised. An alternative to using a larger bicortical compression plate is to use a second miniplate.

When placing the screws for body fractures, one must keep in mind the location of the inferior alveolar canal and remember that the cortical thickness is less than in the symphyseal region. In addition, there is less distance from the root tips to the inferior border of the mandible in the body region. Therefore, monocortical screws must be used or bicortical screw placement must be below the level of the canal. The lack of a neurovascular canal in the symphyseal region allows bicortical screw placement anywhere below the root tips.

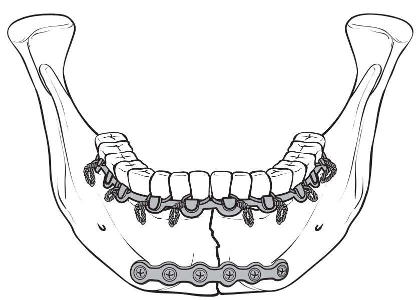

Fig. 16-7 Plating of a parasymphyseal fracture using a bicortical compression plate. A 6-hole bicortical compression plate is secured along the inferior border of the symphysis and parasymphysis. Tension banding may also be used along the superior border instead of IMF.

Lag screws can be used for sagittal fractures of the symphysis and any oblique fracture of the mandible where there is sufficient room to accommodate them. The cortical thickness of the symphysis and lack of neurovascular canal allow the use of these lag screws. In a sagittal symphyseal fracture, two lag screws can be placed through the buccal cortices and extend through the medullary canal into the opposite buccal cortices. Lag screws provide true rigid internal fixation (Fig. 16-8).

Angle fractures involve the complexity of converging horizontal and vertical vectors, multiple musculature forces, the inferior alveolar nerve, and possibly the presence of impacted wisdom teeth. The angle has the highest rate of postoperative complications. For isolated noncomminuted angle fractures, the Champy technique can be used through a transoral approach and is the preferred method of treatment. The plate is secured on the buccal aspect at the superior border of the mandible. If further stability is desired, a second miniplate can be added through the use of percutaneous trocar instrumentation with stab incisions. The second miniplate is placed either inferiorly to the first miniplate or at a more inferior aspect of the mandible. For comminuted angle fractures or fractures that cannot be adequately stabilized with the Champy technique, a compression plate placed at the inferior border through a transfacial approach is required.

Multifocal mandible fractures are more complicated to stabilize and require stronger fixation. When there are two fractures, the bony fragment between the two fractures is free floating. In addition, any movement at one fracture site will compromise the other fracture site because of the application of torque transmitted to the other fracture site. In general, when treating multifocal fractures, one fracture needs to be stabilized using rigid internal fixation. It is best to use rigid internal fixation for anterior fractures such as symphyseal, parasymphyseal, or body

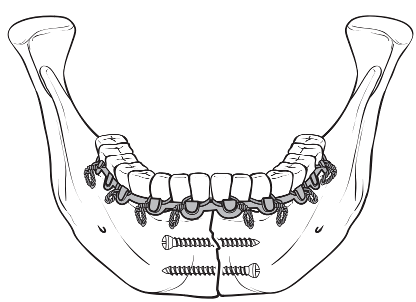

Fig. 16-8 Lag screw placement for a symphyseal fracture. After reduction using bone clamps, two lag screws are placed transcortically into the buccal cortex, into the medullary space, and into the buccal cortex on the opposite side. Notice that the screws are placed in opposing directions.

fractures. This requires less exposure and creates fewer difficulties when treating the posterior fractures of the angle, ramus, or condyle. Multiple miniplates, lag screws, or compression plates combined with postoperative IMF can be used on the symphyseal, parasymphyseal, and body fractures, as described earlier. This converts the second posterior fracture to an isolated fracture, which can then be addressed with a functionally stable fixation.

Comminuted fractures require rigid internal fixation. The surrounding bone cannot bear any load forces. Small miniplates can be used to secure bone fragments together. Once the fracture is properly reduced, a large bicortical compression plate is used to span the entire fracture (see Fig. 16-5).

POSTOPERATIVE CARE

Proper occlusion must be assessed frequently in the perioperative and postoperative period. If the patient is placed in rigid IMF, it is essential that the patient leave the operating room with a pair of wire cutters that have been fastened to the chart. These wire cutters must stay with the patient at all times and should be secured at the head of the bed so they are visible to everyone. When the patient leaves the room or is discharged home, he or she must be instructed to carry the wire cutters at all times. Everyone should be briefed on the danger to the patient's airway because of IMF, including aspiration risk. The patient should be instructed to remove the wires if he or she becomes nauseated and to call or go to the nearest emergency department immediately.

> Everyone caring for a patient with rigid IMF should be instructed on the dangers to the patient's airway, when to use wire cutters, and how to remove the IMF. This includes the anesthesia staff, OR nurses, transport personnel, recovery unit nurses, all residents and house staff, and, most important, the patient and his or her friends or family.

Often elastic IMF is used in lieu of wires. The number of elastic bands used should be the fewest possible to bring the bite into proper occlusion. The number of elastic bands should be reduced as tolerated during the course of postoperative care. A single elastic band per side (guiding elastic IMF) allows range of movement.

For patients who are not placed in IMF and those who are taken out of IMF, physical therapy should be consulted to evaluate the patient and provide education on range of motion exercises. The patient should be encouraged to follow these instructions carefully.

Oral hygiene should be stressed at the very beginning of treatment, ideally in the preoperative period, with the use of chlorhexidine mouthwash. This mouthwash routine should continue every 6 hours after surgery and after each meal.[6]

CONSEQUENCES OF INJURY AND COMPLICATIONS

Problems and concerns may arise in the postoperative period, and routine follow-up allows expeditious recognition of problems and proper intervention.

- *Delayed union* may be addressed through prolonged immobilization. If fixation is not adequate, the option of returning to the operating room should be entertained.
- *Malunion* is the improper alignment of the mandible. It may or may not be clinically significant, and occlusion should be assessed. It can lead to malocclusion. Initially, minor occlusal irregularities may be managed with rigid IMF for an additional period or with multiple or asymmetrical elastic bands. In the case of malocclusion after completion of treatment, the patient may benefit from orthodontics or possible osteotomies.
- *Nonunion* is noted in late follow-up and is a primarily clinical diagnosis that is confirmed radiographically. It is difficult to make the diagnosis of nonunion radiographically in the first 2 or 3 months after injury, because even a healing fracture may not be fully ossified or calcified. In a true nonunion, the patient must be returned to the operating room. These patients frequently complain of pain and abnormal mobility. The most common causes are poor reduction, poor fixation, poor immobilization, compromised blood supply, poor nutrition, use of alcohol or illicit drugs, and immunocompromise.
- *Infection* must be addressed by return to the operating room for washout, debridement, possible removal of hardware, and antibiotic administration. Rigid internal fixation should be used, and bone grafts may be needed.
- *Trismus* is common after release of IMF. Patients should always begin range of motion exercises after release and should be followed closely to monitor progress when trismus is present. Initially patients may use stacked tongue depressors (adding one at a time) along the posterior dentition as an aid to establishing passive range. If no improvement occurs after 1 to 2 weeks, physical therapy may be required.
- *Ankylosis* of the temporomandibular joint can occur from condylar injury or prolonged immobilization. There is the added risk of causing disturbed growth in children from possible damage to the growth centers.

- *Nerve injury* can occur, most commonly as a consequence of injury, but the injury can also be iatrogenic if care has not been taken in the vicinity of the nerves. The patient's sensory and motor nerve examinations should be followed carefully. Preoperatively, the patient should be aware that numbness to the skin, lips, gingiva, and teeth may occur and/or persist. Proper encouragement should be offered, and, ideally before surgery, the patient should be told of the possibility that full sensation may not be recovered.

RECOMMENDED FOLLOW-UP

The patient should be followed weekly or biweekly after surgery. The examiner should evaluate occlusion and range of motion, inspect the incisions, and assess for evidence of erythema, swelling, or other signs of infection. If the patient is in IMF, the wires should be assessed to make certain they are adequately tight. They should be retightened as necessary. It is also important to confirm that the wires are not cutting into the mucosa; they should be trimmed and bent away from the mucosa as needed.

The duration of IMF differs from institution to institution and for each fracture. In general, it is preferable to limit the amount of time a patient spends in wire IMF to avoid trismus. If multiple elastic bands are used, it can have the same effect. If fixation of an isolated fracture is rigid and occlusion is stable at the end of surgery after IMF release, guiding elastic IMF (one band per side) alone may be used for 4 to 6 weeks. Wire IMF is used when a limited period of immobilization is desired, after which guiding elastics can be applied for the remainder of treatment. A good example of this is a parasymphyseal fracture treated with rigid fixation but accompanied by a contralateral condylar fracture. In this case, wire IMF may be necessary for 1 to 3 weeks, followed by guiding elastic IMF for a total of 6 weeks. At the completion of the treatment plan, arch bars can be removed with the use of a local anesthetic, or rarely, in the operating room with general anesthesia for comfort concerns.

Recent evidence supports antibiotic use from the time of diagnosis until completion of surgery. The regimen should cover both skin and oral flora, such as with penicillins or clindamycin. However, antibiotics extending past the 24 hour perioperative period have not been shown to be of any benefit. The exception is for fractures that are infected at the time of presentation.[6]

Pearls

- *Restoration of preinjury occlusion is the most important principle when treating mandible fractures.*
- *The posterior occlusion should be assessed when reducing fractures intraoperatively.*
- *Proper occlusion is rechecked before closing the incisions.*
- *Dental molds and splints are used whenever possible to achieve ideal occlusion.*
- *At the time of surgery, the plan for IMF duration should be determined: rigid, elastic, or a combination. Rigid (wire) IMF is used when needed, switching to elastic IMF after functional healing.*

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17 Mandibular Condyle Fractures

Steven A. Earle, Jeffrey R. Marcus

Background

Condylar and subcondylar fractures account for 17.5% to 52% of all mandible fractures[1] (Fig. 17-1). These fractures are related to motor vehicle accidents, interpersonal violence, falls, and activity-related injuries.[2] Because of the distinctive anatomy of the mandible and temporomandibular joints (TMJs), condyle fractures may result in significant complications if not recognized and treated appropriately. These complications include pain, restricted mandibular movement (trismus), muscle spasm, deviation of the mandible, malocclusion, pathologic changes of the TMJ, osteonecrosis, facial asymmetry, and ankylosis.[3]

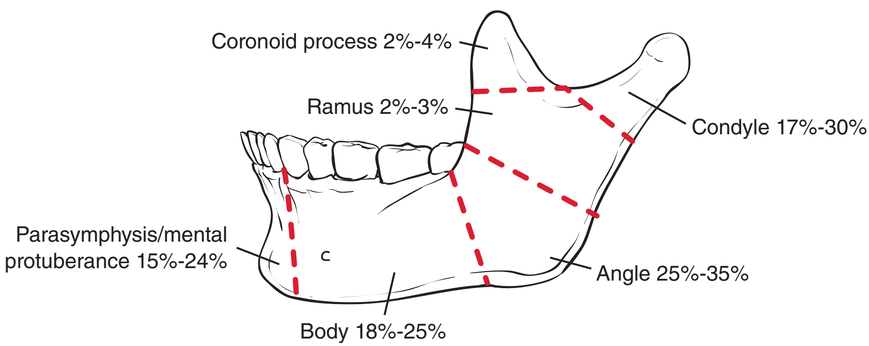

Fig. 17-1 Mandible fracture frequency by location.

Fractures of the mandibular condyle can occur in isolation or in combination with other fractures. Isolated unilateral condyle fractures most frequently result from low- or moderate-energy impacts directly to the side of the face. Bilateral condyle fractures occur more commonly from higher-energy impacts to the chin or anterior mandible. Energy is transmitted through the buttresses of the ascending rami to the condylar necks and condylar heads, which are relatively weaker. Fracture of the symphysis can be seen in this combination as well. Another common pattern is unilateral condyle fracture in combination with contralateral fracture of the parasymphyseal, body, or angle regions. In these moderate-to-high-energy impacts, force is transmitted to the condyle after an initial impact on the contralateral side.

By understanding these patterns and by being alert to possible combinations, it is more likely that all injuries will be identified.

All condyle fractures require some form of treatment, and, as with other mandibular fractures, there are two general strategies: open and closed. However, controversy continues over which general strategy and specific variation is most appropriate for a particular condylar fracture pattern and patient population.

Although recognition and management of condyle fractures dates back nearly 200 years, reports of closed reduction are somewhat more recent, with the first being published in 1924 by Perthes.[4] Open surgical techniques were introduced far later, first incorporating stainless steel wire fixation. Initial experience with nonrigid fixation was associated with unstable osteosynthesis and yielded relatively poor results; therefore enthusiasm for open reduction and fixation was limited. With the advent of rigid fixation osteosynthesis and miniplating and microplating, two important factors could be controlled that had previously not been controllable: maintenance of precise anatomic alignment and prompt mobilization of the joint to preserve and encourage range of motion.[4]

Furthermore, advances in radiographic imaging, particularly CT scans, have improved preoperative visualization and evaluation of fracture patterns. More precise classification has enabled subgroup analysis relative to indications for open versus closed treatment. All mandibular condyle fractures should be evaluated by helical thin-cut (1 mm) face CT with both coronal and axial images.

The optimal management of condylar fractures remains controversial. There are few prospective studies, and many of these have small sample sizes. An early study by Santler et al[5] compared open treatment with closed treatment of mandibular condyle fractures in a total of 234 patients; 150 of these patients were followed long-term, with a mean follow-up time of 2.5 years, and were analyzed using radiographic, objective, and subjective criteria. They found no significant difference in mobility, joint problems, occlusion, muscle pain, or nerve disorders among groups. The only significant difference was toward increased subjective discomfort in the surgical group. Shortly afterward, Ellis et al[6] published a clinical trial assessing occlusion after open versus closed treatment on unilateral condylar neck and subcondylar fractures in 137 patients. They found that the patients treated with closed techniques had a significantly increased percentage of malocclusion, regardless of the fact that the initial displacement of the fractures was greater in the open treatment group.

The first large, prospective, randomized study (involving seven treatment centers) was performed by Eckelt et al[7] in 2006. This study included 66 patients treated for 79 fractures; the patients were followed for up to 6 months. The authors found that the functional results and subjective outcomes were statistically improved with the open approach. This was based on parameters such as mouth opening, range of protrusion, and malocclusion. Symptoms of pain and impairment were less in the open treatment group as well. Finally, Nussbaum et al[8] published a meta-analysis of the past studies that directly compared open versus closed treatment of condylar fractures. Unfortunately, the results of their study were inconclusive; this was attributed to the inadequate quality of the available data. Thus the question of preferred treatment modality remains indefinite, and further research into this topic continues.

Based on the growing and contradictory body of evidence, the decision for open versus closed treatment must be made by the patient and surgeon on an individual basis. In this chapter, we provide guidelines as to which treatment will most likely have the best outcome for specific fracture patterns and patient populations. The complications regarding each approach are delineated as well. To begin, a thorough understanding of the anatomy and physiology of the mandibular condyle and TMJ is essential in planning treatment of these complex fractures.

REGIONAL ANATOMY

Normal Anatomy

The condyle is composed of a head and neck. The condyle is a major growth center for the mandible as it develops throughout childhood and adolescence. Growth at the condyle determines the posterior mandibular height. Just as failure of condylar development in hemifacial microsomia is characterized by profound dentofacial deformities, damage of the condyle during growth and development may also lead to deformities.[4] The mandible is formed as an arch and articulates on either end at the level of the TMJ. The TMJ allows movement in rotational and translational vectors (Fig. 17-2). The jaw opens first by rotation of the condyle within the inferior joint space and then by translation of the condyle and disc in a downward and forward direction (Fig. 17-3). Rotation alone allows 20 to 24 mm of interincisal opening. Translation then allows the maximal interincisal opening of 40 mm or greater.[9]

The mandible is depressed (jaw opened) by its own weight, assisted by the platysma, digastric, mylohyoid, and geniohyoid muscles. It is elevated (jaw closed) by the masseter and medial pterygoid muscles and the anterior part of the temporalis muscle. It is drawn forward by the simultaneous action of the lateral and medial pterygoids, the superficial fibers of the masseter, and the anterior fibers of the temporalis muscle. It is drawn backward by the deep fibers of the masseter and the posterior fibers of the temporalis.

