Converse: Chapter 24

The Clinical Management Of Facial Injuries And Fractures Of The Facial Bones

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(Fracture Of The Condyle, Nicholas G. Georgiade)

In the clinical management of facial injuries, it is the responsibility of the physician to restore appearance and function to the best of his abilities. In some cases, however, the problems are entirely those of restoration of function, while in others the restoration of appearance is the chief indication for treatment.

Economic, sociologic, and psychologic factors operating in a competitive society make it imperative that an aggressive, expedient, and well-planned program be outlined and maintained in order to return the patient to an active productive life as soon as possible with minimal cosmetic or functional disability.

The incidence of facial injuries is high compared to injuries in other areas because the face is in an exposed position without protective covering. Although there are many etiologic agents, the automobile is responsible for a high percentage of facial injuries and deformities in the United States. In automobile accidents, injuries to the head and facial area occur in 72.1 per cent of all victims (Braunstein, 1957). Approximately 50,000 traffic fatalities occur each year in the United States, and for every person killed, 39 require hospitalization (National Safety Council, 1975). This means over 4,000,000 persons are injured in automobile accidents in the United States each year.

Statistics on the number of injuries due to various etiologic factors are not significant. Although statistics are available in a number of series, there is wide variation in different samples due to social, economic, and geographic factors. In one series (Hagan and Huelke, 1961), the automobile was responsible for 38 per cent of all facial fractures in a highly industrial, motorized area of the Midwest, whereas in another series in Great Britain (Rowe and Killey, 1955), automobile accidents accounted for only 8 per cent of facial fractures in a crowded urban area where the social and economic conditions were such that few people used automobiles.

Although protective shoulder slings, head rests, increased padding, "packaging" of the passenger, and decreased speed limits have recently been emphasized, the automobile is here to stay, and "crash" or "crush" injuries of the face involving soft and hard tissues will continue to be a challenge to the plastic surgeon's skill.

Injuries Other Than Automotive

Industrial accidents involve over 2,000,000 persons annually. Most accidents occur in the home, involving over 4,000,000 disabling injuries a year. Dog bites, which often involve the face, are frequent, particularly in children, as a result of the increasing canine population.
Athletic injuries of various types involve the face. Military conflicts are the source of the most severe injuries, ballistic missiles disrupting the soft and hard tissues of the face. The popularity of the motorcycle has added another etiologic factor in the causation of facial injuries.

**Timing Of Treatment**

Timing is especially important in the optimum management of facial injuries. It is axiomatic that soft tissue and bone injuries in the facial area be taken care of as soon as is consistent with the patient's general condition. Early skillful management decreases the possibility of permanent facial disfigurement and serious functional disturbances. It should be kept in mind, however, that facial soft tissue and bone injuries are rarely acute surgical emergencies as far as closure of the wounds or reduction of fractures is concerned. In patients who obviously are losing significant amounts of blood or are in a state of impending shock, bleeding should be controlled and other measures should be instituted to prevent or treat shock and to establish a satisfactory airway.

Facial injuries may be associated with life-threatening lesions; treatment of multiple systemic injuries should take precedence over management of facial wounds. After the airway is cleared, hemorrhage controlled, and measures instituted to control shock, a careful neurologic evaluation is made to rule out intracranial hemorrhage or traumatic lesions of the central nervous system. Damaged or ruptured viscera in the thoracic or abdominal cavity or in the pelvis may endanger life, and every effort should be made to detect and manage these problems before spending valuable time suturing facial lacerations or reducing fractures of the facial bones.

In emergencies, facial lacerations may be quickly sutured by tacking the margins together with a few well-placed sutures. If such a procedure is contraindicated because of the patient's general condition, simply covering the wounds with sterile dressings and applying light pressure will control the bleeding and protect them until it is feasible to achieve definitive closure.

Facial fractures, if they are seen early and if the patient's general condition warrants, may be reduced immediately. When a patient is seen several hours after an accident, the exact condition may be obscured by extensive edema and hematoma in the soft tissue, and delay of treatment is indicated. In these cases, it is best to wait a few days until most of the edema subsides before undertaking reduction and fixation of facial fractures. If it is necessary to defer reduction because of the patient's poor general condition, fractures may be reduced one to three or more weeks later. Fractures treated late may require open reduction, removal of organized tissue from the fracture site, or an osteotomy; nevertheless, fractures can be successfully treated after periods of considerable delay.

**Emergency Treatment**

Establishment and control of the airway is the primary and most important consideration in the clinical management of the acutely injured patient. Asphyxia is a real danger in patients with injuries to the lower jaw or laryngeal region. The mouth should be cleared of broken teeth, clots, dentures, or foreign bodies that might be causing obstruction.
Traction on the mandible will pull the tongue and floor of the mouth forward in displaced fractures of the anterior portion of the body of the mandible, in which the tongue falls back into the pharynx. Protraction of the tongue with a suture, towel clip, or forceps may avert asphyxia. Placing the patient in a prone or a sitting position with the head down and forward is helpful in keeping the airway free of mucus and blood. The tongue is displaced forward by gravity, and secretions flow readily from the mouth.

**Airway**

**Emergency Tracheotomy.** When tongue protraction and clearing of the oral and pharyngeal airway do not relieve restlessness, air hunger, cyanosis, tracheal tug, retraction of the supraclavicular fossa, or retraction of the intercostal spaces and epigastrium, emergency tracheal intubation or tracheotomy is indicated.

In extremely urgent cases, when nasal or oral tracheal intubation is not feasible, the patient is placed on the floor or a table with the shoulders supported and the head extended and fixed. A coniotomy is done by incising transversely through the skin and the cricothyroid ligament (conic ligament) between the thyroid and cricoid cartilages.

An emergency low tracheotomy may be done in the following manner: The trachea is grasped between the fingers and the thumb; an incision is made quickly through the skin in the midline between thyroid cartilage and the sternal notch into the trachea, preferably below the cricoid cartilage; and a cannula, catheter, endotracheal tube, or tracheostomy tube is inserted to keep the opening patent.

**Elective Tracheotomy.** Early tracheotomy may be a life-saving measure in patients in whom the floor of the mouth, tongue, and hypopharynx become increasingly edematous and interfere with the airway. It should be performed routinely in patients with severe facial fractures associated with intracranial injuries. In some instances, the patient seem to have an adequate airway but maintains it only by sheer effort; he will be more comfortable and recover more quickly if an airway is established by means of a tracheotomy. The tracheal opening, in addition, provides a route by which general anaesthesia may be administered. In cases in which it is necessary to pack the nose and to wire the teeth in occlusion to maintain the reduced position of the facial bones, tracheotomy is invaluable in maintaining an adequate airway postoperatively. The tracheostomy tube may usually be removed in three to five days as the airway improves with subsidence of the edema.

Every surgeon who treats patients with severely injured facial structures should be well versed in the indications, technique, care, and complications of tracheotomy. Tracheotomy should preferably be an elective procedure, and as soon as any member of the surgical team feels that a tracheostomy is indicated, it should be done without delay. It is difficult to perform a tracheotomy as an emergency procedure at the patient's bedside. Delay of tracheotomy may result in death; on the other hand, if it is done hurriedly as an emergency measure, it may result in surgical complications.
Indications for Tracheotomy

1. Unrelievable obstruction of the airway in the region of the larynx or hypopharynx.

2. The probability of edema that might result in serious decrease of the airway above the larynx.

3. Intracranial injuries with difficulty in maintaining adequate ventilation by normal reflex activity or tracheal intubation.

4. Chest or high spinal cord injuries with loss of normal cough reflexes to clear the bronchial tree of fluids, blood, or secretions.

5. The possibility of prolonged postoperative airway problems.

Techniques of Tracheotomy

Coniotomy. This procedure is useful in extreme emergencies when time is of the essence. Coniotomy is performed by making a stab wound or passing a large-bore needle through the cricothyroid membranes (conus elasticus); although not recommended as a routine procedure, the coniotomy may be employed as a life-saving measure. The cricothyroid membrane lies superficially, and the overlying tissues are relatively avascular. When there is sufficient time to do an elective procedure, or when it is a semi-urgent situation under satisfactory conditions, the low tracheotomy is the operation of choice.

Low Tracheotomy. The low tracheotomy is made below the thyroid isthmus. The opening is generally made between the second and third or between the third and fourth tracheal rings. (See Technique of Elective Tracheotomy).

Positioning of the Patient. The patient should be placed in the dorsal recumbent position with the shoulders elevated. The neck is extended as much as possible so as to bring the trachea into proper relationship for entry. This is especially important in the short, fat, bull neck type of patient with heavy musculature. In these patients it is difficult, at best, to penetrate the surrounding soft tissue to enter the trachea.

Anesthesia. In the average patient, tracheotomy is relatively easy. The procedure can be done successfully under local anesthesia by infiltrating the skin and deep structures down to the tracheal level. Infiltration of the tissues with local anesthetic solution containing epinephrine (1:100,000) will permit operation with comfort to the patient. A minimum amount of bleeding from small vessels occurs if the operation is deferred for a few minutes after injection of the anesthetic solution.

The operation may be done under general anesthesia when indicated. Endotracheal intubation is desirable. When the trachea opening is complete, the endotracheal tube is retracted to the level of the tracheal opening, the tracheostomy tube is immediately inserted and the inner trochar removed. The anesthetic agent can then be administered through the tracheostomy opening if indicated.
**Technique of Elective Tracheotomy.** The elective operation is performed through a 5-cm transverse incision about 2 cm above the suprasternal notch. The incision should be planned to be directly over the tracheal opening. If possible, the incision line should be planned and marked with ink in the semireclining or sitting patient. This will assure one of making the skin incision directly over the tracheal opening and avoid irritation of the skin, dislodgement of the tube, or tension of the skin against the tube.

The incision is extended through the skin and subcutaneous tissues to the superficial fascia of the neck. Veins that may bleed should be clamped and ligated. The dissection in the midline should be made either by blunt dissection with scissors or by sharp dissection. The isthmus of the thyroid may be encountered after separation of the strap muscles of the neck; if it cannot be conveniently retracted, the isthmus is incised in a vertical direction. Large veins crossing the midline at the level of the tracheostomy may be retracted or divided and ligated. The deep fascia overlying the trachea comes into view, and the glistening cartilages are easily identified. The lower-most portion of the larynx is palpated, and the cricoid cartilage immediately below is identified. A sharp hook on each side of the trachea raises it into position for incision. The hooks securely engaged in the tissues stabilize the trachea for incision. Care in placing the hooks avoid rotation of the trachea. The opening may inadvertently be made off the midline unless care is exercised. The tracheal incision is made in the midline through the third and fourth tracheal rings, cutting upward with the knife so as to avoid cutting the transverse communicating veins. Guiding the depth of the incision with the finger will prevent tracheoesophageal fistula, especially in children.

Opinion varies regarding the need for removal of portions of tracheal rings. Many surgeons make a cruciate incision involving two rings in a vertical direction and a transverse limb between the tracheal rings. The cruciate incision offers exposure for the tracheostomy tube, which is anticipated to remain in place two to five days. When the tracheostomy must be maintained for a longer period, a section of the tracheal rings may be excised to provide a more easily maintained opening.

Some surgeons favor a vertical skin incision, feeling that under emergency circumstances quicker access can be obtained through a vertical incision than through a horizontal incision. We mention the vertical incision only to condemn it. The resultant scar is often objectionable and difficult to correct secondarily. Even under emergency circumstances, a transverse incision will give excellent exposure and in most cases will heal spontaneously without leaving an objectionable scar. Revision, if necessary, is accomplished successfully if the original incision has been made transversely.

A tracheostomy tube of adequate diameter and length with the trochar in place must be carefully inserted under direct vision. Tracheostomy tubes have been inadvertently placed in the fascial space of the neck alongside or in front of the trachea. If the tracheostomy tube is too long, it may irritate the carina or penetrate into one of the main stem bronchi. If the tube is curved too acutely, it may erode the anterior surface of the trachea or cause necrosis of the "party wall" and result in a tracheoesophageal fistula. Semiflexible silicone tracheostomy tubes cause less irritation and are less liable to result in complications than metal tubes.
After the tube has been inserted, it can be secured to the cervical skin by means of sutures, especially if the anesthesiologist tube is to be attached. It can be secured at the end of the operation by means of fabric tape tied around the neck. The fixation must be secure so that the tube cannot be dislodged from the trachea when the patient coughs or moves the neck. Blood and secretions are carefully aspirated from the trachea.

After insertion of the tracheostomy tube, the wound should not be allowed to close so tightly that air will have difficulty in escaping around the tube proper. If the skin is closed tightly, trapped air may pass along the fascial planes of the face and neck, resulting in troublesome subcutaneous emphysema. The wound is sutured loosely, leaving it funnel-shaped outwardly, so that air cannot be trapped in the subcutaneous tissues and fascial spaces.

**Postoperative Care.** Postoperative care of tracheostomy patients requires diligence, imagination, and enthusiasm. It is distressing to see a patient unable to make his wants known, with a tracheostomy tube partially plugged by mucus and crust and a dirty, infected wound and macerated skin about the area of tracheostomy.

The tracheostomy tube should be aspirated frequently with a sterile, disposable catheter to remove mucus, blood, and secretions. The wound should be well protected with gauze dressings changed as frequently as necessary to keep it dry and clean.

The tracheotomized patient is unable to speak. A pad of paper and a pencil at the bedside for adults are helpful in maintaining communication and give the patient a sense of security.

Humidified oxygen administered through a cuff over the tracheostomy stoma is routinely ordered. Humidification prevents drying of the respiratory mucosa, moistens the gases passing into the bronchi, and facilitates the removal of secretions.

Particular attention should also be paid to intermittently deflating the balloon of the cuffed tracheostomy tubes. If the tube has double balloons, they should be alternately inflated. Such care will prevent continuous mucosal pressure and the development of tracheal erosion and tracheoesophageal fistulas.

**Complications of Tracheotomy.** This seemingly simple, safe operative procedure is not without certain avoidable hazards and complications.

**Operative Complications**

1. Severe hemorrhage from vessels of the neck. This may be difficult to control is exposure is inadequate.

2. Inadvertent damage of the cricoid cartilage.

3. Acute tracheoesophageal fistula caused by cutting through the tracheoesophageal wall because of inadequate exposure and vision. This happens most often in children.

4. Pneumothorax due to damage of the apex of the pleura of one or both lungs.
5. Hemorrhage from the innominate artery or anomalous median thyroid artery.

**Postoperative Complications**

1. Secondary hemorrhage.
2. Subcutaneous emphysema.
3. Dislodging of the tracheostomy tube.
4. Reinsertion of tube outside the trachea.
5. Wound infection.
6. Erosion of the trachea.
7. Tracheoesophageal fistula.
8. Aerophagia. This may result in distressing abdominal distention, gastrointestinal atony, paralytic ileus, and death.
9. Recurrent obstruction from blood, mucus, and purulent materials in the tube.
10. Ulcerative tracheobronchitis.
11. Lung abscess.

**Delayed Secondary Complications**

1. Unsightly scar formation.
2. Adherence of the skin to the trachea.
3. Sloughing of tracheal cartilage with tracheal atresia.
4. Persistent tracheocutaneous fistula following long-standing tracheostomy.

**The Control of Severe Hemorrhage in Facial Wounds**

Lacerations and crush injuries of the facial region may result in near exsanguinating hemorrhage. Methods of control include local pressure with dressings, clamping and ligating large vessels, packing wounds with gauze or hemostatic materials, posterior nasal tamponade, and packing the nasal cavity, sinuses, and palate lacerations. The packs may be removed gradually in two or three days or as soon as the patient's general condition improves sufficiently to permit delayed repair. Approximation of the wound edges with a few well-placed sutures will often control bleeding. Careful final suturing can be accomplished later. External carotid ligation is rarely necessary to control bleeding from facial wounds.
Secondary bleeding is not frequently a problem in facial wound management but will respond to the methods mentioned for acute traumatic bleeding. Evaluation of circulating blood volume with replacement therapy if indicated should be done if blood loss has been significant. The patient may swallow several hundred milliliters of blood from severe nasal, oral, or pharyngeal bleeding. Frequent swallowing motions and epigastric distention may give a clue to this type of bleeding. Near exsanguinating hemorrhage may go unrecognized in patients who have persistently swallowed blood.

**Prevention and Control of Shock**

Impending shock or its presence is frequently noted in association with severe facial trauma. Pallor and clamminess of the skin, depressed blood pressure, feeble rapid pulse, shallow respiration, restlessness, anxiety, and disorientation or unconsciousness are signs of acute peripheral circulatory failure due to derangement of circulatory control or loss of circulating fluid secondary to injury.

Intravenous blood, colloids, electrolytes, and fluid replacement are given as indicated. Positioning of the patient with head down and feet up, sedation, pain relief, and control of haemorrhage is indicated in impending shock or in shock.

**Planning of Treatment**

Because of the complexity of facial injuries in patients with multisystem injuries, the team approach to the management of severe facial injuries has become popular in centers in which specialists in various disciplines are available. The overall plan should be coordinated by the surgeon in charge but should be devised with the cooperation of the neurosurgeon, ophthalmologist, otolaryngologist, and dental, orthopedic, and oral surgeons when their services contribute to the achievement of a satisfactory result. When all of the information and suggestions are available, the surgeon in charge should make the final decisions regarding treatment and see that the plan is executed with skill and expediency.

**Clinical Examination**

Careful clinical examination is indicated, even if the patient has only minor superficial wounds. These may be abrasions, contusions, or lacerations without evidence of any underlying bone damage. Lesions that appear to be inconsequential may result in a disfiguring scar or dysfunction if not adequately managed. Careful cleansing of the wound, debridement when necessary, and meticulous suturing may prevent conspicuous permanent deformity. Facial lacerations may extend into the eyes, nose, ears, or cranial cavity and may be associated with severe chest, spinal, abdominal, or extremity injuries. Concomitant injuries may require immediate, life-saving treatment, but when the patient is in reasonably good condition, the treatment of facial injuries can be undertaken concurrently with management of injuries in other parts of the body, without the need for an additional operative session and anesthesia.

**Classification of the Injury.** Wounds of the face and cranium may be classified into three categories: (1) wounds of soft tissue alone; (2) wounds of soft tissue associated with fractures; and (3) fractures without a soft tissue wound.
The soft tissue injury may be a clean, sharp laceration, a laceration with contusion, an abraded wound, a contused wound, an avulsed wound, a puncture wound, a gunshot wound, or a burn wound.

Bone injury is suggested by ecchymosis, edema, or superficial contusion or abrasion over a bony prominence. Subconjunctival hemorrhage with ecchymosis and edema in the region of the orbit suggests fracture of the nasal bones, zygoma, or frontal bone. Ecchymotic and contused tissues over the anterolateral surface of the mandible suggest fracture of the mandible.

Fractures of the facial bones may be diagnosed on the basis of malocclusion of the teeth or open bite deformity due to displacement of the maxilla or mandible. Functional disability suggests fracture of the mandibular condyle, and trismus may be caused by fracture of the zygoma or angle of the mandible. Unequal pupil levels and diplopia are indicative of zygomatic or maxillary fractures.

Bimanual palpation of the supraorbital, lateral, and infraorbital margins may reveal asymmetry indicating fracture of the maxilla. Fractured nasal bones are diagnosed by tenderness, irregularity, mobility, and crepitation on digital palpation. Mobility of the middle third of the face when the maxillary anterior teeth are grasped between the fingers and pressure is applied indicates pyramidal fractures (Le Fort II) of the maxilla and middle third of the face or craniofacial disjunction (Le Fort III). Bleeding from the nose may indicate nasal or septal injuries. Fractures of the body of the mandible can be detected by supporting the angle of the mandible and applying up and down manual pressure on the anterior portion of the mandible. Instability and crepitation may be noted when performing this maneuver.

When seen several hours following the injury, fractures may be difficult to diagnose clinically because of facial asymmetry from extensive edema or subcutaneous hematoma. In crushing injuries, associated basilar skull fractures and cribriform plate fractures should be suspected in the presence of cerebrospinal rhinorrhea, bleeding from the ears, paralysis of one or more of the cranial nerves, unconsciousness, unequal pupils, paralysis of one or more extremities, abnormal neurologic reflexes, convulsions, delirium, and irrational behavior.

Roentgenographic Evaluation

Roentgenograms are indispensable in the evaluation of a patient with head and face injuries. Complete cranial and facial bone roentgenograms should be obtained when indicated. Stereoscopic views are desirable, and tomograms may be useful in demonstrating fractures in the region of the mandibular condyle, blowout fractures in the orbital floor, orbital walls, deep orbital region, or cranial base.

Roentgenographic evaluation may be the most important single diagnostic aid. Even though the clinical evaluation may demonstrate obvious fractures and suggest a standard type of management, thorough roentgenographic examination should be made. It may be quite obvious, for example, that a patient has a fracture through the premolar region of the mandible on one side with mild malocclusion. It would be reasonable to apply rubber band traction or intermaxillary fixation to bring the teeth into occlusion.
Roentgenographic examination, however, may demonstrate a fracture of the condyle of the mandible on the opposite side. Even though the plan of treatment would be the same, the presence of the fracture should be known to the surgeon and to the patient.

Because of the high incidence of litigation arising from injuries, it is of prime importance to have thorough roentgenographic evaluation of all facial bone injuries. The legal position of the physician who treats injuries of this type without adequate roentgenographic examination may be in jeopardy.

In most instances, roentgenographic evaluation is only one of the means of establishing a diagnosis of fracture. In many cases, however, the roentgenogram provides the only evidence of a fracture. Clinically inherent limitations for demonstrating facial bone fractures by radiography are recognized. The extent and amount of displacement of the fragments is difficult to determine by roentgenography alone. In many views the fracture is partially or totally obscured by overlying or superimposed bone structures of the face, skull, or spine. The total clinical picture, in most cases, is more serious than might be suspected from cursory evaluation of the roentgenographic evidence alone.

Facial bone fractures are not infrequently associated with fractures of the skull or fracture-dislocation of the cervical spine. These structures should be included as part of the total evaluation. If the cervical spine is not demonstrated adequately by the routine views, separate roentgenograms of the cervical spine should be taken, inasmuch as fractures or dislocations of the cervical spine occur in association with severe facial injuries.

The standard routine views of the spine, mandible, and skull are generally adequate. The most valuable and most often employed views are the anteroposterior and lateral views of the mandible, detailed tomograms of the temporomandibular joints, and the facial bone studies, including the Caldwell and Waters views, which are the best to show fractures of the orbit, zygoma, and nasal bones. Fractures of the alveolar structures of the maxilla and mandible, including the teeth, are shown by detailed dental or occlusal views. Soft tissue profile views show edema accompanying the fractures. Occlusal views may be helpful in delineating fractures of the anterior maxillary and mandibular areas. Tomographic roentgenograms of the temporomandibular joints are useful in determining injury to the condyle and joint structures. Blowout fractures of the floor of the orbit and fractures in the region of the cribriform plate and base of the skull are best demonstrated by tomographic techniques.

Roentgenographic Positions

It is unnecessary for the surgeon to possess a detailed knowledge of roentgenographic techniques, but an understanding of the commonly employed roentgenographic projections will aid in the evaluation and interpretation of the roentgenograms. The roentgenographic views most helpful and informative in the diagnosis and management of fractures of the facial bones are demonstrated and briefly discussed in the following paragraphs.

The Waters Position. The posteroanterior projection is employed for an oblique anterior view of the upper facial bones; the orbits, the malar bones, and the zygomatic arches are well shown. This view if helpful in the diagnosis of fractures of the maxilla and maxillary
sinuses, the orbital floor and infraorbital rim, the zygomatic bone and zygomatic arches, and to a lesser extent the nasal bones and nasal process of the maxilla.

**The Caldwell Position.** The posteroanterior projection is primarily used for demonstration of the frontal sinuses and the anterior ethmoidal cells. The orbital margin, zygomaticofrontal suture, lateral walls of the maxillary sinuses, the petrous ridges, and the mandibular rami are also demonstrated in this projection.

**The Fronto-Occipital Anteroposterior Projection.** This view is used when injuries prevent examination of the facial bones with the patient in a prone or seated position. This projection gives a satisfactory view of the orbits, lesser and greater wings of the sphenoid, frontal bone, frontal and ethmoidal sinuses, nasal septum, floor of the nose, hard palate, mandible, and upper and lower dental arches.

**The Reverse Waters Position.** The mento-occipital position is also used to demonstrate the facial bones when the patient cannot be placed in a prone position. This projection is used to demonstrate fractures of the orbits, maxillary sinuses, zygomatic bones, and zygomatic arches. The increased part-film distance magnifies the upper facial structures, but otherwise the film is similar to that obtained with the Waters position.

**The Optic Foramen - Oblique Orbital Position.** This view is best demonstrated with stereoscopic projections and shows the optic foramen and its relationship to the posterior ethmoidal and sphenoidal sinuses. It also shows the lateral wall of the frontal sinuses, the vertical plate of the frontal bone, and the roof and lateral wall of the dependent orbit. Under a bright spotlight the lateral wall of the opposite orbit may be clearly defined.

**The Semi-axial (Superoinferior) Projection (Titterington Position).** The zygomatic arches, the facial bones, and orbits are well shown in this projection.

**The Lateral Anterior Projection (Fuchs Position).** This projection gives an oblique view of the zygomatic arch projected free of superimposed structures. The lateral wall of the maxillary sinus is also well shown in this view.

**Lateral and Profile View of the Face.** Stereoscopic projections are usually made of this view because of the complexity of the superimposed shadows of the face. This projection demonstrates the lateral profile of the facial bones and soft tissues of the face. This study is important in evaluation of maxillary-mandibular relationships and fractures of the vertical plate of the frontal bone.

**Nasal Bones, Lateral Views.** This projection gives a detailed view of the nasal bones of the side nearest the film and of the soft structures of the nose. Both sides should be examined radiographically. One view with this projection should be made with intensifying screens to show the frontal sinuses. Fractures of the nasal bones, the anterior nasal spine and the nasal processes of the maxilla are demonstrated in this view.

**Nasal Bones, Axial Projection.** The axial superoinferior view of the nasal bones is used to demonstrate medial or lateral displacement of the bony fragments which are not demonstrated on lateral views. The thin nasal bones do not have sufficient body to cast a
shadow through the superimposed frontal bone or the anterior maxillary structures. This view demonstrates only those portions of the nasal bones which project beyond a line anterior to the glabella and upper incisor teeth. The view is not helpful in children or adults who have short nasal bones, concave face, or protruding maxillary teeth.

**Superoinferior Occlusal Views of the Hard Palate.** Fractures of the hard palate area may be demonstrated by occlusal views with superoinferior projections with the X-ray tube focused and angled to demonstrate the area of interest.

**Superoinferior Central Occlusal View of the Hard Palate.** This demonstrates the palatine processes of the maxilla and the horizontal plates of the palatine bones and the entire dental arch.

**Superoinferior Anterior Occlusal View of the Hard Palate.** This projection gives a view of the anterior part of the hard palate, the alveolar process, and the upper incisor teeth in greater bony detail than the previous view because the obliquely focused central ray does not penetrate any superimposed bony structures.

**Oblique Superoinferior Posterior Occlusal View of the Hard Palate.** This projection gives an oblique occlusal view of the posterior part of the hard palate unilaterally and the alveolar process and all of the teeth on the upper quadrant of the maxilla. Fractures of the teeth or alveolar process may be demonstrated by this view.

**Submentovertex and Verticosubmental Positions for the Base of the Skull.** These views give an axial projection of the mandible, the coronoid and condyloid processes of the rami of the mandible, the zygomatic arches, the bases of the skull and its foramina, the petrous pyramid, the sphenoidal, posterior ethmoid, and maxillary sinuses, and the bony nasal septum.

