Textbook of Oral and Maxillofacial Surgery

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Chapter 19

Fractures of the jaws

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General discussion

Etiology

Fractures of the jaws occur most often because of automobile collisions, industrial or other accidents, and fights. Since the mandible is a hoop of bone articulating with the skull at its proximal ends by two joints, and since the chin is a prominent feature of the face, the mandible is prone to fracture. The mandible has been compared to an archery bow, which is strongest at its center and weakest at its ends, where it breaks often.

The chin is a convenient feature at which an adversary can aim. It is interesting to note that often the patient will not identify his adversary to the oral surgeon or to the police after a fight. He prefers to gain revenge in like manner later. This philosophy increases the number of jaw fractures, and if the patient has not had 6 months of good healing before the second altercation, he himself may be a candidate for a bone graft to the original site of injury.

A recent survey of 540 fractured jaw cases at District of Columbia General Hospital revealed that physical violence was responsible for 69% of the fractures, accidents for 27% (including automobile accidents, 12%, and sports, 2%), and pathology for 4%. Men experienced 73% of the fractures, whereas women experienced only 27%. Private hospitals in the same are report a preponderance of automobile accidents as the main cause of jaw fractures. Hospitals in industrial cities report a high incidence of industrial accidents.

The automobile has made serious injury to the face and jaws commonplace. Violent forward deceleration causes injury to the head, face, and jaws. When the car stops quickly, the head hits the dashboard, steering wheel, rearview mirror, or the windshield. A middle face fracture can result, in which the maxilla, nose, zygoma, and perhaps the mandible are fractured. The National Safety Council, automobile manufacturers, and other groups have instituted various safety features, including seat and shoulder belts, dashboard padding, rearview mirror of different design, telescoping steering wheel, push-away windshield, dashboard with recessed or absent knobs, and air bags. It seems sensible to insist that children always ride in the back seat, since fewer major facial fractures occur to back-seat riders. The most dangerous seat in the automobile is the front seat next to the driver.

A fracture can occur more easily in a jaw that has been weakened by predisposing factors. Diseases that weaken all bones can be factors. Examples include endocrine disorders

such as hyperparathyroidism and postmenopausal osteoporosis, developmental disorders such as osteopetrosis, and systemic disorders such as the reticuloendothelial disease, Paget's disease, osteomalacia, and Mediterranean anemia. Local disorders such as fibrous dysplasia, tumors, and cysts can be predisposing factors. A patient turning over in bed can experience a pathological fracture if the jaw is weak enough.

Classification

Fractures are classified into various types, depending on the severity of the fracture and whether or not the fracture is simple, compound, or comminuted.

A simple fracture is one in which the overlying integument is intact. The bone has been broken completely, but it is not exposed to air. It may or may not be displaced.

A greenstick fracture is one in which one side of a bone is broken, the other being bent. It is difficult to diagnose sometimes, and it must be differentiated on the roentgenogram from normal anatomical marks and suture lines. It requires treatment, since resorption of the bone ends will occur during the healing process. Functioning of the member and muscular pull can result in a nonunion during healing if the bone ends are not held rigidly in place. However, the time required for healing usually is minimal. This type of fracture is seen often in children, in whom the bone will bend rather than break through.

A compound fracture is one in which an external wound is associated with the break in the bone. Any fracture that is open to the outside air through the skin or mucous membrane is assumed to be infected by outside contaminants. Unfortunately, almost all jaw fractures that occur in the region of the teeth are compounded. The jaw will respond to stress by fracturing through its weakest part. Rather than fracture through the full thickness of the bone at an interdental space, it will separate through a tooth socket and then extend from the apex of the socket to the inferior border. The periodontal membrane and the thin alveolar mucosa are broken to a point adjacent to the tooth. The edentulous mandible will harbor a simple fracture more frequently. Even though the fracture may be displaced so that a "hump" appears on the ridge, the periosteum and overlying tissues can "give" a little, since the tissues have no close attachment to the teeth.

The oral surgeon is accustomed to dealing with fractures that are compounded into the mouth. Antibiotics have aided in controlling the potential infection. The bones of the jaws appear to have a degree of natural resistance to oral infection. A fracture that is compounded through the outside skin is more difficult to manage, and an osteomyelitis may develop more readily. The orthopaedic surgeon finds that compounded fractures of the long bones are much more difficult to manage than simple fractures. This is partly the result of the introduction of plain dirt as well as outside organisms and partly of the fact that the fractured bone ends are more distracted so that one end of the bone can penetrate the skin.

A comminuted fracture is one in which the bone is splintered or crushed. It may be simple (that is, not open to outside contaminants) or compounded. Fractures of the vertical of the mandible are composed sometimes of ten or more fragments, and yet, because of the splinting action of the masticatory muscles, no displacement occurs, and compounding is not present. If comminution occurs in the body of the mandible, the treatment is sometimes revised. Although an open reduction might be done normally (in which the bone is exposed surgically, joles are drilled, and wires are placed to hold the fragments in place), such a procedure would force stripping of the periosteum from the many small bone fragments, and

healing would be delayed. A closed procedure may be substituted to ensure viability of the fragments.

Gunshot wounds are usually compound comminuted fractures, and usually bony substance is lost where the missile has traversed.

The District of Columbia General Hospital survey found the following incidence of jaw fractures: simple fractures, 23%; compound fractures, 74%; and comminuted fractures, 3%.