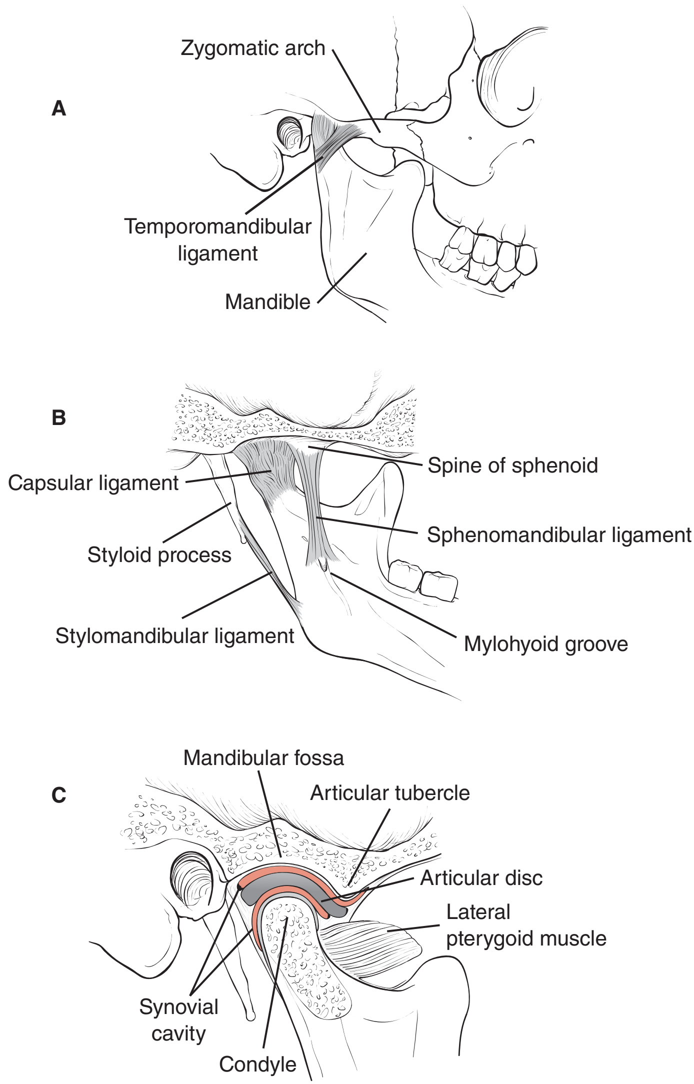

Fig. 17-2 Temporomandibular joint. **A,** Lateral. **B,** Medial. **C,** Articulation.

A

B

C

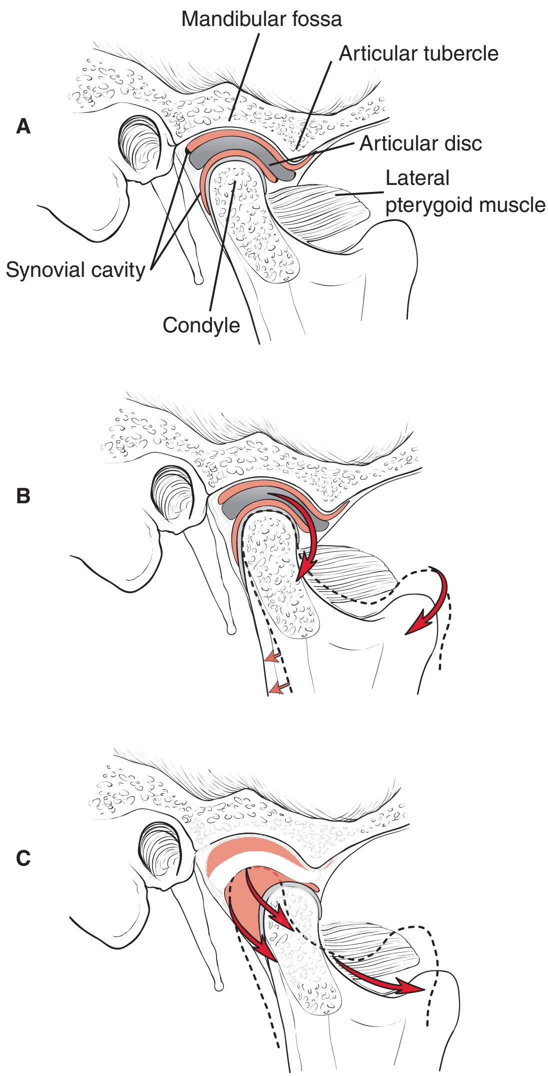

Fig. 17-3 Movement of the temporomandibular joint. **A,** Closed. **B,** Rotation. **C,** Translation.

The lateral pterygoid muscle is responsible for moving the lower jaw from side to side when the right or left lateral pterygoid is active separately. Contraction of the right lateral pterygoid muscle moves the jaw to the left, and contraction of the left lateral pterygoid draws the jaw to the right (Fig. 17-4).

A displaced fracture of the condyle results in shortening of the posterior ramus height because of fragment overlap. This is worsened by the normal resting tone of the muscles of mastication.[10] As a result of overlap, the mandible rotates in a manner that allows premature posterior occlusal contact, and the patient develops an anterior open bite. This may also lead to loss of chin projection.

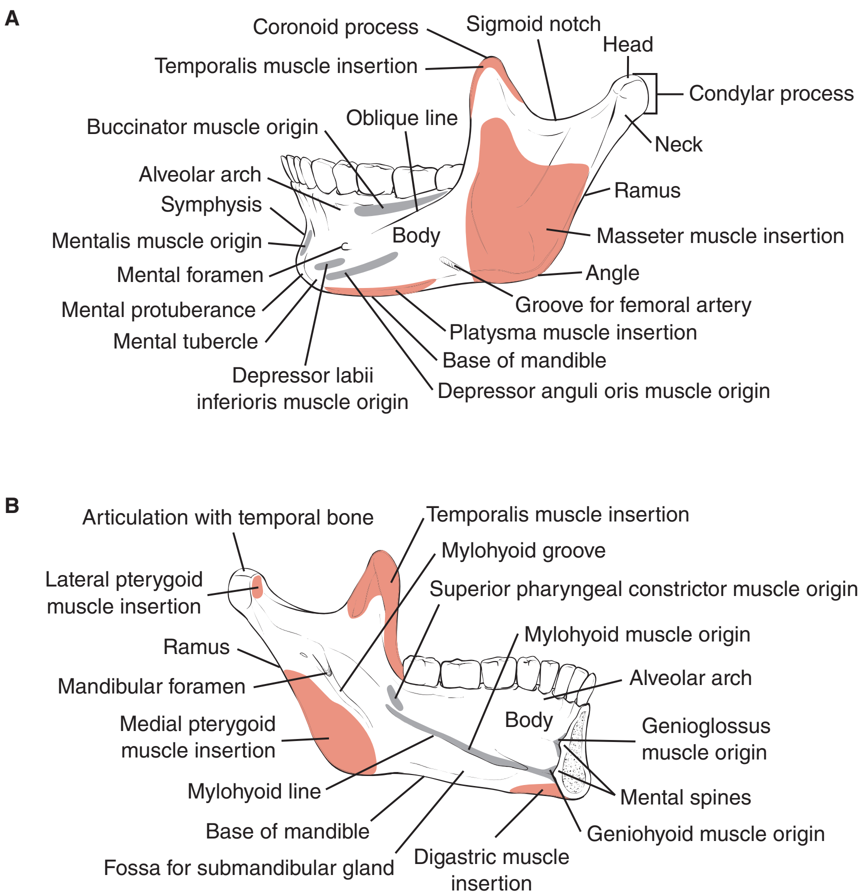

Fig. 17-4 Muscle origins and insertions in the mandible. **A,** Lateral (outer surface). **B,** Medial (inner surface).

The attachments of the lateral pterygoid muscle tend to place the condylar fragment into a flexed position in up to 80% of patients.[10] Further shortening of the ramal height is caused by the lateral pterygoid shifting the condylar head medially. This causes premature contact of the anterior wall of the glenoid fossa, which limits TMJ movement to the rotational vector only.

A malunited condyle results in abnormal joint dynamics and generates late internal derangement. Because of the hinge effect of the mandible on the bilateral TMJs, the contralateral condyle suffers from abnormal biomechanical loads and is subject to early degenerative changes.[10]

FRACTURE PATTERNS

There are two types of mandibular condyle fractures: *intracapsular* and *extracapsular.* However, for practical purposes the anatomic level of the fracture is divided into three areas: the *condylar head* (all intracapsular), the *condylar neck* (extracapsular), and the *subcondylar region* (also extracapsular)[1] (Fig. 17-5). Fractures can be further classified as *displaced, deviated,* and *dislocated* (outside the glenoid fossa). Approximately 70% of condylar fractures are subcondylar, 19.6% occur in the condylar neck, and 9.7% in the condylar head.[2]

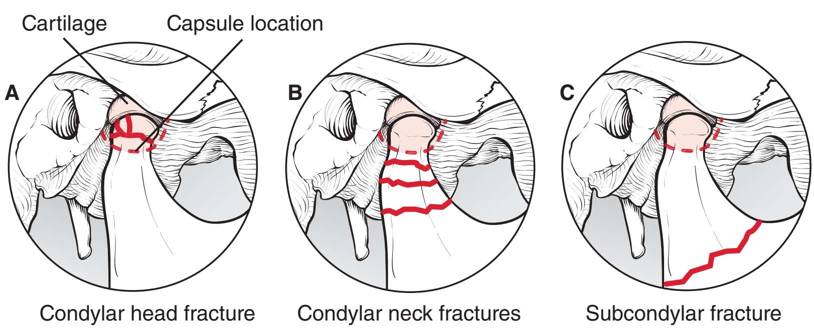

Fig. 17-5 Mandibular condyle fracture patterns. **A,** Head and intracapsular fracture. **B,** Neck fracture. **C,** Subcondylar fracture.

Fractures of the condylar head or high neck are not amenable to open fixation. All other condylar neck and subcondylar fractures may be treated by using open and/or endoscopic fixation.

Displacement refers to the position of the condylar fragment relative to the ascending ramus.[10] *Medial override* indicates a condylar segment that is medial to the ramus. The reverse is true for *lateral override.* Lateral override is more common and is easier to repair because of better fragment visualization, manipulation, and plate fixation (especially with an endoscopic approach). The challenge of a medial override injury can be overcome by first reducing it to a lateral override injury.

SURGICAL INDICATIONS

Closed Treatment

There are certain indications for which most surgeons would agree that closed treatment is the best option. The first is treatment of a child; condylar fractures are among the most common facial fractures in children.[1] If condylar fractures are not identified early and treated properly, they may lead to growth disturbances and asymmetry of the face at multiple levels, including the orbits, cheeks, maxilla, and mandible.[1] There should be a strong index of suspicion in any child who has had a fall with potential for more than low-energy impact and has a chin laceration or contusion. A panfacial thin-cut CT scan should be performed.

Children and young adults have the capacity to establish new temporomandibular articulation by remodeling and adaptation. Therefore the consensus is that all children with condylar fractures should be treated conservatively.

All intracapsular fractures, especially those close to or involving the articular surface, are best managed nonoperatively because of the technical difficulties of exposing this area, the inability to fix a plate to the proximal segment, and the real possibility of devascularizing the proximal segment with the dissection. Intracapsular injuries are at high risk for long-term joint disease, including ankylosis. Therefore nonoperative management should include early and aggressive mobilization. The assistance of physical therapy services should be strongly considered in this group.

When an intracapsular condylar fracture occurs in combination with another mandible fracture (for example, a contralateral angle fracture), the remaining fractures should be treated with open reduction and rigid internal fixation to allow early mobilization of the condylar fracture.

Finally, if the fracture is nondisplaced or the patient is too injured to safely undergo surgery, closed treatment is warranted.

Open Reduction and Internal Fixation

An adult has less ability to remodel and adapt than a child. Taking that into account, there are three main treatment choices for adults, depending on the patient and the fracture pattern: functional therapy alone, intermaxillary fixation (IMF) followed by functional therapy, and open reduction and internal fixation, also followed by functional therapy.[3] The factors to consider when making this decision are those stated in the treatment goals section below. However, there are some absolute indications for open treatment that are consistent among the literature. These include bilateral fractures, significant dislocations when occlusion cannot be reestablished by closed methods, the presence of foreign bodies (such as projectiles), and dislocation of the mandible into the middle cranial fossa.[3]

TREATMENT GOALS

When planning treatment of condylar fractures, the surgeon must consider many factors. These include physical findings and the results of imaging; occurrence in isolation or in combination; the level of the fractures; the degree of displacement and/or comminution; the presence of dislocation, malocclusion, and mandibular dysfunction; the patient's dentition; the presence of associated facial fractures; the clinical experience of the surgeon; and the age, general status, and willingness of the patient to undergo surgery.[1] Management can range from physiotherapy alone to IMF, or to open reduction and internal fixation.

Regardless of the way a fracture is being managed, the standards for outcome are the same: occlusal stability, maintenance of vertical height and good facial symmetry, pain-free mouth opening to 40 mm or greater, a return to normal range of motion, and preservation of TMJ function.[9]

EXPOSURE

Exposure can be achieved through several extraoral and intraoral approaches. Extraoral methods include preauricular, face lift, retroauricular, retromandibular, and submandibular approaches. In most cases, the retromandibular incision provides the safest and most versatile exposure for surgical fixation of subcondylar fractures. The retromandibular incision allows access extending from the coronoid notch superiorly to the angle of the mandible inferiorly. The use of a transbuccal trocar often allows access to more proximal subcondylar fractures as well.

The intraoral approach includes the mandibular vestibular incision, with or without the use of the endoscope with a transbuccal trocar.[10] The technical aspects of these approaches are described elsewhere in this book.

OPERATIVE SEQUENCE

As discussed previously, there are three treatment options for mandibular condyle fractures. The first involves functional oral physical therapy alone, which is sufficient for minimally displaced or nondisplaced fractures that have normal occlusion and minimal pain. Treatment includes a soft diet and immediate mobilization.[1]

For all other fractures—except when the absolute indications for open treatment are met, as stated earlier—closed treatment with IMF may be performed. Because this method is technically simple and offers reduced morbidity with satisfactory results, it is a good option as long as vertical height and occlusion are maintained. Rigid wire IMF is placed for a period of time to allow initial fracture healing, followed by a period of elastic IMF to control and guide the occlusion.

The most important component of any form of treatment for condyle fractures is patient compliance with oral physical therapy. This consists in all cases of active range of motion exercises and stacked tongue blades—sequentially increasing the number of tongue blades stacked between the incisors, day by day. If a patient demonstrates trismus that is unresponsive to initial therapy, formal physical therapy for range of motion should be prescribed. Passive range of motion using intraoral stretching devices may be necessary.

If lateral deviation is noted during active range of motion (week 1), the patient should place a hand on the deviated side and apply gentle medial pressure as he or she opens and closes the mouth. Passive opening with tongue blades may begin at week 2. The goal is 40 mm of excursion, which should be achievable by the end of week 2. Physical therapy treatment is not complete until the patient has stable occlusion and normal function.

The third treatment option is open reduction and internal fixation, followed by oral physical therapy as described. Regardless of the approach used, once the fracture is visualized, it must be anatomically reduced. Two-plate fixation is recommended whenever possible; however, other forms of plate fixation can be used (Fig. 17-6). In bilateral cases, at least one side should be fixated to maintain adequate height and prevent an anterior open bite deformity. If the fracture segment is very small, condylectomy is also an option, followed by extensive oral physical therapy.

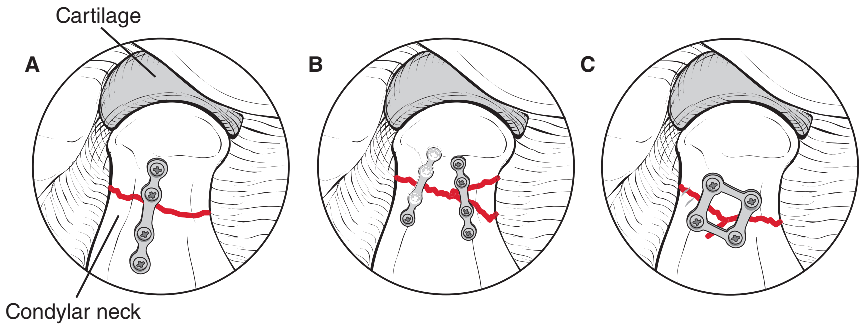

Fig. 17-6 Different osteosynthesis configurations for condylar fractures.

For high condylar fractures treated conservatively, delayed functional or aesthetic disturbances may develop, for which orthognathic surgery can be performed as a secondary procedure. At that time, the neotemporomandibular articulation will have formed, and orthognathic surgery can be used to reposition the mandible. Alternatively, distraction osteogenesis can be used to address the problem of posterior ramus height deficiency.[10]

POSTOPERATIVE CARE

Immediately after surgery, patients in IMF must have wire cutters at the bedside at all times. Elevating the head to more than 30 degrees and administering antiemetics are of paramount importance. If an airway emergency arises, the wires are cut and the patient is immediately intubated. The patient is also given an ice pack to reduce swelling for the first 48 hours. Triple-antibiotic ointment is applied to all external incisions. The patient starts with a liquid diet and is highly encouraged to maintain adequate oral hygiene, including rinsing with 15 ml of chlorhexidine (Peridex) or a similar solution every 6 hours. A posttreatment Panorex film is obtained before the patient is discharged.

Postoperative treatment after open reduction and internal fixation is similar to that for nonoperative treatment, as described previously. This includes 6 weeks of IMF (with a combination of wire and elastic) and a soft mechanical diet. The most important component to any form of treatment for condyle fractures is compliance with oral physical therapy. Physical therapy treatment is not complete until the patient has stable occlusion and normal function.