**Occlusal Inferosuperior Views of the Mandible.** Medial or lateral bony displacement in anterior mandibular fractures is well shown by occlusal inferior-superior views of the mandible. This view affords good bony detail of the entire lower dental arch, the mandibular body, the symphysis, the lower alveolar process, and the teeth.

**Occlusal Inferosuperior Projection.** This projection is used to demonstrate mesial or lateral displacement of fragments in fractures of the anterior portion of the mandible.

**Oblique Inferosuperior Projection.** This projection gives an oblique occlusal view of the anterior mandibular area showing the symphysis, the alveolar process, and the incisor teeth. The bone detail is excellent, and fractures of the symphysis region, alveolar process, or teeth can be well demonstrated.

**Oblique Superoinferior-Submental Projection of the Mandibular Symphysis.** This view gives an oblique anteroposterior projection of the mandibular symphysis.

**Oblique Lateral Views of the Mandible.** These positions are used to demonstrate fractures of the mandibular ramus, the body of the mandible, and the symphysis region.
The Body of the Mandible. This projection provides a lateral view of the mandible posterior to the cuspid tooth and including a portion of the ramus of the mandible.

The Ramus of the Mandible. This posteriorly directed oblique lateral view shows fractures of the ramus, the mandibular condyle, the condylar and condyloid processes, and the posterior body of the mandible.

The Symphysis of the Mandible. The anteriorly directed oblique lateral projection of the symphysis of the mandible demonstrates fractures of the symphysis of the mandible, the region of the mental foramen, and the body of the mandible.

Posteroanterior View of the Mandible. Medial and lateral displacement of fractured segments of the mandible may be demonstrated by this view. It demonstrates the symphysis, the body and rami of the mandible, the condyloid and coronoid processes, and the temporomandibular joints.

The Temporomandibular Joints

Oblique Anteroposterior, Fronto-Occipital View of the Temporomandibular Joints. This projection provides an oblique posterior view of the condyloid processes of the mandible and the mandibular fossae of the temporal bones, the petrous bones, the internal auditory canals, the occipital bone, the posterior cranial fossa, and the foramen magnum. Fractures in the region of the temporomandibular joints with displacement medially or laterally can be detected in these views.

Lateral Transcranial Projection. Oblique Lateral Views of the Temporomandibular Joints. The views are taken by the lateral transcranial projection and demonstrate the temporomandibular joints in open and closed mouth positions. The closed mouth view demonstrates the temporomandibular joint, the relation of the mandibular condyle to the fossa, and the width of the joint cartilage. The open mouth view demonstrates the excursion of the head of the condyle, downward and forward, in relation to the glenoid fossa and tubercle. This projection is useful in demonstrating fractures and dislocations of the mandibular condyle and the condylar process. The external auditory meatus and mastoid processes are also demonstrated.

The Mayer View. The temporomandibular joint, external auditory canal, mastoid process, and petrous pyramid are shown in the unilateral superoinferior view. Medial or lateral displacement of the bony fragments of the mandibular condyle can be shown by this projection. Fracture-dislocation of the bony portion of the external auditory canal can also be demonstrated by this technique.

The panoramic roentgenogram is a helpful aid in defining the location and displacement of mandibular fractures.

Tomographic evaluation of the temporomandibular joint is discussed in Chapter 31 and that of the orbit in Chapter 25.
General Considerations in the Definitive Treatment of Facial Injuries

Prophylaxis Against Tetanus. All facial wounds are potentially contaminated, and even though they occur under what might seem to be clean conditions, it is advisable to take active measures against the possibility of the development of tetanus. The efficacy of immunization with toxoid was well demonstrated by the low incidence of tetanus reported by the U.S. Army in World War II; only one case developed in the European Theater by February 1945 (Graham and Scott, 1946). In the civilian population, most individuals have been actively immunized by their family physician or while in the military service. They should have their serum antibody levels raised by administration of a toxoid booster. If a patient has not been immunized, simultaneous intramuscular injection of 250 units of Hypertet (tetanus antitoxin human) and 0.5 mL tetanus toxoid is recommended. Two additional tetanus toxoid boosters should be given at monthly intervals to complete the immunization.

Treatment of Soft Tissue Wounds. Contusions, abrasions, and lacerations are not life-threatening, but many facial wounds are complex and compound. The more serious ones not only may involve the superficial structures but also may extend into the cranium, orbit, nose, sinuses, or mouth; may affect the seventh cranial nerve, the salivary ducts, or salivary glands; and may be associated with or extend into fractures of the mandible, maxilla, zygoma, nasal bones, orbit, frontal bone, or cranium.

Most civilian wounds occur under relatively clean circumstances, and, with modern techniques under antibiotic coverage they can be treated primarily up to 24 hours following injury. Because of the excellent blood supply of the face, the period from injury to surgery can be extended in clean-cut lacerations. The timing depends upon the judgment of the surgeon, however, and when there is obviously marked contamination with crushing and contusion, delayed primary repair is indicated. The probability of contamination increases rapidly and is directly proportional to the length of time that has elapsed since the time of injury.

Careful examination and evaluation of the wound should be made before any treatment is undertaken. Fractures of the underlying bone should be detected and in many cases treated prior to the soft tissue management. If the fractures are exposed through soft tissue lacerations, it is advisable to ensure fixation of the fractures through the open wound before closing the soft tissues. Injuries to important nerves, ducts, glands, and sinuses require consideration prior to soft tissue closure.

Delayed Primary Wound Closure. When the patient is seen late with extensive edema and subcutaneous hematoma, and when the wound edges are badly contused and some of the tissue devitalized, it is preferable to delay wound closure until conditions for primary healing are more favorable. Limited debridement to remove devitalized tissue, wet dressings, and antibiotic therapy should be the program of treatment until the resolution of edema and acute inflammation and a cleaner appearance of the wound indicate that delayed primary closure will be successful.

The large canine population has resulted in a number of dog bites, particularly in children. An essential precaution, prior to primary suture, is irrigation of the wound with large
amounts of saline. Canine saliva contains necrotizing enzymes; the enzyme will produce continuing necrosis of the tissue in the wound if it is not evacuated.

**Cleaning of the Wound.** All wounds should be carefully inspected for foreign material, and removal of substances such as metal, wood, gravel, dirt, coal, dust, cinders, and powder is imperative to prevent suppuration, delayed healing, and subsequent pigmentation. The wound can be cleansed with detergent soaps and water. In some cases ether, benzene, and alcohol may be necessary to remove materials not soluble in water. Scrubbing with a brush under anesthesia may be required to remove deeply imbedded foreign bodies and to prevent the development of a traumatic tattoo.

**Photography.** Modern simplified methods of photography make it possible to obtain an accurate photographic record of the patient throughout the course of treatment. Good photographic records are important for insurance and legal purposes. Photographs supplement the written word and enhance the value of medical records. Photographs help the surgeon assess the effectiveness of his therapy by providing a means of review of each case at its termination. The adage that a good photograph is worth a thousand words is in no instance more true than in facial injury cases. Photographs may be worthless unless taken with care and consideration as to lighting, positioning, and composition. In order to adequately show facial lacerations, contusions, and abrasions, the patient should be thoroughly cleansed of dirt, blood, and debris, and overlying clothing and dressings should be removed before the photograph is taken.

For effective use, photographs should be identified with the patient's name, age, and diagnosis, and the date and filed with the patient's record or cross-filed as to diagnosis so that they are readily available for coordinated evaluation and summary of the total treatment.

**Instrumentation for the Treatment of Facial Injuries.** To facilitate the care of facial injuries, a carefully selected high quality armamentarium is essential. A tray of instruments selected and reserved for the care of facial injuries is recommended. It is distressing at the operating table to find that one or more essential instruments are missing from the set-up. To avoid delay and frustrations, a kit of instruments including the materials usually employed in the management of facial soft tissue and bone injuries should be available for ready sterilization at all times. The instruments should be kept in good repair so that the procedures can be performed without annoyance by mechanical problems.

General surgical instruments are available in all operating rooms and consist of basic instruments used in all operations, such as knife handles, hemostats, and suture scissors. A loose-leaf book containing lists of instruments and photographs of instrument table arrangements for various operations done by each surgeon should be available for use by the operating room nurses. Selection and inclusion of all necessary instruments in the set-up before the operation is started will save time at the operating table. Each surgeon has favorite instruments or specially designed instruments for various operations. These should be included in the armamentarium.

**Preoperative Considerations.** The patient should be in the optimum conditions for operative procedures on facial structures. Correction of shock, hypovolemia, dehydration, and electrolyte imbalance should precede all procedures except emergency care. Diabetes should
be under control or well covered by the use of insulin and the patient covered with steroids if indicated. Patients with rheumatic or valvular heart disease should be protected by preoperative and postoperative antibiotic therapy. It is advisable to share the responsibility of the patient's general welfare with an internist who may have valuable suggestions in general management.

Anesthesia

General Anesthesia. The use of local or general anesthesia or a combination of the two depends upon the desires and ability of the surgeon, the general condition of the patient, and the facilities available. The extent of the injuries, the general condition of the patient, and the psychologic reaction to surgery in most cases dictate the use of general anesthesia. General anesthesia is usually indicated because the tissues are hypersensitive, and prolonged operative procedures or manipulation of the facial structures may be distressing to the patient under local anesthesia.

Although general anesthesia is preferable for the management of extensive facial trauma, there may be competition for working space owing to the presence of anesthetic equipment in the operative field. A skilled anesthesiologist is needed for the administration of the general anesthesia under these difficult circumstances, and frequently when local anesthesia is utilized, he can offer assistance by the judicious use of intravenous sedative drugs as a supplement to local anesthesia.

Endotracheal transnasal anesthesia is usually satisfactory for the reduction and fixation of fractures of the maxilla and mandible in which the nasal passages are not involved. Endotracheal anesthesia with oral intubation is indicated for fractures of the upper facial area in which it is not necessary to establish intermaxillary fixation. When there is involvement of the mandible, maxilla, and nasal and other facial bones, preoperative tracheotomy under local anesthesia and the administration of an anesthetic agent through the tracheostomy tube are the methods of choice. Anesthesia by this method permits reduction and fixation of the facial fractures, wiring of the teeth, packing of the nose, and application of splints, head frames, and other appliances without concern for airway obstruction during the course of the operation. Postoperative edema of the mouth, neck, and hypopharyngeal area may also present problems if a tracheostomy has not been performed.

Local Anesthesia. An attitude of reassurance, understanding, and sympathy, together with adequate premedication, will permit extensive operations under local anesthesia. Less complicated wounds such as small cuts, bruises, lacerations, and uncomplicated fractures of the facial bones can often be treated under local anesthesia in the operating room or an outpatient treatment room.

Adequate premedication is imperative with the use of local anesthesia. The dosage of the selected drug varies with the patient's age and weight. The elderly patient usually requires less premedication. If excitement occurs during surgery, additional sedative medication may be given intravenously.

Local anesthesia is the method of choice in the repair of most soft tissue lacerations. This can be given skillfully without discomfort to the patient if a small, sharp needle is used.
The first insertion can be made with minimal discomfort with a 30-gauge needle. Subsequent insertions are made only into already anesthetized areas. In open wounds, pain can be minimized by injection through the wound.

The most effective anesthetic solution at present is lidocaine (Xylocaine), 1 per cent, with 1:100,000 epinephrine. If over 60 mL will be required, the solution may be diluted with equal amounts of balanced saline solution, which will result in a 0.5 per cent solution with 1:200,000 epinephrine. If injected properly this will give anesthesia and satisfactory vasoconstriction if a waiting period of 10 to 15 minutes is permitted before commencing the operation. Infiltration or block anesthesia containing vasoconstrictive drugs is satisfactory and effective for most operative procedures. If the patient's condition contraindicates the use of a general anesthesia, even extensive facial fractures can be operated upon under moderate sedation with gasserian ganglion block or fifth nerve division blocks along with cervical block. In cases in which distortion of the soft tissues due to local injection of anesthetic solutions may be a disturbing factor, local nerve block may be effective. Block anesthesia can be employed in the region of the mandible where the inferior alveolar nerve or the mental nerve may be injected, or into the greater palatine foramen where infraorbital and zygomaticofacial nerve blocks will provide regional anesthesia without distortion. Injection of the supraorbital and frontal nerves suffices for forehead and anterior scalp repairs.

Repair of Soft Tissue Wounds of the Facial Area

Debridement and Care of Soft Tissue Wounds. Thorough, careful cleansing of all soft tissue wounds is imperative before attempting any definitive treatment. All blood and debris should be carefully washed from the tissues by utilizing copious amounts of water and mild detergents. Foreign materials such as glass, hair, clothing, tooth structures, pieces of artificial dentures, paint, grease, gravel, and dirt should be removed. Usually detergent solutions and water will clean the wound adequately. However, in some cases, dirt, carbon, tar, grease, asphalt, etc., may be ground deep into the soft tissues. If permitted to remain, a pigmented scar will result or infection will ensue. Careful scrubbing of the wounds with handbrush or toothbrush under anesthesia may be necessary to remove foreign material. Dermabrasion over the area will facilitate the removal of intradermal foreign bodies. The use of ether or benzene as a solvent for grease and tar may be necessary.

Careful preoperative attention to these details will avoid infection, faulty healing, scarring, and the need for secondary repair.

In blast injury, minute particles of debris may be forced into the face. These particles should be carefully and individually removed with small curettes. This is a time-consuming procedure, but it assures better end results.

Except for the removal of obviously devitalized portions of tissue, debridement has no place in the management of facial injuries. All tissues that may participate in a satisfactory repair should be retained if there is any possibility of residual vitality in the structures. It is preferable to err on the side of retaining tissues that may not survive than to debride or destroy any tissues that might be important in the final reconstruction. The excellent blood supply of the face makes extensive debridement unnecessary and will permit the survival of
tissues retained by only a small pedicle. Wounds of the same magnitude in other areas would necessitate a more radical debridement program.

Pieces of tissue almost completely detached and some small structures that have been avulsed can be sutured back into position as grafts. Many of them will survive. This is useful and practical only in places where reconstructive procedures are unusually difficult, such as the eyelid margin, the ala and tip of the nose, or a segment of the ear. Cooling of the reapplied part may be employed in the postoperative period.

**Abrasions.** Care should be exercised in the management of abrasions even though the injury may be superficial, since many of these contain dirt. When first seen, a child with superficial abrasions may not appear to have an injury of consequence. Upon healing, it may be discovered, however, that there is a pigmented residual defect. Dirt, grease, carbon, and other pigments should be carefully scrubbed out of the wound and a light grease dressing applied. This will avoid accidental or traumatic tattoos which result in considerable cosmetic disability.

**The Contused Wound.** Contusions usually result in extensive edema, ecchymosis, and hematomas which generally subside without active treatment. Subcutaneous hematomas, even though large, will usually absorb gradually, leaving no residual deformity. Contusions may be associated with lacerations and may retard healing. The final results may be inadequate, and secondary repair may be required.

**The Lacerated Contused Wound.** The contused margins of the lacerated wound should be excised. This will lead to earlier, less complicated healing with a superior end result. If the contused marginal tissues are of anatomical importance, it is best to avoid debridement and perform secondary definitive surgery as necessary. This is especially important in eyelid, ear, and nasal alar wounds in which sacrifice of any of the tissues might jeopardize the result.

**Deep Lacerations.** Lacerations caused by sharp, clean objects, such as a knife, windshield, flying glass, or sharp metal, may extend through all the layers of the soft tissues and may involve important muscles, nerves, glands, and ducts. The muscles of facial expression are so closely associated with the skin that careful closure of the wound in layers will give adequate approximation. Muscle layers should be identified, if possible, and accurately approximated with fine sutures. Lacerations of the muscles of mastication occur, but complete severance is uncommon. Closure of the muscles in layers, including the overlying fascia, restores adequate function.

It is impractical and unnecessary to identify and suture the terminal branches of the facial nerve. Usually, with reasonably accurate approximation of the tissues, the nerves will regenerate and function will return within 12 to 18 months, if not earlier. If the seventh nerve is severed in the parotid gland, care should be taken to identify and suture the major branches. The branches distal to the laceration can be identified with the help of a faradic nerve stimulator during the first three days after severance of the nerves; no response can be elicited after three days, and the nerves must be located by careful dissection with the aid of binocular magnifying loupes. Dissection of the proximal portion of the nerve is also necessary in order
to identify it and to permit approximation with fine sutures under microscopic aid. Every
effort should be made to approximate the large segments of the seventh nerve.

The sensory branches of the fifth nerve in the region of the skin are small, and
approximation is impractical and unnecessary. Recovery of sensation usually occurs within
a few months to a year.

**Parotid Duct Lacerations.** Laceration of the parotid duct should be repaired at the
time of the wound closure to prevent parotid fistula to the skin surface or to the mucous
membrane of the mouth. The latter is not significant, but a parotid fistula to the skin is an
annoying lesion. To identify the course of the parotid duct, a line is drawn from the tragus
of the ear to the midportion of the upper lip. The duct traverses the middle third of the line.
Any laceration extending deeply through this area should be suspected of having damaged the
parotid duct. Injury can be identified readily by passing a small Silastic tube or silver probe
into the opening of Stensen's duct, which is opposite the upper second molar tooth. A tube
or probe can be passed through the duct, and if it appears in the wound, it indicates severance
of the duct. The proximal end of the duct is then identified by expressing saliva, and the tube
is passed into it as far as possible and left in the duct as a splint. An adequate number of
sutures are placed in the substance of the duct to approximate the severed ends around the
Silastic catheter. The tubing is cut with the end protruding into the mouth and sutured
securely to the mucous membrane so that it cannot be accidently dislodged. The catheter is
removed in five to seven days with reasonable assurance that the duct will remain patent.

If Silastic tubing is not available, a 2-0 nylon suture on a large needle can be passed
through the substance of the cheek into the duct near the point of laceration, out through the
lacerated area into the duct on the proximal side, and brought to the surface of the skin. The
suture will act as a splint, and the duct can be repaired by suturing. The wound is then closed
in layers, and the 2-0 nylon suture is tied loosely over the skin area.

The buccal branch of the seventh nerve traverses the face along the course of Stensen's
duct and is usually severed if the duct has been lacerated. If the facial laceration is closed
without repair of the parotid duct, the parotid duct syndrome may be evident after a few
hours. This is indicated by the presence of paralysis of the muscles of expression to the upper
lip, swelling at the site of the wound closure due to pooling of saliva under the skin surface,
or draining of saliva between the sutures.

**Lacrimal System Lacerations.** Lacerations near the medial canthus may sever the
canalculi or damage the sac or other parts of the lacrimal system. If a canalculus is severed,
the severed ends are sutured over Silastic tubing using visual magnification with loupes or
a microscope (see Chapter 28).

**Submaxillary Duct Injuries.** The submaxillary duct is not often injured in fractures
or soft tissue injuries unless there is a comminuted type of fracture or gunshot wound to the
floor of the mouth. Repair of the submaxillary duct is unnecessary. If unrepaired, a fistula into
the floor of the mouth usually results. Scar with obstruction of the duct may require
reestablishment of the duct opening or excision of the submaxillary gland.
Injuries of the Soft Tissues of the Orbit. The eye should be carefully inspected for abrasions or lacerations of the cornea or puncture of the globe. In all severe injuries in the orbital area, consultation with an ophthalmologist is desirable in order to detect intraocular injury. An ophthalmologist may not always be immediately available. Visual function should always be checked prior to treatment of a deep laceration or fracture of the orbit region, because decrease or loss of visual function should be verified preoperatively in order to avoid litigation after the treatment is completed. Miller and Tenzel (1967) have reported a number of simple tests that can be done in the emergency room. Reading a newspaper (the elderly patient wearing his presbyopic correction glasses), the finger counting test (in four quadrants), and the Marcus Gunn pupillary sign are practical means of determining visual function. In the Marcus Gunn test, each pupillary response to a hand-light is sought. If the response is normal on both sides, the light is moved rapidly from one side to the other. If conduction of the optic nerve is lesser on one side, the pupil will appear to dilate as the light is moved from the sound eye to the involved eye. These simple tests are helpful but should not preclude a careful ophthalmologic examination. Eyelid and associated injuries deserve priority in the scale of the patient's wounds, including those away from the facial area. Lacerations through the eyelid margins require a special technique for repair if a serious cosmetic and functional disability is to be avoided (see Chapter 28).

Lacerations of the Nose. Lacerations of the nose may involve the skin, the lining in the vestibule of the nose, or the mucous membrane of the nasal cavity, most commonly at the junction of the bone and the cartilages. The blow may produce sudden telescopic movements of the soft tissues which are sheared off at their attachments at the bony nasal margin. A thick, boggy, edematous septum may indicate a hematoma, and a septal cartilage laceration may be seen through a tear in the mucoperichondrium. Intranasal suturing following reduction of the soft and bony structures approximates the lacerated margins. Intranasal lacerations usually need no suturing, as intranasal packing will hold the soft tissues in their proper relationships. The skin of the nose heals well, and even in cases involving extensive lacerations, the final scars are minimal.

Avulsions of the section of the nose near the tip and ala may be repaired by means of the original piece of skin and cartilage if it is available. If the severed tissue is recovered and thoroughly cleansed with saline, it may be sutured into position. In many cases, healing occurs uneventfully, and an important anatomical structure that otherwise might be difficult or impossible to reconstruct can be saved.

Avulsed Wounds of the Facial Area. If the wounds cannot be closed because of avulsion and loss of soft tissue, dressing of the area with a split-thickness skin graft provides immediate closure and avoids infection and prolonged dressing care. Full thickness losses of nasal alar tissue can be repaired by the use of composite grafts from the ear margin as a primary procedure. These grafts will survive if no part of the graft is more than 1.0 to 1.5 cm away from the nutrient bed (see also Chapter 29).

Lacerations of the Lips. Lacerations of the lips may involve only the superficial skin and subcutaneous tissues or may extend into the muscle and, not infrequently, involve the mucosa. Bleeding may be profuse if the labial arteries are severed. Pressure or clamping and tying the vessels will control hemorrhage without difficulty. Repair consists of suturing the structures in layers utilizing absorbable sutures for the deep mucosal structures. Accurate
approximation of the muscle, the vermilion-cutaneous margin, the vermilion-mucosal margin, and the skin is necessary to assure adequate function and appearance of the lip. After careful and thorough cleansing, the lip structures should be closed in layers beginning at the deepest layer and working outward to the skin. Every effort should be made to approximate the musculature in its normal position. The vermilion-cutaneous margin and the mucosal margins are landmarks from which to begin suturing. Inadequate or inaccurate approximation of the vermilion-cutaneous margin leaves a noticeable defect.

Injuries of the Auricle. The ear may be involved in abrasions, contusions, and lacerations. Usually the abrasions heal, and application of a light dressing with moderate pressure will usually control the hemorrhage and prevent subsequent perichondritis and deformity.

Lacerations of the auricle are usually associated with lacerations of the cartilage. The ear may be totally or incompletely avulsed. Even with small pedicle attachments, the ear will usually survive if it is carefully sutured into place and adequately supported with dressings. A few fine catgut sutures to approximate the cartilage will give stability to the ear. Accurate placement of nylon sutures in the skin margins produces excellent results with minimal postoperative deformity.

Avulsion of small or moderate-sized segments of the auricle can be adequately repaired by replacement with composite grafts. Subtotal and total avulsion of the auricle is discussed in Chapter 35.

Care of Extensive Soft Tissue Wounds with Loss of Structure and Tissue. Loss of tissue may preclude wound closure. If an extensive wound, such as one that is produced by gunshot injury, cannot be treated by means of a skin graft or by rotation of tissue from the immediate area, the mucous membrane of the mouth or nasal cavity should be advanced to the skin margin and secured with sutures. By primary closure, infection, delayed healing, and scar contracture will be prevented. Early healing will facilitate the definitive repair and minimize the postoperative dressing problem. Every effort should be made to cover the bone ends with adjacent tissues to prevent infection and necrosis.

The most satisfactory results from repair of facial lacerations are seen in those cases in which the laceration parallels the lines of minimal tension, which are parallel to the expressive skin folds of the face. Fortunate is the patient who has lacerations running in the right direction. The final results may be less than optimal when the lacerations run at right angles or at variance with the lines of minimal tension.

In clean lacerations vertical to the skin surface, it may only be necessary to approximate the tissues to obtain a satisfactory result. When the laceration runs tangential to the skin surface, it is necessary to excise the wound margins at right angles, or slightly less, to the skin surface (Straight, Lawson and Hipps, 1961). Careful debridement of the contused margins will hasten healing and minimize chances of a conspicuous scar developing. Excision should be conservative, usually not more than 1 or 2 mm into the unaffected skin. The wound must be changed from one of traumatized, uneven margins to one with clean, sharp edges. The margins of the wound must be undermined or undercut sufficiently to prevent undue
tension on the wound margins and to permit closure of the wound in layers with subcutaneous sutures.

The undermining should not produce distortion of adjacent features, such as the angle of the mouth or the ala of the nose. Undermining may be more extensive on one side of the wound than on the other to avoid damage to vessels, nerves, or other important structures. Excision of excess fat and subcutaneous tissues will relieve tension of the wound margins and permit eversion of the skin edges.

Buried fine, clear, nylon or catgut sutures provide subcutaneous fixation with minimal reaction. Sutures should be placed close enough to relieve all surface wound tension. Interrupted sutures, if used, must be carefully placed and tied without undue tension to avoid suture marks. Interrupted surface sutures should not be used patients who are subject to the formation of scars.

The subcuticular suture is excellent for skin closure, as it provides adequate approximation of the tissue margin and can be left in place for three to four weeks without fear of a reaction or leaving suture marks.

Use of fine caliber suture material and atraumatic needles is desirable in facial wounds. Catgut sutures should not be used on the skin surface for the repair of skin wounds, as the cosmetic result is important. These materials cause a foreign body reaction which results in increased inflammation and scar tissue formation.

Sutures placed through the skin surface should be tied at the proper tension so that edema will not cause them to cut through and leave suture marks. Suture marks are caused by thin sutures tied too tightly or by sutures left in the tissue too long. Surface sutures should be removed on the third or fourth day and the wound supported with adhesive strips fixed across the wound.

If the wound is long and has been sutured with interrupted sutures, a few sutures should be removed and the wound support with transverse strips. A few more sutures are removed and another strip applied, and so forth, until all of the sutures have been removed. The supporting strips are maintained for a period of two to three weeks until the tensile strength of the wound will better withstand the adjacent skin tension.

The Nonsuture Technique of Wound Closure. Gillman, Penn, Bronks, and Roux (1955) proposed that simple approximation of wound margins by use of adhesive tape would be an atraumatic, biologically sound method of wound closure. The nonsuture technique would eliminate the usual disadvantages of surface sutures. This technique has been applicable to the treatment of small superficial wounds for many years, but lack of suitable material for firmly approximating large wounds has prevented its adaptation to large wounds. Superficial wounds, especially in children, respond very well to approximation with commercially available sterile adhesive strips.

Dunphy and Jackson (1962) advocated the use of a plastic tape which has the quality of porosity and semitransparency; it is nonirritating and can easily be lifted off the skin. The material provides strong resistance to traction in the lateral direction. The authors reported that
this tape has practical value for wound closure in a wide variety of operations. Adhesive strapping gives uniform approximation of the tissue margins and eliminates the trauma from sutures. Tapes can be left in place for two to three weeks if indicated, and scar formation is avoided by the lack of lateral pull on the incision.

Dunphy and Jackson states that there are two phases in gaining tensile strength of the wound: an initial phase of approximately two weeks' duration during which no more than 10 to 30 per cent of the ultimate strength of the wound is obtained, and a second phase, dependent upon function, which may last six weeks, three months, or indefinitely. The first phase in the gain of tensile strength is related to the laying down of collagen, while the second is related to an alteration of the physical state of the collagen fiber (see Chapter 3).