CONSEQUENCES OF INJURY AND COMPLICATIONS

Several problems may occur, regardless of the approach taken. Condylar injuries themselves are inherently difficult because of the potential sequelae of the injury itself. These include ankylosis, chronic pain, restricted range of motion (trismus), malocclusion, nonunion, facial asymmetry, and maldevelopment or impaired growth in children (especially when injury occurs in a child under the age of 4).[1]

The open approach can be associated with several known complications, including facial nerve damage, scarring, hemorrhage, and vascular necrosis of the proximal segment. An unpleasant scar has been reported in up to 4% of cases.[10] The proximity of the facial nerve to the condyle makes the dissection tedious and risks direct or traction injury to the nerve; the risk of permanent injury is approximately 1%.[10] Using an endoscope may reduce the risk of injury to the facial nerve.[10]

RECOMMENDED FOLLOW-UP

In our practice, patients are treated with IMF for a total of 6 weeks. They are seen in clinic every 2 weeks during this time. Depending on the circumstances of the case, this 6-week period may consist entirely of elastic IMF or some combination of wire and elastic IMF (such as 2 weeks wire, followed by 4 weeks elastic). Elastic may be removed only to perform oral hygiene and physical therapy exercises. For most patients, one elastic band at the canine/premolar area on each side is adequate. The patient is placed on a mechanical soft diet. During this time oral physical therapy is of utmost importance, as described earlier. By week 6, the elastic and arch bars can be completely removed if the patient's occlusion remains stable. Diet can then be advanced. The patient is followed regularly until he or she is pain free and demonstrates near-normal range of motion (30 to 40 mm opening). Follow-up radiographs are obtained to document status at completion of treatment, and further radiographs may be performed at the discretion of the treating surgeon.

Pearls

- *Open or closed treatment is determined by the patient and surgeon, taking into consideration factors of the case along with the risks and benefits of each approach.*
- *Mandibular condyle fractures at high levels (intracapsular and high neck fractures) should be treated closed.*
- *Fractures in children are best treated closed.*
- *Unilateral nondisplaced fractures with normal occlusion in adults can be treated conservatively.*
- *Absolute indications for open reduction and internal fixation include bilateral fractures, significant dislocations, cases in which closed treatment will not establish occlusion, the presence of foreign bodies, and dislocation of the condyle into the middle cranial fossa.*
- *Orthognathic surgery may be used as a secondary salvage procedure at a later date.*
- *Oral physical therapy that is goal directed and individualized to each patient is paramount to achieve good outcomes, no matter what treatment method is used.*

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18 Zygomaticomaxillary Complex

Ivo A. Pestana, Jeffrey R. Marcus

Background

Zygomatic fractures are among the most common facial fractures seen in emergency departments and trauma centers. The nomenclature of zygomatic fractures can be confusing. One important distinction that must be understood is the difference between an isolated fracture of the zygomatic arch and a fracture of the entire zygomaticomaxillary complex (ZMC). As described below, the zygomatic arch is only one of four main buttresses of the ZMC. The arch itself can be injured in isolation by a blunt force originating immediately lateral to the patient. Forces originating anteriorly or obliquely tend to strike the malar eminence and result in fracture of all four ZMC buttresses, causing corresponding displacement of the ZMC. Zygomaticomaxillary complex fractures are often called zygomatic, tripod, tetrapod, malar, *or* orbitozygomatic *fractures. For the purposes of this chapter, the terms* zygomaticomaxillary complex *(ZMC) and* isolated zygomatic arch *will be used for clarity. Despite its many names, it is agreed that optimal management of this fracture type depends on accurate preoperative diagnosis, aggressive and appropriate fracture mobilization, and anatomic fracture reduction and stabilization.*

REGIONAL ANATOMY

Bony Anatomy

The ZMC is considered a tetrapod with four projections creating a quadrangular shape. The base of the tetrapod is the lateral orbital wall with four projections, consisting of the lateral orbital rim, the inferior orbital rim, the zygomaticomaxillary buttress, and the zygomatic arch (Fig. 18-1, *A*). The four legs of the tetrapod represent buttresses of the facial skeleton and thus stabilize the position of the face with respect to the cranium as well as provide definition of facial width and midface projection. Fractures of the ZMC involve all four legs of the tetrapod in addition to the fracture that extends along the orbital floor and the lateral orbital wall (Fig. 18-1, *B*).

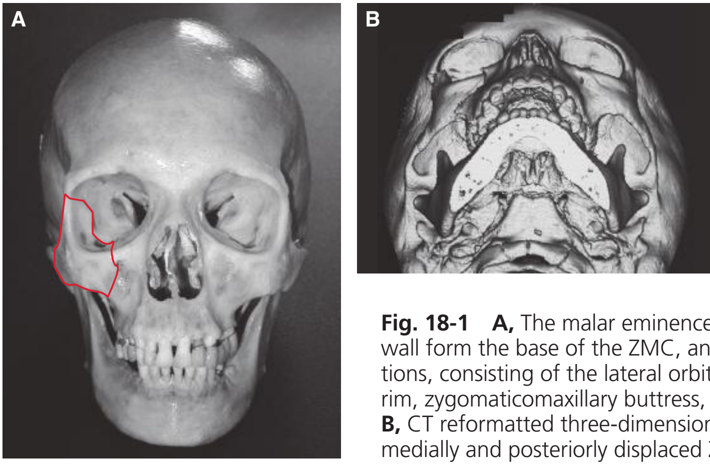

Fig. 18-1 **A,** The malar eminence and lateral orbital wall form the base of the ZMC, and it has four projections, consisting of the lateral orbital rim, inferior orbital rim, zygomaticomaxillary buttress, and zygomatic arch. **B,** CT reformatted three-dimensional image showing a medially and posteriorly displaced ZMC fracture.

Soft Tissue Anatomy

The soft tissue anatomy pertinent to ZMC fractures includes the major facial musculature contributing to the deforming forces acting on a fractured ZMC, as well as the structures potentially injured in the fracture pattern (Fig. 18-2). The zygomatic arch serves as the origin of the masseter on its inferior margin and the attachment of the superficial musculoaponeurotic system (SMAS) and temporoparietal fascia (TPF) superficially. The masseter muscle is the main deforming force that acts on the fractured zygoma, interfering with fracture mobilization and reduction and contributing to the relapse of inadequately fixated fractures. The temporalis fascia produces resistance to inferior displacement of a fractured fragment by the downward pull of the masseter muscle.

The sensory nerve associated with the zygoma is the second division of the trigeminal nerve. The infraorbital nerve, the distal continuation of the second division, passes through the orbital floor and exits the infraorbital foramen in the body of the zygoma and supplies sensation to the anterior cheek, lateral nose, upper lip, and maxillary anterior teeth. The orbital floor is relatively thin, yet the infraorbital nerve travels within or just beneath its substance. It travels inferiorly as it approaches the infraorbital rim, finally exiting 1 cm below the rim. Because of its anatomic path, it is frequently injured in this fracture pattern and produces the characteristic cheek anesthesia seen in these injuries. A finding of anesthesia involving the ipsilateral cheek, upper lip, and maxillary dentition is quite consistent with ZMC fractures and is a generally (but variably) self-limited neurapraxic injury.

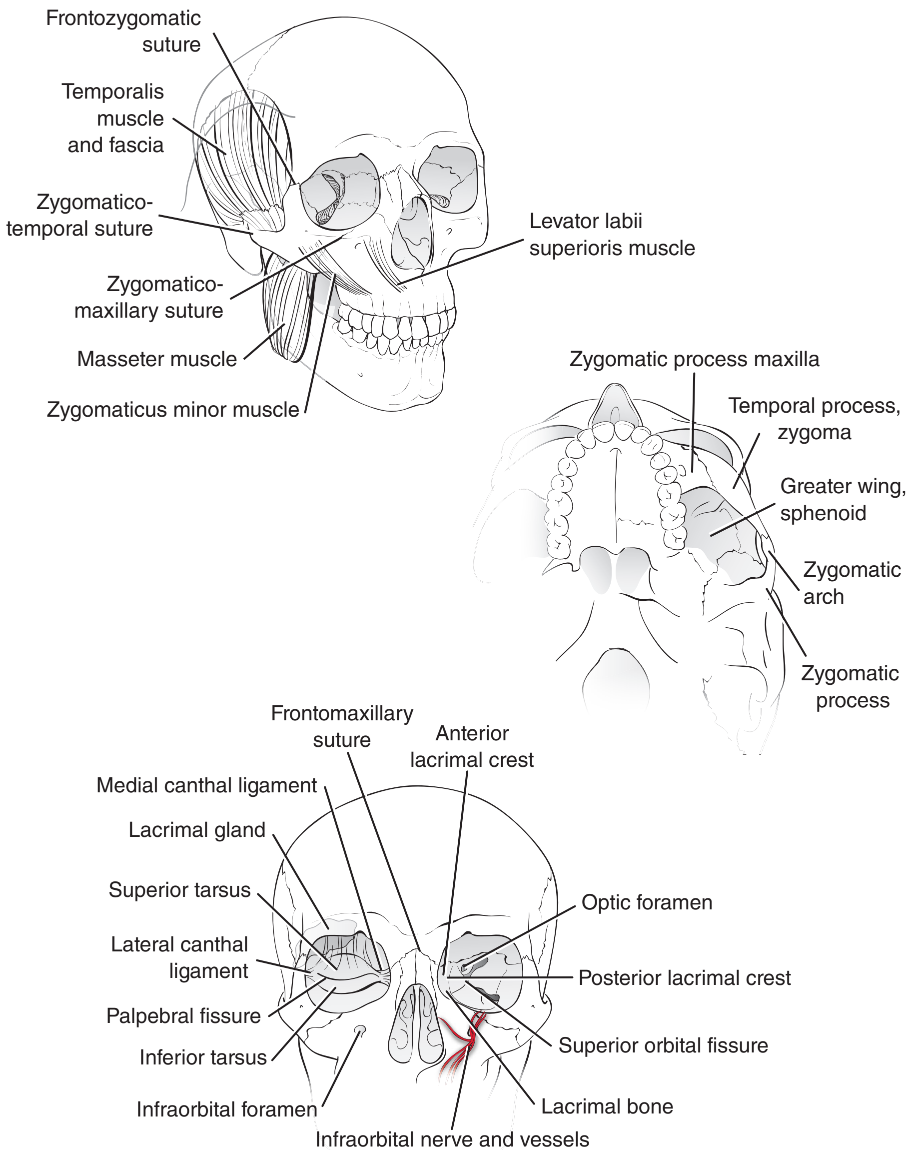

Fig. 18-2 Regional soft tissue and bony anatomy of the ZMC.

EVALUATION

Management strategies and treatment goals for ZMC fractures are based on complete preoperative evaluation of the fracture pattern and resultant aesthetic and functional deficits. ZMC fractures produce cheek depression and, depending on the degree of zygomatic arch displacement, alterations in facial width. Physical signs and symptoms of ZMC fractures include periorbital ecchymosis and edema, subconjunctival hemorrhage, visual disturbances such as diplopia, malposition of the globe, irregularities in sensation along the distribution of the infraorbital nerve, visible or palpable contour irregularities of the lateral and inferior orbital rim, and trismus.

Because all ZMC fractures involve the orbital walls and floor, preoperative evaluation should include ophthalmologic examination consisting of a visual acuity test, evaluation of extraocular muscle movements, and assessment of the globe for injury.

In addition to physical signs and symptoms, CT scanning is the modality of choice for the evaluation and diagnosis of facial fractures. CT imaging of facial fractures involves scanning from the top of the head to the mandible with the use of 1.5 mm axial cuts. Based on these data, coronal, sagittal, and three-dimensional reformatting can then be generated. Complete characterization of the ZMC fracture pattern requires examination of the degree of displacement and comminution of the zygoma's articulations (see Chapter 2 for radiographic descriptors associated with this injury):

- The lateral orbital rim
- The inferior orbital rim
- The zygomaticomaxillary buttress
- The zygomatic arch
- The lateral orbital wall

Once a diagnosis of ZMC fracture has been confirmed, the need for operative intervention is determined.

SURGICAL INDICATIONS

The most common indication for surgery in ZMC fractures is displacement of the fracture fragment.[1] Historically, multiple classification systems have been used to predict which fractures would remain stable after reduction, thus allowing the surgeon to identify those fractures that would require ORIF. In 1961 Knight and North[2] classified zygomatic fractures by direction of displacement on plain (Water's view) radiographs. Manson et al[3] in 1990 classified these fractures according to the pattern of segmentation and displacement. The most recent fracture classification system was published by Zingg et al[4] in 1992 (Table 18-1). All three classification schemes vary, but each method indicates that, as the amount of displacement and comminution increases, the role for open reduction and internal fixation increases.

Table 18-1 Zingg Classification of Zygomaticomaxillary Complex Fractures

Fracture Type	Description
A1	Isolated zygomatic arch fracture
A2	Isolated lateral orbital fractures
A3	Isolated orbital rim fractures
B	Monofragment zygomatic fractures (tetrapod fracture)
C	Multifragment zygomatic fracture

Data from Zingg M, Laedrach K, Chen J, et al. Classification and treatment of zygomatic fractures: a review of 1,025 cases. J Oral Maxillofac Surg 50:778-790, 1992.

By definition, every ZMC fracture has an orbital floor component. In many cases, the floor does not require treatment. One cannot always determine preoperatively whether treatment is required, but the degree of displacement of the ZMC fracture is helpful information. The orbital injury associated with ZMC fracture is different than that seen in an isolated orbital injury (an orbital blowout). In an orbital blowout, compressive force produces an acute intraorbital pressure increase that expands the total volume of the orbit as the floor yields and fractures. When the ZMC is fractured, the compressive force on the malar eminence results in a decrease of orbital volume as the buttresses yield and the ZMC is driven posteriorly and medially. In a ZMC injury, the defect of the orbital floor is not apparent until it is reduced. Therefore it is sometimes not possible to ascertain the need for floor repair until after the reduction has been performed.

As a general rule, if the ZMC is minimally displaced, there is unlikely to be a significant floor defect after reduction. If the ZMC is severely compressed, there is a higher likelihood that a significant orbital floor defect will be present.

A recent study at Duke University demonstrated that a 10 mm displacement in a frontozygomatic or infraorbital rim fracture was associated with a 20% orbital volume reduction, which is considered significant.[5] Because the extent of volume change in orbital fractures correlates with the severity of the floor injury, a 10 mm buttress displacement would warrant exploration of the floor and probably would predict the need for repair.

The management of isolated zygomatic arch fractures is different from that of ZMC fractures. Frequently, isolated fractures of the zygomatic arch do not require operative reduction. The most common indications for surgical management of isolated zygomatic arch fracture are facial contour irregularity and trismus. Depression of the zygomatic arch produces alteration of facial width as well as a visible or palpable contour irregularity of the lateral face. Such cosmetic facial deformity is an indication for reduction of the zygomatic arch fracture. Furthermore, depression of zygomatic arch fracture fragments can impinge on the coronoid process of the mandible, producing an inability to fully open the mouth (trismus) (Fig. 18-3).

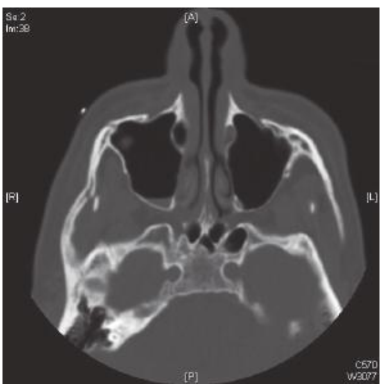

Fig. 18-3 Zygomatic arch fracture fragment impinging on the coronoid process of the mandible, producing trismus.

TREATMENT GOALS

Management strategy in operative cases involves anatomic reduction and stabilization of the ZMC fracture segment to restore proper facial projection, adequate facial width, and normal orbital volume.

EXPOSURE

There are several possible approaches to the buttresses of the ZMC. The exposure needed will depend on the surgeon's determination of which buttresses require reduction and fixation. The first determination for any ZMC injury is how the arch is to be reduced and treated. Open reduction and fixation of the arch is rarely performed, because it requires a coronal scalp incision. With this approach, the entire arch can be visualized and plated, with protection of the frontal branch of the facial nerve. The coronal approach is reserved by most surgeons for severely comminuted zygomatic arch fractures, those which have relapsed following Gillies approach, and in circumstances in which the coronal incision is otherwise already needed (such as a frontal sinus fracture). In relapsed injuries, the presence of significant trismus would play a factor in the decision to proceed with coronal exposure. If the coronal exposure is being performed, the zygomaticofrontal (ZF) buttress fracture can also be fixated from this approach.

In most ZMC injuries, open reduction can be performed through the anterior approach. The anterior approach provides exposure of critical zygomatic articulations and consists of three incisions (Fig. 18-4):

1. Lateral extension of an upper blepharoplasty (or lateral brow) incision provides access to the ZF buttress fracture and lateral orbital wall.
2. A lower eyelid incision with the subciliary, subtarsal, or transconjunctival technique exposes the infraorbital rim and orbital floor.
3. A gingivobuccal sulcus incision exposes the maxilla for reduction and stabilization of the zygomaticomaxillary (ZM) buttress.

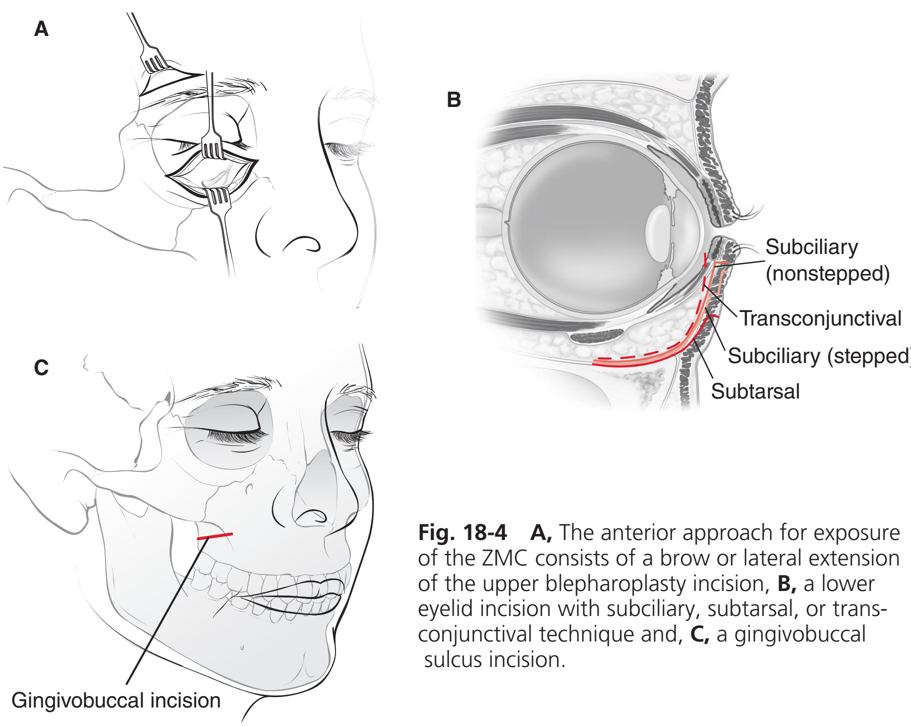

Fig. 18-4 **A,** The anterior approach for exposure of the ZMC consists of a brow or lateral extension of the upper blepharoplasty incision, **B,** a lower eyelid incision with subciliary, subtarsal, or transconjunctival technique and, **C,** a gingivobuccal sulcus incision.

Historically, the textbook approach to ZMC fractures required fixation of at least three buttresses (typically all but the arch). Therefore all three exposures would be required. Recently, there is a trend toward fixation of fewer buttresses, depending on the severity or displacement of the injury.[6] Here, the surgeon's judgment governs decisions on minimal stabilization needs for a given fracture.

In isolated zygomatic arch fractures, access to the zygomatic arch is provided by either an extraoral or an intraoral approach. The extraoral approach is traditionally referred to as the *Gillies approach* and consists of an incision in the temporal hair line with subsequent dissection through the temporoparietal fascia and deep temporal fascia to a plane deep to the zygomatic arch (Fig. 18-5). Once this dissection is completed, outward pressure on the arch forces the fracture fragment into a reduced position. The intraoral approach involves a small (2 cm) upper gingivobuccal sulcus incision, with dissection lateral to lateral maxillary buttress and posterior to the zygomatic arch. The elevator is placed within the temporal fossa, following the osseous surface anterior to the temporalis muscle. Again, outward pressure on the arch fracture fragment forces it into a reduced position. Because of instability in the reduced position, splinting of the reduced arch fracture may be indicated.

Reduction of ZMC injuries without fixation may be possible in certain circumstances. Using either the Gillies or intraoral technique, the entire ZMC can often be reduced anatomically. Among children and adolescents, the periosteum is thick and limits the extent of comminution in low- to moderate-force injuries. In these age groups, stability after reduction can often be observed and exposure for fixa-

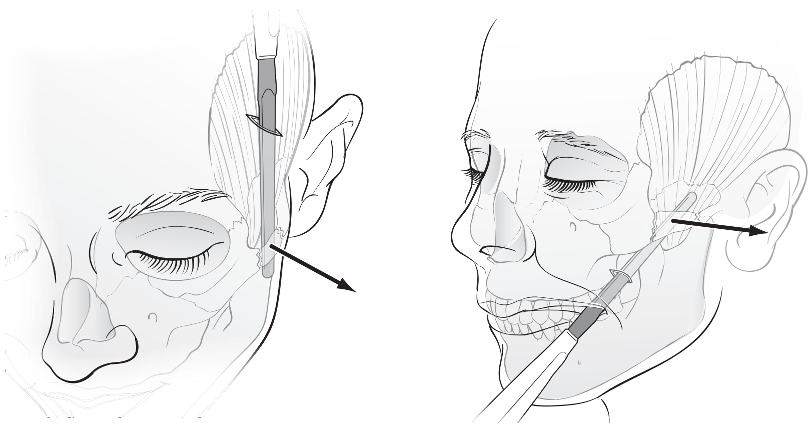

Fig. 18-5 Reduction maneuvers for an isolated zygomatic arch fracture. The Gillies approach involves a 2 cm incision placed within the temporal hairline. A blunt elevator is placed beneath the superficial layer of deep temporal fascia, allowing the tip of the elevator to pass behind the arch without risking injury to the frontal branch of the facial nerve. In the intraoral approach, a 1 to 2 cm incision is made laterally in the buccal sulcus. Subperiosteal elevation allows the elevator to be placed behind the arch.

tion avoided. Two caveats are that no step-off along the infraorbital rim should be tolerated, and strict activity restriction must be enforced postoperatively, along with a soft diet for 14 days.

OPERATIVE SEQUENCE

The accepted standard of ZMC fracture operative management is reduction and rigid fixation with plates and screws.[7] Stabilization of three points of fixation (buttresses) will usually correct both translational and rotational deformities of the zygoma. The arch is reduced regardless of the approach; however, it is most frequently omitted from fixation, except in very severe or panfacial fractures. Orotracheal intubation is a satisfactory approach for the airway unless other injuries are present requiring intermaxillary fixation. Corneal protectors and lubrication should be utilized to prevent iatrogenic corneal or globe injuries.

Dissection Sequence

1. Lower eyelid incision. Several eyelid incision and dissection techniques (subciliary, subtarsal, transconjunctival) provide exposure of the orbital rim and floor. The eyelid exposure is the most delicate and therefore is often performed first. Complete exposure of the floor is not performed until after reduction of the ZMC has been performed.
2. A lateral brow or lateral extension of the upper blepharoplasty incision provides exposure of the frontozygomatic articulation and lateral orbital wall. A postoperative lateral canthopexy can be accomplished through this exposure at conclusion.
3. A unilateral gingivobuccal sulcus incision is made, sparing the midline labial frenulum, and dissection of lateral (zygomaticomaxillary) buttress and medial (nasomaxillary) buttress is completed. This provides exposure on either side of the infraorbital nerve to allow its identification and protection. Dissection through this incision can be carried cephalad to the orbital rim. The exposure should be performed delicately to avoid further injury along the anterior wall of the maxillary sinus.

Reduction/Fixation Sequence

1. Reduction of the ZMC is performed after the exposures have been completed. Reduction can be performed through the brow/lateral blepharoplasty incision by placing an elevator behind the lateral orbital wall with the tip behind the malar eminence. Alternatively, the elevator may be placed through the gingivobuccal incision passing posterior to the lateral maxillary buttress, or a Carrol-Girard screw may be used.

2. Fixation of ZF fracture is completed first and sets the vertical position of the ZMC fracture. A 25-gauge pivot wire can be used for fixation initially, allowing some rotation and alignment of the other buttresses. This can later be replaced with a microplate or miniplate (1.2 to 1.5 mm). The lateral orbital wall is the thickest portion of the orbit and rarely is comminuted. Furthermore, it is the longest interaction of the zygoma with the rest of the facial bones. This makes the zygomaticosphenoid (ZS) fracture line the single most reliable indicator of anatomic alignment of the zygoma in all three dimensions.
3. Reduction is finalized at the infraorbital rim and then plated with a low-profile plate (1.0 to 1.3 mm). Plates on the lateral orbital rim and infraorbital rim tend to be more palpable; smaller plates can be used at these locations, because they face less force or stress.
4. Next, the lateral (ZM) buttress is stabilized. A 1.5 to 2.0 mm plate is indicated in this location, because this strong buttress directly opposes the deforming forces of the masseter muscle.
5. The final decision to be made with regard to ZMC fracture fixation is whether the injury to the orbital floor requires repair. In general, if a floor defect of 50% or greater is seen, it should be repaired. Material choices include bone graft, titanium mesh, or other alloplastic implants, such as porous polyethylene. A final forced-duction test should be performed to confirm the unimpaired mobility of the globe.
6. Soft tissue suspension should always be performed at completion of the procedure. The extent of the midface degloving required can lead to descent of the soft tissues over the long term. Sutures placed in the periosteum or deep tissues of the malar eminence can be secured to the infraorbital rim plate.
7. Lateral canthal suspension should be performed to minimize the risk of postoperative ectropion. A true lateral canthopexy or lateral retinacular suspension should secure the canthus to the inner surface of the lateral orbit through a drill hole by placing the suture or wire from inside to outside. If a transconjunctival incision has been performed, the conjunctiva should be repaired before securing the canthal suspension, because access will be limited after the lower lid has been tightened. Only one or two sutures are needed, and bites of tissue should be small and carefully placed to avoid potential entropion from foreshortening of the posterior lamella (the conjunctiva).
8. A Frost suture is placed along the gray line of the lower lid at the level of the lateral limbus and secured to the forehead using adhesive to further maintain the position of the lower lid during initial healing.

POSTOPERATIVE CARE

Postoperatively, decongestants, nasal irrigation with saline solution, and a short course of antibiotics are recommended. Antibiotic coverage should include gram-positive activity, and careful observation for signs of infection is warranted. A follow-up eye examination should be performed to document visual acuity and rule out potential complications such as corneal abrasions. Although not a requirement, postoperative imaging may be performed to evaluate ZMC reduction and orbital reconstruction. The patient should have a gross vision check in the recovery area or shortly after the surgery has been completed.

COMPLICATIONS AND CONSEQUENCES OF INJURY

Diplopia

Diplopia is observed frequently in cases of ZMC fractures. Fifty percent of *untreated* ZMC fractures will result in permanent diplopia, with most abnormalities identified in the patient's primary field of gaze. In most treated cases, diplopia is transient; the most common cause is nonmechanical and results from soft tissue swelling after the injury, contusion of the extraocular musculature, or injury to supplying nerves.

Traumatic Optic Neuropathy

Optic neuropathy (ON) is an infrequent complication of ZMC fracture, occurring in 1.3% to 2.1% of cases. When ON is present, the predominant findings are vision changes, such as visual field deficits and changes in color perception. Typically, when a diagnosis of ON is made at the time of presentation, surgery for fracture fixation is delayed pending administration of steroids and stabilization or improvement of the visual deficits.

Infraorbital Nerve Anesthesia

The anatomic course of the infraorbital nerve (ION) near the malar eminence weakens this area, and fracture lines through the nerve foramen are common; 24% of patients with malar injuries suffer some form of ION dysfunction. Neurapraxia of the ION manifests as diminished sensation in the cheek, upper lip, and maxillary dentition. These sensory abnormalities are typically transient, but may last several months.

Lower Lid Malposition

All types of periorbital trauma and surgery carry the risk of lower eyelid malposition in the form of ectropion, lower lid retraction, or entropion. The overall incidence of these deformities approaches 5%, with ectropion being the most common type of lower lid malposition.[8] Possible causes of lower lid malposition include scar contracture, hematoma, orbital septum adhesions, and paralysis of the orbicularis oculi muscle. Specific to the management of ZMC fractures, lack of midface soft tissue resuspension after degloving of the ZMC for operative exposure or stabilization can contribute to lower eyelid malposition and postoperative facial asymmetry. As noted earlier, intraoperative strategies to prevent or minimize postoperative lower lid malposition include operative lower lid suspension (canthopexy or canthoplasty) and resuspension of the degloved midface soft tissue. Postoperative management of lower lid malposition depends on the duration and severity of the deformity. Such nonoperative techniques as scar massage and taping should be implemented in the early postoperative period, whereas operative intervention in the form of middle or posterior lamellar spacer grafts and canthal suspension may be indicated in patients with refractory lower lid malposition or those with complications of lid malposition, such as corneal abrasions.

Ectropion is more common after external lid exposures, but entropion typically results after the transconjunctival approach. When the conjunctiva is repaired, only one or two carefully placed sutures are needed.

Enophthalmos

Enophthalmos with globe malposition is the most challenging complication associated with ZMC fractures. This occurs in approximately 3% of cases; the most common cause is volume increase of the orbit after ZMC reduction. This emphasizes the importance of orbital floor evaluation and appropriate repair when needed.

Trismus

Trismus results from swelling of the temporalis muscle traversing beneath the zygomatic arch. Typically, this is transient and resolves as swelling abates. However, inadequate reduction of the arch can result in a continued mechanical impingement of the coronoid process of the mandible.

RECOMMENDED FOLLOW-UP

Postinjury follow-up after ZMC fractures treated nonoperatively includes a 6-week course of soft diet, protection of the malar eminence, and periodic clinic visits to assess for sequelae related to the traumatic event as well as those associated with poor wound healing (bony malunion). ZMC fractures treated operatively should be followed with periodic clinic visits as patients advance from a soft diet to a regular diet. The patient should be seen within 1 week after discharge, then again at 3 to 4 weeks. Examination should focus on identification of each of the aforementioned complications and consequences, as well as proper healing of incisions. At 6 to 8 weeks, if the patient has a satisfactory outcome and has no evidence of complication, he or she can be released for a final follow-up 3 months after the injury and repair.

Pearls

- ✓ *Treatment of ZMC fractures must be based on a complete preoperative evaluation, including a CT scan with axial and coronal images to fully appreciate the nature of the injury.*
- ✓ *The determination to proceed with surgical intervention is based on the degree of displacement and comminution of the ZMC fracture.*
- ✓ *By definition, the orbital floor is involved in ZMC injuries. Preoperatively, the need to repair the orbital floor may not be clear. When in doubt, the surgeon should assess the floor intraoperatively after ZMC reduction. The greater the displacement of the ZMC, the higher the likelihood that the orbital floor will open after reduction.*
- ✓ *Most fractures can be managed through an anterior approach consisting of an upper and lower eyelid incision and gingivobuccal sulcus incisions.*
- ✓ *Because of the nature of a ZMC fracture and the locations of operative dissection and manipulation, corneal protectors should be used intraoperatively to prevent iatrogenic corneal or globe injuries.*
- ✓ *Thorough fracture mobilization and careful assessment of globe position at the end of the procedure aid in the prevention of postoperative facial asymmetries.*
- ✓ *Resuspension of the lower lid and midface soft tissues is critical to prevent lower eyelid malposition and postoperative facial contour irregularities.*
- ✓ *Lower lid position should be assessed at each follow-up visit. Malposition usually can be seen by the third to fourth postoperative week; therefore a follow-up visit at this specific time is warranted. Initial treatment with massage is critical to avoid mature contraction.*

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19 Nasoorbital Ethmoid Complex

Matthew G. Stanwix, Eduardo D. Rodriguez

Background

Central midface injuries pose complex diagnostic and therapeutic challenges to craniomaxillofacial surgeons. The delicate anatomy of the nasoorbital ethmoid (NOE) region and the difficulty of correcting deformities in this area present a particular problem. Inadequate or delayed treatment results in deformities that may be only partially correctable, such as telecanthus, enophthalmos, shortened palpebral fissure, ocular dystopia, or a shortened nose with a saddle deformity.[1]

REGIONAL ANATOMY

The framework of the NOE area comprises a confluence of bones between orbits, nose, maxilla, and cranium that consist of the frontal process of the maxilla, the internal angular process of the frontal bone, the lamina papyracea of the ethmoid bone, and the lacrimal bone. The central fragment, represented by the lower two thirds of the medial orbital wall (the frontal process of the maxilla) is a keystone to this area (Fig. 19-1). The medial canthal tendon inserts into this fragment, performing a functional as well as a cosmetic role.

The medial canthal tendon supports the eyelid, maintains the globe, and aesthetically creates the palpebral fissure. It comprises three limbs: anterior, posterior, and superior. A fan-shaped anterior limb inserts into the lateral aspect of the anterior lacrimal crest and nasal bones. The superior limb first surrounds the lacrimal sac before inserting at the articulation between the internal angular process of

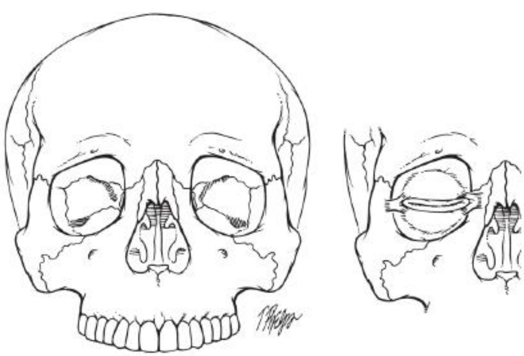


Fig. 19-1 Anatomy of the nasoorbital ethmoid segment and central fragment. (Modified from Markowitz BL, Manson PN, Sargent LA, et al. Management of the medial canthal tendon in nasoethmoid orbital fractures: the importance of the central fragment in classification and treatment. Plast Reconstr Surg 87:843-853, 1991.)

the frontal bone and the frontal process of the maxilla. A thinner posterior limb attaches at the posterior aspect of the lacrimal fossa (posterior lacrimal crest).