**Dressings.** Dressings are applied to the wound to relieve tension, to prevent dead space and hematoma formation, to apply pressure for control of oozing or postoperative bleeding, or to provide splinting action for the wound. Dressings vary with the problem and may be individualized to meet the needs. Adhesive strips stuck to the skin will provide support at the wound edges. Light pressure may be applied by the use of elastoplast or an Ace-type bandage. If hematoma or unusual edema is a possibility, elastic pressure bandages must be placed with care and frequently observed to prevent undue pressure and possible necrosis.

Gauze lightly impregnated with petrolatum or xeroform and placed over the wound for the first 24 hours will prevent blood clots and serum from crusting about the sutures. At the end of 24 hours the wound should be carefully inspected, and any tight sutures which seem to be cutting the skin should be cut at the knot but not necessarily removed.

Most wounds in the facial area can be left exposed without danger of contamination. This permits aeration of the wound and an opportunity for frequent inspection.

With meticulous care, the primary procedure in most instances will be the definitive procedure.

**Multiple Small Glass Cuts.** A patient who has been injured by multiple pieces of flying glass or whose face struck a shattered automobile windshield may have hundreds of small, tangential, slicing lacerations. It is obvious that all of these cannot be debrided and sutured, and this is unnecessary. The debris and foreign material should be carefully scrubbed out of the wounds. Those wounds that are significant should be sutured. Surface irregularities, if present after a few months, usually respond to surgical abrasion treatment, as first described by Iverson (1947) (see Chapter 17).
Fractures of the Jaws

The Importance of Teeth in the Management of Fractures of the Jaws

**The Dentition.** The deciduous teeth begin to erupt at five or six months of age. The lower central incisors are generally the first to be noted. By the age of 20 to 24 months, the child has total of 20 teeth: 10 upper and 10 lower. This is known as deciduous or temporary dentition. At the age of six, in addition to the temporary dentition, the first permanent or six year molars erupt behind the second deciduous molars. At the age of seven, the maxillary and mandibular central incisor teeth are replaced by the permanent teeth. At the age of nine, the permanent lateral incisors have erupted. At the ages of 10 to 11, the deciduous molar teeth are replaced by the permanent premolar teeth. At ages 12 and 13, the second permanent molar teeth come into position and the deciduous canine teeth are lost and replaced by the permanent canine teeth. At the age of 14, usually all of the deciduous teeth have been exfoliated and replaced by the permanent teeth and the first and second permanent molars in all quadrants are present. The third molars are missing, impacted, or unerupted in some but erupt in most persons after 16 years of age.

If all of the permanent teeth have erupted, the adults has 32 permanent teeth, 8 in each quadrant.

**Dental Occlusion.** The grinding or incising surfaces of the teeth fit or mesh together into what is known as the occlusion. In normal occlusion the lower arch is smaller than the upper arch and the lower teeth fit just inside the outer surface of the upper teeth. A knowledge of dental occlusion is helpful in the management of facial fractures. A brief study of the mouth of the normal patient will orient the surgeon to the average occlusal relationships. Examination of a nurse or colleague or resident assistant will suffice to remind the examining physician of gross occlusal relationships.

The examiner must be on the alert for abnormalities or deviations from the accepted normal, which for the patient may be his preinjury physiologic occlusion. The preexisting occlusion is easily recognized. Obviously, if the patient had a protruding lower jaw - Class III malocclusion - before injury, it would be impossible to obtain adequate reduction of fragments by attempting to force his teeth into neutroclusion.

Class I occlusion or neutroclusion is that in which the mesiobuccal cusp of the upper first molar occludes with the mesiobuccal groove of the lower first molar. The protruding or jutting type of jaws is known as Class III malocclusion (mesioclusion), and the retrusive jaw or the underdeveloped jaw is Class II malocclusion (distoclusion). In addition, there are abnormalities in a lateral direction generally referred to as crossbite or laterognathism.

In the injured patient in whom teeth or segments of bone are missing, it may be difficult to determine what the normal occlusal relationships should be. Usually the patient is not helpful in advising the physician about the preexisting occlusion. Information may be obtained from the patient's dentist, who may have taken X-ray films or casts of the dentition (often referred to as "models") prior to the patient's injury. In older patients, abrasion marks on the teeth may give a clue to the preexisting occlusion. The patient who has had neutroclusion shows worn surfaces on the outer edge of the lower anterior teeth and on the
undersurface of the maxillary anterior teeth. The patient with a severely retruded jaw usually will have no wearing of the incisal edges of the lower anterior teeth. The patient who has a protruding lower jaw may have worn surfaces on the outer anterior edge of the maxillary teeth. If the patient has premolar and molar teeth in large segments of the upper and lower jaw, these teeth usually fit into the contours of the opposing teeth. Dental consultation may be helpful in determining the preexisting occlusion.

Inasmuch as the restoration of function is important in the rehabilitation of the patient, it is necessary that the teeth be brought into the best possible occlusal relationship, so that an adequate chewing surface will be restored following reduction, fixation, and consolidation of jaw fractures.

The Dentoalveolar Process. The teeth are intimately associated with the main body of the mandible and maxilla and are held in place by supporting alveolar bone. The alveolar bone is dense on its cortical surface, with a medullary portion supporting the teeth which is highly vascular and spongy in character. Following loss of all of the permanent teeth by extraction or disease, the alveolar portion of the bone usually undergoes atrophy of disuse, with final reduction in size of the mandible to pencil-size thinness and recession of the maxillary alveolar process to the nasal and maxillary sinus cavities.

The Dentition as a Guide in the Reduction and Fixation of Jaw Fractures. The normal teeth are so intimately associated with the mandible and the maxilla that restoration of the occlusion in fractured jaws is tantamount to anatomical reduction of the fractured segments. In many cases of fracture, simple wiring of the teeth in occlusion provides satisfactory reduction and fixation. The restoration of occlusion is a guide to proper positioning of the maxilla and upper facial bone structures. When the mandible and maxilla are involved, ligation of the teeth in occlusion maintains fixation of the fractured segments.

Surgeons who treat patients with fractures of the facial bones should be acquainted with the normal anatomy of the teeth and tissues of the mouth.

Dental Wiring and Intermaxillary Fixation Techniques

The Gilmer Technique. The simplest method of establishing intermaxillary fixation is by the Gilmer method (1887). It was not until 1887 that the importance of the teeth in the fixation of fractures was recognized and described in the American literature. The technique is simple and effective but has the disadvantage that the mouth cannot be opened for inspection of the fracture site without the removal of the wire fixation. This method consists of passing a wire ligature around the neck of all of the available teeth and twisting in a clockwise direction until the wire is tightened around each tooth. After an adequate number of wires have been placed on both the upper and lower teeth, the teeth are brought into occlusion and the wires twisted, one upper to one lower wire. To be consistent and avoid difficulty in removal, it is always advisable to twist wires in one direction, for example, clockwise. The twisted wires are cut short and the ends turned in against the necks of the teeth. Stainless steel wire is most satisfactory because of its tensile strength and malleability, but brass ligature wire may be used. Gauge 22 to 28 wire is most satisfactory. The size used depends upon the amount of force and stress anticipated. With the Gilmer method, the wires
are twisted in a vertical direction or crisscrossed to prevent slipping in an anterior-posterior direction.

**The Eyelet Method.** The eyelet method (Eby, 1920; Ivy, 1922) of intermaxillary fixation is useful and has the advantage that the jaws may be opened for inspection by removal of only the intermaxillary ligatures. This method consists of twisting a 20-cm length of 22- or 24-gauge wire around an instrument to establish a loop. Both ends of the wire are passed through the interproximal space from the outer surface. One end of the wire is passed around the anterior tooth and the other around the posterior tooth. One end of the wire may be passed through the loop. In the upper jaw the eyelet should project above and in the lower jaw below the horizontal twist to prevent the ends from impinging upon each other. After the establishment of a sufficient number of eyelets, the teeth are brought into occlusion and ligatures are passed loop-fashion between one upper and one lower eyelet. The wires are twisted tightly to provide intermaxillary fixation. If it is necessary to open the mouth for inspection, the ligature loop wires may be cut and if necessary replaced without difficulty. If heavy wire is used to form the eyelets, they may be turned to form hooklike projections to which intermaxillary orthodontic rubber bands are attached for traction.

**The Arch Bar Method.** Prefabricated arch bars are commercially available. These can be ligated to the external surface of the dental arch by passing 22- or 24-gauge steel wires around the arch bar and around the necks of the available teeth. The wires are twisted tightly to hold the arch bars in the form of an arc completely around the dental arch. The arch bars have hooklike projections which are placed in a downward direction on the lower jaw and in an upward direction in the upper jaw.

If an inadequate number of teeth are present owing to trauma or previous extractions, supplementary wiring may be necessary for stabilization of the arch bars. This is sometimes done even if there is a full complement of teeth when traction is expected to be applied with great and prolonged force. Such traction may result in loosening of the teeth if additional support is not provided. Greater stability may be obtained by suspension of the maxillary arch bar from the margin of the pyriform aperture or the anterior nasal spine of the maxilla; greater stability can be attained by drilling through the nasal spine to and through the floor of the nose on the contralateral side. The mandibular arch bar can be stabilized by one or more circumferential wires around the mandible.

After the arch bars are secured, orthodontic rubber bands are used between the two arches to bring the teeth into occlusion. The rubber bands pull the teeth into their proper relationship and provide secure fixation. Fractures of several days’ duration usually cannot be completely reduced manually because of the presence of organized tissue in the line of fracture. Strong rubber band traction within a period of 24 hours usually brings the teeth into their proper relationship. The use of rubber bands is highly advantageous because they are easily removed. In seven to ten days when the occlusion has settled, the rubber bands are replaced, a few at a time, by 26- or 28-gauge stainless steel wires. The wires are less bulky and easier to clean with a small toothbrush or Water Pic. At the end of the usual course of treatment, if there is springiness at the site of fracture, fixation is easily reestablished.

**The Stout Method.** This method (Stout, 1942) consists of the formation of small wire loops around the upper and lower dental arches to which rubber band traction is supplied.
Other Methods. There are other ways to use wire appliances with rubber bands. An effective method on isolated teeth is that of Kazanjian (1933): a heavy gauge wire is twisted around the neck of the tooth in a very firm fashion, leaving a button or wire at the neck of the tooth for the attachment of a rubber band.

The arch bar may be attached to the teeth by means of orthodontic bands. This is a precise and accurate method of securely holding the bar. The appliance is time-consuming to construct and is expensive to use in fractures and requires the presence of an orthodontist as a member of the time.

Adaptations of the use of wire ligatures are many. A fracture in which there are stable teeth on each side can be secured with a single wire encircling the teeth across the line of fracture or with several wires twisted around adjacent teeth and twisted together.

Splints in Maintenance of Intermaxillary Fixation. Dental splints cast from metal or acrylic resin are useful in maintaining intermaxillary fixation and the continuity of the maxillary or mandibular arch. Appliances of this type are effective but require detailed dental knowledge for construction. The prosthodontist may be able to fabricate acrylic splints to maintain the fragments in alignment during healing.

Monomaxillary Versus Bimaxillary Fixation. When teeth are present on each side of the fracture line, the use of a splint or prefabricated arch bar obviates the need for intermaxillary bimaxillary fixation to the considerable increase of the patient's comfort. A wiring technique for monomaxillary fixation is illustrated.

Fracture of the Mandible

The position and anatomy of the mandible is such that it is frequently subjected to injury and is the facial bone most likely to be fractured. The mandible is a movable U-shaped bone, consisting of a body and two rami and articulating with the skull bilaterally at the temporomandibular joints; it is attached to other facial bones by muscles and ligaments. It also articulates with the maxilla by way of the teeth.

The mandible is a strong bone but has certain areas of weakness. The body of the bone is composed principally of dense cortical bone with a small substantia spongiosa through which blood and lymphatic vessels, and nerves pass. The mandible is thin at the angles where the body joins with the ramus and at the neck of the condyle. The mental foramen through which the mental nerve and vessels extend to the tissues of the lateral aspect of the face and lower lip is large in some individuals and is an area of weakness through which fractures frequently occur. With loss of the teeth from the mandible, atrophic changes in the alveolar portion weaken the bone. Fractures are more frequent through edentulous areas than through areas well supported by adequate tooth structures.

Mandibular movements are determined by the action of muscles attached to the bone. When fracture occurs, displacement of the segments is influenced by the pull of the muscles.

The mandible may be fractured by any external force, the most common causes being automobile accidents, falls, kicks, missiles, blows from fists, trauma from animals, and sports.
Classifications of fractures of the mandible are many and varied. Factors according to which they may be classified are:

**The Etiology of the Fracture**

- Civilian
- Military
- Crash-type
- Gunshot

**The Direction of the Fracture and Favorability for Treatment**

- Horizontal
  - Favorable
  - Unfavorable
- Vertical
  - Favorable
  - Unfavorable

**The Severity of the Fracture**

*Simple fracture* - the type in which there is no contract of the fracture site with the outside environment. There is no discontinuity of the overlying soft structures.

*Compound fractures* - these are fractures in which there is a break through the skin or mucosa and overlying structures with direct communication of the fracture site with the outside environment through tears in the soft tissue.

**The Variety of the Fracture**

"Greenstick" fracture - in which there is incomplete discontinuity of the bone. The bone structure is bent or partially fractured to resemble a green stick which has been forcibly bent or partially broken.

*Simple fracture* - in which there is no communication with the outside environment.

*Compound fractures* - in which there is a communication with the outside environment.

*Complex fractures* - those in which fractures occur in multiple directions; sometimes into a joint with severe injury to surrounding tissues.
**Comminutive fractures** - in which there are many small fragments. These may be simple or compound.

**Impacted fractures** - in which the bone ends are driven firmly together out of position. Force is required to disengage the fragments.

**Depressed fractures** - those with depression and dislocation of the segments.

The Predisposing Causes to Fracture

**Generalized bone disease**, such as rickets, osteomalacia, fragilitas osseum.

**Localized bone diseases**, such as benign and malignant neoplasms, cysts, osteomyelitis or hemangioma of the bone.

Certain anatomical considerations:

Thin areas - the region of the angle of the mandible and the neck of the condyle.

Edentulous areas - in which there is atrophy of the alveolar bone and loss of supporting structures.

The region of a foramen of the mandible or of the maxilla.

The Causes of Fractures

**Trauma**

**Direct** - a blow at the site of the fracture which results in discontinuity of the bone.

**Indirect** - a blow on the opposite side of the jaw or a blow at a distance from the fracture site. This is seen in fractures of the condyle, which may occur from a blow on the chin on the contralateral side. A blow on the symphysis may result in fracture of both mandibular condyles.

The Presence or Absence of Serviceable Teeth in the Segments of the Mandible. Kazanjian and Converse (1949) emphasized this classification because it has a practical relationship to the management of the fracture.

**Class I** - Teeth present on both sides of the fracture line. The teeth can be used as a guide to anatomic reduction and can be utilized for the attachment of wires or appliances to maintain the fragments in position during the healing period. One or more teeth on each side of the fracture may be sufficient even though the upper teeth are not present to permit intermaxillary fixation.
Class II - Teeth present on only one side of the fracture line. The teeth are used for fixation of the mandibular to the maxillary teeth or to hold an appliance to stabilize an edentulous segment.

Class III - The fragments contain no teeth. The teeth may have been dislodged or fractured at the time of injury or may have previously been removed.

**Mandibular Fractures Classified as to Location** (Dingman and Natvig, 1964)

*Parasymphyseal* - those that occur in the symphysis area between the lower canine teeth. Fractures vertically through the true symphysis are rare.

*Canine* - through the cuspid teeth.

*Body of the mandible* - from the cuspid teeth to the angle of the mandible.

*Angle* - through the angle of the mandible behind the second molar tooth.

*Ramus of the mandible* - those fractures between the angle of the mandible and the sigmoid notch.

*Coronoid process* - in which the coronoid is broken off on a level above the mandibular notch.

*Condyle* - all fractures of the condyle above the level of the sigmoid notch of the mandible.

*Alveolar fractures* - segments of alveolar bone with or without attached teeth may be fractured separately or in association with other fractures of the mandible.

**The presence of Teeth or Absence of Teeth in the Jaw**

Dentulous.
Partially dentulous.
Edentulous.

**Muscular Contraction**

Seen in some cases of severe destruction of bone due to disease. Muscular contraction in eating may break the weakened bone. This also occurs in electroshock therapy if the jaws are not adequately protected.

**Clinical Examination**

The common symptoms of fractures of the jaw are the following:
Pain. Pain is usually present on motion and may be noted immediately after the fracture as a result of injury to the inferior alveolar nerve and to adjacent soft tissues.

Tenderness. There is exquisite tenderness over the site of the fracture. This is helpful in localizing the fracture site.

Disability. The patient is unable to open his mouth and refuses to eat usual foods because of discomfort.

Edema. Enlargement of soft tissues at the fracture site is the result of hemorrhage and edema. Immediately after the injury there is usually distortion and enlargement of the overlying soft tissues.

Ecchymosis. Hemorrhage may appear as ecchymosis or as hematoma in the soft tissue near the site of the fracture.

Deformity. Owing to fracture-dislocation of the segments, the patient may be unable to open his mouth or may be unable to close it. Open bite deformity may be present, or the mandible may be shifted to one side or posteriorly, giving a bizarre appearance to the lower facial area.

Abnormal mobility. In fractures of the condyle with displacement, the mandible may shift toward the involved side as the patient attempts to open his mouth. This is caused by nonfunction of the lateral pterygoid muscle on the side of the fracture. On protrusive motion the jaw shifts to the side of the fracture.

Crepitation. The patient may notice a grating sound on movement of the mandible. This is caused by movement of the fracture segments against one another.

Salivation. Pain and tenderness stimulate overactivity of the salivary glands.

Fetor oris. Because of the absence of the normal cleansing activity of mastication, after a day or two debris accumulates around the teeth. Food, blood clots, devitalized tissue, and mucus undergo bacterial putrefaction, resulting in a very offensive breath.

Diagnosis

The diagnosis of mandibular fracture is made on one or more of the following findings:

Clinical Findings

Mobility at the site of the fracture. Bimanual manipulation causes springiness at the site of the fracture, especially in the body of the mandible. One hand stabilizes the ramus of the mandible, while the other manipulates the symphysis of the mandible. Fracture will be demonstrated by movement and discomfort.
Malocclusion. Probably the most reliable finding in fractures of the mandible in dentulous patients is malocclusion. Even the most minute dislocation caused by the fracture will be obvious to the patient inasmuch as the teeth do not mesh or come together in the usual manner.

Dysfunction. The patient is unable to use his jaw and will request soft foods which require minimal movement of the jaw on mastication. Speech is difficult because of pain on motion of the mandible.

Crepitation. This may be noticeable by manipulation at the fracture site, but it is not a frequently used sign because of discomfort to the patient.

Swelling at the fracture site. Swelling is usually quite obvious and may be associated with ecchymosis and subcutaneous hematoma.

Abnormal mobility of the mandible on function with deviation to one side or the other may lead to the diagnosis of fracture.

Tenderness over the fracture site, especially in the region of the temporomandibular joint, is highly suggestive of the presence of a fracture.

Roentgenologic Findings. Roentgenographic examination is imperative. Careful single, stereoscopic views, tomograms, and panoramic roentgenograms should be taken of all fractures, as indicated, with particular attention to the condyles. Occlusal films and dental roentgenograms are helpful in detecting fractures of the symphysis and the alveolar structures of the mandible. (See section on Roentgenographic Positions.)

Muscles Influencing Movement of the Mandible. Muscle action is an important factor influencing the degree and direction of displacement of fractured segments of the mandible. Overcoming the forces of displacement is important in reduction and fixation of the mandibular fragments.

The Posterior Group of Mandibular Muscles. The posterior group of muscles is commonly referred to as the "muscles of mastication." The muscles are short and thick and are capable of exerting extremely strong forces on the mandible. The muscles of mastication are the temporalis, masseter, and medial (internal) and lateral (external) pterygoid muscles. The overall activity of this group is to pull the mandible upward, forward, and medially.

Masseter muscle. This is a thick, short, powerful, heavy muscle attached to the zygoma and zygomatic arch. It arises from tendinous fibers in the anterior two-thirds of the lower border of the zygomatic bone and from the medial surface of the zygomatic arch and inserts into the lateral surface of the ramus and into the bone at the angle of the mandible. The masseter muscle is an elevator of the jaw and functions to pull the mandible upward and forward.

Temporalis muscle. This muscle arises from the limits of the temporal fossa. It is broad and fan-shaped. Its fibers converge as it descends to pass under the zygomatic arch and
insert into the tip of the coronoid, the lateral and medial surface of the coronoid, and the anterior surface of the ramus as far down as the occlusal plane of the third molar tooth. The anterior fibers are elevators, and the posterior fibers are retractors of the mandible.

Medial pterygoid muscle. This muscle originates in the pterygoid fossa, mainly from the medial surface of the lateral pterygoid process and from the pyramidal process of the palatine bone and maxillary tuberosity. It inserts into the medial surface of the ramus and angle of the mandible. The fibers of the medial pterygoid muscle pass in a downward posterior and lateral direction to the angle of the mandible. Its function is to pull the mandible upward, medially, and forward.

Lateral pterygoid muscle. This muscle has two heads of origin. The upper head arises from the infratemporal crest, the infratemporal surface of the greater wing of the sphenoid bone, and a small area of the squamous part of the temporal bone. The lower head arises from the lateral surface of the lateral pterygoid plate. The upper head inserts into the capsule of the joint and into the articular disc of the temporomandibular joint. The lower head inserts into the anterior surface of the neck of the condyle. The innermost or upper portion pulls the mandible upward, medially, and forward; the external portion pulls the condyle downward and medially and forward. Contraction of the muscle on one side pulls the mandible to the opposite side. Contraction of both muscles simultaneously protrudes the mandible.

The Anterior or Depressor Group of Mandibular Muscles. These muscles are considered the opening muscles of the mandible. With the hyoid bone fixed, they depress the mandible. When the mandible is fractured, they displace the fractured segments downward, posteriorly, and medially. This group is made up of the geniohyoid, genioglossus, mylohyoid, and digastric muscles.

Geniohyoid muscle. This muscle arises from the inferior medial spine of the mandible and passes downward and posteriorly to insert into the body of the hyoid bone. Its function is to elevate the hyoid and to depress the mandible.

Genioglossus muscle. This is the main muscle of the tongue and is attached to the genial tubercles on the inner anterior inferior surface of the mandible. Its fibers pass primarily into the substance of the tongue and into the upper surface of the hyoid bone. Its function is to protrude the tongue, elevate the hyoid, and depress the mandible.

Mylohyoid muscle. This fan-shaped muscle acts as a diaphragm for support of the floor of the mouth. It arises from the mylohyoid line on the inner surface of the body of the mandible. Its fibers pass medially to insert into a median raphe and posteriorly to insert into the hyoid bone. Its function is to elevate the hyoid bone and to depress the mandible. Its fibers pull medially, posteriorly, and downward.

Digastric muscle. The digastric muscle arises from the digastric fossa at the inferior medial portion of the mandible bilaterally and extends posteriorly to pass beneath a fibrous sling attached near the lesser cornu of the hyoid bone. Its tendon is continuous with that of the posterior portion which originates from the digastric fossa of the temporal bone. The
function of this muscle is to elevate the hyoid and depress the anterior portion of the mandible.

**The Temporomandibular Joint.** The function and anatomy of this joint is important in consideration of injuries to the mandible condyle. The temporomandibular joint is known as a ginglymodiarthroidal joint; it is capable of a hingelike action as well as a gliding and rotating action. The joint is composed of the articular head of the condyle of the mandible and the mandibular fossa of the squamous portion of the temporal bone (glenoid fossa). The articular surface of each bone is covered by a thin, smooth layer of cartilage surrounded by connective tissue which differentiates into an inner and outer layer. The inner layer, which is known as the synovial membrane, secretes a viscid fluid lubricant that minimizes friction and aids smooth functioning of the joint. The outer layer of connective tissue is intimately associated with the ligaments which surround the joint and provide an enveloping capsule within which the articular surfaces function. The temporomandibular joint is a compound joint. It is separated into two distinct chambers, one above and the other below an articular disc of fibrocartilage known as the meniscus. Movement of the articular disc is controlled by the attachments of the lateral pterygoid muscle which insert, through the capsule, into its anterior edge and by attachment of the disc to the posterior portion of the joint capsule. The hinge, rotating, and gliding movements of the temporomandibular joint are controlled by the muscles attached to the mandible.

**Factors Influencing Displacement of Fractured Mandibular Segments.** The direction and extent of displacement of fragments depends upon the site of the fracture, the direction of the fracture, the direction of pull of the strong muscles attached to the mandible, the direction and intensity of force, and the presence or absence of teeth in the fragments. In fractures of the mandible, the segments may be displaced in the direction of the strongest muscle action.

**Direction and Angulation of the Fracture Line.** Fry, Shepard, McLeod, and Parfitt (1942) pointed out that fractures may be favorable or unfavorable for displacement according to their direction and bevel. The muscular force in some fractures pulls the bone into a position favorable for healing, whereas in other fractures the muscle pull is unfavorable and separation of the bone fragments occurs.

Mandibular fractures that are directed downward and forward are classified as horizontally favorable (H. F.) because the posterior group of muscles and the anterior group of muscles pull in antagonistic directions favoring stability at the site of fracture. Fractures running from above downward and posteriorly are classified as horizontally unfavorable fracture (H. U.). The bevel of the fracture may influence the displacement medially. If the fracture runs from posteriorly forward and medially, displacement will take place in a medial direction because of the medial pull of the elevator muscles of mastication (V. U.). A fracture that passes from the lateral surface of the mandible posteriorly and medially is a favorable fracture because the muscle pull tends to prevent displacement. It is called a vertically favorable fracture (V. F.).

**The Presence or Absence of Teeth in the Fractured Segments.** Upper displacement of the posterior segment is prevented by the occlusal contact of the lower against the upper teeth. The elevator muscles of the mandible pull the posterior fragment forward. The anterior
group of muscles depresses the anterior segments of the mandible, separating the teeth anterior to the fracture from the upper teeth. A single tooth in the posterior fragment may be extremely important and should be retained. Even if damaged, it will provide stability.

**Soft Tissue at the Site of Fracture.** Fractures of the ramus of the mandible, even though extensively comminuted, have very little displacement because of the splinting action of the medial and lateral pterygoid and the masseter muscle attachments. Some degree of stability is also provided by the periosteum and soft tissue attachments surrounding the body of the mandible, but these are usually weak, and very little stability is offered by their presence. In extensive soft tissue wounds, such as gunshot injuries, no stability is offered from the torn tissues. Some degree of stability is provided to the fragments by the replacement of soft tissues and by suturing them carefully into position over the bone.

**Direction and Intensity of the Traumatic Force.** The force on the mandible may directly or indirectly influence the site of fracture and the amount of displacement. Direct lateral force in the region of the premolar teeth may result in a fracture of the involved side and a fracture of the condyle on the contralateral side. Traumatic forces applied to the anterior portion of the mandible may break a segment between the canine or premolar teeth and drive it posteriorly into the floor of the mouth. Displacement will be aided by the muscles of the floor of the mouth which exert a downward and posterior force. Blows to the symphysis region may cause bilateral or unilateral condylar fractures or may force the condyle into the middle cranial fossa. The condyles may be forced into the external auditory canal by fracture of the tympanic plate.

**Fractures of the Alveolar Structures and Damage to the Teeth.** Damage of the anterior teeth occurs more frequently than damage of the posterior teeth because of their forward position and single conical root structure.

Teeth may be completely avulsed from the bone or may fracture at the gingival line with the roots remaining in the bone, or segments of alveolar bone may be fractured with the teeth remaining firmly attached. The crowns and edges of the teeth may be fractured with exposure of the dental pulp.