> Separation of the tendon from the NOE area allows rounding of the palpebral fissure and telecanthus.

Important additional soft tissue structures include the lacrimal system, the trochlea, and various nerves and blood vessels. Injury to the lacrimal canaliculi may result in excessive tearing. The trochlea originates from the internal angular process of the frontal bone and helps redirect the vector of pull for the superior oblique muscle. Inadequate repositioning of the trochlea after injury may lead to diplopia on downward gaze. Various sensory nerves and regional minor blood vessels pass through this area before supplying their specific distribution. The surgeon may encounter branches off the infraorbital, supratrochlear, infratrochlear, and anterior ethmoidal nerves during meticulous surgical exploration.

FRACTURE PATTERNS

Multiple classification systems have evolved over the years as surgeons have gained greater familiarity with the NOE complex and advancements in computed tomography have been introduced. Appropriate use of a particular classification system can assist in formulating the plan for surgical exposure and stabilization. Regardless of the classification system used, NOE fractures, in their simplest form, isolate the lower two thirds of the medial orbital rim, creating a separate segment at the medial canthus insertion. Five separate fractures must be present to create a true NOE fracture:

1. Lateral nose
2. Inferior orbital rim
3. Medial orbital (ethmoidal) wall
4. Nasomaxillary buttress at the piriform aperture
5. Frontal process of the maxilla at the internal angular process of the frontal bone

Segments created by these fractures may be unilateral, bilateral, comminuted, nondisplaced, or have variable displacement, depending of the acuity of the insult. Some of these areas may not actually appear to be fractured. A greenstick pattern is frequently found at the frontal process of the maxilla, with the internal angular process of the frontal bone above the insertion of the medial canthal tendon.[2] Surgical management, exposure, and technique are based on the type of fracture pattern encountered.

Markowitz et al[1] described a useful classification system based on the central medial orbital wall fragment that drives surgical decision making for most craniomaxillofacial surgeons. Type I fractures, the simplest of the three, have a single, central fragment with either no displacement or displacement at the internal angular process of the frontal bone. Comminution of the central fragment external to the canthal tendon insertion (medial orbital segments) represents a type II pattern. When bony comminution extends into the insertion of the medial canthal tendon, or complete tendon avulsion occurs, a type III fracture pattern is present. Bilateral injuries are often of two types. However, these should be classified according to the most severe type, because this suggests the appropriate exposure and stabilization to use[1] (Fig. 19-2).

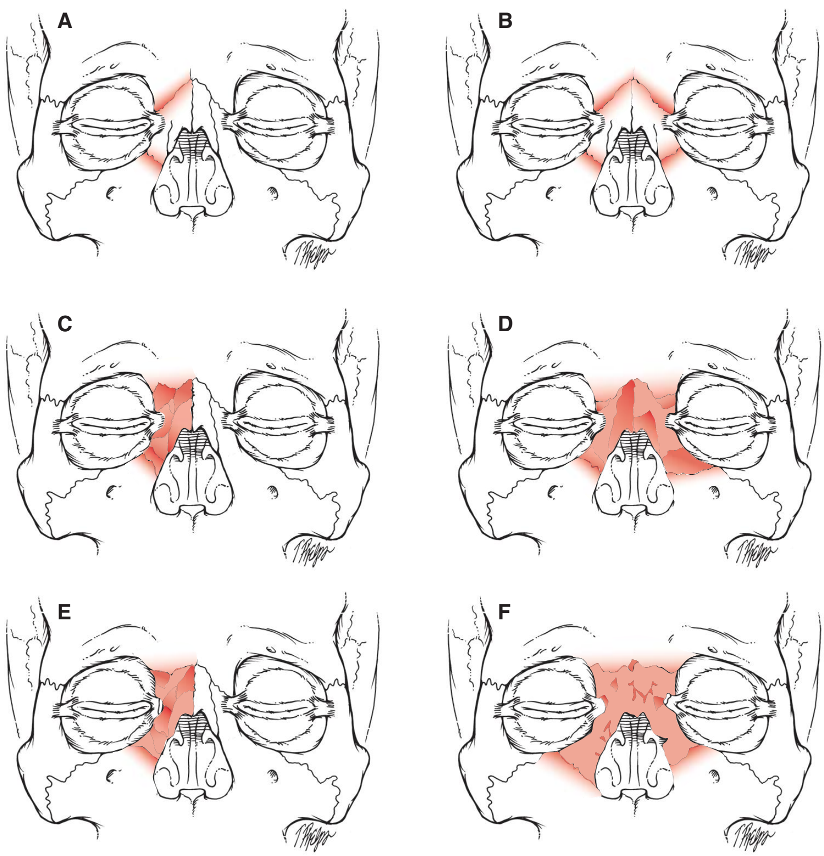


Fig. 19-2 **A** and **B,** Type I fracture. **C** and **D,** Type II fracture. **E** and **F,** Type III fracture. (Modified from Markowitz BL, Manson PN, Sargent LA, et al. Management of the medial canthal tendon in nasoethmoid orbital fractures: the importance of the central fragment in classification and treatment. Plast Reconstr Surg 87:843-853, 1991.)

SURGICAL INDICATIONS

A diagnosis of NOE fractures is confirmed by a combination of physical examination and evaluation of CT scans. Patients who sustain midface trauma have consistent and identifiable physical examination findings that are discrete from their premorbid state. Suspicion for NOE fractures must be increased when a patient has specific evidence of periorbital or midfacial trauma:

- A short and displaced nasal bridge
- Telecanthus
- Shortened palpebral fissures
- Subconjunctival hematomas
- Epiphora
- Nasal airway obstruction

Occasionally, the diagnosis may be obvious if the entire nasal pyramid is posteriorly depressed. However, in a noncomminuted or minimally displaced fracture, manual palpation of the medial canthal segment is crucial for determining surgical intervention.

To assess the stability of the canthal segment, the examiner should place the thumb and index finger over each of the canthal-bearing, medial orbital rim fragments on both sides, posterior to the nasal bones. When pressure is exerted by squeezing, any mobility or crepitus implies instability and requires open operative management. Bimanual examination can similarly be performed by inserting a Kelly-type clamp intranasally, with the tip against the medial orbital rim caudal to the medial canthal tendon insertion. The contralateral index finger is placed externally over the medial orbital rim to appreciate any instability when pressure is placed intranasally by the clamp against the tendon insertion. Measurement of the intercanthal distance may also be part of a full examination. Typically, the intercanthal distance is approximately half the interpupillary distance. Quantitatively, a measurement of 35 mm suggests an NOE fracture, whereas 40 mm is diagnostic.

> It may be necessary to examine the patient's appearance on a preinjury photograph to assess the true extent of the deformity.

Thin-cut, high-resolution, multidimensional CT scans may be used to confirm the diagnosis and assess the pattern, comminution, displacement, and associated fractures. Axial, coronal, and sagittal views must be meticulously examined. Three-dimensional images are often reconstructed but fail to appreciate the detail and extent of the fractures.

Fractures that do not move during physical examination or show displacement on the CT scan can be safely observed. However, any crepitus or instability of the medial orbital wall segments on manual manipulation or displacement on the CT scan warrants surgical intervention. The only exception is a type I fracture with a greenstick pattern at the angular process of the frontal bone, with displacement at the inferior orbital rim segment (see Fig. 19-5). Patients typically present without telecanthus; however, they exhibit a strung bow appearance of the lower eyelid. A subtle inferior and medial displacement of the canthal ligament on the involved side is present, as well as a lengthened palpebral fissure. Rarely, these fractures can be adequately reduced by closed manipulation.[2]

Manipulation of the lacrimal system should not be routinely included in the surgical management unless a clearly delineated sharp transection is identified with an overlying laceration near the canthus. Although lacrimal obstruction may not be symptomatic, routine exploration should be avoided, because this may result in injury to the canaliculi.

TREATMENT GOALS

Surgical management of NOE fractures follows the functional and aesthetic objectives of two anatomic areas: the orbit and the nose. The premorbid intercanthal width must be reestablished while supporting the eyelid, maintaining the globe, and re-creating the aesthetic properties of the palpebral fissure. Overcorrection of the intercanthal distance is preferable, because any resultant deformities occurring from undercorrection are difficult or impossible to repair. Four key principles must also be applied to NOE reconstruction, as described by Potter et al[3]:

1. Rigid fixation of the nasal pyramid and restoration of nasal height and length
2. Restoration of tip projection
3. Septal reduction and reconstruction
4. Lateral nasal wall augmentation

Careful attention to the interface of the soft tissue and bony skeleton significantly improves the results. Nowhere else in the facial skeleton is that interface more important. The goal is to fully restore the normal delicate appearance and contour of the skin in the medial canthus and nasoorbital concavity. Early surgical intervention, appropriate soft tissue handling, correct vectors of transnasal wiring, well-designed exposure, and postoperative compression can help achieve this goal.

EXPOSURE

The subtype of NOE fracture, along with consideration to concomitant facial fractures, indicates the appropriate surgical exposure(s). Four different incisions may be required to adequately reduce the fracture fragments:

- Coronal
- Midline
- Lower eyelid
- Upper buccal sulcus

Often a combination of two approaches, typically a coronal and lower eyelid incision, is needed for complete surgical management. Up to one third of fractures are associated with lacerations overlying the nasal dorsum or glabella, allowing additional exposure that is occasionally helpful in combination with these approaches.[4] The bicoronal approach consistently provides excellent exposure for the NOE area, frontal sinus, and superior and lateral orbits. A lower eyelid incision (preferably transconjunctival or fornix) exposes the inferior orbital rim and allows subsequent internal orbital floor exploration. Reduction and rigid fixation of the nasomaxillary buttress and piriform aperture requires a maxillary gingival buccal approach. Isolated NOE fractures may be suitable for a limited vertical midline incision over the nasal dorsum (for the angular process of the frontal bone) in combination with lower eyelid and/or upper buccal sulcus approaches. This combination may avoid a bicoronal scar in elderly or balding patients who present with isolated NOE fractures.

OPERATIVE SEQUENCE

The stabilization of the fracture segments can only commence after all appropriate exposure techniques are completed.

Type I Fractures

Type I (single segment) NOE fractures require junctional miniplate and screw fixation. Clinical experience, along with current literature, supports the use of fewer and smaller plates than previously employed. As originally described, four-hole or five-hole inferior orbital rim, piriform, and superior plates were used to fixate the fragments. If the angular process of the frontal bone has only a greenstick pattern in combination with a displaced inferior segment, then only a single inferior rim or piriform plate is required.[2] Likewise, for the more common scenario in which there is displacement of both fracture areas, only a single, four-hole inferior rim *or* piriform plate to the stable frontal process of the maxilla is required for inferior stabilization (Fig. 19-3, *A*). Inferior stabilization must be followed with superior fixation at the angular process to the stable nasal process of the frontal bone; a three-hole plate typically suffices.[4] Bilateral type I fractures require similar fixation. Inferior stabilization is identical, with a single four-hole plate on each side of the piriform aperture or both inferior orbital rims. However, the complete posterior and inferior displacement of the internal angular process here necessitates a single four-hole or five-hole Y-type plate (Fig. 19-3, *B*).

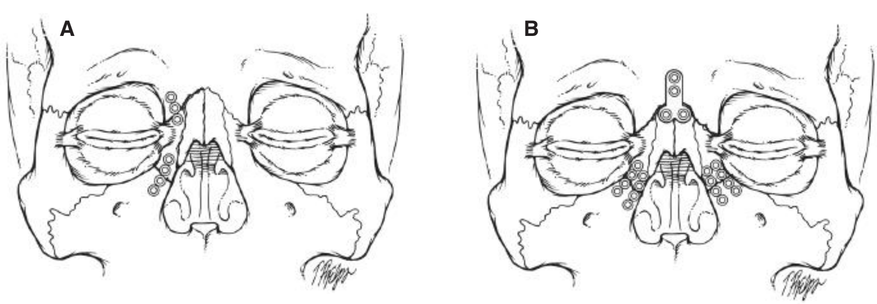


Fig. 19-3 **A,** Treatment of unilateral type I fracture. **B,** Treatment of bilateral type I injuries. (*A* modified from Sargent LA. Nasoethmoid orbital fractures: diagnosis and treatment. Plast Reconstr Surg 120[7 Suppl 2]:S16-S31, 2007. *B* modified from Markowitz BL, Manson PN, Sargent LA, et al. Management of the medial canthal tendon in nasoethmoid orbital fractures: the importance of the central fragment in classification and treatment. Plast Reconstr Surg 87:843-853, 1991.)

Type II and Type III Fractures

The more common fracture patterns, types II and III, require wider exposure to allow adequate stabilization and reduction. A combination of coronal, lower eyelid, and upper gingival buccal incisions provides sufficient space for miniplate and wire fixation. Integral to this exposure is identification of the medial orbital rim bone, into which the medial canthal tendon inserts. Meticulous dissection must be applied to avoid inadvertent stripping of the medial canthal tendon. Specifically, approaching from the nasal side may assist in more easily and safely identifying this segment. The nasal bones must be temporarily dislocated or removed to allow visualization of the medial orbital wall during this technique. This also allows easier placement of transnasal wires and an accurate assessment of reduction.[4]

Type II Fractures

Type II fractures require both transnasal wiring and miniplate fixation. Stabilization of the canthal-bearing segment in type II fractures demands an appropriate placement of and vector for the transnasal wiring. The exact transnasal wiring technique depends on the shape and size of the central fragment. Most surgeons prefer to drill two holes in a vertical fashion 4 to 5 mm apart (using a 1.5 mm drill bit) posterior and superior to the lacrimal fossa (Fig. 19-4, *A*). Dislocating the central fragments anteriorly and laterally can facilitate drilling these holes. The two ends of a 28-guage wire are passed through the holes and twisted together on the nasal or medial side. This end and the contralateral side are then twisted together in the midline until reduction of the fragments is complete. Junctional miniplate or microplate fixation with a three-hole plate at the internal angular process of the frontal bone further stabilizes the reduction (Fig. 19-4, *B* and *C*). However, fixation at the inferior aspect is not important; it provides only contour without further stabilization.

> Surgeons must avoid placing plates around the anterior canthal area; therefore excluding an inferior plate may be more beneficial in this technique.

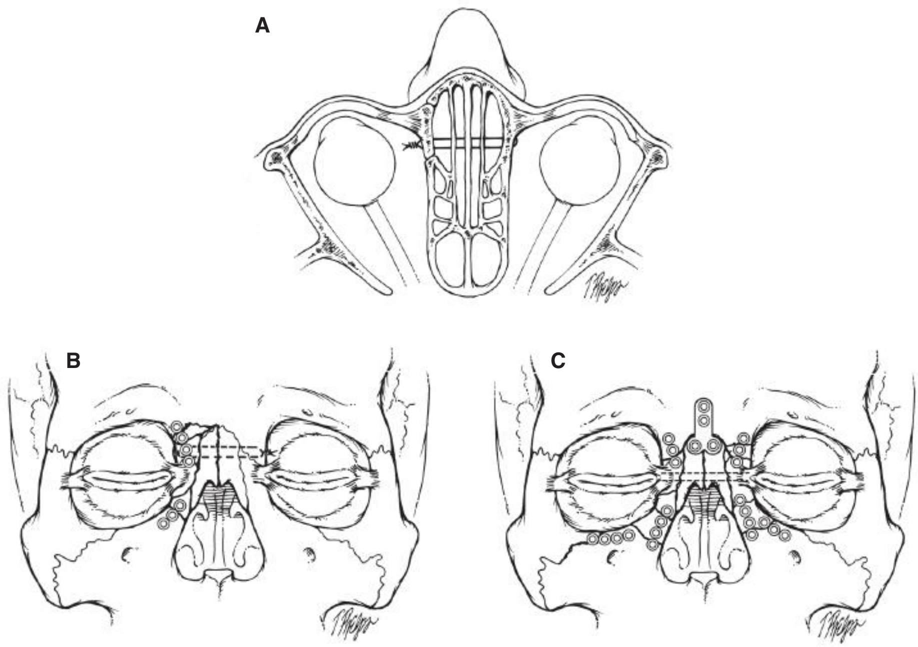
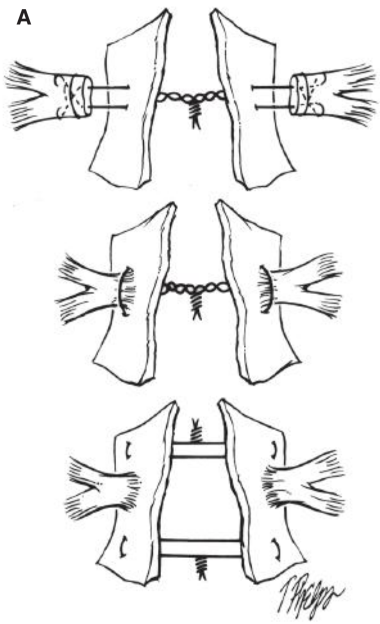


Fig. 19-4 **A,** Appropriate placement of transnasal wiring. **B** and **C,** Treatment of type II fractures. (Modified from Markowitz BL, Manson PN, Sargent LA, et al. Management of the medial canthal tendon in nasoethmoid orbital fractures: the importance of the central fragment in classification and treatment. Plast Reconstr Surg 87:843-853, 1991.)