Reimplantation of avulsed teeth may be successful in children, as the root apex is still open and the blood supply may be reestablished. Reimplantation sometimes is successful in adults if the pulp is removed and the root canal is filled and treated before the tooth is reimplanted. If the crown of a tooth has been fractured with exposure of the dental pulp, it is best to extract the tooth or remove the pulp prior to intermaxillary fixation. If this is not done, infection or severe pain may be troublesome. If segments of alveolus which contain teeth have been fractured and have an adequate blood supply by virtue of the soft tissue attachments, attempts should be made to replace the segments along with their contained teeth and wire them securely into position. Most of these tooth-bearing segments will survive and provide a satisfactory masticating surface.

Injury to the teeth without avulsion or fracture may result in devitalization owing to hemorrhage in the dental pulp. The teeth become insensitive and discolored as a result of infiltration of blood pigments into the tooth structure. If infection occurs, the teeth must be
treated or extracted. Some of them, even though discolored and nonvital, remain as asymptomatic useful teeth.

As mentioned, teeth in the line of fracture should be retained if they offer any degree of stability to the bone fragments. Antibiotic therapy protects against infection. If teeth are loose or interfere with reduction, they should be removed. The retention of even one-half a tooth on the posterior segment may be helpful in maintaining the position of the proximal segment. After healing of the bone, the teeth can be given necessary attention by the patient's dentist.

**Principles of Treatment**

The primary consideration in the management of fractures of the mandible is to restore the function of the mandible and the masticating efficiency of the dentition. To accomplish this, the principles of fracture management must be applied. These are:

1. Reduction of the fractured bone segments to their anatomical position.
2. Fixation that will hold the fractured bone segments in position until healing takes place.
3. Control of infection.

Generally speaking, the simplest method of attaining and satisfying these requirements is the best method. Methods may vary with the age and general state of health of the patient, with the training and ability of the surgeon, and with the facilities and circumstances under which the patient is to be treated. A satisfactory end result may be accomplished by use of any one of several methods, but no method is acceptable that will jeopardize the function, appearance, or safety of the patient.

**Treatment of Class I Fractures of the Mandible**

Class I fractures are those in which there is a tooth on each side of the fracture. They usually can be managed by dental appliances or intermaxillary fixation. Some can be managed best by open reduction and direct interosseous wiring in combination with dental appliances or intermaxillary fixation. The use of dental splints without intermaxillary fixation (monomaxillary fixation) is appealing to the patient because it is unnecessary to wire the teeth in occlusion. This permits the intake of solid foods and early return to work. Convenience to the patient should not influence the treatment if a more satisfactory result can be obtained by intermaxillary fixation. Four to six weeks of complete immobilization is not too long a period to be tolerated by the patient if a better result can be obtained. The factor of solid food versus liquid food for a period of four to six weeks is not of great significance and should not influence the operator in the use of less effective methods.

Fixation of the fractures segments can be accomplished without intermaxillary fixation by use of a number of simple methods.
**Horizontal Interdental Wiring.** The fracture can be reduced manually and held together with 25-gauge stainless steel wire twisted around the necks of selected teeth on both sides of the fracture site and then twisted to a wire on the opposite side of the fracture site. This method is simple and expedient and can be utilized on any Class I fracture in which there are stable teeth on each side of the fracture site. This may also be used in the lower anterior region when there is overriding of the fragments by passing the wire in such a way as to produce a leverage that will reduce and maintain the fracture. It is inadvisable to use the teeth immediately adjacent to the fracture site, since their attachments are loosened and they may be dislodged by the force of the ligature wire.

**Prefabricated Arch Bars.** Winter type arch bars as modified by Erich are made of semirigid pliable metal and can be contoured to the dental arch and carefully fitted to the necks of the teeth without special equipment. Arch bars are generally used for intermaxillary fixation, but a single arch bar attached to the lower teeth for support of the Class I type of fracture may be used for monomaxillary fixation. This is done by shaping a bar long enough to pass completely around the dental arch. This is securely ligated to the necks of the teeth on the larger fragment, and wires are loosely placed around the teeth and arch bar on the displaced fragment. The fracture is reduced manually and held firmly in position while an assistant tightens the wires.

Sections of arch bars attached to the teeth of the posterior segment can be ligated in the anterior region after reduction of the fracture. This provides adequate fixation and holds the fractured segments together. If maxillary teeth are present, supplementary fixation with intermaxillary rubber band traction will bring the teeth into optimum occlusion.

**Cable Arch Wires.** If no arch bars are available, a cable wire can be fashioned to provide stability across the site of the fracture and a means of intermaxillary fixation. This is fabricated by using a long length of 22-gauge stainless steel wire, which is passed around the last tooth on each quadrant of the dental arch and twisted up tightly to the teeth but left long. The wire from the right side is twisted to the wire of the left side at the midline and the excess is cut and removed. Ligature wires are then passed around the necks of the teeth and around the cable arch bar until all of the available teeth have been ligated. The teeth can be wired into occlusion by passing small wires around the upper and lower cable and twisting these tightly to provide perpendicular intermaxillary fixation.

**The Banded Dental Arch.** Angle (1890) devised a banded arch wire for fixation of mandibular fractures. These consist of prefabricated bands in sizes to fit the molar or bicuspid teeth. The bands are held with a jackscrew and nut attachment twisted tightly until the band is securely fixed to the tooth. A long section of 14-gauge annealed brass wire flattened to 19-gauge is soldered to the band. This malleable brass wire is then contoured along the lateral surface of the teeth to which it is ligated with fine stainless steel wire.

The orthodontist also may be helpful in applying a rigid lugged bar to several banded teeth. Banded appliances on upper and lower teeth serve well as fixation appliances for intermaxillary fixation but are complicated and expensive. Usually simpler methods will suffice.
Cast Cap Splints. Cast cap splints are utilized extensively abroad but have not gained much favor in the management of fractures in the United States. These dental appliances are designed to cover the occlusal and exposed portions of the teeth and require the services of a skilled dentist and dental technician. Cast splints are especially useful when a strong appliance is needed. The cast cap splint is cemented to the occlusal surfaces of the teeth. This is a disadvantage inasmuch as the exact occlusion cannot be determined with the splint in position. Discrepancy in occlusion must be corrected orthodontically or by selective grinding of the teeth after the splint has been removed. Effective, equally useful, but less expensive appliances can be constructed by an orthodontist. The transparent acrylic splint is thin, strong, and easily fabricated by a prosthodontist and is an excellent alternate technique.

External Pin Fixation Appliances. External pin fixation or intramedullary wire pinning has little use in the management of Class I fractures in the presence of sound teeth at the site of the fracture (see chapter 30).

Treatment of Compound Comminuted Anterior Mandibular Fractures. Comminuted fractures of the mandible, because of the very intimate attachment of the thin overlying periosteum and mucosa, are almost always compound, either through the skin or through the mucous membrane. With modern antibiotic therapy these fractures can be managed aggressively by open methods with an excellent chance of survival of the bone fragment. Conservative management will generally result in continuity of the bone upon healing if the fragments can be covered adequately by soft tissue with sufficient blood supply.

Fixation of the posterior segments is imperative. This may be accomplished by intermaxillary wiring between the retained mandibular teeth and the maxillary teeth or by construction of a cast splint with an anterior retaining bar passed from one side to the opposite side. If the posterior segments contain sufficient teeth, a commercially available arch bar can be used. The management of the segments depends upon the presence or absence of a satisfactory amount of soft tissue for coverage. If soft tissue is adequate, the fragment may be approached through the wound or through an external incision. The fragments are identified, aligned, and approximated by direct wiring techniques. Periosteal attachments should be retained, since even loose fragments may survive if stabilized and adequately covered with soft tissue with good blood supply. If the fragments are of sufficient size, they may be held by means of a Kirschner wire in a shish kebab fashion with the wire being attached to the solid proximal segments.

If there has been extensive loss of soft tissue of the lip, chin, and floor of the mouth along with bone, the posterior bone segments should be covered with skin and mucosa and properly splinted into position to prevent displacement by scar tissue contraction in the floor of the mouth. A vertical T bar soldered to the splint anteriorly will provide an attachment for an acrylic prosthetic mold to give support to the soft tissues during the period of reconstruction. These appliances are complicated and must be especially designed to fit the individual case. An acrylic splint made in a horseshoe fashion fitted over the remaining posterior segments and secured by means of circumferential wires is effective in maintaining the position of the posterior segments. It also supports the soft tissue replacement during the phases of reconstruction. Conservatism in the management of the fractured segments is important. Bone fragments should never be discarded if they can be used to help reestablish
continuity of the bone or if they can be covered and salvaged under a soft tissue flap. These
fragments of bone are invaluable in the reconstructive phase.

**Open Reduction Techniques.** It is impossible to reduce and adequately hold certain
Class I fractures by closed methods, even though a satisfactory number of teeth are present
in the dental arch. This applies especially to fractures in the region of the symphysis which
run in an oblique direction downward and posteriorly, sometimes as far back as the molar
teeth. The long splinter of the lingual segment has a tendency to telescope and override owing
to pull of the muscles of the floor of the mouth. Even though the teeth are brought into what
appears to be satisfactory occlusion, there is medial rotation of the inferior border of the
mandible. Fractures in the anterior region that run in an unfavorable direction require open
operation for reduction and direct wire fixation. When sufficient teeth are present,
terosseous wiring should be supplemented by intermaxillary fixation. Continuous moderate
traction by rubber bands for a few days will result in anatomically correct occlusion.

**Treatment of Class II Fractures of the Mandible**

In Class II fractures, teeth are present on only one side of the fracture site. The
fracture may occur in any portion of the body of the mandible. The problems of control of
the edentulous fragment vary according to the direction and bevel of the fracture and the
position of the teeth.

Open reduction and direct osseous wiring is indicated rather than the use of appliances
in fractures with displacement and absent teeth in the posterior segment.

**Fractures Horizontally and Vertically Favorable.** If the fracture occurs from above
downward and forward, the forces will resist separation and the fracture will be favorable
from the standpoint of treatment. If the fracture is favorable but is oblique along a frontal
plane, upward displacement of the posterior fragment will occur. When the line of fracture
is directed downwards and backwards, the elevator (or posterior) muscles displace the
posterior fragment upwards and medially. In this type of fracture, fixation of the teeth in
intermaxillary occlusion alone does not suffice to give stability at the fracture site.

Fixation in favorable Class II fractures can be accomplished by the band and bar
attachment, by the cable with intermaxillary wire ligatures, or by Erich bars with wire
ligatures or rubber bands. The Kazanjian button may be useful for fixation of fractured
segments with isolated teeth.

Fractures in which the angle is unfavorable do not resist displacement. The pull of the
elevator muscles attached to the posterior segment displaces it upward and medially and
favors displacement. Wiring of the remaining anterior teeth will not hold the posterior
fragment in its normal position. A number of methods can be utilized to control the posterior
fragment.

**Interlocking the Fragments.** Kazanjian and Converse (1974) described the technique
in which, by digital manipulation, fragments are placed in anatomical position and forced
together; while they are in this position, the teeth are brought into intermaxillary fixation.
Interlocking, if the fragments have the proper contour, will hold the proximal segment in position.

**Use of a Bite Block in the Edentulous Posterior Segment.** A bite block placed between the maxillary and mandibular teeth may serve to hold the proximal fragment in position during the course of healing. The bite block may be fabricated into an upper denture. This method is generally unsatisfactory because the posterior segment is difficult to control and the bite block causes irritation to the gingival tissue and may result in pressure necrosis of the soft tissue and bone.

**Forked Wire Extension.** A band with a bar appliance attached to the teeth, with a 14-gauge wire prong projecting posteriorly across the fracture line and pressing down against the bony ridge of the posterior fragment, may prevent upward displacement. This type of appliance is usually ineffective. It provides questionable stability of the proximal fragment and may result in irritation of the soft tissues and the bone. The modern technique is open reduction and direct interosseous wiring.

**Use of a Splint or the Patient's Dentures with Circumferential Wiring.** If the patient is wearing a partial denture and the fracture is through the portion of the mandible below the saddle of the denture, it may be used to maintain fixation of the fractured segments. This is done by circumferential wiring on each side of the fracture and around the saddle portion of the denture. One end of a 22-gauge wire passes through a 3-mm skin incision and through a wire-passing needle into the buccal vestibule. The other end is passed through a needle medial to the inferior margin of the bone, up through the lingual vestibule, and through a drill hole in the denture. The two ends are twisted tightly at the lateral side of the denture.

**Open Reduction and Interosseous Wiring**

**Indications for Interosseous Wiring in Mandibular Fractures**

1. In complex fractures when the use of the teeth as points of fixation for appliances is not sufficient.

2. In fractures with a displaced posterior fragment.

3. In edentulous patients.

Under the protection of antibiotic therapy, satisfactory anesthesia, careful preparation of the mouth, and aseptic technique, open reduction for Class II fractures is expedient, positive, and safe.

The most important precaution following direct interosseous wiring of bony fragments through the intraoral approach is the avoidance of hematoma. Infection follows hematoma formation and may require removal of the wire. Avoidance of hematoma is best achieved by placing at the fracture site a noncollapsible catheter connected to a suction apparatus. A sufficient time to ensure hematoma prevention is usually 48 hours. The catheter can be brought through the pressure dressing and pulled for removal.
Interosseous wiring results in anatomical reduction and positive fixation at the site of the fracture. The procedure may be performed under local anesthesia. An incision is made 1 to 2 cm below the inferior border of the mandible in or parallel to a skin crease in the neck and long enough to provide adequate exposure of the fracture site. The incision is extended through the skin, the subcutaneous tissues, and the platysma muscle. The dissection exposes the inferior border of the mandible, care being taken to identify and protect the mandibular branch of the facial nerve which lies along the inferior border of the mandible or slightly below it (Dingman and Grabb, 1962). The soft tissues are retracted, and by careful dissection the angle of the mandible and the anterior segment is identified. The fragments are grasped and reduced with the Dingman bone forceps (1954). With an electric drill and small drill points, holes are drilled on each side of the fracture site. Figure-of-eight or crisscross wires may be used through the drill holes, depending upon the difficulty encountered in maintaining the position. Usually two drill holes will suffice; if there is difficulty in maintaining position with one figure-of-eight wire, a single wire can be placed at a higher level. The twisted end of the wire is cut short and is forced into one of the drill holes alongside the wire passing through the hole. The musculature is secured by sutures at the inferior border of the mandible. This is accomplished by passing a suture from the fascial attachment of the masseter muscle to the fascial attachment of the medial pterygoid around the inferior border of the mandible. This holds both muscle insertions in position and favors healing of the bone. The wound is closed in layers with absorbable sutures in the deep structures, and nylon sutures are used to approximate the skin edges. Careful skin closure will give an acceptable inconspicuous scar within a few weeks.

Intraoral Interosseous Wiring. Interosseous wiring may be done through the intraoral route in edentulous or partially edentulous patients. When the fracture line runs in a horizontally unfavorable direction, interosseous wiring at the alveolar ridge utilizes the muscle pull to advantage. The wire fixation provides a fulcrum at the crest of the ridge, and the muscle pull is in a direction that favors fixation of the segments.

The authors have employed the intraoral approach for interosseous wiring of parasymphyseal, body and angle fractures. After the fracture site is exposed, drill holes are made from the outer table through the bone. One 26-gauge wire is passed through each tunnel through the bone. One wire is doubled upon itself, and the loop thus formed threads the second wire from the medial to the lateral aspect of the bone. The wire is twisted, impacting the ends of the fractured bone. With agree with Paul and Acevedo (1968), who stated that intraoral open reduction can be achieved in most fractures of the mandible in about half the time as extraoral open reduction.

External Fixation. If external pin fixation has a place in fracture management, it is in the control of the edentulous posterior fragment with extensive comminution at the fracture site. Pins in this area maintain the position of the posterior fragment by resistance against the elevator muscles of the mandible until consolidation of the fractured segments has taken place.

Kirschner Wire Fixation. Brown, Fryer, and McDowell (1949) favored intramedullary Kirschner fixation for immobilization of Class II and III fractures. The fracture is reduced manually. With the bones held in position by an assistant or by the operator, a three-sided, sharpened, pointed wire is passed through a small skin incision and driven through the bone.
into the medullary canal with an electric drill. It is driven across the fracture site and through the cortex of the opposite fragment, or it may be left in the fragment if it is solid before passing through to the outer cortical surface. The wire ends are cut at the skin level and left in place for six to eight weeks. Supplementary wiring of the teeth may be required. While alignment is achieved, impaction is not. Nerve damage and osteomyelitis are possible complications of this technique.

**Comminution Fractures**

**Open Operation and Bone Plate in Comminuted Fractures At The Angle.** The use of metal plating is preferable to direct wiring of the multiple fragments or to external pin fixation for bridging areas of comminuted bone. The mandible is exposed through an incision below the inferior border. The main proximal and distal segments are identified and realigned. A thin metal plate is screwed or wired securely to the outer inferior margin, and the comminuted fragments are manipulated into a position of contact if possible. A trough-shaped plate may be fashioned at the operating table from firm thin metal. This can be shaped to fit the inferior border of the mandible and will support the comminuted fragments until organized (Hayward, 1962). The wound is closed in layers without drainage. This will maintain fixation of the fracture segments until healing takes place and the bone continuity is restored. If the splint causes reaction, it can be removed later.

**Extraskeletal Wire Traction for Control of Proximal Segments.** Control of the proximal edentulous segment by an external wire attached to a rubber band and head cap was advocated by Lenormant and Darcissac (1927). This is said to be useful in cases of comminution at the angle of the mandible where other methods are not advised. The operation is done by exposing the angle of the mandible through a small skin incision. A hole is drilled through the angle with a bone burr, and a stainless steel wire is passed through the hole and both ends of the wire are brought out through the skin wound. The incision is closed around the wire, the two ends of which are twisted together in loop fashion for attachment of a rubber band. The plaster head cap techniques has been largely replaced by the use of various types of external head frames maintained by direct fixation to the outer table of the skull. Georgiade's halo apparatus or "crown of thorns" is such an apparatus (Georgiade and Nash, 1966).

**Control of Comminuted Fragments.** If the bone is protected and supported by adequate adjacent periosteum and soft tissue, direct interosseous wiring techniques should be used in favor of complicated insecure dental appliances. If complicated by soft tissue loss, comminuted fractures of the mandible should be stabilized by adequate splints maintained by circumferential wiring or with splints on the remaining teeth. This technique, together with intermaxillary fixation, if possible, will control the posterior segments and immobilize other segments until consolidation provides stabilization of the bone. All small segments of bone and soft tissue that might be useful in the reconstructive period should be saved.

The T bar of Kazanjian is used for attachment of an acrylic appliance to provide soft tissue support if full thickness lacerations or partial loss of the lower lip requires primary reconstruction.
**Fixation in Class II Fractures When the Maxilla is Edentulous.** Fixation of the Class II fracture with an edentulous maxilla may be accomplished by a bite-block against which the mandibular teeth occlude. The bite-block is maintained in position by internal wiring, the wires being looped around the zygomatic arch or attached to the frontal bone. Fixation of the mandible to the bite-block is accomplished by means of a circumferential wire around the anterior portion of the mandible.

Open reduction and direct wiring techniques can be achieved by wiring through the nasal spine, through the edge of the pyriform aperture, looping a wire around the zygomatic arch, or wiring to the zygomatic process of the frontal bone.

**Fractures of the Condyle**

Nicholas G. Georgiade

**Fractures of the Condyle of the Mandible.** The mandibular condyle is protected by the zygomatic portion of the temporal bone and is supported by the capsule, ligaments, and muscles around the joint. The condyle is most often fractured by indirect trauma. Although open reduction methods are indicated in some fractures of the mandibular condyle, the majority of condylar fractures will respond to simple conservative methods. Usually intermaxillary fixation will suffice. The temporomandibular joint will withstand long periods of fixation without ankylosis or dysfunction. One of our patients, a 65 year old man who had developed bony ankylosis of the mandible at age 5, decided to submit to condylectomy after 60 years of immobility. Condylectomy of the ankylosed joint was done, and within a few weeks the patient was able to open his mouth to the normal extent. He had a complete range of motion in the opposite normal joint which had been immobilized for 60 years.

**The Condyloid Process.** The condyloid process of the mandible consists of a broad thick head with a narrow, thin supporting neck. The lateral pterygoid muscle attaches to a shallow depression just below the articular surface on the anterior border of the neck of the condyle. The upper fibers of the lateral pterygoid pass through the thin capsule and attach to the articular disc which separates the temporomandibular joint into two spaces. The insertion of the fibrous capsule which surrounds the condylar head of the joint attaches to the base of the glenoid fossa immediately above the lateral pterygoid insertion on the condyle. The posterior and lateral surfaces of the condylar head are surrounded by the firm, tough, ligamentous joint capsule. The capsule thins out medially and anteriorly, and its thin structure is a predisposing factor in its rupture. Anterior and medial displacement in fractures of the condyle is caused by the pull of the lateral pterygoid muscle.

The condylar neck is the thinnest portion and is most likely to be fractured by blows to the mandible. Blows to the lateral aspect of the mandible may cause a fracture of the condylar neck on the contralateral side. Violent force to the symphysis region may result in bilateral condylar fractures. The thinness of the condylar neck appears to be a safety mechanism which prevents the condyle from being driven into the middle cranial fossa or through the tympanic plate immediately behind the joint. When fracture of the condyle neck fails to occur, the head of the condyle may be forced into the middle cranial fossa or through the tympanic plate into the auditory meatus. Fortunately, the force is usually dissipated by a fracture at the condyle neck, and these injuries are rare.
Classification

Fractures above the level of insertion of the lateral pterygoid muscle. Fractures above the level of insertion of the lateral pterygoid muscle may be totally or partially within the capsule of the joint. The articular surface may be fractured or the break may extend from above downward and posteriorly. A fracture in this category shows little displacement because there are no muscle attachments to pull it out of position.

Fractures below the insertion of the lateral pterygoid muscle: subcondylar fractures. Fractures below the insertion of the lateral pterygoid muscle occur immediately below the lowermost muscle fibers or at the level of the sigmoid notch and extend downward along the posterior border of the ramus of the mandible. The short fragment is generally displaced more than the long fragment. Fractures below the insertion of the lateral pterygoid almost invariably are displaced forward and medially by the pull of the muscle. The fractured segment may be pulled out of position but remain within the intact capsule; this is classified as a "dislocation" fracture. The condylar head may be displaced in an anterior, posterior, medial, or lateral position, and in one of our cases it was displaced upward into the middle cranial fossa. Upward displacement is relatively rare. The direction and degree of displacement of the remainder of the mandible depend upon the direction of the force of the blow, the presence or absence of teeth, and the direction and force of the muscles of mastication.

Diagnosis. The diagnosis of fracture of the condyle is usually made on clinical examination and confirmed by roentgenographic findings. Clinically it will be noted that there is asymmetry of the face on the involved side due to shifting of the mandible posteriorly and laterally toward the affected side. Premature occlusion on the involved side is caused by upward pull of the elevator muscles of the mandible. This results in a Class I lever with the fulcrum on the molar teeth on the involved side. An open bite deformity anteriorly and on the opposite side of the mandible is noted. Tenderness on palpation over the temporomandibular joint and in the external auditory canal is a common finding. Moderate to severe edema, ecchymosis, and occasionally hemorrhage may be noted in the external auditory canal. If both mandibular condyles are fractured, the patient will have a bilateral open bite deformity with occlusion only on the posterior teeth.

Bilateral open bite deformity is caused by contraction of the strong elevator muscles of the mandible, upward displacement of the ramus, and telescoping of the fractured segments.

In bilateral subcondylar fractures which occur below the attachment of the lateral pterygoid muscle, the patient is unable to protrude the mandible. In unilateral fractures at the same level, the patient is unable to perform lateral motions to the opposite side. Lateral movements of the mandible can be made only toward the affected side, because the lateral pterygoid muscle on the unaffected side shifts the mandible medially and forward, while the muscle is completely out of function on the affected side.

The patient usually will have dysfunction and pain on attempting to open the jaw. If the posterior fragments have been displaced posteriorly, the mandible may shift forward as the segments of the ramus distal to the fracture ride upward and glide forward on contact with
the condyle fragments. This may produce an open bite with protrusive relationships of the mandible.

Fractures above the level of the lateral pterygoid insertion do not exhibit displacement because of the absence of the contracting muscles attached to the proximal segment. The patient may complain of severe pain in the temporomandibular joint, and it will be noted that there is tenderness on palpation over the joint and in the external auditory canal. It may be noted that the teeth are separated and do not come into occlusion on the affected side because of hemorrhage and edema in the joint which force the condyle downward. It may be several weeks before the teeth come into their normal occlusal relationships. In this type of fracture, especially in children, the parents should be warned about the possibility of the development of ankylosis owing to septic necrosis of joint surfaces and secondary bony proliferation. In some cases, even though ankylosis does not occur, the head of the condyle (especially the cartilage) may be damaged, thus affecting growth, with subsequent maldevelopment.

**Roentgenography.** A fracture of the condyle may be overlooked unless the fracture is demonstrated on roentgenography. If the fractures are linear without displacement or with minimal displacement, tomograms may be necessary to demonstrate the site of fracture. In most fractures of the condyle it will be noted that the condylar head is displaced anteriorly and medially. The head may be within the limits of the articular capsule, or it may be completely avulsed and dislocated. If the condyle fracture is very low in the region of the sigmoid notch or extends down along the posterior border of the ramus, the condylar head may be displaced medially, and the end of the posterior fragment will be noted protruding lateral to the site of the fracture. Stereoscopic views may demonstrate posterior displacement with fracture of the tympanic plate.

**Treatment of Fractures of the Condyle.** Fractures of the mandibular condyle may be treated by closed reduction methods or by open reduction and direct wire fixation.

The nonoperative or closed reduction treatment has been the principal method of management of condylar fractures. This consists of immobilization of the mandible by means of intermaxillary fixation. Closed reduction was the only method known until a few years ago. In 1947 the combined efforts of the members of the Chalmers J. Lyons Academy of Oral Surgery produced a report on a study of 120 cases of fractures of the mandibular condyle treated by immobilization of the mandible. It was found that, without exception, the results were clinically acceptable, except for slight malfunction due to deviation of the mandible to one side on opening in seven cases.

In most centers closed reduction and intermaxillary fixation comprise the method or choice in the management of fractures of the mandibular condyle. Some surgeons prefer to manipulate the mandible prior to intermaxillary fixation in an attempt to improve the position of the fractured condylar segments. Some have manipulated the condyle head with a sharp pointed instrument passed intraorally or through the skin in an attempt to force the condyle head back into the fossa. These manipulations are generally unsuccessful, and X-ray examination following reduction usually shows no improvement in the position of the fragments.
There is evidence to indicate that subcondylar fractures with medial displacement of the head may finally heal in good alignment. This probably results from spontaneous or gradual movement of the condyle head back into the glenoid fossa rather than from resorption and reconstitution of the condyle (Gregory, 1957). It is the opinion of MacGregor and Fordyce (1957) and of Walker (1960) that most fractures of the mandibular condyle with displacement, deviation, or dislocation undergo modeling resorption with ultimate reproduction of a comparatively normal articular process and normal or near normal function and appearance. Other observers believe this process of resorption and reconstruction occurs within 6 to 12 months in children whose mandibular condyle is under the stress and strain of mastication. The authors believe that this view is unrealistic and that the fractured displaced condyle returns to the fossa under the influence of functional forces after the spasm and inflammatory reaction subsides.

Undisplaced or displaced condylar fractures without dislocation are treated by reestablishment of normal dental occlusal relationships with intermaxillary fixation by means of arch bars or eyelet wiring of the teeth. Intermaxillary stabilization is thus maintained for a period of four to six weeks. In many instances, however, if the patient is able to reestablish or maintain adequate occlusal relationships, fixation is not necessary, and maintenance of the patient on a soft diet may be all that is necessary during the healing phase. This is particularly true in younger children who heal very rapidly. If there is moderate overriding of the condylar fragments, opening the bite posteriorly in the molar area on the side of the fracture for 1 to 2 mm, with interposition of a thin plastic wedge, will further reduce the malalignment of the fragments when a satisfactory occlusal relationship cannot be established by the usual conservative means. The great majority of condylar fractures respond well to such conservative therapy.

Intracapsular condylar fractures are difficult to diagnose and usually give rise to a number of complications many months later, including clicking in the joint space, pain, and, in some instances, ankylosis. The latter is caused by the inflammatory process resulting from the injury accompanied by partial degeneration of the joint surfaces and eventual fibrosis and ankylosis. Minimal restriction of motion for approximately three weeks, weekly intra-articular injections of steroid, a soft diet, and a gradual increase in excursions of the mandible constitute the best plan of treatment rather than complete immobilization for four to six weeks (Georgiade).

In some cases it is not possible to reduce the fragment manually, but orthopedic traction with rubber bands will bring the teeth into functional occlusion in a matter of a few hours. In patients appearing late for treatment, slow intermaxillary traction may be necessary over a period of three to four days before the teeth come into satisfactory occlusion.

Gregory (1957) and others have reported cases in which there was spontaneous repositioning of markedly displaced fractured condyle segments two or three years after treatment by intermaxillary fixation. In Gregory's case there was a subcondylar fracture on the right side with marked medial angulation. This was treated by intermaxillary fixation, and a few months after fixation the condyle remained angulated out of the fossa. It was noted three years later, however, that the condylar process had resumed an adequate vertical relationship and was in position in the glenoid fossa. The exact mechanism is unknown, but
it must be assumed that certain forces of mastication favor drifting of the condyle head back into its normal position.

Leake, Doykos, Habal, and Murray (1971) reported 20 cases of condylar fractures in children who had subsequent normal growth, occlusion, and function without any treatment. Fractures varied from greenstick to severe displacement with anteromedial positioning and angulation of the condyle neck. Thirteen patients were followed for from 2 months to 17 years. Fifteen fractures were unilateral and five were bilateral condylar fractures. Intracapsular fractures in children, however, may lead to aseptic necrosis of the condylar head, fibrosseous ankylosis of the temporomandibular joint, and loss of the condyle growth center.

Open reduction. Because of the deep position of the mandibular condyle, the proximity of the branches of the seventh nerve and the internal maxillary artery, and the strong action of the lateral pterygoid muscle causing displacement, open operation for the reduction of mandibular fractures may be a complicated procedure.

Indications for open reduction. In condylar fractures with displacement of the condylar head out of the glenoid fossa, the head can usually be found in the pterygoid space, and consideration in these situations should be given to surgical replacement of the head in the fossa when there is an approximately 90 degree angle of the displaced condylar head from its normal position. An absolute anatomical alignment is not necessary, since it is often impossible to obtain. However, an end-to-end stabilization of the condylar neck fracture when the condylar head is replaced into the fossa is felt to be desirable, particularly in children and in patients who are edentulous and who, as a result, have a loss of vertical dimension of the ramus because of the malposition of the condyle and overriding of fragments. Maintenance of the condylar head in the glenoid fossa with slight overriding of fragments usually results in satisfactory bony union and the reestablishment of a normal bite pattern (Henny, 1951; Heurlin and coworkers, 1961; Georgiade, 1964).

Two types of roentgenograms are obtained before a decision is made whether to perform an open reduction of the displaced condylar fracture. A posterior-anterior view of the mandible or modified Towne view is helpful in establishing the position of the condyle in a frontal plane. Tomograms of the joint area are essential in order to locate accurately the relationship of the condylar head to the glenoid fossa.

Techniques of open reduction. Prior to extraoral reduction, arch bars or suitable wiring must be applied to the teeth if present. If the patient is edentulous, the patient's own dentures or a similar type of prosthetic appliance is used for immobilization following reduction of the condylar fracture; fixation can be obtained by means of nasomandibular wires. In children with a deciduous dentition, immobilization has been adequately achieved by attaching bilateral nasomandibular wires to a lower mandibular prosthesis, with circum-mandibular wires around the prosthesis or circum-mandibular wires around the mandible attached to the nasomandibular wires. Associated fractures are managed according to their type and the areas involved.

The indications for operation in the treatment of fractures of the condyle in children are not specific. The surgeon must rely upon his judgment and experience in making the decision.
The surgical approach to the fracture areas is preferably accomplished by some type of preauricular incision, usually an inverted "hockey stick" type of incision. The branches of the facial nerve are outlined by the use of a nerve stimulator and are retracted inferiorly and medially. Reduction of the condylar fracture is aided at this time by the use of muscle relaxing agents. The condylar head is usually found to have been displaced medially into the pterygoid space. A curved elevator and tracheotomy hook is employed to obtain leverage on the medial aspect of the condyle so that it can be displaced laterally and back into the glenoid fossa (Georgiade). While the condyle is being displaced laterally, traction is maintained on the ramus of the mandible in order to allow sufficient room for the displaced fragment to be brought into an appropriate position. A Kocher type of clamp is useful in grasping the displaced condylar head in order to stabilize it and replace it in the condylar fossa. The articular disc is usually not sufficiently damaged to warrant its removal and is replaced into the fossa to minimize the danger of ankylosis. If possible, the lateral pterygoid musculature which attaches along the medial aspect of the condyle is left intact, as the blood supply to the condylar head enters in this area. This caution minimizes the changes of necrosis of the condylar head. The use of a single 28-gauge wire threaded through the condylar fragment and ramus and immobilization of the fractured fragment in an end-to-end position will usually be sufficient.

If the fractured condyle cannot be maintained in the glenoid fossa, a 28-gauge stainless steel looped wire is used to maintain the condylar fragment in satisfactory position (Messer, 1972). Other types of fixation have been described by Thoma (1954), Henny (1951), Georgiade and coworkers (1956), and Heurlin and coworkers (1961).

An alternate method is to stabilize the condylar head in the fossa when the pull of the pterygoid muscle continuously dislocates the condylar head. This technique involves the use of two or three stainless steel pins fixed to the zygoma, the condylar head, and the ramus. Wire fixation of the fragments is accomplished, and the pins can be removed three weeks after the initial fixation of the fragments. This procedure is required only when stabilization cannot be maintained by the simplified wiring technique previously described (Georgiade and coworkers, 1956).

Reduction through the Risdon Approach (1925). This approach is useful only when the condylar fragment is long owing to a fracture extending downward through the sigmoid notch to the posterior border of the mandible. A 5-cm incision is made about 1 cm behind and below the angle of the mandible. The masseter muscle insertion is raised from the bone and elevated to expose the site of the fracture. A 22-gauge wire is passed through a small drill hole at the angle of the mandible for use in retracting the bone and identifying the posterior fragment. The posterior or condylar fragment is the closest to the articular surface of the condyle; the anterior fragment is the main mandibular fragment. When the fracture site is identified, a drill hole is made through the anterior fragment and a wire is passed through it and looped out of the wound, where it can be used to further distract the ramus. The posterior fragment is identified and a drill hole passed through it. The operator is looking up through a long narrow wound to the fracture site which does not permit drill holes to be made at right angles to the bone surface. By puncturing through the soft tissues lateral to the fracture site, the tip of the bone drill can be placed perpendicular to the bone in order to drill holes in the desired direction. The fragments are held together with a 25-gauge stainless steel wire which
is twisted, cut short, and flattened against the bone. The wound is closed without a drain. Intermaxillary fixation for four to six weeks is indicated.

Reduction through a preauricular approach. The preauricular incision is preferable in most instances for the approach to the region of the temporomandibular joint. The incision begins at the anterior border of the lobule and is extended upward over the posterior portion of the tragus and the anterior attachment of the helix into the temporal area, where it sweeps in a curve anteriorly for 3 cm. The tissues are dissected downward over the temporalis fascia to the joint area (Dingman and Constant, 1969). The dissection must be carefully done to avoid injury to the branches of the seventh nerve in the region of the joint. After identification and retraction of the branches of the nerve, the fascia overlying the temporomandibular joint is divided and the fractured segments identified. It may be extremely difficult to reduce the posterior fragment because of the strong pull of the lateral pterygoid muscle. Fixation is attained by means of drill holes passed through the bone fragments and securely wiring the neck of the condyle in position. Hoopes, Woolfort, and Jabaley (1970) reported a four-year follow-up of two children who underwent surgery at 2.5 and 8 years of age involving a postauricular incision and transauditory canal approach to the temporomandibular area for reduction and fixation of severe fracture-dislocation. Both showed excellent results, and the authors stated that the surgical approaches provided satisfactory exposure.

Hendrix, Sanders, and Green (1959) and Georgiade (1960) advocated removal of the condyle head and replacement in the glenoid fossa as a free bone graft. They reported good results using this method.

Compound Comminuted Subcondylar Fractures. This type of fracture results from penetrating injuries over the region of the temporomandibular joint or from gunshot wounds in this area. Treatment consists of repair of soft tissue wounds and fixation of the remaining portion of the mandible. If the joint is completely comminuted or infection is imminent, it is advisable to remove the condyle to control infection and prevent fibro-osseous ankylosis. Removal of the condyle results in a flail joint, generally with satisfactory function.

Dislocation of the Condyle of the Mandible. Dislocation of the condyle of the mandible without fracture may be caused by opening the mouth too widely or by sudden violence. The head of the condyle may be dislocated out of the glenoid fossa anterior to the articular eminence, where it is held securely by contraction of the muscles of mastication. Dislocation of the mandible may be unilateral or bilateral.

In many instances mandibular dislocation can be reduced by the patient without difficulty. In some cases, reduction is not possible except by the use of muscle relaxing drugs and general anesthesia. Most dislocations can be reduced by grasping of the mandible with the thumbs in the region of the mandibular molars and applying downward pressure on the posterior border of the mandible while simultaneously pressing upward and backward on the anterior portion. With this type of forceful movement the condyle usually snaps back into its proper position.

Johnson (1958) reported excellent results in obtaining spontaneous reduction of the dislocated mandibular condyle by injection of a local anesthetic solution into the joint area. He theorized that interruption of the reflex arc releases the muscle spasm and permits the
condyle to slip back into position. Johnson stated that it is necessary to inject only one side to give relief in bilateral dislocations.

Recurrent dislocation may be frequent and chronic so that dislocation may occur whenever the patient opens his mouth too widely or bites too firmly. Dislocation lasting several months to two years has been reported by Gottlieb (1952). In a review of the literature he found only three cases of long-standing dislocation of the jaw reduced by manual methods. He stated that the dislocations had been present for three months as reported by Müller (1946), two months by Berg, and two months by Bouisson. Ginestet, Desorthes, and Houessou (1948) reported the presence of ankylosis three years after a forceful open reduction. Gottlieb treated his three cases successfully by condylar resection. Litzow and Royer (1962) reported a unilateral dislocation of six months' duration which was successfully treated by condylectomy. The condyle was cut with bone burrs and chisels through a Risdon (1925) approach at the angle of the mandible. Dislocation of the condyle is also discussed in Chapter 31.

Fractures of the Coronoid Process of the Mandible. This portion of the bone is so well protected by the overlying zygoma, the dense temporalis fascia, and the attachments of the temporalis muscle that fracture is a rare occurrence. Penetrating wounds or gunshot wounds may result in fracture of this area. Generally, the fracture shows little displacement by the insertions of the temporalis muscle and fascia. Treatment is usually not necessary, as the displacement is minimal.

Treatment of Class III Fractures of the Mandible

Fractures in the Edentulous Mandible. Fractures of the edentulous mandible are seen less frequently in older persons than in the younger age group, since the older patient is less frequently exposed to hazardous situations in industry, sports, or travel. The fractures usually occur through the portion of bone in which the atrophy is the most advanced, and the bone is thin and weak. Quite often fractures occur bilaterally with moderate displacement. Because of the loose tissues over the bones, the fractures are less liable to be compound than they are in the mandible with teeth. Deformity is obvious when there are displacement and overriding of the bone fragments. Complications due to infection are infrequent, and healing generally takes place without difficulty.

The usual methods of fixation of the mandibular fragments are not applicable in the case of the edentulous mandible. Treatment is limited to the use of intraoral appliances, circumferential wiring, interosseous wiring, and pin fixation appliances.

Intraoral Appliances. Intraoral appliances are useful in the simple fracture in which displacement is minimal or absent. The patient's dentures or specially made bite-blocks prepared by a prosthodontist are fitted to the upper and lower laws to maintain stability of the mandibular segments. If displacement is minimal, the patient's own dentures, if undamaged, may be placed in the mouth and support against the mandible is applied with a head cap and chin strap. Relining the denture with softened dental compound or soft acrylic will compensate for the change of contour of the alveolar process caused by the fracture and avoid
pressure necrosis. Fixation for a week to ten days will result in sufficient organization at the
fracture site to prevent displacement. Broken dentures can be repaired, and all fragments of
dental appliances should be saved until it is determined that they are no longer useful.

Impressions of the alveolar ridges are required for the construction of bite-blocks to
fit the upper and lower jaws. When brought into occlusion, the bite-blocks provide the same
stability as the patient's dentures.

**Circumferential Wiring.** Baudens (1840) was the first to use circumferential wiring
for reduction of a mandibular fracture. His wire went around the mandible and was tied over
a molar tooth. Robert (1852) used a single circumferential wire for reduction of a mandibular
fracture. The wire was twisted close to the bone.

According to Ivy (1922), Black (about 1896) was the first American to employ
circumferential wiring of the mandible. This consisted of passing a wire around the mandible
and over a bite-block on the alveolar ridge to give stability to the fractured segments after
reduction. Circumferential wiring can be used with an acrylic bite-block or the patient's
dentures or around the bone without splints to hold oblique fractures in position after
reduction.

**Direct Interosseous Wiring.** Interosseous wiring is indicated in the management of
displaced fractures in the edentulous mandible in which there is overriding of the fragments.
It may be used in compound or comminuted fractures. The intraoral or extraoral route may
be employed.

*The extraoral route.* The approach is through an incision about 1 cm below the inferior
border of the mandible. The incision is made long enough to give adequate exposure to the
fractured segments. The fractured is identified, reduced, and held in position with bone
forceps. Drill holes are placed through the bones on each side of the fracture site. The bone
is securely fixed by interosseous 24-gauge stainless steel wire to provide positive fixation at
the site of the fracture. The wound is closed in layers.

*The intraoral route.* Intraoral interosseous wiring is an effective technique in fractures
of the edentulous mandible. The fracture line is exposed through an incision lateral or medial
to the crest of the alveolar ridge. The mucoperiosteum is raised on both the buccal and lingual
surfaces of the mandible. In thin mandibles, the attachment of the mylohyoid muscle is near
the crest of the alveolar ridge, and dissection should not be as extensive on the lingual surface
as it is on the buccal surface. Interference with the muscle attachments will result in edema
of the floor of the mouth and postoperative pain and discomfort on swallowing. The motor-
or turbine-driven bone drill is used to make small holes through the bone near the end of each
fragment. A 24-gauge stainless steel wire is passed from the buccal to the lingual surface and
back through the other hole to the buccal surface. The two ends are twisted so that the
fragments are firmly and positively fixed into position. The wires are cut short, and the cut
end is pressed against the bone. The soft tissue is closed over the fracture site. The wires may
remain permanently and cause little, if any, reaction. It may be necessary, occasionally, to
remove the wire several months later if pressure from the denture causes discomfort int he
mucous membrane overlying the ridge. Removal can be done easily under local anesthesia
as an outpatient procedure by reopening the area and cutting the wire.
Interosseous wiring through the intraoral route is relatively simple and provides a mechanical advantage at the fracture site. The wire placed near the upper border of the fracture provides a fulcrum against which the muscle forces are favorable for stabilization. The upward pull of the posterior muscles and the downward pull of the anterior group create forces that favor reduction. If the wire is placed low at the site of the fracture, an unfavorable situation is present, and the fragments have a tendency to become separated.

Infection following intraoral surgery is uncommon, and adequate antibiotic therapy provides additional protection.

The advantages of the intraoral approach are:

1. It is simple to accomplish.

2. There is no danger of surgical damage to the mandibular branch of the seventh nerve, the submaxillary gland, or the external maxillary artery.

3. It can be done with a minimal amount of instrumentation.

4. Healing takes place quickly and without complication.

**Compound and Comminuted Fractures of the Edentulous Mandible.** Kazanjian and Converse (1974) reported management of severe gunshot wounds of the anterior portion of the mandible in which only fragments of bone remained with no teeth in any of the fragments. The ends of a horseshoe-shaped heavy wire conforming to the dental arch were embedded in drill holes in the proximal segments of bone. This gave stability to the proximal segments and provided an opportunity for fixation of the small fragments by suspension with fine steel wires to the arch wire. This procedure is useful in those cases in which there is adequate soft tissue with a good blood supply to cover the bone fragments.

Similar cases are treated by direct wiring of the bony fragments to each other in order to reestablish the contour of the arch. The repair of soft tissues over the bone fragments will usually provide an adequate blood supply for reconstitution of the mandibular arch.

If large segments of the anterior mandible are missing, it is important to stabilize the remaining posterior segments so they will not be submitted to medial displacement by scar formation in the floor of the mouth. Stabilization can be obtained by acrylic splints fixed to the posterior segments by circumferential wiring. In certain favorable cases, a perforated metal tray appliance (Titanium), fastened to the inferior border of the proximal segments and extended around the anterior portion in the form of an arch, may be used to hold the posterior fragments in position and to support the anterior fragments and soft tissue. It is desirable to utilize all the fragments of bone to aid in the reconstruction of the mandibular arch.

Obwegeser and Sailer (1973) have advocated the placing of bone grafts over the mandibular ridge to aid in the healing of the fractured atrophic edentulous mandible. The bone grafts are maintained by circumferential wiring around the mandible. This technique has the advantage of providing the patient with an alveolar ridge capable of supporting a denture, as well as helping to consolidate the fracture.
**External Fixation in Mandibular Fractures.** External pin fixation was used for fractures of the long bones by Lambotte (1913) but was not popularized for use in other areas until Anderson (1936) developed an appliance which was extensively utilized in the fixation of fractures of the facial bones. This appliance gained popularity from 1936 until about 1942, when the use of pin fixation appliances largely gave way to open reduction and direct wire fixation methods. Numerous variations of the pin fixation appliances were devised and described by Stader (1937), Berry (1939), Haynes (1939), and Griffin (1941).

The indications for external fixation are:

1. Those cases which cannot be treated by simpler methods, such as interosseous or circumferential wiring.

2. Fractures of the angle of the edentulous mandible when there is loss of bone immediately anterior to the posterior segment.

3. Cases in which control of the fragments during reconstructive bone grafting procedures is required.

4. Rare cases when wiring of the jaws is contraindicated.

At the present time the most popular technique involves the use of the Morris biphasic fixation appliance (Morris, 1949), which has been employed extensively for the fixation of bone fragments in bone grafting for defects of the mandible (see Chapter 30).

**Complications in Mandibular Fracture Treatment**

**Early Complications**

**Primary Hemorrhage.** Extensive bone and tissue injury may result in severe blood loss. Usually there is little hemorrhage in closed fractures in which the soft tissues are not extensively involved. Clamping and ligation of major vessels and secure packing of the wounds with pressure dressings are effective treatments for control of hemorrhage. External carotid ligation is seldom necessary unless the vessel has been severed.

**Respiratory Complications.** These are seen in bilateral fractures of the body of the mandible with posterior displacement of the bone, which permits the tissues of the floor of the mouth and the tongue to fall back into the airway. Protraction of the tongue, repositioning of the anterior mandibular bone segments, or tracheotomy will establish the airway. Following intermaxillary fixation, the patient may have airway problems due to vomiting and aspiration of stomach contents (if the stomach contents have not been evacuated, an essential precaution), but this is a rare occurrence. It may be necessary to remove the intermaxillary rubber bands or wires to establish an airway or provide an improved airway. Usually a satisfactory airway can be established by insertion of an intranasal pharyngeal soft rubber tube, or large-bore rubber tubing can be placed along the teeth in the buccal sulcus and between the last molar teeth.
**Infection.** With modern methods of fracture treatment, infections are relatively rare. Most complications from infection can be avoided by elimination of foreign material from the wound, accurate fixation, and antibiotic therapy. Foreign bodies such as infected teeth, portions of fractured teeth, dirt, metal, glass, and other materials in the line of fracture predispose to infection.

Inadequate fixation may be the cause of infection owing to movement and a pumping action at the site of fracture which forces foreign material into the fracture site. Continuous damage to the young granulation tissue from movement in the line of fracture prevents healing, invites bacterial invasion, and interferes with the process of repair. Nonvital or abscessed teeth in the line of fracture may lead to infection of the bone or the adjacent soft tissues. However, it is desirable to retain teeth or root fragments in the line of fracture if they aid in the stabilization of the fragments, and with antibiotic therapy it is safe to retain these structures until they have served a useful purpose. If teeth or roots are present in the line of fracture but have no value in maintaining the position of the fracture segments, they should be removed.

Preexisting disease in the area of fracture, such as an abscessed tooth, osteomyelitis, a dental cyst, or partially devitalized irradiated bone, predisposes to infection.

Once established, a purulent collection is incised and drained, making sure that the fixation of the fragments is secure. Procrastination in instituting drainage of an abscess with fluctuation leads to spread of the infection through the spongiosa of the bone or along the periosteum, resulting in extension and more serious infection. Drainage may be established by intraoral or extraoral incision and insertion of a rubber drain. Antibiotic therapy is no substitute for the surgical establishment of adequate drainage.

**Infection and buried stainless steel wires.** Stainless steel wire may be placed through the ends of bone fragments via both the extra- and intraoral routes. Hematoma must be avoided. Continuous suction, using noncollapsible silicone tubing, of the operative site prevents hematoma formation and possible consequent infection and abscess formation. Once infection has become established, the wire usually prolongs the suppuration, and removal of the wire is indicated.

**Avascular necrosis and osteitis** of bone may occur when bone has been denuded of its periosteal and muscular attachment. When bone is exposed, it is deprived of its blood supply from the covering soft tissues. Osteitis and avascular necrosis are the fate of loose, denuded bone fragments. These complications can be minimized by early coverage of exposed bone with well-vascularized soft tissue containing a sufficient blood supply. Undermining of the adjacent mucoperiosteum or skin and muscle usually will provide adequate soft tissue for covering exposed bone. If adjacent tissues do not suffice, rotation of a local flap over the bone may prevent osteitis and aseptic necrosis.

**Osteomyelitis** of the mandible is relatively uncommon as a complication in the management of facial fractures. Before the use of antibiotics and modern surgical techniques in fracture treatment, approximately one-third of all patients with fractures developed osteomyelitis. Many times this was extensive, with loss of large segments of bone. Incision and drainage, fixation of the bone segments, and intensive antibiotic therapy are indicated in
cases of osteomyelitis. Sequestra should be removed as they form. In general, conservative management in osteomyelitis gives the best end result with the least amount of deformity.

**Ankylosis** of the temporomandibular joint may complicate compound comminuted fractures of the mandibular condyle or the coronoid process of the mandible. Ankylosis may also develop in intracapsular fractures of the articular head of the condyle in which there is aseptic necrosis with loss of the articular surface and destruction of the meniscus. Fibro-osseous ankylosis may occur following extensive comminuted compound fractures of the condyle. If it appears that infection is a complicating factor resulting in loss of bone with scar tissue formation, the devitalized head of the condyle should be removed.

**Late Complications.** The late complications include nonunion, malunion, delayed union, ankylosis of the temporomandibular joint, anesthesia of the inferior alveolar nerve, scar tissue contractures of the mouth, and facial deformity.

**Nonunion.** Healing at the site of fracture in most instances is accomplished in a period of four to eight weeks, depending upon the degree of fracture and the age and general condition of the patient. Healing is determined by clinical examination, as roentgenograms can show a radiolucency at the fracture site even in the presence of bony union. Nonunion may occur as a result of interposition of foreign substances, of muscle or soft tissue, improper immobilization, poor position of the fractured segments, loss of portions of the bone, sequestration of bone fragments, the presence of infection, or the debilitated condition of the patient. In one of our patients, union at the site of fracture of the mandible had not occurred after three months of fixation. It was found that the patient had lost approximately 30 pounds during this period because she did not like liquid foods and refused to take enough to provide an adequate nutritional intake. When she was placed upon a therapeutic feeding schedule, healing rapidly occurred.

On roentgenographic examination in nonunion, dense eburnated bone is noted covering the ends of the fractured segments.

The management of nonunited fractures is surgical. The bone ends should be exposed through an extraoral approach and the eburnated bone removed with bone burrs or rongeurs. If it is possible without shortening the mandible, the freshened bone ends are placed in apposition and held by interosseous wiring supplemented by intermaxillary fixation. In most cases of nonunion, there is insufficient bone to bridge the gap without forming a defect in the dental arch, and bone grafts are necessary. Before placing the bone graft, eburnated bone should be excised and the outer table partially decorticated. In small losses bone chips may be adequate to bridge the gap. In larger defects it is advisable to use solid segments of iliac bone as grafts. These should be fitted into the space between the segments of the mandible and securely fixed by direct wiring. The graft should be covered with adequate soft tissue to provide a blood supply for healing. Accurate intermaxillary fixation is imperative.

The mandible may be used as a donor site for small size bone grafts. These can be removed from the inferior border or angle of the mandible.

**Malunion.** Malunion occurs as a result of inadequate reduction and healing of the bone in an abnormal position. Malunion may also result from inadequate fixation in which
the fragments slip out of position and heal out of alignment, or from rotation of segments of the bone or overlapping of segments. Telescoping of the bone segments in the ramus of the mandible may result from the strong muscle pull of the muscles of mastication. If they are permitted to remain in this position, malunion will occur with open bite deformity in the anterior portion of the mandible. In early cases in which ossification is not complete, malunion may be overcome by strong orthopedic traction with arch bars and rubber band traction between the mandible and maxilla. This is effective if there is partial fibrous union but incomplete calcification.

The treatment of malunion consists of osteotomy at the site of malunion, repositioning of the bones, and fixation by direct bone plating or interosseous wiring. If bone segments have been lost, it may be necessary to supplement with bone grafts.
Fractures of the Maxilla

Fractures of the maxilla are less common than fractures of the mandible. The ratio of frequency appears to be changing from that of 4 to 1 stated by Rowe and Killey (1955) and Converse (1974). Recent series indicate a higher incidence of maxillary fractures in relationship to mandibular fractures.

The maxilla forms a large part of the bone structure of the middle third of the face and is attached to the cranium by a system of strong buttresses. The architectural and structural arrangement of these bones forms a mass capable of resisting considerable violence and is an important factor in protecting the brain case and intracranial structures. Violent forces in injuries of the anterior face are dissipated and absorbed by the maxilla and other facial bone structures, thus protecting the brain and spinal cord.

Anatomical Considerations

The maxilla is formed by the midline junction of two irregular, pyramidal component parts. It contributes to the formation of the midportion of the face and forms part of the orbit, nose, and palate, and its hollow interior comprises the maxillary sinuses. A large portion of the orbit, the nasal fossa, the oral cavity, and most of the palate, the nasal cavity, and the pyriform aperture are formed by the maxilla. The frontal processes of the maxilla support the nasal bones and nasal cartilages. As previously stated, the maxilla is attached to the cranium by a strong system of buttresses formed by the nasal bones and the frontal processes medially and by the zygoma laterally. The maxilla obtains its stability by intimate association with nine other bones of the face.