Type III Fractures

Type III fractures include comminution that extends into the canthal tendon insertion and typically contains various small fragments. Unless sharp penetrating trauma was involved, the medial canthal tendon is almost never completely avulsed. Careful examination of the medial canthal tendon, its insertion, and the bony segment must be performed. Any partial avulsion of the tendon demands reinforcing it with wire to the medial orbital wall at the posterosuperior aspect for a combination transnasal wire reduction/stabilization and canthopexy. However, the central fragment rarely contains enough surface area for two drill holes to be placed 4 mm apart, and a bone graft is almost always needed to provide adequate skeletal support. Bone graft donor sites, such as a larger local medial orbital rim segment or distal parietal skull outer table, may substitute as a central fragment. Reduction starts by detaching the canthal tendon and properly arranging the bone graft and other segments. A 4 mm horizontal incision at the eyelid commissure facilitates passing a 3-0 braided suture to secure the lateralmost aspect of the canthal tendon with a modified Kessler stitch. The suture is connected to a pair of transnasal wires that are subsequently placed in the central bone graft as described previously (Fig. 19-5, *A*). Up to four sets of transnasal wires may be required: one for medial orbital rim reduction (because plates anterior to the canthal tendon can be detrimental), one for each canthus, and one for an external nasal bolster.[1] Microplate fixation can then be employed to stabilize the segments at the superior and, if required, inferior aspects as discussed previously (Fig. 19-5, *B*). The transnasal wire is then tightened to the contralateral transnasal wire or over a frontal screw just before closure of the coronal incision.



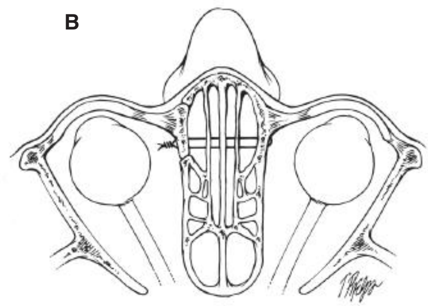


Fig. 19-5 **A,** Reattachment of the medial canthal tendon. **B,** Final treatment of type III injuries. (Modified from Sargent LA. Nasoethmoid orbital fractures: diagnosis and treatment. Plast Reconstr Surg 120[7 Suppl 2]:S16-S31, 2007.)

Treating Associated Deformities

Treatment of associated midface deformities, such as the nasal and orbital structures, plays a considerable role in the successful management of NOE injuries. Restoration of nasal length and tip projection by dorsal nasal grafts camouflage residual contour irregularities and produce a long-term aesthetic result. For example, dorsal nasal length affects the perceived intercanthal width: as dorsal length increases, the intercanthal distance appears smaller. Simple nasal fractures at the nasofrontal suture may only require miniplate fixation; however, more comminuted fractures necessitate a cantilevered bone graft. Parietal skull outer table or costochondral grafts (usually from the ninth rib with placement of the cartilaginous component at the tip) can provide appropriate structural support and strength.[3] Weakened cartilaginous lower vaults may additionally require a columellar strut.[1] Type III fractures often have overlooked nasal septal deformities. Reduction of the septum to a midline position and stabilization to the nasal spine with a 5-0 figure-of-eight suture can help minimize secondary nasal deformities.

As part of the overall injury, the NOE fracture extends into the medial wall and floor of the orbit. Restoration of orbital volume and shape must be attentively addressed and promptly treated. Exploration of the internal orbit is indicated if defects are identified on preoperative CT scans. Medial and inferior bone grafts may play a role in acute internal orbital defects, but the preference is now for preformed orbital titanium mesh plates. These provide precise anatomic reconstruction of the internal orbit to maintain globe position and function. It is important that the surgeon strictly follow the organization of panfacial fractures and reduce all rim fractures (such as zygomatic, supraorbital, and NOE) before placing the mesh plate.

POSTOPERATIVE CARE

Soft tissue reduction and appropriate splinting in the immediate postoperative period can help restore the delicate medial canthal contour. Soft tissue compression bolsters do not contribute to stabilization or reduction of NOE bony fragments, but they have been effective in reducing hematoma and edema.[1] The padded plates are positioned over the medial canthus, lateral to the nose. Made of lead plates with thick orthopedic foam or gauze, they are connected with one transnasal wire superiorly and inferiorly. The wire is passed transnasally inferior to the nasal bones and just anterior to the margin of the piriform aperture. Each bolster is then connected to the contralateral wire across the midline. Overtightening of the wires creates injury to the skin or excessive narrowing of the nose. These splints stay on for 7 to 10 days. Furthermore, Doyle nasal splints are often also indicated after nasal manipulation for septal stabilization, structural support, and mucosal healing.

Patient-centered postoperative care revolves around concomitant intracranial and other traumatic injuries. Neurosurgery and trauma surgery team involvement typically facilitates intensive care and overall treatment plans. Specific care directed toward NOE fracture treatment can be followed much like that of other craniomaxillofacial fractures: head of bed elevation, visual light/perception checks, suture line care (such as bacitracin ophthalmic and chlorhexidine gluconate [Peridex] oral rinses), tarsorrhaphy suture care, and nasal precautions.

CONSEQUENCES OF INJURY AND COMPLICATIONS

Underappreciation of the extent of injury, insufficient knowledge of the underlying anatomy, and treatment delay hinder the management of NOE complex injuries. Unfortunately, suboptimal surgical treatment leaves patients prone to severe cosmetic and functional deformities. These devastating long-term sequelae are very complex and often only partially correctable.

Evolution of contour irregularities, shortened palpebral fissure, enophthalmos, telecanthus, and displaced bones may be noticed initially following resolution of soft tissue edema. Scarring and the contracture of soft tissue to the misshapen skeletal framework occur if not treated in the initial postinjury period. Although medial wall osteotomies may be performed to reposition the medial orbital wall, the scarred and thickened soft tissue of the medial canthal region never truly reaches its preinjury appearance. True telecanthus resulting from stretching or avulsion of the medial canthi requires repositioning the orbital wall as well as bilateral medial canthopexies. Overall, dissection, complication rates, and unsatisfactory results increase with delayed treatment.

Nasal reconstruction of NOE fractures has been underemphasized for creating optimal aesthetic results. The nose may be foreshortened (because of inadequate projection and/or lateral displacement of the medial orbital walls), and a saddle deformity may occur. Septal deviation and dislocation, as well as poor lateral wall support, can affect airway patency. Addressing each of the four key principles of nasal reconstruction and the structural pathology underlying the problem can assist with adequate immediate or secondary treatment.[3]

RECOMMENDED FOLLOW-UP

Patients must be followed closely for incisional, tarsorrhaphy, and bolster dressing care within the first postoperative week. Incisional healing, nasal examinations, and visual acuity tests can be performed during clinic visits at 2 weeks, 6 weeks, and 3 months postoperatively. A multidisciplinary team of neurosurgery, traumatology, and ophthalmology can assist in providing long-term collaborative postoperative care.

Pearls

- *NOE fractures are a diagnostic and therapeutic challenge to craniomaxillofacial surgeons.*
- *Inadequate or delayed treatment leads to devastating deformities that are only partially correctable secondarily, if at all.*
- *A high level of suspicion should be present for any patient with signs of midfacial trauma.*
- *Careful physical examination of the structural support in the medial canthus along with meticulous evaluation of the CT scan can delineate which fractures need operative fixation.*
- *NOE fractures can be classified according to their central fragment, comminution, and involvement of the medial canthal tendon.*
- *Open reduction internal fixation typically involves at least two or three separate approaches to stabilize and examine the superior and inferior segments, as well as the status of the medial canthal tendon.*
- *Miniplate fixation of the superior segment (internal angular process of the frontal bone) and inferior segment (of the medial orbital rim) stabilizes the segments, and bone grafting may be required for the central fragment.*
- *Intercanthal transnasal wires must be placed* superior and posterior *to the medial canthal tendon.*
- *Overcorrection of the intercanthal reduction using transnasal wiring is preferred.*
- *Soft tissue draping, reapproximation, and bolster dressings play a significant role in achieving excellent cosmetic results.*
- *Concomitant loss of nasal projection and tip support, septal injury, and orbital volume must be concurrently addressed and corrected.*

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20 Panfacial Fractures

Detlev Erdmann, Jeffrey R. Marcus

Background

Facial fractures often do not occur independently, but in combinations. The challenge of managing panfacial fractures is that one not only must be familiar with the individual fractures, but also must have a strategy for addressing them all collectively and sequentially. Facial fractures, including panfacial injuries, are caused by traumatic events, such as assault, motor vehicle collision, occupational injury, and others.[1] *The Greek word* pan *means* entire *or* multiple; *therefore* panfacial fractures *are fractures of the upper, middle, and lower facial bones. Such injuries are commonly associated with other concomitant injuries*[2] *or polytrauma, and treatment planning requires good communication and a team approach.*[3] *Multiple specialists are typically involved in caring for patients with these kinds of high-energy injuries. From the moment the patient arrives, communication among services is vital. At most level one centers, a trauma surgery team provides leadership and coordination of immediate care for polytrauma management. The patient is stabilized, and any life-threatening injuries are treated expeditiously. A thorough systematic evaluation is conducted, and all injuries are identified. The craniomaxillofacial (CMF) trauma team may be needed urgently to manage hemorrhage associated with facial injury; however, in most cases, the work of the CMF team occurs after stabilization and the systematic evaluation have been completed. It is important for the CMF surgeon to carefully review all of the injuries, because they will influence the timing and management of the facial injuries.*

REGIONAL ANATOMY

The facial skeleton is commonly divided into four subunits: the frontal, the upper midface, the lower midface, and the mandible (Fig. 20-1). The frontal region includes the forehead, frontal sinuses, supraorbital rims, and orbital roofs. The upper midface consists of the orbital floors, medial and lateral orbital walls, nasoorbitoethmoid (NOE) region, nasal bones, septum, and zygomaticomaxillary complexes (malar eminences). The lower midface includes the tooth-bearing portions of the maxilla and the hard palate. To clarify, a LeFort I fracture line traverses the medial and lateral maxillary buttresses and destabilizes the maxillary dental arch. *This fracture line occurs between the upper and lower maxillary subunits.* Therefore the upper half of the face contains the frontal and upper maxillary subunit; the lower half contains the mandibular and lower maxillary subunits. Despite the multiple publications and textbooks that detail the management of panfacial fractures, there is no widely accepted definition of panfacial fracture. We have introduced a clinically applicable definition that says a panfacial fracture has occurred if at least three of the four facial subunits are involved, in various combinations.[4]

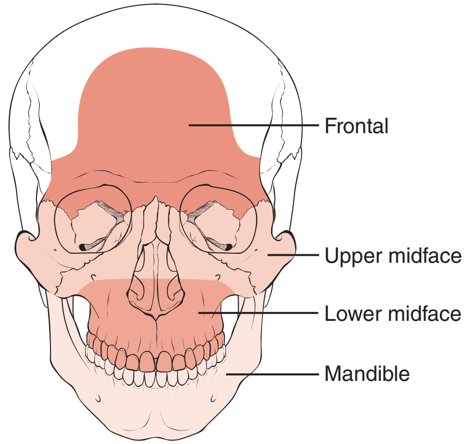

Fig. 20-1 Facial subunits.

FRACTURE PATTERNS

Fracture patterns in panfacial fractures are similar to any of the other commonly encountered facial fracture patterns, such as LeFort or zygomaticomaxillary complex (ZMC) fractures. However, they occur as a combination of patterns within all the facial subunits. It is important to describe the fractures in a manner that corresponds to the treatment elements needed to develop a sequence and strategy for the operation. For example, Fig. 20-2 illustrates a group of fractures that could be classified a number of ways, but the most appropriate description is that which assigns the injuries to the individual components.

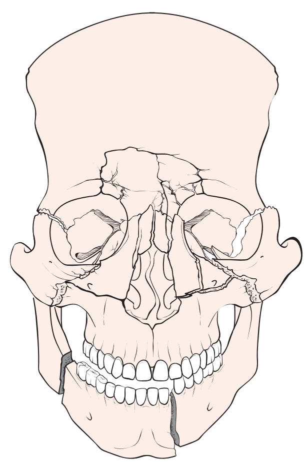

Fig. 20-2 All of the subunits in this example contain fractures. The set of maxillary fractures could be called a comminuted, bilateral, LeFort III fracture. Some radiologists may describe this as a LeFort I, II, and III fracture, because the fracture lines traverse the traditional sites of all three LeFort patterns. However, the most practical description reflects the way it is treated: bilateral type I NOE fractures, bilateral ZMC fractures (with orbital floor components), and bilateral LeFort I fractures.

SURGICAL INDICATIONS

Indications for operative intervention of panfacial fractures are instability and functional and aesthetic considerations. Unstable fractures such as those of the midface have the highest priority, and they are broadly considered to be an absolute indication for stabilization. Functional considerations for operative intervention include occlusal abnormalities, visual disturbances, or nasal airway obstruction associated with typical fracture patterns. Aesthetic considerations are contour irregularities, such as those of the forehead or zygoma.

Panfacial fractures result from high-energy forces, and the incidence of concomitant injuries is high, such as intracranial injury, rib fracture/pulmonary contusion, cervical spine fracture, pneumothorax, intraabdominal injury, and others. The indications for treating panfacial fractures are relatively clear, but the timing for treatment may not be. At our center, panfacial fracture treatment is undertaken *as soon as the patient is thought stable enough to undergo surgery.* The two factors most commonly precluding early surgical management are hemodynamic or neurologic instability. Intracranial injury with increased intracranial pressure (ICP) often occurs in association with severe facial injuries. The neurosurgical team's management of elevated ICP can range from medical measures to external drainage/pressure monitoring or decompressive craniectomy. Under these circumstances, the treatment of facial fractures may be delayed. If a patient has reached hemodynamic and neurologic stability, appropriate treatment should be provided with the assumption that the patient has a potential to recover. If care is deferred or delayed too much, the likelihood of achieving an acceptable result is exceedingly low.

> The CMF team must be prepared to provide definitive reduction and fixation of all facial injuries as soon as the patient is thought to be stable.

Specific preoperative treatment planning considerations for panfacial fractures include the location and extent of all fractures; the structures injured or involved along the fracture sites, such as nerves and the lacrimal duct; the amount and location of soft tissue loss, including skin and mucosa; the extent of bone loss; and the presence of dentoalveolar injury. CT and three-dimensional CT, along with occasional three-dimensional models and model surgery, are helpful tools for diagnosis and treatment.

TREATMENT GOALS

After stabilization, the main goal is early and total restoration of facial form and function, which is generally attempted using a one-stage approach. Disfigurement is generally severe from panfacial injuries because of the displacement of skeletal features in combination with soft tissue injury or swelling. It is very helpful to have preinjury photographs of the patient, if family members are able to provide them. Of specific consideration in panfacial fractures is the restoration of facial height and width to the preinjury state. Facial height is most affected by the relationship between the lower midface (maxilla) and mandible. Impaction of the maxilla, without proper disimpaction at surgery, can affect facial height. The presence of mandibular angle and ramus fractures can compromise mandibular height; more commonly though, bilateral condyle fractures reduce facial height when the vertical supports of the posterior mandible collapse.

Facial width is affected most significantly by the presence of ZMC fractures, particularly when there is severe buckling of the zygomatic arch. A high-energy anterior force on the malar eminence can fracture the articulations of the ZMC at the infraorbital rim, zygomaticomaxillary buttress, zygomaticofrontal buttress, and the arch. The malar eminence is driven posteriorly, resulting in loss of projection, and the fractured arch can either telescope onto itself or become displaced outwardly. The latter results in increased facial width. The most common reason for increased postoperative width is the failure to properly reduce the zygomatic arch. Projection of the malar eminence is restored by elevating and reducing the ZMC; as it is elevated, medial pressure on the midarch can often provide adequate reduction with correction of width. If this is inadequate (including in cases with significant comminution), the arch should be exposed and plated. It is important to note that the midportion of the arch is straight, rather than curved. A curved plate here will create a convexity that appears as increased facial width.

Many (if not all) panfacial fractures include injury to the orbit, either as a blowout or as a component of a ZMC or NOE complex fracture. The goal of orbital repair is to restore preinjury volume by reducing and stabilizing the surrounding buttresses and rims, and then reconstructing the affected orbital walls with a graft or implant. When fractures of the internal orbit are a component of panfacial injury, it is important to reconstruct the surrounding rims before repairing the floor/walls.