The maxilla consists of a body and four processes - the frontal, zygomatic, palatine, and alveolar processes. The body of the bone contains the large maxillary sinuses. In childhood the sinuses are small, but in the adult they are large with the overlying bone thinned to eggshell thickness.

When teeth are present in the maxilla, the alveolar process is a strong and thick bone giving excellent support to the horizontal processes and protection to the upper portion of the bone. In old age, when the teeth have been lost, there is marked atrophy of the alveolar process and thinning of the bone. The entire alveolar portion of the bone may recede to the nasal spine and as far as the floor of the maxillary sinuses.

The nerves to the teeth pass through the anterior wall of the bone, and the infraorbital nerve passes through the infraorbital canal of the maxilla to supply the soft tissues of the upper lip and lateral aspect of the nose. The mucosa overlying the bony palate and the mucosa of the soft palate are innervated by the palatine branches of the second division of the fifth nerve which pass through the palatine canal between the maxilla and the palatine bones. The nasopalatine nerves traversing each side of the vomer pass from the nasal cavity through the small incisive foramen to contribute to the innervation of the mucoperiosteum of the anterior portion of the hard palate.

Surgical Anatomy. The maxilla is designed to absorb the shock of mastication and of the occluding teeth and to distribute the load over the craniofacial skeleton. Forces are
distributed through the arch of the palate and the articulation of the maxilla against the frontomaxillary, zygomaticomaxillary, and ethmoidomaxillary sutures. The palatine bone and pterygoid plates of the sphenoid give stability posteriorly. The vomer, the perpendicular plate of the ethmoid, and the zygoma distribute the load to the temporal and frontal bones. The upper half of the nasal cavity, situated below the anterior cranial fossa and between the orbits, is designated as the interorbital space.

Fractures of the maxilla are usually caused by a direct impact to the bone and vary from simple alveolar fractures and fractures involving the maxillary bone to extensive fractures of the entire midfacial skeleton.

Muscle contraction does not play an important role in displacement of maxillary fractures. The muscles of expression have no influence upon displacement of fractured maxillary segments. The pull of the pterygoid muscles exerts a backward displacement in high maxillary fractures. When maxillary fractures are associated with fractures of the zygoma, masseter muscle action may be a factor in displacement.

Injuries of the nasolacrimal system may occur in fractures of the maxilla as the lacrimal groove is formed partially by the maxilla. The roof of the ethmoid sinuses and the cribiform plate contribute to the anatomy of the anterior cranial fossa, and fractures of the maxilla at a high level (Le Fort III fractures) are occasionally associated with fractures of these structures. Dural laceration, cerebrospinal fistula, and brain damage may result.

Shapiro (1947) has emphasized that the heavier portions of the maxilla give strength to the bone, and the thinner portions are the areas through which fractures are most likely to occur. Le Fort's (1901) experiments determined the areas of structural weakness of the maxilla and led to the Le Fort classification of fractures of the maxilla.

Classification

Alveolar Fractures. The dentoalveolar portion of the maxilla may be fractured by direct force or by indirect force against the mandible, which may shutter the maxilla. This may occur from a blow to the undersurface of the mandible with transmission of upward and outward forces against the maxillary teeth, causing alveolar fractures with lateral displacement.

Transverse Fractures (Le Fort I). Fractures above the level of the apices of the teeth may include the alveolar process, the vault of the palate, and the pterygoid processes in a single block. This type is known as the Le Fort I, or Guérin's, fracture.

Pyramidal Fractures (Le Fort II). Blows to the upper maxillary area may result in fractures through the thin portion of the frontal process, extending laterally through the lacrimal bones, the floor of the orbit, through the zygomaticomaxillary suture line, along the lateral wall of the maxilla, and through the pterygoid plates into the pterygomaxillary fossa. This fracture, because of its general shape and configuration, is known as the pyramidal fracture. With marked posterior displacement, damage may occur to the ethmoidal area, to the septum, and to the lacrimal area with lateral splaying of the interorbital space.
**Craniofacial Disjunction (Le Fort III).** Craniofacial disjunction may occur when the fracture extends through the zygomaticofrontal suture and the nasofrontal sutures and across the floor of the orbits to effect complete separation of the structures of the middle third of the face. In these fractures, the maxilla may not be separated from the zygoma or from the nasal structures, the entire midfacial skeleton being completely detached from the base of the skull and suspended only by soft tissues.

**Vertical Fractures.** Fractures of the maxilla may occur in a vertical direction in which the maxilla is split along a sagittal plane. This usually occurs just to one side of the midline, which is reinforced by the vomer. The bone is thin at the site of fracture.

Vertical fractures are usually associated with other fractures of the maxilla. Displacement depends upon the direction and the degree of force.

**Etiology**

The most common cause of fractures of the maxilla is the force sustained from the so-called "guest passenger" type of injury. This injury occurs in automobile, airplane, and other high-speed accidents when the patient is thrown forward and strikes the middle third of his face against the instrument panel, the back of a seat, or the head of another individual. If the force is sustained low on the maxilla, in the region of the upper lip, an alveolar fracture or a transverse fracture is most likely to occur. If the force is more violent and sustained at a higher level, comminuted fractures of the maxilla of the pyramidal type may be expected.

Although most traumatic forces are directed from the anterior or lateral direction, upward forces on the anterior portion of the maxilla may occur. Displacement is generally posteriorly and downward, giving the patient a "dish face" appearance in the middle third of the face and overall elongation of the facial structures. The posterior and downward displacement may be aided by the forces of the pterygoid musculature. Partial fracture of the maxilla or the alveolar process with displacement of the segments into the sinus or the region of the palate may occur from lateral forces. In sagittal fractures due to upward forces, the fragments may be displaced outward on one or both sides. Vertical fractures are caused by forces transmitted through the mandible to the maxilla or by direct upward force to the anterior maxilla. Impacted fractures are infrequent, but in some cases the entire maxilla is driven upward and backward into the interorbital space or pharyngeal region and may be so securely impacted that no movement can be elicited on clinical examination.

**Examination and Diagnosis**

**Inspection.** Epistaxis, periorbital, conjunctival, and scleral ecchymosis, edema, and subcutaneous hematoma are suggestive of fractures of the maxillary-nasal area. Malocclusion with anterior open bite is suggestive of fracture of the maxilla. A maxillary segment may be displaced downward and posteriorly, resulting in premature occlusion in the posterior region. On intraoral examination, tearing of the overlying soft tissues of the labial vestibule or the palate generally indicates underlying fractures. The face will have a long, donkey-like appearance, suggestive of a fracture of the maxilla, and particularly of a cranio-facial disjunction (Le Fort III fracture).
Palpation. Simultaneous bilateral palpation may indicate a steplike defect at the zygomaticomaxillary suture, indicating fractures of the pyramidal type. Intraoral palpation may reveal fractures of the anterior portion of the maxilla or fractured segments of alveolar bone. Fractures at the junction of the maxilla and zygoma may be detected by digital palpation along the inferior rim of the orbit. Movement of the nasal bones by palpation suggests that nasal fractures may be associated with fractures of the maxilla.

Digital Manipulation. Force applied by grasping the anterior portion of the maxilla between the thumb and index finger will elicit mobility of the maxilla or the entire zygomaticomaxillary complex. The manipulation test for mobility is not entirely reliable, because impacted fractures may be extensive and exhibit no movement. These may be overlooked unless the occlusion is carefully checked. Manipulation of the anterior maxilla may show movement of the entire middle third of the face, including the bridge of the nose (Le Fort III fracture). Crepitation may be heard when the anterior maxilla is manipulated.

Cerebrospinal Rhinorrhea or Otorrhea. These complications involve the leaking of cerebrospinal fluid from the nose or ear. This signifies the presence of a fistula extending from the intracranial arachnoid space through the skull into the nose or ear. This signifies the presence of a fistula extending from the intracranial arachnoid space through the skull into the nose or ear. Clear fluid drainage from the nostrils, ears, or pharynx may be noted in fractures of the maxilla involving the cribriform plate and base of the anterior cranial fossa, or the middle cranial fossa in the case of otorrhea.

Malocclusion of the Teeth. With the mandible intact, malocclusion of the teeth is highly suggestive of maxillary fracture. It is possible, however, to have a high craniofacial dislocation and still have fair occlusion of the teeth. If the maxilla is rotated or markedly displaced backward and downward, there is complete disruption of the occlusal relationships.

Roentgenographic Findings. The clinical diagnosis of fractures of the maxilla should be confirmed by careful roentgenographic examination. Fractures of the maxilla may be difficult to demonstrate on roentgenographic examination because of the superimposition of other structures. The Waters view is excellent for demonstrating fractures of the maxilla and associated structures. Unless there is displacement, fractures may not be demonstrated by roentgenographic examination. The presence of an opaque maxillary sinus suggests fracture of the maxilla. The opaque shadow represents serum or blood in the sinus resulting from disruption of the sinus mucosa incident to the fracture. Separation in the nasofrontal area may be noted if the fracture is associated with nasal fractures. Steplike irregularities may be noted in the infraorbital margins, and the zygomaticomaxillary junction will be widened. Irregularity of the lateral wall of the maxillary sinus is usually noted. Vertical and alveolar fractures are best determined by the occlusal X-ray technique.

Treatment of Fractures of the Maxilla

Emergency Treatment. Treatment should be directed toward the establishment of the airway and control of hemorrhage.

The Airway. If considerable displacement of the fractured maxilla has occurred, the upper airway may be blocked by structures forced into the pharyngeal region or by blood
clots, loose teeth, bone, broken dentures, or other foreign material. These should be removed and, if an adequate airway cannot be established, endotracheal intubation or tracheotomy should be done.

**Control of Hemorrhage.** Some maxillary fractures are associated with deep lacerations of the overlying skin and oral mucosa. Shearing fractures may tear the greater palatine vessels, or wounds may involve the internal maxillary artery, resulting in severe hemorrhage in the nasal and pharyngeal area. The bleeding may threaten exsanguination and may respond only to clamping of the deep vessels and packing of the wounds. Posterior nasal tamponade may control bleeding in the posterior pharyngeal region. In gunshot or avulsing wounds of the maxillary area, ligation of the external carotid artery may be indicated.

**Definitive Treatment**

**Alveolar Fractures.** Simple fractures of portions of the maxilla, including the alveolar bone and teeth, usually will respond to digital manipulation and reduction. If the occlusion is satisfactory, the position of the teeth may be maintained by ligating the teeth in the fracture segment to the adjacent teeth. The segments can also be stabilized by ligation of an arch bar to adjacent normal segments of the maxilla and ligation of the teeth of the fragments to the arch bar. Individual teeth or segments containing several teeth may be stabilized by a splint fabricated at the operating table with quick curing acrylic resin moulded to the teeth and alveolus. If the fragments cannot be adequately reduced and there is premature contact between the teeth of the mandible and the teeth of the fractured segment, the application of upper and lower arch bars and intermaxillary rubber band traction for a few days will usually force the segment into position. Fixation should be maintained for approximately three to four weeks.

**Transverse Fractures.** Fractures of the Le Fort I or Le Fort II type, in which there is an adequate complement of teeth and intact mandible with teeth, may be treated by intermaxillary fixation with arch bars and rubber bands and the application of a simple head cap with a chin support.

The primary consideration is the reestablishment of functional dental occlusion, and this should be accomplished before upward traction is applied. The force of the mandible against the maxilla will reduce the fractured maxilla and hold it in position until consolidation takes place. In utilizing this method, care must be used to avoid necrotizing pressures against the soft tissues along the inferior border of the mandible. Ulcers may occur if pressure is intensive.

Head caps are usually unreliable and uncomfortable; more positive fixation of fractures of this type can be obtained by suspension of the mandible and maxilla by internal wire fixation to the first solid structure immediately above the fracture site. This is usually the pyriform margin, the infraorbital rim, or the frontal bone just above the frontozygomatic suture.

Infraorbital fixation is achieved through percutaneous lid or transconjunctival incisions to expose the bony margin. Small drill holes are made through the infraorbital rim on both sides. A fine stainless steel wire is passed through each hole and looped over the infraorbital
margin. The ends of the wire are led into the mouth through a needle and passed around the superior arch bar. After the teeth are secured in occlusion by rubber band traction, the assistant applies pressure against the mandible, which repositions the maxilla. The wires are then securely twisted around the upper arch bar. The maxilla is guided into proper occlusal relationship with the mandible and is help by the suspension wire. This method provides positive fixation with minimal effort and maximal comfort to the patient. The concealed wires and arch bars permit early return to productive activity.

Pyramidal fractures of the maxilla and fractures of the maxilla associated with the nasal bones can be reduced and maintained by open reduction and interosseous wire fixation.

**Malunited Fractures or Fractures Partially Healed in Malposition.** Impacted fractures or those seen two or three weeks after injury and partially healed fractures may be impossible to reduce manually or by the usual methods.

Intermaxillary traction by means of rubber bands placed between an arch bar or Kazanjian buttons placed on the maxillary dental arch and similar appliances on the mandibular dental arch will reposition the displaced maxilla if consolidation is not too advanced. An open bite ill be closed by the vertical traction of the rubber bands. If advancement and downward rotation of the impacted maxilla is required, the rubber bands are placed obliquely between the maxillary and mandibular arches: the mandibular points of purchase of the rubber bands are further forward than the maxillary. Once reduction has been achieved, as judged by adequate occlusal relationships, intermaxillary fixation is established. A bandage may be adequate in simple fractures; internal suspension wiring may be required in more severe cases to provide cranial fixation.

When consolidation is more advanced, more energetic methods of disimpaction can be obtained by forceps, such as Rowe's or Hayton-Williams'. Continuous traction can be exerted by means of an extraoral appliance attached to a cranial fixation appliance, such as a head frame (Georgiade's "crown of thorns") or a plaster head cap, are required. Extracranial orthopedic traction has also been employed in the past.

Such methods have progressively been replaced, in many cases, by the direct surgical approach. Experience gained in craniofacial surgery has shown that such an approach can be employed safely and efficiently.

In malunited fractures of the maxilla, whether completely or partially consolidated, the direct approach, either through a transcutaneous or an intraoral approach, or both, is indicated. The Le Fort I malunited fracture is approached through an oral vestibular incision, and the line of fracture is exposed. The bone is liberated after transection of the fracture line, and the lower maxillary segment is replaced in the correct occlusal relationships with the mandibular teeth.

The Le Fort II and Le Fort III fractures are also approached through appropriate cutaneous and intraoral incisions, and the malunited portions of the facial skeleton are disengaged and repositioned according to the principles established in craniofacial surgery. In some cases an intracranial approach may be required.
Fractures of the Edentulous Maxilla. Fractures of the edentulous maxilla are seen infrequently unless associated with extensive fractures of the other bones of the mid-third of the face. The absence of teeth, through which fracturing forces are usually transmitted, provides a measure of protection for the edentulous patient. Older edentulous patients are not exposed to the traumatic hazards of younger age, which also reduces the incidence of maxillary fractures. Dentures give protection from fracture by absorbing traumatic forces which are dissipated by the breaking of the denture.

Fractures of the edentulous maxilla with minimal displacement. If the displacement is minimal, causing little facial deformity, it is reasonable to expect that the discrepancy in the maxillary-mandibular relationships will be corrected by means of adjustment or reconstruction of the patient's denture. Treatment is therefore unnecessary. Fractures of this type heal within a matter of two to three weeks. As soon as the edema and hematomas have disappeared, the patient may have a new denture constructed.

Edentulous fractures with significant displacement. If the displacement is such that it results in deformity of the midthird of the face and a problem for denture construction, efforts should be made to reduce and immobilize the fractured segments. If the fracture is transverse (Le Fort I type) and the patient has a usable upper denture, the fracture may be reduced manually. The denture is inserted and brought into occlusal relationship with the lower teeth or the patient's lower denture, and a head bandage or plaster bandage is applied. After a week to ten days, the fracture segments will remain in position without further fixation.

If the displacement is moderate and the patient has no upper denture, open exposure of the fracture site and wiring to the edge of the pyriform margin will provide fixation.

In the pyramidal or Le Fort II fracture, the patient's upper denture may be wired to the fractured segment anteriorly and posteriorly. The denture is brought into occlusal relationship with the patient's teeth or lower denture; this then determines the position of the maxillary segment, which is advanced and rotated into the denture. The denture is secured by internal wire fixation through the infraorbital margins, to the zygomatic process of the frontal bone or by a wire looped around each zygomatic arch.

If the fractured maxilla is associated with other fractures, the patient's dentures or prepared splints and internal wire fixation are necessary for reduction and fixation.

Comminuted displaced fractures of the anterior maxillary wall with penetration of the maxillary sinus require reduction by the open method through an incision in the canine fossa. The maxillary sinus cavity is packed with rubber dam drain or gauze strips impregnated with petrolatum to maintain contour of the anterior maxillary wall and support the fractured segments. The end of the gauze may be brought out through a nasal antrostomy under the inferior turbinate for ease of removal. Fixation and support with the gauze packing for five to seven days will permit the fractured segments to consolidate into position.

Postoperative Care of Maxillary Fractures. Postoperative management of fractures of the maxilla consists of the usual general care, including adequate nutrition and antibiotics when indicated. The nasal cavity is usually involved, and it may be difficult to maintain an adequate nasal airway. Frequent suctioning of the nasal cavity will keep the airway free of
mucus and blood clots. Vasoconstricting drugs may be helpful in keeping the airway open and may provide ventilation to the maxillary sinuses so that disintegrated clotted blood in the sinuses will have an opportunity to escape readily. Oral hygiene should be maintained by frequent use of mouthwashes and proper toothbrushing technique. This is especially important when the patient's dentures are fixed by circumferential wiring to the mandible and maxilla. Food particles under the denture or around the fixation appliances increase the possibility of infection and may give a foul odor to the breath.

Complications of Fractures of the Maxilla

Early Complications

Hemorrhage. The early complications are those associated with acute trauma incident to the injury. Extensive hemorrhage due to laceration of the overlying soft tissues or to fracture and tearing of major vessels passing through the maxilla may be serious and should be managed by clamping and tying vessels, by tamponade, or by packing the wounds with gauze.

Airway Obstruction. The maxilla forms a large portion of the boundary of the nasal cavities and in almost all cases of extensive fracture of the maxilla, the airway will be compromised owing to displacement of fragments or edema of the soft tissues of the nasal cavity. Segments of bone may be forced into the oropharyngeal area, further interfering with the airway. Blood clots and fragments of bone and tooth structure should be removed from the upper pharyngeal and nasal area as early as possible. A soft rubber nasopharyngeal tube passed through the nostril may help in establishing an airway.

Infection. Maxillary wounds may be complicated by infection caused by contamination at the time of injury, by loose teeth or bone fragments in the maxillary sinus, or by fractures through a sinus with preexisting chronic infection. The appropriate methods of management of local infection must be instituted; this may require opening and drainage of the maxillary sinus, removal of foreign bodies, bone fragments, or teeth from the maxillary sinus or the nasal cavity, and the administration of antibiotics. Fractures of the maxilla may be associated with fractures of the cribiform area and cerebrospinal fluid rhinorrhea. Treatment consists of antibiotic therapy and reduction of the fractures. Blowing of the nose and nasal packing should be avoided.

Blindness. Bilateral total blindness is fortunately rare as a complication of severe Le Fort III facial fractures. It has been suspected that bone fragments projected backward into the apex of the orbit could sever the optic nerve, a cause of unilateral blindness. Ketchum, Ferris and Masters (1976) had the opportunity to witness the mechanism of bilateral blindness in the course of a craniotomy in a patient with bilateral blindness following a Le Fort III fracture. The backward displacement of the fragments resulting from the orbital fractures had shredded the optic nerve, "as a piece of glass would shred twine, fraying it on one side and completely transecting it on the other."

Late Complications. Late complications of fractures of the maxilla include nonunion, malunion, lacrimal system obstruction, infraorbital anesthesia, and extraocular muscle imbalance.
Nonunion. Nonunion of fractures of the maxilla is rare unless there has been considerable destruction of bone as a result of comminution. Usually nonunion indicates failure to provide even the most elementary type of fixation. Should nonunion occur, the treatment consists of exposure of the fracture site, resection of fibrous tissue in the fracture site, placement of cancellous autogenous bone chips, and adequate fixation after restoration of adequate occlusal relationships.

Malunion. In multiple, complex (panfacial) fractures, malunion may result from inadequate diagnosis of the fracture. The tooth-bearing segment of the maxilla may be placed in adequate occlusal relationships with the mandible, but other segments of the bone may remain unreduced. The treatment of panfacial fractures is discussed at the end of this chapter. Secondary osteotomies to restore contour and dental occlusion are discussed in detail in Chapter 30.

Lacrimal System Obstruction. The nasolacrimal duct may be severed or obstructed in transverse comminuted fractures extending across the facial skeleton at the level of the nasolacrimal duct. A dacryocystorhinostomy is usually indicated. In Le Fort II fractures, when they are associated with naso-orbital fractures, the lacrimal sac and canaliculi may be injured by displacement of bone fragments (see Chapter 28).

Extraocular Muscle Imbalance. The inferior oblique muscle may be injured at its point of insertion at the medial portion of the orbital floor formed by the maxilla. Disturbances of the oculorotary mechanism of the eye are more frequent in maxillary fractures associated with orbital, naso-orbital, and zygomatic fractures.

Fractures of the Zygoma

The zygoma is a buttress of the facial skeleton and the bone of the face that gives prominence to the cheek area. The zygoma, commonly known as the malar bone, is a quadrilateral bone with frontal, maxillary, temporal, and orbital processes. It articulates with the frontal bone, the maxilla, the temporal bone, and the greater wing of the sphenoid. On its outer surface it is convex, forming the prominence of the cheek; on its inner surface it is concave and participates in the formation of the temporal fossa. The bone has its broadest and strongest attachment with the maxilla, a thin, weak attachment with the frontal bone, and a weak attachment with the thin zygomatic process of the temporal bone. The zygoma forms the greater portion of the lateral orbital floor. In most skulls, it forms the lateral superior wall of the maxillary sinus and may be pneumatized with air cells connecting with the maxillary sinus. The bone furnishes attachments for the masseter, temporalis, zygomaticus, and zygomatic head of the quadratus labii superioris muscles. The zygomaticotemporal and zygomaticofacial nerves pass forward through small foramina in the zygoma to innervate the soft tissues over the malar prominences.

Surgical Pathology

Although sturdy, the zygoma is in a prominent location and is frequently subjected to injury. Moderately severe blows will be absorbed by the bone and its buttressing attachments. Severe blows, such as from a fall or a fist, may cause separation of the zygoma at its articulating surfaces. It is usually separated and displaced in a downward, medial, and
posterior direction. Violent shattering injuries to the region of the zygoma may result in extensive comminution as well as separation at the suture lines.

The zygoma is the principal buttressing bone between the maxilla and the cranium. Fractures usually involve the orbital rim, resulting in hematoma or extravasation of blood into the tissues near the lateral canthus. Direct lateral force may result in fractures of the temporal portion of the zygoma and the zygomatic process of the temporal bone which make up the zygomatic arch. Fracture with medial displacement of the arch may cause impingement of the bone fragments against the temporal muscle attached to the coronoid process of the mandible. This may result in difficulty in or inability to open the mouth because of interference with the forward and downward movement of the coronoid process. Fragments of bone driven through the temporal muscle into contact with the coronoid process may be the causative factors in the formation of a fibro-osseous ankylosis, necessitating excision of the coronoid process.

Fracture-dislocation of the zygoma with sufficient backward displacement to impinge on the coronoid process will interfere with mandibular motion. Fracture-dislocation of the zygoma results in separation of the zygomaticofrontal suture line, which is palpable through the skin overlying the lateral orbital margin. Separation with a steplike deformity of the infraorbital margin can often be detected clinically. The lateral superior wall of the maxillary sinus is involved in fractures of the zygoma, resulting in a tear of the maxillary sinus lining and accumulation of blood in the sinus with unilateral epistaxis, which may last a short time. The lateral canthal ligament is attached to the zygomatic portion of the orbital rim; displacement of the bone carries the lateral canthal attachment with it, producing a visible deformity. Dysfunction of the ocular globe may be noted as a result of disruption of the floor and lateral wall of the orbit. The septum orbitale, which attaches to the inferior orbital margin, may be displaced, causing retraction and shortening of the lower lid. Displacement of the globe and orbital contents may occur as a result of downward displacement of the suspensory ligament of Lockwood attached to the lateral wall in its zygomatic portion immediately behind the lateral canthal ligament. When there is fragmentation of the bony floor, the orbital contents may herniate into the maxillary sinus, where they become incarcerated between the fractured bone segments. Although diplopia is usually transitory in uncomplicated fractures of the zygoma, it may persist when the fracture extends to the maxillary portion of the orbital floor (see Chapter 25).

The orbital fracture may also be complicated by a fracture of the inferior rim of the orbit. When the lower rim of the orbit is displaced backward by fracture, the septum orbitale attachment to the orbital rim is also displaced backward. A downward pull upon the lower eyelid and a tendency to eversion are the results of this anatomical derangement by the fracture.

The infraorbital nerve runs through a canal in the maxilla, but the close proximity of the zygoma usually causes damage by impingement against the nerve when the zygoma is fractured. Laceration of the nerve in the canal or fragments of bone impacted into the area may result in permanent anesthesia. Infraorbital nerve anesthesia usually disappears progressively. Persistent anesthesia is an indication for exploration and decompression of the infraorbital nerve.
Knight and North (1961) proposed a classification of fractures of the zygoma based on the anatomy of the fracture. This is helpful in predicting the clinical features and planning treatment.

**Classification of 120 Cases of Fracture of the Zygoma**

- **Group I.** No significant displacement - fractures visible on roentgenogram but fragments remain in line 6%
- **Group II.** Arch fractures - inward buckling of the arch - no orbital or antral involvement 10%
- **Group III.** Unrotated body fractures - downward and inward displacement but no rotation 33%
- **Group IV.** Medially rotated body fractures - downward; inward and backward displacement with medial rotation 11%
- **Group V.** Laterally rotated body fractures - displacement is downward, backward and medialward with lateral rotation 22%
- **Group VI.** Includes all cases in which additional fracture lines cross the main fragment 18%

**Diagnosis of Fractures of the Zygoma**

**Clinical Evaluation.** A history of the type of injury and the direction of force may be helpful in arriving at a diagnosis. A blow from a fist, a fall against a hard object, or a shattering wound to the side of the face from an automobile accident is likely to result in fracture of the zygoma.

A few hours after an injury resulting in fracture, the clinical picture may be obscured by edema and hematoma. Inspection may show ecchymosis of the lids, conjunctiva, and sclera, swelling of the face in the cheek area, displacement of the lateral canthal ligament, depression of the globe, retraction of the lower lid, a deeply sunken upper lid, unilateral epistaxis on the involved side, and inability to open the mouth as presumptive signs of fracture of the zygoma.

The patient may complain of pain on trying to open the mouth and will note that the mandible can move only a short distance. Anesthesia of the upper lip, lower lid, and lateral nasal area is usually present. Diplopia may not be noted after the onset of edema but may be a prominent feature when swelling subsides.

Bimanual palpation of the bone and the structures of the face may be helpful. With the patient seated or lying in a semirecumbent position, the bony prominences on both sides of the face are palpated simultaneously. With the fingers passing around the orbital rim, fractures of the zygomaticofrontal or zygomaticomaxillary suture area may be palpated. Fractures of the zygomatic arch may be detected by flatness or indentation over the infraorbital rim or zygomatic arch. Introra oral palpation with the finger passing along the lateral and anterior wall of the maxilla, over the region of the zygomatic process of the maxilla and tuberosity, may permit the surgeon to feel irregularities over the bone; the index finger, when palpating the buccal sulcus beneath the zygoma, will note a depression of the fractured
zygoma, as the groove between the undersurface of the zygoma and the maxilla is absent if the bone is displaced downward, medially, and posteriorly.

**Roentgenographic Evaluation.** The usual findings of disjunction at the zygomaticofrontal, zygomaticomaxillary, or zygomaticotemporal suture line are noted. The maxillary sinus is usually opaque owing to the presence of blood in the cavity. The Waters' view will demonstrate the orbital margins and the body of the zygoma. The zygomatic arches can be demonstrated by the Titterington position, the semiaxial superoinferior projection. Tomograms are especially useful for detection of fractures of the orbital floor and orbital walls.

**Treatment of Fractures of the Zygoma**

The degree of fragmentation and the direction and amount of displacement may influence the management of fractures of the zygoma. Numerous approaches for reduction of the fractured zygoma have been described. Fixation may be obtained by impaction against the adjacent articulating bones, by support from normal muscle and fascial attachments, by the use of cranial fixation appliances, by direct fixation with interosseous wiring, or by the use of gauze packing in the maxillary sinus and the infratemporal region.

Disappointment and frustration in the management of zygomatic fractures after use of the usual closed methods of reduction have been experienced. In many cases of simple fracture without comminution, in which reduction was easily accomplished by the usual methods, later complications were observed in the form of diplopia, malunion, and residual deformity. It was obvious that either the reduction had not been complete or dislocation of the fracture was recurring in the postoperative period. A careful study of the problem indicated that the fracture-dislocation was usually more severe than it appeared to be from the radiologic and clinical evaluation. Edema often obscured the true condition. Intraorbital edema gave support to the globe during the early stages, and after the edema subsided, diplopia was present. Displaced fractures and blowout fractures of the orbital floor were often overlooked, and the action of the masseter muscle in the face of a tear of the temporalis fascia resulted in postoperative displacement of the zygoma.

These observations led to investigation. In a number of cases, fractures of the zygoma were treated in the usual manner by elevation in what appeared to be a satisfactory position clinically. The fracture sites were then exposed surgically in the zygomaticofrontal and zygomaticomaxillary areas. In many instances, the fractures actually had not been adequately reduced. Investigation of the orbital floor in some cases showed depressed fractures with herniation of orbital contents into the maxillary sinus. (See Chapter 25.) From these clinical studies, it is suggested that almost all fracture-dislocations of the zygoma should be treated by open reduction and direct wire fixation. This has proved to be an effective program resulting in a high degree of satisfaction.

**Methods of Reduction**

**Intraoral Approach.** Keen (1909) described the intraoral approach for reduction of fractures of the zygoma. General anaesthesia is preferable. With the cheek retracted by an assistant, the operator passes a sharp elevator up through the buccal vestibule behind the
tuberosity of the maxilla. An incision may be made, but with a sharp, pointed, sturdy elevator the mucosa can be punctured and the instrument introduced on the posterior aspect of the zygoma beneath the zygomatic prominence. Pressure applied in an upward, forward, and outward direction will elevate the zygoma, which snaps back into its position and remains in position without fixation. Infection following this method is unlikely. It is not necessary to suture the opening in the buccal mucosa. Because of the heavy masseter attachments, this method is not applicable to fractures of the zygomatic arch.

**Reduction Through The Maxillary Sinus.** Lothrop (1906) employed an antrostomy approach under the inferior turbinate and passed a curved trocar into the maxillary sinus, contracted the lateral superior wall, and rotated the depressed fractured zygoma in an upward and outward direction into position.

**Temporal Approach.** A temporal approach for reduction of zygomatic fractures was described by Gillies, Kilner, and Stone (1927). The temporal approach is useful and effective, especially for impacted fractures or those of several weeks' duration. Through this approach, strong leverage can be placed against the zygoma in the desired direction.

The operation is accomplished through a vertical temporal incision about 2 cm long above and behind the hairline. The incision is extended through the skin and the subcutaneous and superficial temporal fascia. After the latter is incised, the glistening temporal fascia can be easily identified. A sturdy elevator is slipped down along the temporal fascia, underneath the temporal surface of the zygoma. A towel or sponge is placed over the scalp area, which provides a fulcrum against which considerable leverage may be applied to elevate the bone. Care must be taken to pass the instrument between the superficial and the deep layers of the temporal fascia; otherwise the elevator will pass lateral to the zygomatic arch instead of into the temporal fossa. Palpation of the bone with the other hand will guide the bone into position and guard against overcorrection. The wound is closed in layers with absorbable sutures in the fascia and nylon in the skin.

**The Dingman Approach.** Under general anaesthesia, a solution containing epinephrine 1:100,000 is injected into the tissues of the lateral brow area and the infraorbital area. An incision is made in the lateral brow about 1.5 cm in length. Another incision is made in the lower lid. By means of a periosteal elevator, the zygomaticofrontal and the zygomaticomaxillary suture lines are exposed. Fracture separation will usually be found at these sites. A moderately heavy periosteal elevator is passed through the upper incision behind and lateral to the orbital margin into the temporal fossa. Excellent control of the zygoma is obtained through this approach, and by an upward, forward, and outward movement, depending upon the displacement of the fractured segments, the bone can be elevated into position. During elevation the zygoma is palpated through the skin and guided into position.

At this time, if indicated, the orbital floor can be explored (see Chapter 25 for details). Any herniation of orbital contents can be reduced and the defect in the orbital floor corrected.

Drill holes are placed through the bone on each side of the fracture site at the zygomaticofrontal and zygomaticomaxillary sutures. Wires are passed through the holes and twisted to maintain the bony fragments in position.
The zygomatic arch can also be elevated through the supraorbital approach. Usually the heavy fascial and muscular attachments to the arch will hold it in position, and direct wire fixation is not indicated.

**Comminuted Fractures of the Zygoma.** Violent blows to the zygoma result in shattering of the bone into multiple fragments. The methods of management of this type of fracture include the intraoral approach through the anterior wall of the maxillary sinus with packing of the sinus, intraoral exposure with direct wire fixation, the suspension method, interosseous wiring, and packing of the temporal fossa.

**Packing of the Maxillary Sinus.** The maxillary sinus approach to comminuted fractures of the zygoma may be effective but is infrequently used by the authors for zygomatic fractures because of the small part of the zygoma contributing to the maxillary sinus. If the fracture is associated with maxillary fractures involving the orbital floor, maxillary sinus packing may be effective. Manipulation of the orbital floor through the maxillary sinus should be done in conjunction with exposure of the orbital floor to lessen the opportunity for bone fragments to damage the globe or nerves of the orbit. Packing is done through a Caldwell-Luc intraoral incision. The mucoperiosteum over the canine region of the maxilla is elevated, and if there is no fracture of the anterior wall of the maxilla, an opening is made with chisels, bone drills, or biting forceps. Through this opening it may be possible to reduce the fragments of the zygoma by upward and outward pressure. Any fragments of the orbital floor that may have been herniated into the maxillary sinus are elevated into position and held by packing the sinus firmly with salvage-edge gauze permeated with petrolatum. Blood clots and hematomas should be aspirated from the sinus, and the walls, floor, and roof of the sinus should be inspected and examined with a palpating finger to determine the presence of comminution in the orbital floor and possibly herniation of orbital contents into the maxillary sinus. A Penrose gauze-type rubber drain may be utilized to pack the sinus, or gauze impregnated with a suitable antibiotic and petrolatum may be used. An antrostomy opening is made beneath the inferior turbinate, and the end of the packing is brought into the nasal cavity. This provides adequate drainage to the sinus and a route through which the packing may be removed gradually after it has served its purpose. The oral wound is securely sutured. The packing is removed gradually in a week or ten days. Sinus infection is an unlikely complication with this method.

**The Intraoral Approach.** Reduction of malposed zygomatic fractures can be accomplished by reflecting a large mucoperiosteal flap from the lateral wall of the maxilla to expose the zygomaticomaxillary junction. Impacted or partially healed fractures are dislodged by an elevator or an osteotome passed through the line of fracture. Direct wire fixation may be used here. This approach may be useful in conjunction with another, the lateral brow approach, but alone it is not an effective method because of difficulty in visualizing the posterior extent of the fracture. It is possible to reduce a fracture in this manner, but additional fixation is necessary.

**The Suspension Method.** This method was suggested by Kazanjian (1933) and was employed in fractures which, after reduction, tended to relapse. Direct exposure of the infraorbital margin is obtained, and a small drill hole is made through the infraorbital margin in its zygomatic portion; the lower border of the zygoma may also be exposed through an intraoral approach and drill hole is made, passing the burr through the skin when the zygoma
is rotated backward. A stainless steel wire is passed through the drill hole, and both ends are brought out through the wound and twisted into a small loop. The wire is then attached by a rubber band to an ingenious appliance placed on the forehead and imbedded in dental compound with an outrigger, which passes in front of the cheek area and is used to suspend the zygoma. Upward and outward traction is maintained for a period of two to three weeks, after which time the bone stays in position without support.

This is indicated (a halo frame appliance or plaster head cap may also be used) in cases that will not respond to other methods of management. In some patients, in spite of what seems to be adequate mobilization with no difficulty in reducing the fragment, the fragment has a tendency to relapse posteriorly and downward. In this type of case, suspension is most useful.

**Open Reduction and Direct Wiring.** This technique is effective in obtaining accurate reduction and positive fixation and is effective in the simple as well as the complex comminuted type of fractures. Incisions 1.5 cm in length through the eyebrow and a subciliary eyelid incision will provide adequate exposure and access to the inferior and lateral orbital margins. The tissues can be shifted so that the entire inferior and lateral orbital margins can be inspected through these two incisions. The fragments are reduced, and small drill holes are placed, using motor-driven drills, through the bone wherever indicated. Fixation is provided with 28-gauge stainless steel wire. It is possible to reconstruct the entire orbital margin by wiring several small fragments of bone together.

**Compound Comminuted Fractures of the Zygoma.** Fractures of the zygoma may be compounded intraorally or extraorally when the force is severe enough to cause soft tissue wounds extending into the bone. Removal of foreign bodies, debris, and blood clots should be the first step in the treatment of the compound fracture. The fractured zygoma can be reconstituted by joining the comminuted fragments by interosseous wiring through the wound. Careful debridement and closure of the soft tissues over the comminuted fragmented bone usually results in satisfactory healing.

If medial displacement is a problem in zygomatic arch fractures, the segments may be supported after reduction by placing packing under the medial surface of the zygoma (Nattrig, 1962). The fragments are elevated through the Gillies approach. If the fragments do not remain in position, a Penrose drain is packed into the infratemporal space beneath the zygoma to give it support. This is left in the wound for a week to ten days, at which time consolidation is completed.

**Open Reduction and Direct Fixation.** Open reduction and fixation with direct interosseous wiring may be done quickly, safely, and effectively. Open reduction with direct fixation is supplanting the older methods, which depended upon closed or blind operations and complicated gadgets for fixation.

**Pin Fixation.** Brown, Fryer, and McDowell (1949) devised a technique utilizing one or more stainless steel pins (Kirschner wire or Steinman pin) for fixation. Through the use of a hand-driven or electric drill, stainless steel pins are driven through the zygoma in a transverse direction and into the bones of the maxilla or zygoma on the contralateral side. The pins are cut off at skin level and are left in for a period of four weeks during consolidation.
of the fragments. This appears to be an effective method in the hands of experienced surgeons. Lange (1965) developed an instrument for holding the fractured segment of the zygoma in position during pin insertion and made other significant refinements in the technique. Complications in the form of osteomyelitis, malunion, nonunion, and facial deformity have been seen following use of this method by inexperienced operators.

Delayed Treatment of Fractures of the Zygoma. The best results are seen in cases treated relatively early. Fixation by organized fibrosis at the site of fracture occurs within two to three weeks, after which time it is difficult to mobilize and reposition the bone. This can be done, however, after several years. It requires exposure of the bone through the zygomaticofrontal area and through the oral route. The malunited bone may be mobilized by osteotomies through the old fracture lines and fibrous tissue. This can usually be done successfully if exposure is adequate. After mobilizing the bone, it is reduced and held with direct interosseous wiring.

The procedure must be done under direct vision: exposure of the floor of the orbit, of the zygomaticofrontal junction, and of the anterior surface of the maxilla is required through an intraoral approach. The Gillies techniques provides strong leverage for reduction. Blind reduction carries the risk of radiating fracture lines extending into the apex of the orbit and loss of vision.

Complications of Fractures of the Zygoma

Early complications are relatively rare. Bleeding into the maxillary sinus is usually of short duration. It is unnecessary to remove the blood clots from the sinus. Clots disintegrate and drain spontaneously from the sinus without producing untoward results. Infection may be an immediate complication in compound fractures. This should be managed by adequate debridement of soft tissue and bone structure, establishment of drainage, and the administration of antibiotics. Acute exacerbation of a preexisting chronic sinus disease may be a complicating factor. Malfunction of ocular muscles as a result of damage from fractured fragments or injury of the cranial nerves has been seen. Kazanjian and Converse (1959) reported two cases of blindness following zygomatic fracture, in which segments of bone presumably were driven into the optic nerve.

Late Complications. The late complications of zygomatic fracture are nonunion, malunion, diplopia, persistent infraorbital nerve anesthesia, and chronic maxillary sinusitis. Gross downward dislocation of the zygoma may result in diplopia and require repositioning by open reduction.

Orbital blowout fractures and the ocular complications resulting from such fractures, which occur concomitantly with fractures of the zygoma, are discussed in Chapters 25 and 28.

The late complications result mainly from malunion. In many cases correction can be obtained by osteotomy and replacement of the zygoma with direct wire fixation. In those cases that cannot be managed by osteotomy, restoration of contour and elevation of the orbital floor can be accomplished by means of bone or cartilage grafts (see Chapters 25 and 28).
Impacted fracture of the zygomatic arch against the coronoid process may result in fibro-osseous ankylosis. If the zygoma cannot be adequately repositioned, resection of the coronoid process through the intraoral route will usually free the mandible and permit normal function.

Persistent anesthesia in the area of distribution of the infraorbital nerve after a period of six months should be an indication for exploration and decompression of the infraorbital canal. Bone splinters or constricting portions of the canal should be removed so that the nerve will have an adequate opportunity for regeneration. Permanent anesthesia is temporarily annoying, but the patient finally becomes accustomed to it.

Fractures of the Nasal Bones and Cartilages

The external nose is a triangular pyramid composed of cartilaginous and osseous structures which support the skin, musculature, mucosa, nerves, and vascular structures. The upper third of the nose is supported by bony structures, while the lower portion gains its support from cartilaginous tissues. The skin in the upper part of the nose is freely movable, but in the lower portion it is thick, rich in sebaceous glands, and intimately attached to the cartilages. The excellent blood supply permits extensive dissection with safety and results in early rapid healing with minimal scar formation.

The supporting framework of the nose is made up of semirigid cartilaginous structures which are attached to the solid, inflexible bony structure of the nose. The cartilaginous tissues include the lateral nasal cartilages, the alar cartilages, and the septal cartilage. There are several sesamoid cartilages in the lateral portions of the ala and in the base of the columella. The cartilaginous structures support the overlying subcutaneous tissue, skin, mucosa, and lining of the nose. The cartilages are intimately attached to the bony structures, which consist of the frontal process of the maxilla and nasal spine of the frontal bone, the paired nasal bones and the bones of the septum, the vomer, and the perpendicular plate of the ethmoid.

The paired nasal bones articulate in the midline and are supported laterally by the frontal process of the maxilla and superiority by the nasal spine of the frontal bone. The lower third of the nasal bones is thin and subject to fracture, but the bones are thicker in their upper portion and are supported by the nasal spine of the frontal bone. The nasal bones seldom fracture in the upper portions, where they are thick and firmly supported by their articulations, but frequently they fracture in the thinner lower half. For additional details of nasal anatomy see Chapter 29.

Types and Locations of Fractures

Fractures in adults vary with the site of impact and the direction and the intensity of the force. Direct frontal blows over the nasal dorsum result in fracture of the thin lower half of the nasal bone or, if more severe, may result in separation of the nasofrontal suture. The margin of the pyriform aperture may also be fractured and dislocated into the nasal cavity, obstructing the airway.

Lateral forces account for most nasal fractures and may produce a wide variation, depending upon the age of the patient and the intensity and direction of force. Younger
patients tend toward fracture-dislocation of larger segments, whereas in older patients with dense, brittle bone, comminution may be observed more frequently.

The usual fracture occurs through the lower thinner portion of the nasal bone, the upper portion being thicker and more resistant to traumatic forces. Kazanjian and Converse (1959) reported that 80 per cent of nasal fractures occurred at the junction of the thick and thin portions of the nasal bones in a series of 190 nasal fractures. A direct force of moderate intensity from the lateral side may fracture only one nasal bone, with displacement into the nasal cavity. The frontal process of the maxilla may be associated with fracture of the nasal bones and be depressed on one side, or the entire bony structure of the nose may be fractured and dislocated to the side opposite the injuring force.

Violent frontal blows result in fracture of the nasal bones, the frontal processes of the maxilla, the lacrimal bones, and the septal cartilage, with all the components being driven into the ethmoid area. These displaced fractures are usually associated with damage to the nasolacrimal system, the perpendicular plate of the ethmoid, the ethmoid sinuses, the cribriform plate, and the orbital plate of the frontal bone. Displacement in severe comminuted fractures results in broadening and widening of the interorbital space and traumatic telecanthus.

Fractured bone segments may be driven into the nasolacrimal system at various levels, resulting in dacryocystitis, interference with drainage of the tears, and permanent epiphora. The telescoping comminuted nasal fracture involving the nasal-ethmoidal-frontal area is commonly seen in the automobile crash injury, in which the middle third of the face strikes against the instrument panel or other projecting objects inside the automobile.

Fractures and dislocations of the septal cartilage may occur independently or in association with fractures of the nasal bony framework. Because of their intimate association, it is unusual to observe fractures of the bony structures without damage to the cartilaginous structures. The caudal portion of the septum has a certain degree of flexibility and will bend to absorb moderate blows. More severe direct blows may result in fracture with dislocation of the septum from the vomer groove, with displacement into the adjacent airway. The cartilage may be fractured in any direction, the most frequent being in a vertical plane, but it also may be torn or fractured in a horizontal plane parallel to the crest of the vomer.

Fractures of the septum may be associated with a telescoping type of displacement. In the vertical fracture, the anterior portion of the septal cartilage may be driven backward to telescope over the posterior segment, which remains in its normal position owing to firm attachments to the vomer and to the perpendicular plate of the ethmoid. The cartilage may be fractured posteriorly and may be driven back under the mucoperiosteum of the perpendicular plate. This results in shortening of the nose, retraction of the columella, and deepened nasolabial folds. Septal fractures may be overlooked in children only to become evident with adolescent development.

Septal fractures result in angulation of the anterior portion of the septum with dislocation into one of the nostrils, deflection of the nasal tip, and separation of the alar cartilages with a flat and broad-tipped nose.
Diagnosis of Fractures of the Bones and Cartilages of the Nose

Diagnosis is made on the basis of the history of injury, which may provide information concerning the direction and intensity of the force. Diagnosis may be difficult because of edema and hematoma, which occur within a few hours after the injury. Edema, periorbital ecchymosis, and subconjunctival hemorrhage are usual findings. Obstruction due to displacement of nasal structures, edema, blood clots, or swelling of the mucosa and turbinates is present. Subcutaneous emphysema from blowing the nose and forcing air through the lacerated mucoperiosteum is seen occasionally. Increased mobility and crepitation on palpation along with tenderness are usually prominent signs except in the infected or displaced telescoped type of fracture. Fractures of the intranasal structures and lacerations of the mucosa are difficult to see in the presence of edema and dislocation of tissues. To evaluate the intranasal damage accurately, the mucosa should be shrunk if possible with vasoconstricting drugs, blood clots should be removed, and the hematoma of the septum should be evacuated or aspirated.

Roentgenograms are helpful in the diagnosis of nasal fracture but may frequently be negative in the usual views. Gillies and Millard (1957) recommended increasing the backward tilt of the occipitomental view from 15° to 30° to 45° to illustrate fractures not apparent in the usual occipitomental projection. Soft tissue techniques on profile views demonstrate fractures of the thin anterior edge of the nasal bones. (See section on Roentgenographic Positions).

Treatment of Nasal Fractures

When seen early before edema of the soft tissues becomes a complicating factor, fractures of the nasal bones are easily reduced. Most simple fractures can be managed on an outpatient basis in the emergency room by closed reduction methods. The more extensive comminuted compound fractures require special management.

If, when first seen, the patient has severe edema with no open wounds, treatment should be deferred until the edema subsides and a more accurate evaluation can be made. This requires postponing treatment for five to seven days.

Anesthesia. Nasal fractures in children are best managed under general anesthesia. Even if a short procedure is anticipated, it is best to anesthetized the patient completely. Endotracheal intubation is the technique of choice. This gives the operator an opportunity to assess the damage accurately and to obtain adequate reduction and fixation.

In both children and adults, the operation can be facilitated by packing the nose with cotton pledgets, soaked in vasoconstricting drugs for 10 to 15 minutes. The packs should be wrung out carefully before insertion. This will reduce the edema and result in less bleeding from manipulation. Ten per cent cocaine solution with an equal amount of epinephrine 1:1000, or 1 per cent xylocaine with epinephrine (1:100.000) will provide anesthesia and vasoconstriction. Cocaine packs should be avoided over raw areas to avoid excessive absorption of the drug. If severe edema is present, it may be necessary to spray the nose two or three times over a period of 15 to 20 minutes before the passages can be opened satisfactorily to permit intranasal inspection.
Most nasal fractures in adults can be successfully reduced with the aid of intranasal topical and infiltrative anesthesia. Adequate preoperative medication and intraoperative intravenous injection of tranquilizing drugs such as diazepam (Valium) facilitate the procedure.

Instrumentation for Reduction of Simple Nasal Fractures

A headlight is necessary for good intranasal illumination. Intranasal specula of various sizes and lengths are essential for adequate intranasal examination, reduction of fractures, and placement of packs. Almost all nasal fractures can be reduced by upward and outward forces, with an instrument placed in the nose under the nasal bones. A small nasal elevator upon which a rubber tubing is stretched or around which cotton has been twisted makes an excellent instrument for this purpose. The cotton should be covered with a layer of petrolatum.

Forceps designed for intranasal use, such as the Asche and the Walsham types, are useful, as force can be applied through both nasal cavities at one time.

Care must be exerted to place the instrument under the fracture site in a position not too high in the nose, lest it impinge under the nasal portion of the frontal bone and cause damage to the mucosa without being effective in reducing the fracture. As the nasal structures are manipulated upward and forward with the instrument in one hand, the other hand is used to apply external digital pressure to mold the bones into position. The dislocated nasal septum will often be replaced in position by elevation of the nasal bones.

Intranasal fractures should be carefully examined after elevating the bones, and, if they are not in position, the Asche forceps should be used to straighten the septum.

Many fractures can be reduced and will remain in position without the need for nasal packing or nasal splints. If the bones are comminuted and loose, it is preferable to support the fractured nasal bones and septum by means of intranasal gauze packing impregnated with petrolatum. Gauze impregnated with a waxy lubricant provides an excellent material for packing the nose or maxillary sinus. It will not adhere to the mucosa and can be removed without bleeding.

After the nasal bony and cartilaginous structures have been reduced and manipulated into position, they are usually held by the intranasal packing and an external splint. The use of small Silastic tubing as an airway in each nasal floor adds considerably to the comfort of the patient. The tubes do not provide a satisfactory airway but permit equalization of pressure in the nasopharynx during the act of swallowing and prevent the usual discomfort of negative pressures in the middle ear. The tubes are placed carefully in the floor of the nose on each side, and packs made up for several folds of gauze impregnated with petrolatum or strips of petrolatum-soaked gauze are carefully packed into the nasal cavity to give support to the fractured bone and cartilaginous structures.

The external nasal splint can be fabricated with Asche metal and dental compound. A splint can also be fashioned from commercially prepared gauze impregnated with plaster, which is folded into a square four to six layers in thickness, soaked in water, and then cut to
the desired shape. The plaster splint can be applied directly to the skin, where it will fit securely and cause no reaction. The plaster splint is held to the skin of the face with porous paper adhesive tape.

The rubber tubing is cleaned once or twice each day with a suction pipette. Intranasal packing and an external nasal splint are kept in place from five to seven days.

**Treatment of Fractures and Dislocation of the Septal Framework**

The septum should be straightened and repositioned soon after injury. The elevator used for the reduction of the nasal bones raises the nasal bones and also the lateral cartilages, which have an intimate anatomical relationship with the nasal bones as they extend under, and are adherent to, the undersurface of the nasal bones. Because the lateral cartilages also have an anatomical continuity with the septal cartilage, raising the lateral cartilage with an elevator may successfully reduce a horizontal fracture or replace the cartilage into the vomer groove from which it may have been luxated. Correction of the position of the septum is completed with Asche forceps. The realigned septal fragments are maintained by intranasal packing or Silastic or acrylic splints held by mattress sutures through the septum. The mucoperichondrium heals rapidly.

If correction is delayed, it may not be possible to obtain the desired result. When there is considerable displacement and overlapping of septal fragments, exposure of the septal framework by subperichondrial elevation, as for a submucous resection, may be the best approach. Such cases may require an immediate submucous resection of the nasal septum, but it is usually possible to realign the septal cartilage fragments and maintain their position by means of intranasal packing. These measures are indispensable if the surgeon is to be successful in reestablishing adequate nasal airways and realigning the external bony structures (see also Chapter 29).

**Hematoma of the Septum.** A hematoma develops between the septal mucoperichondrium and the cartilage in fracture or dislocation of the septum or simply as a result of excessive bending of the septal cartilage. Hematoma of the septum is often bilateral, for fracture of the septum permits passage of the blood from one side to the other.

Fibrosis may follow an untreated septal hematoma. Fibrosis of a long-standing hematoma results in permanent thickening of the septum, which blocks the nasal airway. This condition is similar to subperichondrial thickening of the auricle, commonly referred to as cauliflower ear, which is observed in pugilists. Necrosis of the cartilage can also be caused by a voluminous hematoma, even in the absence of infection. The authors have observed massive absorption of septal cartilage in patients who had been maintained under antibiotic therapy for two weeks; the hematoma had not been evacuated. After surgical intervention to evacuate the hematoma, fracture of the septal cartilage was discovered; in the absence of sepsis, the septal cartilage was partly absorbed and very soft. Infection of the hematoma and septal abscess usually results in complete necrosis of septal cartilage and collapse of the cartilaginous dorsum. In addition to surgical therapy, antibiotic therapy should be routine.

Septal hematoma is treated by incising the mucoperichondrium, and suction is employed to evacuate the blood clots and serum. A horizontal incision is made through the
mucoperiosteum at the base of the septum to prevent refilling of the cavity with blood or serum, thus establishing a drainage incision in a dependent position. In bilateral hematoma, it is preferable to resect a portion of the septal cartilage to allow the two areas of hematoma to communicate. In comminuted septal fractures with hematoma, septal cartilage resection is also the best treatment. This approach affords a wide exposure between the mucoperichondrial flaps and permits removal of obstructing septal fragments and blood clots between the flaps. The horizontal incision through the mucoperichondrial flap along the floor of the nose insures drainage and prevents accumulation of blood between the flaps. Nasal packing is not necessary except to arrest epistaxis.

Comminuted Fractures. If seen within a few days after the injury, comminuted fractures can usually be reduced without difficulty. Internasal packing and a nasal splint may not be sufficient to provide adequate fixation. If there is comminution and telescoping of the fragments, there is a tendency for the fractures to sink backward, and the patient may have a sunken or flat nasal dorsum following healing.