If surgery is delayed by the severity of concomitant trauma, simple early operative intervention procedures such as laceration repair and mandibulomaxillary fixation (MMF) should be considered until definitive treatment can occur. In many cases of panfacial trauma, (prolonged) ventilation with tracheostomy and feeding through percutaneous endoscopic gastrostomy is imperative and should be initiated before operative intervention.

EXPOSURE

The patient is prepared and draped widely to allow all needed exposures. If coronal exposure is required, a horseshoe head frame is used. The airway is typically secured using a tracheostomy or nasotracheal tube (see Chapter 9). If a tracheostomy has been performed, it should be visible in the field to avoid disconnection. If a nasotracheal tube is used, it should be secured at two points with sutures to avoid inadvertent extubation and so that there is no pressure on the nostril. Exposure to panfacial fractures is similar to any of the other commonly encountered facial fracture patterns and includes standard incisions such as the extraoral or lower buccal sulcus approach to the mandible, upper buccal and lower eyelid approach to the lower midface, the lower eyelid and coronal approach to the upper midface, and the coronal approach to the frontal unit.[5] However, exceptions should be made when lacerations and other soft tissue injuries preclude standard incisions to avoid further soft tissue insult. Soft tissue injuries may often be used to gain access to underlying fractures for stabilization.

> Exposure of the orbit through a lower lid approach is the most delicate dissection in the sequence, so it may be helpful to perform this at the very beginning of the procedure. A limited dissection of the orbital floor can also be initiated. Fractures may then be reduced at the appropriate time later.

OPERATIVE SEQUENCE

A number of organizational sequences have been proposed for repairing panfacial fractures,[6,7] including top-to-bottom, bottom-to-top, inside-out, and outside-to-inside, which emphasizes the zygomatic arch.[8] However, the exact order is not as important as developing a plan that permits accurate anatomic reduction of the various fragments. The surgeon must *identify* stable starting points and/or *create* stable starting points. Three important aspects are to be kept in mind:

1. Identification of the fractures
2. Exposure (access)
3. Anatomic fixation of the facial buttresses

In all cases, the injuries are surveyed, and a written plan is devised to provide a step-by-step sequence catered to the patient. For the purpose of this discussion, refer to Fig. 20-3. In our practice, the approach varies depending on the patterns seen, but we think it is necessary to give particular emphasis to achieving appro-

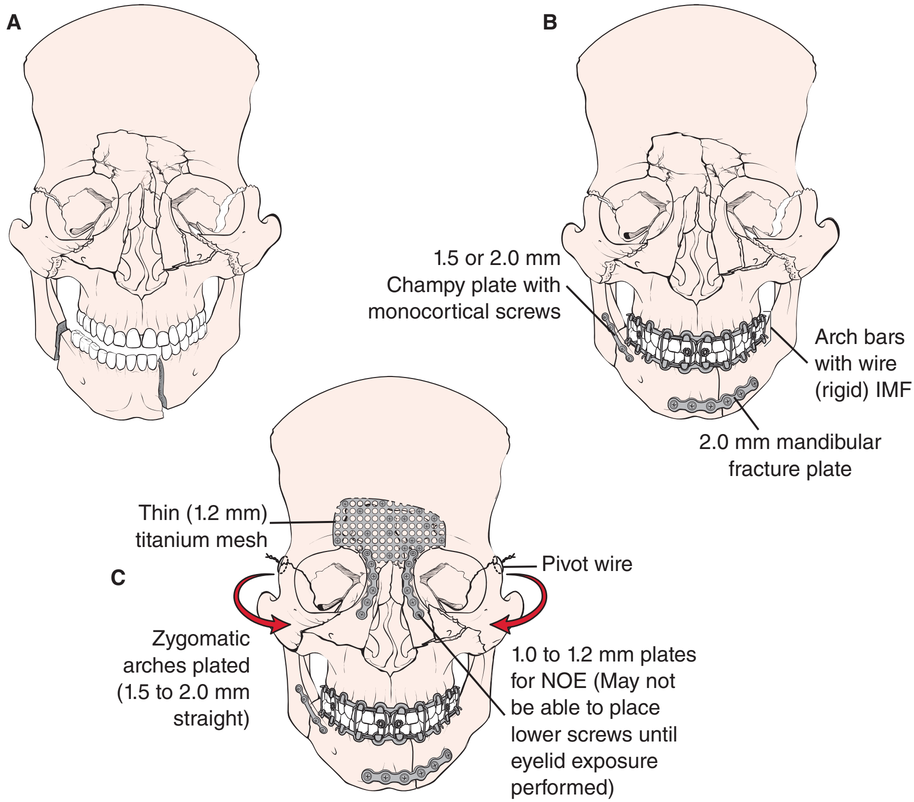

Fig. 20-3 It is important to develop a plan that permits accurate anatomic reduction of the various fragments. **A,** To reflect treatment, the injuries pictured here are described as bilateral type I NOE fractures, bilateral ZMC fractures (with orbital floor components), and bilateral LeFort I fractures. **B,** Arch bars are applied, incorporating reduction of the parasymphyseal fracture. IMF is applied with mobilization of the LeFort I segment and reduction at the mandibular angle. The parasymphyseal and angle fractures are plated appropriately. When complete, the lower midface and mandible move as a single unit, articulating at the TMJs. **C,** Lower eyelid and coronal exposure are performed. The frontal sinus fractures (the anterior table only in this example) and the supraorbital rims are reduced and stabilized. Titanium mesh stabilizes the comminuted anterior table fragments. The superior aspects of the NOE fractures are reduced and plated to the stabilized radix region. Microplates are passed inferiorly where they are visible from the lower eyelid exposure. The central face is now stabilized. Pivot wires are placed at the zygomaticofrontal buttresses. The malar eminences and zygomatic arches are reduced. If needed, the zygomatic arches are exposed and plated to secure facial width.

priate facial width by properly reducing and plating the zygomatic arches when needed. Some authors advocate application of intermaxillary fixation first (often even before preparing and draping) if the dental arches can be brought into occlusion. If, however, there is an impacted LeFort I fracture, the segments may not be mobile enough to come into occlusion and may require disimpaction. The exposure to accomplish this is achieved through an upper buccal sulcus incision, wide subperiosteal elevation, and possible completion osteotomy. Rowe disimpaction forceps can be used, but are rarely necessary. Once occlusion has been established, fractures of the mandible are reduced using the appropriate exposure, and fixation is applied. This creates stability of the mandible and lower midface so that the two subunits can be joined together with intermaxillary wire fixation (IMF) as a single construct to later be affixed to the completed upper subunits (frontal and upper midface) at the level of the LeFort I fracture line. If bilateral condyle fractures are present, it is preferable to reduce and stabilize at least one side to maintain posterior mandibular height.

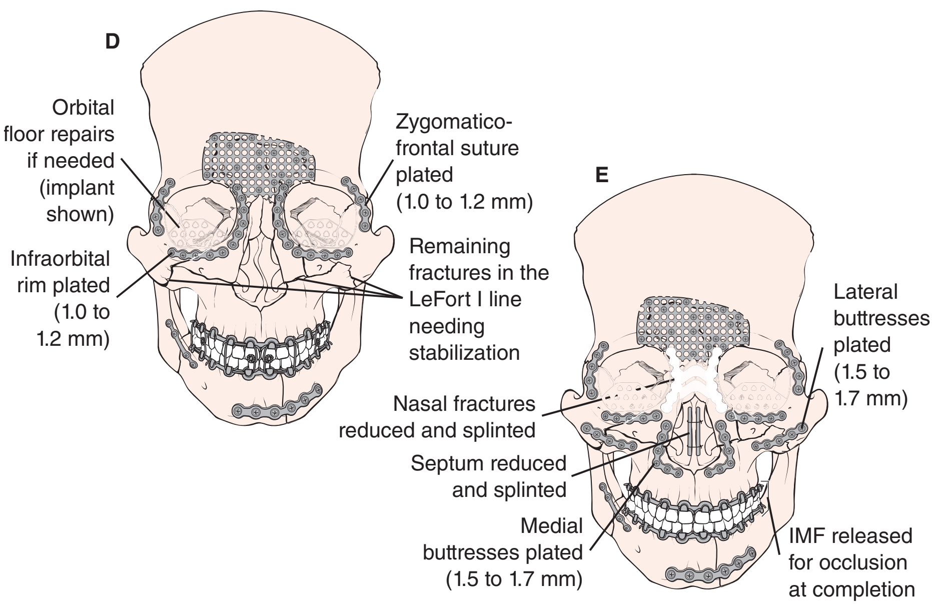

Fig. 20-3, cont'd D, The final facial width is set by plating across the infraorbital rims, which moves the malar eminences centrally. The orbital rims are now stabilized circumferentially. The orbital floors and walls can be repaired with bone grafts or alloplastic implants. The zygomaticofrontal pivot wires can be exchanged for low-profile titanium plates if desired. **E,** The frontal and upper midface are completed, and the two lower subunits are joined with IMF. All that remains is plating along the LeFort I line to finalize fixation. The condyles are seated, and the lower units are rotated up to reduce at the LeFort I line. The medial and lateral buttresses are plated. The IMF is released, occlusion is checked, and wire or elastic IMF is reapplied. Nasal and septal fractures are reduced and splinted.

We prefer to perform lower lid exposure early if needed, because the dissection is more delicate than any of the other steps in the sequence. If the frontal subunit is involved (frontal sinus), or if the zygomatic arches are to be plated, a coronal exposure is performed next. The frontal sinus fractures are addressed. At this stage the goal is to create stability across the supraorbital rims. The zygomaticofrontal buttress is temporarily stabilized with a pivot wire, which allows some rotation of the ZMC for later final reduction. Facial width is set initially by reducing and plating the zygomatic arches, keeping in mind that the arches have a relatively straight (not curved) contour along most of their length. If NOE fractures are present, stabilization along the midline to the reconstructed or intact forehead/nasal radix is done next to establish a stable midline unit for the upper midface. When plating a type I NOE, microplates are applied (1.0 to 1.2 mm); the upper screw sites should be visible through the coronal exposure, but the lower screws may require that the lower lid exposure be completed. The plates are passed inferiorly into view from the lid exposure and situated before screws are placed superiorly. At this point, the lateral upper face has been stabilized at the arch and zygomaticofrontal suture. The central face has been stabilized down the midline. The final step in setting facial width is then to join the ZMC with the stable midline unit along the infraorbital rim. After plating the infraorbital rim (1.0 to 1.2 mm), the orbital floors and walls are explored and reconstructed as needed. Calvarial bone grafts may be harvested and used instead of alloplastic implants if preferred. At this point, the frontal and upper midface have been completed, and the mandible has been linked to the lower midface (maxilla) with IMF. All that remains is joining the upper and lower halves of the face by plating the medial and lateral maxillary buttresses, corresponding in many cases to a LeFort I fracture line. The condyles are seated, and the lower face is rotated up, articulating the TMJs. If the fractures have all been satisfactorily reduced, reduction at the LeFort I line will also be satisfactory. The lateral and medial maxillary buttresses are plated with 1.5 to 1.7 mm miniplates. The IMF is released and occlusion is checked. Rigid or elastic IMF is then reapplied. The nasal bones and septum are reduced and splinted; septal splints and nasal packing are placed if needed.

POSTOPERATIVE CARE

Postoperative care is similar to that provided for any commonly encountered facial fracture patterns. Refer to specific chapters for guidelines for each site.

CONSEQUENCES OF INJURY AND COMPLICATIONS

The word *complication* often carries an implication that the treatment itself has caused a problem; however, the severity and extent of panfacial injuries may themselves lead to unfavorable sequelae. The surgical team should anticipate and avoid the potential and preventable problems associated with each injury site to the greatest degree possible. The challenge is increased by the need for multiple exposures and the presence of skin and soft tissue injury. Assuming that proper occlusion (including IMF release, recheck, and reapplication at the end of the procedure) and anatomic skeletal stabilization have been attained, the soft tissues must be resuspended. In addition, free movement of the globes must be confirmed with a forced duction maneuver. The lower lids must be supported and suspended using canthopexy and Frost sutures to avoid lid malposition. Postoperative sequelae for panfacial fractures are similar to and typical for any commonly encountered facial fracture pattern and include nonunion, malocclusion, or asymmetry. Each injury and the associated exposure and treatment bring their own potential sequelae that must be considered.

RECOMMENDED FOLLOW-UP

Postoperative follow-up is determined according to the fractures treated. In the operating room, a plan for the type and duration of postoperative IMF is made. In our practice, the IMF plan and the short-term follow-up plan are included in the operative dictation. Weekly or biweekly checks are performed until the IMF has been discontinued and arch bars have been removed. Each of the associated injury sites is checked at each of these visits. Jaw excursion is carefully examined to rule out the presence of trismus. Physical therapy for active range of motion is frequently needed. Thereafter, the frequency of follow-up is determined on a case by case basis until satisfactory healing has occurred without ongoing concerns from the surgeon or patient. Specific attention may be directed to injured soft tissues. When skeletal alignment and occlusion have been optimized, soft tissue problems such as scarring are among the main factors causing an unfavorable outcome in panfacial fracture management.[9] Postoperative wound care must be meticulous, with frequent cleansing. In most cases, revision of soft tissue injuries is delayed until scar maturation has occurred (typically after 1 year). Postoperative radiographs are performed at the surgeon's discretion. Frontal sinus fractures require long-term follow-up to recognize potential development of mucocele, and a repeat CT scan is often done 1 year after surgery.

Pearls

- *Panfacial fractures do not have specific fracture patterns, but fractures occur in combination within all facial subunits.*
- *According to the Duke classification, a panfacial fracture is present if three or all four of the facial subunits are involved, in various combinations.*
- *Preinjury photographs should be made available in the operating room.*
- *If prolonged ventilator needs are anticipated, a tracheostomy and feeding through a percutaneous endoscopic gastrostomy are essential.*
- *Specific attention to soft tissues is needed with most panfacial fractures, including operative suspension of the cheek fat pad and lower lids and meticulous postoperative wound care.*
- *The actual sequence of repair can vary, depending on the fractures present. A written step-by-step plan should be made for each case and kept in the operating room for reference.*
- *If needed, lower lid exposure may be performed early in the sequence, because it is the most delicate dissection.*
- *When coronal exposure is performed, split calvarial bone grafts are easily obtainable if needed.*
- *All buttresses and rims are reduced and stabilized before addressing the orbital walls or floor.*
- *The zygomatic arch is relatively straight, and proper reduction influences facial width.*

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21 Dental Trauma

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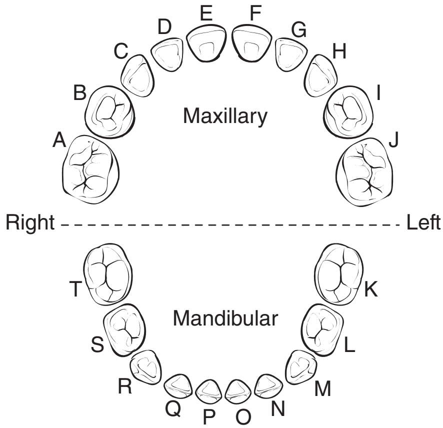
Background

Management of acute dental trauma in the emergency department is a unique challenge for physicians treating trauma to the head and neck. Typically, surgeons who specialize in plastic and reconstructive surgery, otolaryngology head and neck surgery, and even oral and maxillofacial surgery have limited exposure and even less experience in treating injuries to the dentition. Surgeons often are called to the emergency department only to find an anxious patient in a hectic environment, with limited resources and equipment. This chapter focuses on dental trauma in adults and children. Specifically, we describe practical treatment of these injuries in an emergency department setting.

ANATOMY

The pediatric or primary dentition includes 20 teeth denoted by letters A through T, totaling 20 teeth. Lettering begins from the right maxillary second molar. After reaching the left maxillary second molar (tooth J), lettering proceeds from the left second mandibular molar (K-T). Primary teeth include 4 incisors, 2 canines, and 4 molars per arch. There are no premolars.

The adult or secondary dentition includes 32 teeth denoted by numbers. Numbering follows the same order as described for primary dentition, starting from the right maxillary molars (1-16), then continuing from the left mandibular third molar (17-32). Figs. 21-1 through 21-4 provide a brief overview of basic anatomy and anatomic relationships.



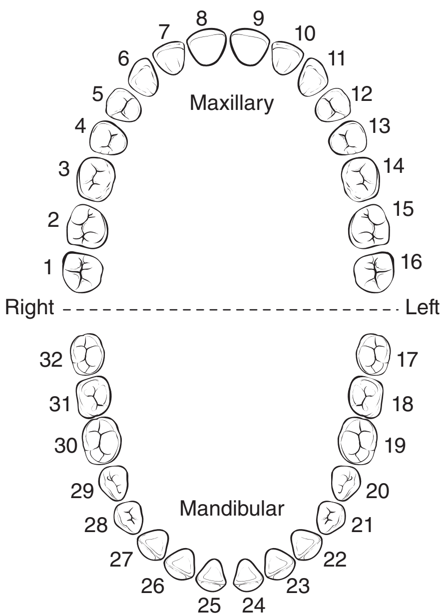
Upper teeth

F. Central incisor
G. Lateral incisor
H. Canine (cuspid)
I. First molar
J. Second molar

Lower teeth

K. Second molar
L. First molar
M. Canine (cuspid)
N. Lateral incisor
O. Central incisor

Fig. 21-1 Primary (pediatric) dentition.



Upper teeth

9. Central incisor
10. Lateral incisor
11. Canine (cuspid)
12. First premolar (first bicuspid)
13. Second premolar (second bicuspid)
14. First molar
15. Second molar
18. Third molar (wisdom tooth)

Lower teeth

17. Third molar (wisdom tooth)
18. Second molar
19. First molar
20. Second premolar (second bicuspid)
21. First premolar (first bicuspid)
22. Canine (cuspid)
23. Lateral incisor
24. Central incisor

Fig. 21-2 Secondary (adult) dentition.

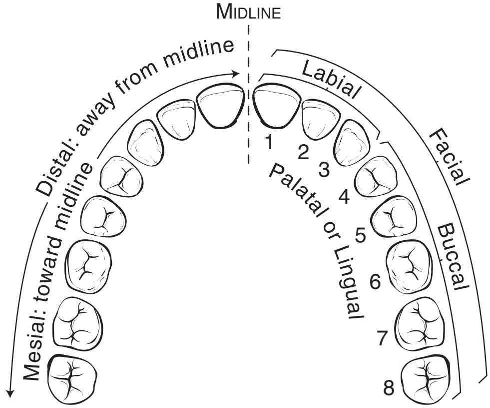


Fig. 21-3 Dental relationships.

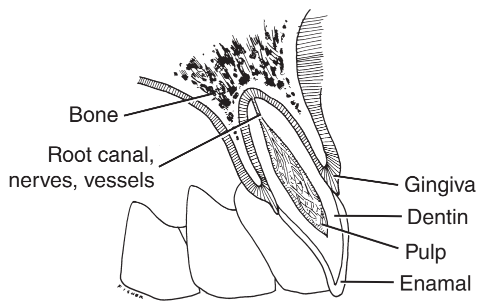


Fig. 21-4 Normal cross-sectional anatomy of a maxillary central incisor.

TERMINOLOGY AND DEFINITIONS

Dental injuries have been classified according to a variety of factors, such as cause, anatomy, pathology, or therapeutic considerations. The present classification is based on a system adopted by the World Health Organization in its *Application of International Classification of Diseases to Dentistry and Stomatology.*[1] However, for the sake of completeness, it is necessary to define and classify certain trauma entities not included in the WHO system. The following classification includes injuries to the teeth, supporting structures, gingiva, and oral mucosa and is based on anatomic, therapeutic, and prognostic considerations. This classification can be applied to both the permanent and primary dentition. An illustrated glossary of terms and definitions can be found in the Appendix at the end this chapter.

STEPS IN INITIAL TRIAGE

1. *Reassure the patient and family:* Explain that his or her smile can be restored.
2. *Obtain a thorough history of the injury:* Time of injury, where the injury occurred, how the injury occurred. A careful history and clinical examination are imperative with cases that involve dentoalveolar trauma, because concomitant injuries can be life threatening. Potential abuse must be ruled out.
3. *Perform a systemic assessment:* Any period of unconsciousness, cranial nerves assessment. Examine the ear canals and nose for bleeding (to rule out basal skull fracture or zygoma-maxillary fracture). Examine the floor of the mouth for hemorrhage (an indicator of a mandibular fracture), the date of the patient's last tetanus inoculation, and other evaluations.
4. *Perform an extraoral examination:* Assess the patient for facial fractures, lacerations, contusions, swelling, abrasions, foreign bodies, and TMJ deviation on opening the mouth.
5. *Examine the intraoral soft tissue:* Evaluate lip, frenae, buccal mucosa, gingiva, palate, tongue, floor of mouth, blood-tinged saliva. An obvious laceration or hematoma in the overlying oral mucosa may indicate an underlying fracture.
6. *Examine the patient's teeth:* Asking the patient whether his or her "bite is off" may focus the clinician on the source of the problem. Note any missing crowns, bridges, or dental "fillings." If any of these are noted, a chest radiograph may be indicated to rule out aspiration. The examination should include a mobility test, which is done by placing the handle of a metal instrument on the facial surface of the tooth and an index finger on the lingual surface. A percussion test is accomplished by tapping the incisal surface of the tooth with a metal handle. A high, metallic tone implies that the tooth is ankylosed or fused to the bone.
7. *In children, assess coping abilities:* Determine whether sedation or general anesthesia is needed for management of the injuries.
8. *Order radiographs as needed:* CT scan, Panorex, periapical films.
9. *Consult an adult or pediatric dentist, as needed.*
10. *Provide necessary treatment and postoperative instructions.* Make sure that the patient has a dental home if dental follow-up is indicated.

FURTHER TRIAGE AND MANAGEMENT

Having accurately classified the injury, the physician can make a definitive diagnosis and, what is most important, prioritize treatment. We make detailed treatment recommendations for loose or avulsed teeth as well as alveolar process fractures only, because these are the truly urgent conditions that must be addressed in the emergency department.

Tooth Avulsion

A tooth avulsion requires immediate attention, because a very strong relationship has been found between storage time and storage condition and healing outcome. There is a broad difference of opinion as to the optimal timing for replantation. Some authors recommend no more than a 20-minute delay from injury to replantation, whereas others support replantation as long as 2 hours after the injury.[2,3] Ultimately, it is most important for the surgeon to strive for replantation and stabilization as soon as possible to prevent short-term complications (such as infection and tooth mobility) or long-term sequelae (such as root resorption).

Often the physician is notified of an avulsed tooth before the patient's arrival to the emergency department. It is imperative to optimize the storage of the tooth during transport. Ideally, the tooth should be gently rinsed and immediately reimplanted. The patient can bite on a tissue or gauze to stabilize the tooth until he or she arrives at the emergency department. If reimplantation is not possible, other options for storage include placing the tooth in the patient's mouth, placing the tooth in a transport medium such as Save-A-Tooth, or simply keeping the tooth in a glass of milk. The reimplanted tooth should then be stabilized as described below.

Fractures of the Alveolar Process

Fractures of the alveolar process also require emergent care. It has been shown that when treatment is delayed for more than 3 hours, an increase in pulp necrosis of the affected tooth occurs.[2,4]

The primary objective in the management of a fracture of the alveolar process is to reposition the fragment to minimize disruption of the vascular supply, which can result in pulp necrosis and root resorption. A local anesthetic is administered, either by infiltration or as a regional block, to allow reduction using simple finger pressure. Stabilization is accomplished with a resin splint or arch bar and is maintained for 3 to 4 weeks.[2,4] Antibiotics are given, along with diet and oral hygiene instructions. Rinsing 2 to 3 times a day with a mouth rinse, such as chlorhexidine, is recommended. After removal of the stabilization device, the patient should be referred to a general or pediatric dentist for management of the affected teeth.

Stabilization of a Single Tooth

Several methods have been proposed for stabilization of a single tooth. Splinting the tooth with a semirigid splint is the most accepted technique.[2] Splinting material such as composite resin is applied in a thin layer to the facial surfaces of the traumatized tooth and the two adjacent teeth. Next, a 24-gauge wire is placed into the material and positioned to span the three teeth. The splinting material is then cured (either self-cured or with ultraviolet light). The major disadvantage to this technique is that the emergency department is rarely equipped with splinting material, and most emergency department surgeons have little or no experience in handling it.

In the Duke Medical Center emergency department, the following technique is used routinely for initial stabilization. An Erich arch bar is fashioned to span at least two teeth on either side of the affected tooth, which is then stabilized to the arch bar with 28-gauge wire (Fig. 21-5). Care is taken to position the lingual wire above the convexity of the crown to ensure that an apical force is applied to secure the tooth in the socket. This technique is attractive to most emergency department surgeons who have experience in arch bar placement. Most emergency departments have arch bars and appropriate wires readily available. Antibiotic coverage is recommended (penicillin or clindamycin given immediately and for 4 days thereafter). The patient is instructed to remain on a soft diet that minimizes chewing. The patient should practice excellent oral hygiene and use a chlorhexidine mouth rinse. The splint or arch bar is removed in 1 week, and the patient is referred to a general or pediatric dentist who will assess the long-term vitality of the tooth. Teeth that become nonviable may require root canal therapy.

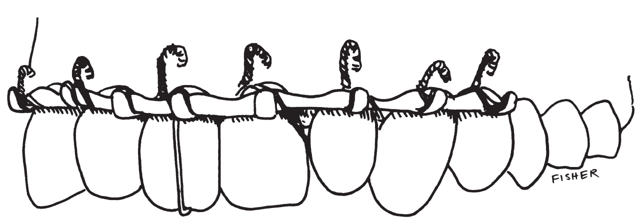


Fig. 21-5 Tooth stabilization with an arch bar.

Injuries of Less Urgency

Extrusion, lateral luxation, and root fracture are injuries that are not as pressing, and treatment can be delayed for up to 5 hours after the injury.[2,6,7] Often this allows time for referral from the emergency department to a local dental professional for definitive treatment. A delayed approach (more than 24 hours) can be used to treat other injuries, including intrusion, concussion, subluxation, and crown fracture, with or without pulp exposure.[2,6,7] Further recommendations for management are detailed in Table 21-1.

Table 21-1 Treatment Summary

	Treatment	
Type of Injury	**Primary Tooth[2,5-7]**	**Permanent Tooth[3,4,6,7]**
Craze line	Apply clear sealant	Apply clear sealant
Crown, minor chip	No treatment required, or smooth the edge	No treatment required, or smooth the edge
Crown fracture with no pulp exposure (<50% of crown)	Apply a "tooth band-aid": a resin coating to protect the exposed dentin	Apply a "tooth band-aid": a resin coating to protect the exposed dentin
Crown fracture with pulp exposure (>50% of crown)	Extract the tooth or refer for root canal therapy	Refer for root canal therapy
Root fracture without mobility	Observe	Observe
Root fracture with mobility	Stabilize or extract	Stabilize or extract
Displaced with slight mobility	Immediately reposition, prescribe soft diet	Immediately reposition, prescribe soft diet
Displaced with significant mobility	Extract	Immediately reposition, splint 7-10 days
Intruded	Allow to reerupt	Age dependent: Allow to reerupt or orthodontically extrude; possible root canal therapy
Avulsed (out of mouth)	Do not replant	Replant immediately or transport in milk to a dentist Splint until stable or store in a Save-A-Tooth kit Possible root canal therapy, soft diet, antibiotics?

For injuries shown in red type, the patient needs **immediate treatment**—the pediatric dentist on call should be paged.

POSTOPERATIVE INSTRUCTIONS FOR DENTAL INJURY[2]

1. Consume a soft diet for 6 weeks.
2. Avoid biting down on the injured tooth for 6 weeks.
3. Maintain meticulous oral hygiene.
4. Use chlorhexidine or antibiotics if prescribed.
5. Make a follow-up appointment with the dental clinic.

Pearls

- *Abuse should be ruled out with dental injuries.*
- *Obvious lacerations in the oral mucosa may signal underlying fractures.*
- *Missing crowns, bridges, or dental fillings may have been aspirated by the patient. A radiograph should be ordered if aspiration is suspected.*
- *Tooth avulsion requires immediate attention, because tooth survival depends on the time from injury to replantation.*[3]
- *Primary teeth are not replanted when avulsed.*[5]
- *Avulsed permanent teeth should be preserved either in a Save-A-Tooth kit or in milk until replantation is possible.*
- *Alveolar process fractures also require emergent care. Timely repositioning of the fragment can minimize the potential for pulp necrosis and root resorption.*[2,6,7]
- *Injuries that can tolerate up to 5 hours before definitive treatment include extrusion, lateral luxation, and root fractures. As a result, these injuries can often be referred to a local dentist from the emergency department for definitive treatment.*[2,6,7]
- *A delayed approach (more than 24 hours) can be used to treat other injuries, including intrusion, concussion, subluxation, and crown fracture, with or without pulp exposure.*[2,6,7]

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Appendix

Glossary of Injuries to the Hard Dental Tissues and Pulp

Enamel infraction An incomplete fracture, *A* (crack), of the enamel without loss of tooth substance (Fig. 21-6).

Enamel fracture (uncomplicated crown fracture) A fracture with loss of tooth substance, *B,* confined to the enamel (Fig. 21-6).

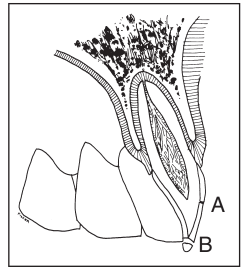

Fig. 21-6

Enamel-dentin fracture (uncomplicated crown fracture) A fracture with loss of tooth substance confined to enamel and dentin, but not involving the pulp (Fig. 21-7).

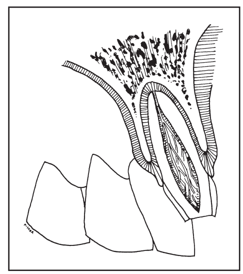

Fig. 21-7

Complicated crown fracture A fracture involving enamel and dentin and exposing the pulp (Fig. 21-8).

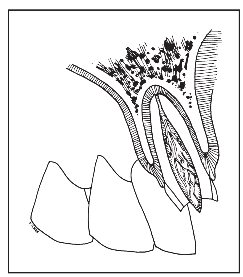

Fig. 21-8

Injuries to the Hard Dental Tissues: The Pulp and Alveolar Process

Crown-root fracture A fracture involving enamel, dentin, and cementum. It may or may not expose the pulp (uncomplicated and complicated crown-root fracture) (Fig. 21-9).

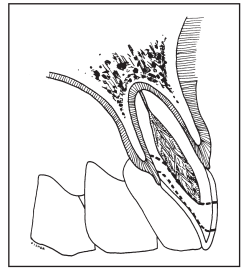

Fig. 21-9

Root fracture A fracture involving dentin, cementum, and the pulp. Root fractures can be further classified according to displacement of the coronal fragment (see luxation injuries) (Fig. 21-10).

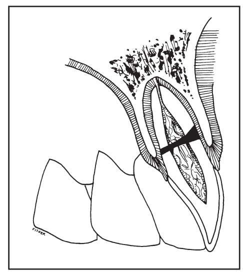

Fig. 21-10

Fracture of the mandibular or maxillary alveolar socket wall A fracture of the alveolar process that involves the alveolar socket (see lateral luxation) (Fig. 21-11).

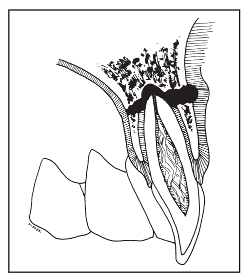

Fig. 21-11

Fracture of the mandibular or maxillary alveolar process A fracture of the alveolar process that may or may not involve the alveolar socket.

Injuries to the Periodontal Tissues

Concussion An injury to the tooth-supporting structures without abnormal loosening or displacement of the tooth, but with marked reaction to percussion.

Subluxation (loosening) An injury to the supporting structures of the tooth with abnormal loosening, but without displacement of the tooth (Fig. 21-12).

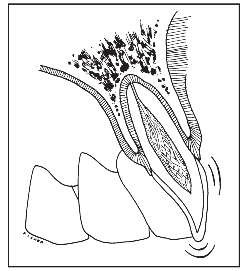

Fig. 21-12

Extrusive luxation (peripheral dislocation, partial avulsion) Partial displacement of the tooth out of its socket (Fig. 21-13).

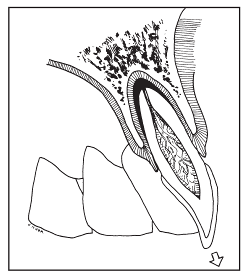

Fig. 21-13

Lateral luxation Displacement of the tooth in a direction other than axially. This is accompanied by comminution or fracture of the alveolar socket (Fig. 21-14).

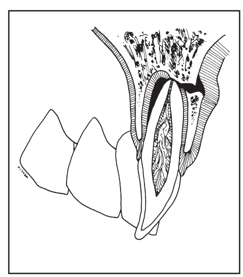

Fig. 21-14

Intrusive luxation (central dislocation) Displacement of the tooth into the alveolar bone. This injury is accompanied by comminution or fracture of the alveolar socket (Fig. 21-15).

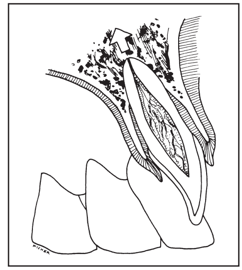

Fig. 21-15

Avulsion (exarticulation) Complete displacement of the tooth out of its socket (Fig. 21-16).

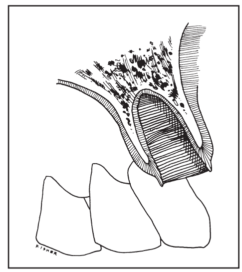

Fig. 21-16

Injuries to the Gingiva or Oral Mucosa

Laceration of gingiva or oral mucosa A shallow or deep wound in the mucosa resulting from a tear; usually produced by a sharp object.

Contusion of gingiva or oral mucosa A bruise, usually produced by impact with a blunt object and not accompanied by a break in the mucosa, often causing submucosal hemorrhage.

Abrasion of gingiva or oral mucosa A superficial wound produced by rubbing or scraping of the mucosa, leaving a raw, bleeding surface.