Through-and-Through Wiring over Acrylic, Silastic, or Metal Plates. Support may be obtained by using plates on the side of the nose. Soft lead, Silastic, or acrylic plates 2 or 3 mm in thickness are satisfactory. These are held in position by passing a 25-gauge steel wire on a Keith needle through the plates and between the fractured segments. The wire is twisted over the plates to give support to the lateral aspect of the nose. The plates can be in contact with the skin without causing damage if the edges are everted so that no sharp edges contact the skin. The plates are effective only for treatment of fractures of the external nasal bone structures. More severe naso-orbital fractures require open reduction (see Chapter 250.

Compound Nasal Fractures. The bone and the cartilaginous structures of the nose may be observed through external wounds in compound fractures with open wounds. The bone fragments can be reduced and fixed through the external wound. The lining, muscles, and subcutaneous layers are approximated with fine absorbable sutures before closure of the skin. Careful attention to closure of soft tissue wounds will alleviate unsightly scars and prevent intranasal constricting scars and stenosis of the airway.

Delayed Treatment of Nasal Fractures. Purposeful delay in the treatment of nasal fractures is indicated in the presence of other injuries which contraindicate early management of the facial fractures. If this occurs and the patient is not seen until a week or ten days following the injury, the usual methods of manipulation and reduction of the nasal fractures may not be satisfactory. Open operations are required, but it is preferable to wait until the edema has subsided in order that the deformity can be fully evaluated. Septal hematoma or abscess should be treated and treatment delayed until reduction and fixation can be done conveniently and safely. Intentional delay is advisable to reduce the possibility of operative complications.

Complications of Nasal Fractures. Early complications are rare and consist of edema and ecchymosis of the skin and eyelids, epistaxis, hematoma of the nasal septum, and infection. The edema is temporary and disappears within a few days. Bleeding from the nose, usually of short duration, ceases spontaneously or may be controlled by intranasal packing. A large hematoma under the soft tissues of the nasal septum is controlled by evacuation or incision and drainage. Infection is best treated by adequate drainage, the use of hot packs, and
the use of antibiotic therapy. Emphysema of the face and neck may occur from violent blowing in an attempt to dislodge blood clots from the lacerated nose but resolves spontaneously.

**Late Complications.** An untreated hematoma of the nasal septum may become organized, resulting in subperichondrial fibrosis with thickening of the nasal septum and partial nasal obstruction. The septum may be as large as 1 cm in thickness, and in cases of repeated trauma the cartilaginous septum may be largely replaced with calcified material. Submucous resection of the thickened or deviated nasal septum may be required to produce a satisfactory airway (see Chapter 29).

Synechiae may form between the septum and the turbinates in areas where injured tissues are in contact. These are treated by cutting and placing an intervening nonadherent material between the cut surfaces for a period of five days. During this time, epithelization occurs.

Obstruction of the nasal vestibule may occur as a result of malunited fractures of the pyriform margin or scar tissue contracture from loss of vestibular lining. Osteotomy of the bone will correct the former; the scar tissue contractures may be corrected by Z-plasty procedures or by excision of scar and replacement with skin grafts in the nasal vestibule.

Osteitis is occasionally seen in compound fractures of the nose or in fractures associated with infected hematomas. The entire nasal bony framework may be lost as a result of infection. Appropriate antibiotic therapy, incision for drainage, and removal of sequestra from the wound constitute the regimen of treatment.

Nonunion is rare, but malunion of the nasal bone structures is a frequent complication resulting in external deformities which require secondary reconstructive operative procedures. These operative procedures are described in Chapter 29.

Naso-orbital fractures resulting from a strong impact over the nasal bony bridge, projection of the bony structures into the orbital space or the orbital cavities, and fractures of the frontoethmoidal region are discussed in Chapter 25.

**Multiple and Complex Fractures of the Facial Skeleton: Panfacial Fractures**

In a treatise encompassing the entire field of reconstructive plastic surgery, space does not allow for a complete coverage of all aspects of the diagnosis and early treatment of facial injuries. A number of books entirely devoted to the subject have been published (Dingman and Natvig, 1964; Rowe and Killey, 1968; Schultz, 1970; Kazanjian and Converse, 1974).

In this chapter, the early treatment of fractures of individual bones of the face has been discussed singly for the sake of simplicity. Under the term "complex fractures," that authors designate multiple fractures of the facial bones. In some cases there are fractures of all facial bones (panfacial fractures), and these are often associated with multiple injuries in other areas of the body.
Incidence

This type of injury is becoming more common with the advent of high-speed transportation; the magnitude of the traumatic force sustained and the greater number of survivors of such accidents are a result of improved methods of resuscitation and treatment of multiple systems injuries. The front seat "guest passenger" type of injury, which was described by Straith in 1948 and is characterized by extensive fractures of the middle third of the face, occurs as a result of the guest passenger being thrown against the windshield or instrument panel of the automobile and is now commonplace. According to Georgiade (1969), 20 per cent of individuals who have sustained injuries to the facial skeleton have multiple facial bone fractures. McCoy and his associates (1962) reported a study of 855 patients with fractures of the facial skeleton. Forty per cent of these patients had fractures of the midfacial skeleton; the mandible alone was fractured in 38 per cent, and the nasal bones alone in 22 per cent. Of the 337 patients with middle-third facial fractures, 41 per cent had associated fractures of the mandible and 28 per cent associated nasal fractures. These figures may have to be revised in view of the considerable diminution in the number of injuries sustained in automobile accidents as a result of the 55 mile speed limit initiated in the United States in 1974.

Facial Fractures and Multisystem Injuries

Complex facial bone fractures are usually the result of a high-speed accident, such as the violent encounter of two cars traveling in opposite directions. In this type of accident, the maxillofacial component is only one manifestation of severe generalized trauma to which the victim is subjected. Craniocerebral injuries and associated orthopedic or thoracoabdominal injuries are frequently present and complicate the clinical management of the patient.

Because of the magnitude of the facial injuries, the plastic surgeon may be the first to be called and thus must assume the responsibility of immediate resuscitation of the patient and overseeing the overall treatment of the multiple systems injuries.

The treatment of complex fractures is best undertaken in a specialized center where plastic surgery and multidisciplinary specialists are present. The patient with multiple systems injuries must be given rapid resuscitation and treated for shock, ensuring that the patient is physiologically stabilized. The repair of multiple system injuries should be undertaken in the proper sequence, namely that the thoracic or abdominal injury be cared for as a first priority; brain injury in a comatose patient with multiple facial fractures requires that the trachea be intubated and that the necessary neurosurgical procedures be completed; fractures and soft tissue injuries of the extremities and hands are next in priority.

Treatment of multiple facial fractures must take second place until the above injuries are treated. The airway must be ensured by the insertion of an endotracheal tube or by tracheotomy. A tracheotomy is imperative in severe panfacial fractures with multiple fractures of the mandible. Routine use of gastric aspiration and lavage eliminates the dangers associated with emesis of recent meal contents and swallowed blood.

Facial injuries are not surgical emergencies. The only surgical emergency aside from the physiologic stabilization of the patient is the maintenance of the airway.
Clinical Examination. Except when the patient is seen within the first six hours after the accident, edema masks the magnitude of damage and skeletal displacement resulting from multiple facial bone fractures.

The patient's face is flattened, and the edema obliterates the bony contour of the facial skeleton. Traumatic telecanthus is often the outstanding deformity. These patients show distortion of facial form which is caused not only by the edema, which forms rapidly, or by hematoma but also by a flattening of the contour of the face. The eyes are closed by edema, and in naso-orbital fractures the telecanthus is evident. An elongation of the face may also be observed. Mobility of the tooth-bearing bones or other bones of the face may also be noted by palpation.

The classic lines of fracture observed by Le Fort (1901), which were described in the days of the horse-drawn carriage, have been complicated by fracture-dislocation and comminution of the maxilla and naso-orbital, zygomatico-orbital, and frontal skeletal structures as a result of increasing accelerating forces associated with automobile travel.

In many cases of "crash" and "crush" injuries, the soft tissue injuries may be minimal, and the magnitude of the facial bone fractures may not be recognized in the early stages, as it is masked by hematoma and edema, which often attains enormous proportions. An orbital fracture may not be diagnosed because of the extent of the edema, the eyelids being shut tight, and the patient cannot complain of diplopia. Examination of the eyes is possible by retracting the edematous eyelids and evaluating the intraocular damage, extraocular muscle derangement, and oculorotary disturbances. These findings are indicative of a blowout fracture or a massive disruption of the orbital framework.

Multiple fractures of the mandible, particularly when associated with multiple fractures of the midfacial bones, result in obstruction of the oropharyngeal airway. Some idea of the number of and extent of displacement of the fractures may be obtained by observing the disruption in the occlusal relationships of the teeth.

Complex facial fractures may also be compound, resulting from lacerations by an incisive object, such as the windshield of an automobile; bursting of the soft tissue may also be produced by a blunt force.

Radiologic Examination. Radiologic investigation has been discussed earlier in the text. It is obvious that additional information will be gained by careful tomographic diagnosis done in both frontal and sagittal planes. Thus a picture may be assembled of the location and number of fractures and of the extent of osseous displacement.

Treatment

General Considerations. There are certain considerations in managing panfacial fractures. The first is the timing of the operative interventions. The optimal time for treatment is within six hours after the accident, before the development of the massive edema which follows these injuries. Such early treatment is possible only when other systems are not involved and the facial fractures are not too severe.
In patients with multiple fractures of the midfacial area and in patients with panfacial fractures which also involve the mandible, clinical evaluation of the extent and number of fractures is essential if the structural architecture of the facial skeleton is to be reestablished.

There is an argument, therefore, for waiting until the edema has subsided and until a thorough roentgenologic examination can be completed. This should include tomograms, which will show the extent of the fractures and fracture-dislocations, and should be completed by a panoramic radiographic film of the mandible.

**The Direct Approach.** At the present time, one-stage restoration of the architecture of the face is the preferred method of treatment of severely comminuted multiple facial bone fractures.

Open reduction and interosseous wiring of severe multiple fractures of the facial bones is the keystone to success. This may be combined with cranial fixation by internal wiring and orbital floor replacement (usually different modalities of treatment in various combinations). Adams (1942) originated the concept of treatment of facial fractures by internal suspension wires, and considerable emphasis has been placed on internal suspension wiring, which is adequate for fractures of moderate severity.

In "crush" and "crash" multiple fractures, in addition to permitting internal wiring, the direct approach through selective cutaneous and intraoral incisions offers other advantages. The direct approach and interosseous wiring of the fragments after realignment have proved to the best techniques for preventing the development of traumatic telecanthus, for verifying the integrity of the lacrimal apparatus, for treating orbital fractures, and, generally, for restoring the architecture of the facial skeleton (see Chapter 25).

When a considerable number of teeth and portions of the dentoalveolar process have been lost, early prosthetic restoration should be provided to support the lips and cheeks, particularly if these structures have been subjected to full thickness lacerations. This approach requires the application of a certain number of principles heretofore not entirely recognized.

**Order of Procedure**

1. The mandibular fragments are realigned and fixation is obtained by arch wire appliances. Interosseous wiring should also be employed for difficult and unfavorable fractures or for stabilization of edentulous fragments of the mandibular arch. The intraoral degloving approach (see Chapter 30) is employed.

2. The realigned mandibular arch serves as a guide for the assembly and realignment of the maxillary fragments.

3. The maxillary fragments are often best reassembled and maintained in fixation by direct interosseous fixation, as the traumatic force which has comminuted the maxilla is often strong enough to avulse or damage the teeth, which are no longer available for fixation. When the teeth are present, fixation of the dentoalveolar fragments by an arch and wire appliance is possible.
4. Once the maxillary fragments have been realigned and intermaxillary fixation has been established, internal wires are placed and will eventually be tightened to suspend the maxillary arch (or the mandibular arch) to the frontal bone or will be looped around the zygomatic arch if it is intact. In edentulous patients, intermaxillary fixation is established by means of the patient's dentures, which are lined with dental compound and maintained by circumferential wires. The tightening of the wires for cranial fixation by internal wires is postponed until the bones of the midface have been realigned and maintained in fixation. The wires should extend obliquely backward and upward. In this manner the condyles are maintained in the glenoid fossae; the lateral pterygoid muscle propulsive movements are thus neutralized, and adequate forward projection of the maxilla is maintained.

The tooth-bearing segments of the maxilla having been realigned and intermaxillary fixation established, attention is directed to the midfacial fractures.

5. Cutaneous incisions placed in the lateral portion of the eyebrow, in the lower eyelid, and along the lateral wall of the bony nose provide exposure of the frontozygomatic junction, the infraorbital rim and orbital floor, the major portion of the anterior surface of the zygoma, the lateral wall of the orbit, the nasal bones, and the medial wall of the orbit. Orbital fractures are treated by restoration of the continuity of the rim and floor of the orbit (see Chapter 25).

A wide exposure of the midfacial area can be obtained by raising a coronal flap, as advocated by Tessier and his associates (1967) in craniofacial operations. This exposure, supplemented by lower eyelid incisions for exposure of the orbital floor, is indicated in the most severe fractures.

In panfacial fractures associated with extensive soft tissue wounds, after the appropriate debridement and removal of glass and other foreign debris (steering wheel fragments, ingrained road grit and dirt), the wounds serve as a direct approach to the fracture sites, thereby obviating the necessity for separate incisions.

Interosseous fixation of multiple fractures should be initiated by establishing cranial fixation of the zygoma at the frontozygomatic junction by interosseous wiring. This procedure restores the lateral wall of the orbit. Other zygomatic fragments are wired to the larger zygomatic fragment, and the inferior orbital rim is restored by realigning the fragments and wiring them to each other. The individual fragments are held with forceps, a small hole is drilled in each of the fragments, and they are aligned and joined by the stainless steel interosseous wire which is twisted upon itself and cut. The remaining end of the twisted wire is buried in the hole through one of the fragments. Attention should then be directed to an orbital fracture if it is present. The next step is the reduction of a nasal bone or naso-orbital fracture. Transosseous wires reattach the medial canthal tendons to the medial orbital walls, and acrylic plates reapply the skin of the naso-orbital valley against the restored bony framework.

The facial structures are now realigned, and the facial architecture is reestablished; the last procedure is the tightening of the internal wires to maintain cranial fixation.

The basic principle, therefore, is to provide interosseous fixation to a stable bone in the midfacial area: the zygoma if it is not fractured, the frontal bone if both zygomas are
fractured. The application of this principle leads to an order of procedure: *provide fixation of the larger bone fragments; these provide points of fixation for the smaller fragments. Usually it is best to proceed from lateral to medial, reconstructing the midface piece by piece.*

**Order of Procedure When the Mandible is Severely Mutilated.** If the mandible is severely comminuted and the continuity of the bone is interrupted, it cannot be employed as a guideline for the replacement of the maxilla. The approach to the architectural restoration of the facial skeleton must be reversed, and reconstruction must proceed *from above downward.*

Fixation of the zygoma to the zygomatic process of the frontal bone should be first established; this usually requires elevation of the zygoma and the lateral portion of the floor of the orbit prior to interosseous wire fixation. If the zygoma is fragmented, each fragment should be wired to its neighbor and to the maxilla. The maxillary fragments are realigned and fixation is established by an arch bar and wire appliance. The floor of the orbit is then explored and continuity restored if necessary. The naso-orbital fractures are approached through either cutaneous nasal incisions or the bicoronal flap, the main fragments being wired to the frontal bone. Through-and-through transosseous wiring not only maintains the contour of the nasal skeletal framework and the medial orbital walls but also reattaches the medial canthal tendons to the medial orbital wall. The remaining mandibular fragments are placed into fixation with the maxilla after realignment and fixation, and cranial suspension is established by means of internal wiring extending upward through the zygomatic fossa to the frontal bone.

**Fractures Involving the Anterior Cranial Fossa.** In patients with frontoethmoidal fractures involving the anterior cranial fossa, a dual approach is required from above, through a craniotomy which exposes the anterior cranial fossa, and from below, by means of the techniques of exposure described earlier in the chapter. These patients may have penetration of the brain by a bone fragment or destruction of dura or a portion of the frontal lobe. The destroyed brain should be removed and the dura sutured or repaired by a graft of temporalis fascia. Cerebrospinal fluid leakage is arrested by suture of the dura or by a graft of fascia or dermis, and bone defects of the anterior cranial fossa, including the roofs of the orbit, should be repaired by primary bone grafting (see Chapter 25).

**Considerations on Primary Bone Grafting.** Primary bone grafting has been performed for the restoration of the floor of the orbit for the past 20 years. Bonanno and Converse (1974, 1975) have also reported the use of primary bone grafting in the management of severely comminuted maxillary fractures to assist in maintaining the projection of the fractured maxilla, in the restoration of contour of the nose, and in reestablishing bony continuity when comminution of certain areas of the facial skeleton reduces these areas to a state of pulp. A thin onlay bone graft of cancellous iliac bone will restore contour and assist in the consolidation of fractures.

Areas in which primary bone grafting is applicable are the nasal skeleton, the medial wall of the orbit, the orbital rims (see Chapter 25), the frontal bone, the canine fossa, and defects of the mandible. Experience gained from craniofacial surgery has shown that bone grafts are successful even though one surface of the bone graft lies exposed over a cavity, such as the maxillary sinus. The soft tissues, however, must be well vascularized and provide
adequate cover of the bone graft. It is obvious that in cases in which soft tissue has been destroyed, the soft tissue must be restored, and primary bone grafting is usually contraindicated. Primary bone grafting is also dependent on the general condition of the patient.

Primary bone grafting of the dorsum of the nose is often feasible through cutaneous lacerations or either transcutaneous or intranasal operative incisions. The addition of a bone graft at the primary stage of treatment when the nasal bones are comminuted and crushed will prevent saddling of the dorsum and shortening of the nose, often a difficult post-traumatic deformity to correct.

In severely comminuted midfacial fractures, after reduction and fixation by the usual methods (interosseous fixation of fragments, intermaxillary fixation, cranial fixation by internal wiring), if mobility is still present, the retromaxillary space should be explored by means of a curved hemostat. If there is indication of bony destruction in the pterygomaxillary area, a supportive bone graft placed in the pterygomaxillary interface and around the maxillary tuberosity is an important addition to conventional methods of treatment. An incision is made through the mucoperiosteum anterior to the tuberosity of the maxilla, the periosteum is raised around the posterior aspect of the tuberosity, and a measured bone graft is wedged into the area. The procedure is repeated on the contralateral side. This technique is, at the present writing, subject to criticism as to its value. Although the tuberosities of the maxilla and pterygoid plates may be severely comminuted or even pulverized, a bone graft may be wedged between the comminuted fragments. The bone grafts provide buttresses maintaining the forward projection of the maxilla; more importantly, they also fill a void, and the additional bone may consolidate during the weeks of intermaxillary fixation, restoring the posterior buttresses and preventing secondary recession of the maxilla.

In naso-orbital fractures, the restoration of the medial orbital walls done in conjunction with the bone grafting of the nasal dorsum will assist in the correction of traumatic telecanthus (see Chapter 25).

The indications for primary bone grafting must be carefully evaluated. Panfacial fractures without soft tissue lacerations are particularly favorable for primary bone grafting. When extensive soft tissue wounds are present, bone grafting is a successful technique if the wounds are cleanly incised and if sufficient soft tissue coverage of the bone graft can be ensured. Contraindications are infected or severely contaminated soft tissue wounds.

Posttraumatic Facial Pain

D. A. Crockford

Pain persisting after the primary treatment of facial trauma is a relatively uncommon complication that can be disabling to the patient and can lead even to drug addiction. This problem has been considered by Crockford (1975a).
Pathogenesis

Seddon's well known triple classification (Seddon, 1942) of neurapraxia, axonotmesis, and neurotmesis is used to correlate the degree of injury and the characteristic clinical symptomatology. Although there has been little research into the effects of trauma on cranial nerves, it seems likely that facial pain is experienced by mechanisms similar to those of spinal nerves (Wilson, 1974).

Peripheral nerves may be cut, crushed, or subjected to some form of traction injury at the moment of trauma. Subsequently, infection, compression by scar contracture, or callus formation may occur. The infraorbital nerve is damaged in about 80 per cent of the fractures of the zygoma (Barclay, 1960), infraorbital sensory disturbance being one of the classical symptoms of this injury. As is well known, after reduction of a displaced fracture, recovery of sensation in the ensuing weeks or months is usual; neurapraxia or axonotmesis has occurred as the nerve passes through the infraorbital canal. The supraorbital and supratrochlear nerves are particularly at risk where they lie just superficial to the unyielding surface of the superior margin of the orbit and the frontal bone. In this location, laceration or contusion are not uncommon. The external nasal nerve may be crushed as it emerges between the nasal bone and upper lateral cartilage (McNeill, 1963).

The crude mechanisms of the nerve injuries described above are not in dispute. The wonder is, however, that overt injury in such anatomical situations is not more frequent. In fact, it is probable that damage to these nerves does occur much more often than is clinically apparent, as histologically demonstrable intraneural fibrosis and axonal disturbance following trauma give little indication of the presence or severity of clinical symptoms (White and Sweet, 1969). As yet, there is no universally accepted explanation of the mechanisms of peripheral or central pain, although the "gate theory" of Melzak and Wall (1965) is considered to be nearest the truth. In particular, there is no good electrophysiologic explanation of the pain generated by amputation neuromas or nerve entrapment (Wilson, 1974), but it has been suggested that a possible mechanism for the persistence of pain is ascending constriction of sensory axons by collagen. Nerves so affected are often tender and swollen several centimeters proximal to the site of injury, and microscopic examination shows an ascending neuropathy with infiltration of collagen between individual axons (White, 1968). It is generally recognized that in certain cases, pain at the periphery that is not controlled within a few months spreads centrally to become established in an apparently self-perpetuating way, making relief much more difficult.

Clinical Symptoms

The patient usually gives a history of facial trauma, although the late onset of pain after a forgotten or apparently trivial injury may cause diagnostic difficulty (Henry, Michelet and Loiseau, 1972). The great majority of patients with overt sensory nerve damage will also give a history of an anatomically recognizable area of resolving hypoesthesia or paresthesia.

In the small group of patients to be considered, the symptoms are worse. In their mildest form, dysesthesia will still be anatomically localized but of sufficient severity to prevent adequate toilet of the part. Pain may develop in the area, precipitated by physical or psychogenic stimuli. Analgesics may be regularly required, and significant interference with
social activities will occur. The attacks of pain may become spontaneous, and radiate beyond
the original area of involvement. Associated secretomotor and vasomotor activity may
develop, thus culminating in a state analogous to the dreadful but rare complication of
causalgia. These severe syndromes may occur within hours of injury, or onset may be so
delayed that other causes of facial pain must be excluded. However, the majority of such
patients experience a progressive increase in their painful manifestations as indicated above.
It is the clinician's task to try and select the patients in this group, so that they may receive
the sympathetic and energetic care that can prevent the establishment of a recycling pain
syndrome. Although the majority of the patients, because of their history and the presence of
tenderness and paresthesia in an anatomically recognizable distribution, are relatively easy to
assess, those with spontaneous pain radiating outside such an area can be more difficult. The
help of an able and sympathetic psychiatrist may be invaluable in separating organic pain
from an endogenous psychiatric state. If available, referral to the local pain clinic will
obviously be considered, while no time should be lost in consulting an interested
neurosurgeon if the simple measures to be described do not bring early relief. Finally, besides
these medical factors, aggravating social, emotional and economic circumstances, together
with the possibility of further financial compensation, may have to be considered.

Methods of Treatment

These may be broadly divided into nonsurgical (local and systemic) and surgical
(peripheral and central). It is presumed that adequate primary care, including reduction and
stabilization of fractures and the removal of obvious foreign bodies, has been carried out.

Nonsurgical Local Treatment. The single most helpful procedure is undoubtedly a
local anesthetic block of the appropriate nerve. If successful, it may aid in making a diagnosis
by localization, and may allow further examination of the part. Such an injection may also
be prognostic, as variations in the response of the patient to an objectively successful block
can indicate how much of the symptomatic reaction is psychologic or psychiatric. It often
happens that pain relief occurs for a longer period than may be expected from the effects of
the local anesthetic alone; relief may even be permanent after a single injection. This may be
due to the interruption of a self-perpetuating pain cycle. The use of a long-acting local
anesthetic such as bupivacaine, often with adrenaline, is worthwhile. To this may be added
a relatively insoluble steroid such as triamcinolone hexacetonide. Although the mechanism
of its antiinflammatory action is not fully understood, resolution of hypertrophic skin scars
by this drug is well documented. Crockford (1975b) has used it frequently in the hand for the
relief of painful neuromas, usually with success. Recent work suggests, however, that it is not
active against mature collagen (Rudolph and Klein, 1973), so that if indicated, a trial of its
use should not be delayed. Injection of this "cocktail" into an intensely sensitive area can be
extremely disagreeable in spite of its local anesthetic content; therefore, this is often done
under a short general anesthesia. If the initial injection brings improvement, further injections
may be given at monthly intervals until relief is obtained or a plateau of improvement is
reached. Even if the first injection gives little improvement, a second will occasionally have
a greater effect. If, in spite of adequate immediate anesthesia, such a course fails to bring
permanent relief, and particularly if there are signs of secretomotor and vasomotor
overactivity, a diagnostic trial of a stellate ganglion block is indicated. If complete pain relief
occurs, a course of such blocks - four or five in 10 days - should be given. Interspersed with
these, a placebo injection should be tried. Such a therapeutic course can be successful
(Leriche, 1949); but, if only temporary relief occurs, excision of the superior cervical sympathetic ganglion may be indicated (Bingham, 1947). Stellate ganglion block sometimes followed by sympathectomy is a well recognized treatment for causalgia of the upper limb. Phenol and alcohol blocks of peripheral nerves for posttraumatic facial pain are no longer widely advocated because these drugs will cause further damage to the affected nerve.

**Nonsurgical Systemic Treatment.** Probably the most important factor in the successful use of systemic drugs is that they should be given as a course of treatment and not on demand. It takes at least a month for the full benefit of this treatment to develop. A "pain cocktail" containing minor analgesics such as aspirin and paracetamol, coupled with an antihistamine such as diphenhydramine, can be made up with a syrup base in such a way that its contents can be varied without the knowledge of the patient. Adequate sleep is, of course, essential, and regular use of an antidepressant with a strong hypnotic effect, such as amitriptyline, may be necessary. Full antidepressant therapy may also be indicated.

With regard to more specific therapy, carbamazepine, which is one of the drugs of election for trigeminal neuralgia and migraine, may be worth a trial in resistant cases, but unfortunately it can produce serious side-effects such as blood dyscrasias and liver damage.

**Surgical Peripheral Treatment.** Neurolysis alone seldom gives permanent improvement, but, if combined with decompression, eg, of a painful infraorbital nerve crushed in its foramen, lasting relief can be achieved. This particular operation should always be considered in any patient in whom infraorbital sensory deficit persists for a year or more after trauma. It is theoretically reasonable to suggest that perineural triamcinolone should be instilled during neurolysis. No trial of this has been reported, but some initial success has been achieved with silicone rubber sheeting wrapped around the affected part of the nerve. White and Sweet (1969) from their considerable experience suggest that instead of neurolysis, excision of the damaged nerve and repair be done if possible. With recent advances in microsurgery and grafting of peripheral nerves, this approach may be worth trying. Neurotomy has, as is to be expected, a high recurrence rate, as the proximal end will inevitably develop a neuroma, which is again likely to be painful. Patakay, Graham and Mungar (1973) have shown experimentally that instillation of triamcinolone at the time of nerve division markedly reduces the inflammatory response; the integrity of the adjacent perineurium is preserved, thus preventing the outgrowth of axons, and hence reducing the chance of pain recurrence (Sutherland, 1968).

**Surgical Central Treatment.** Surgical sympathectomy has been mentioned in the previous section. More complex neurosurgical procedures, such as trigeminal rhizotomy and tractotomy, are beyond the scope of this treatise.