Examination

Every patient who has suffered a head or face injury should be examined for the possibility of a jaw fracture. Not infrequently a leg fracture is treated and facial wounds are sutured only to discover several days or weeks later that a jaw fracture exists. Fractures are more difficult and in some cases impossible to treat satisfactorily at the later date. In most large hospitals every head injury is examined routinely by the oral surgery service while the patient is still in the emergency room.

The general condition of the patient and the presence or absence of more serious injuries are of prime concern. Asphyxia, shock, and hemorrhage are conditions that demand immediate attention. Extensive soft tissue wounds of the face are cared for before or concomitantly with the reduction of bony fractures, except in the few cases in which the fractures can be treated by direct wiring before soft tissue closure is accomplished. However, treatment of minor facial wounds is delayed until intraoral arch bars have been placed, since a beautiful skin closure can be reopened by the stresses imposed by the intraoral procedure.

A history should be written as soon as feasible. If the patient cannot give a good history, the relative, friend, or police officer should be asked for a statement. Relevant details of the accident should be placed in the record. The events that took place between the time of the accident and the time of arrival at the hospital should be recorded. The patient should be questioned regarding loss of consciousness, length of unconscious period if known, vomiting, hemorrhage, and subjective symptoms. Medications given before arrival at the hospital are recorded.

Questions regarding past illnesses, current medical treatment immediately preceding the accident, drugs being taken, and known drug sensitivity should be asked now. If the patient is uncomfortable, the detailed medical history can be deferred until later. Routine physical examination can be done now or later, according to the judgment of the examiner.

When examining the patient to determine if jaw fracture is present and its location, it is well to look for areas of contusion. This will provide information about the type, direction, and force of the trauma. The contusion sometimes can hide severely depressed fractures by tissue edema.

The teeth should be examined. Displaced fractures in dentulous areas are demonstrated by a depressed or raised fragment and the associated break in the continuity of the occlusal plane, particularly in the mandible. Usually a tear in the mucosa and concomitant bleeding are noted. A characteristic odor is associated with a fractured jaw, which perhaps results from a mixture of blood and stagnant saliva. If no obvious displacement is present, manual examination should done. The forefingers of each hand are placed on the mandibular teeth

with the thumbs below the jaw. Starting with the right forefinger in the retromolar area of the left side and with the left forefinger on the left premolar teeth, an alternate up-and-down motion is made with each hand. The fingers are moved around the arch, keeping them four teeth apart, and the same movement is practiced. Fracture will allow movement between the fingers, and a peculiar grating sound (crepitus) will be heard. Such movement should be kept to a minimum, since it traumatizes the injured site further and allows outside infection to enter.

The anterior border of the vertical ramus and the coronoid process should be palpated within the mouth.

The mandibular condules should be palpated on the side of the face. The forefingers can be placed in the external auditory meatus with the balls of the fingers turned forward. If the condyles are situated in the glenoid fossae, they can be palpated. Unfractured condyles will leave the fossae when the jaw is opened. This maneuver should be done carefully and sparingly. The patient will experience pain on opening the jaw and inability to open properly if a fracture is present. The unilateral condylar fracture is suspected in the presence of a shift of the midline toward the affected side on opening. A step sometimes is noted on the posterior or lateral borders of the vertical ramus of the jaw in a low condylar neck fracture if edema has not obscured it.

The maxilla is examined by placing the thumb and forefinger of one hand on the left posterior quadrant and rocking gently from side to side, following with the same procedure on the right posterior quadrant and then on the anterior teeth. If a complete fracture is present, the entire maxilla might move. An old fracture or one that has been impacted posteriorly will not move. The latter will be reflected in a malocclusion.

In a unilateral fracture, one half of the maxilla will move. This must be differentiated from an alveolar fracture. The unilateral maxillary fracture usually will have a line of ecchymosis on the palate somewhere near the midline, whereas the alveolar fracture will be confined to the alveolar ridge.

If a maxillary fracture is demonstrated, the facial aspect of the maxilla and the nose should be observed. A pyramidal fracture extending upward in the nasal area may be present. Besides loose bones, the patient usually will have a nosebleed (epistaxis) and black eyes.

All patients with facial injury should be examined for a transverse facial fracture. These fractures are overlooked sometimes because of facial edema and soreness. The examining finger should palpate the infraorbital ridge. A step in this area indicates a fracture. The normal ridge has a roughened area here, which should not be mistaken for a fracture. The lateral aspect of the bony orbit should be palpated next. Careful examination may reveal a separation of the frontozygomatic suture line. It is found usually if the infraorbital ridge is fractured.

The arch of the zygoma should be palpated. A fracture may be found here even if no other facial or jaw fracture is present. If the infraorbital and lateral orbital areas reveal fractures, the body of the zygoma is detached from the maxilla, and, frequently, one or more posterior fractures are present in the zygomatic arch. Careful palpation may reveal the fracture. A dimple over the course of the zygomatic arch is pathognomonic of a fracture. Overlying edema may make the clinical diagnosis difficult. By standing in front of the patient and pressing a tongue blade from the center of the zygoma to the lateral aspect of the

temporal bone on each side, the examiner will note a difference in angulation between the blades that will aid in the diagnosis of a depressed zygomatic arch. A depressed body of the zygoma may allow a gravitational depression of the orbital contents. The edge of a tongue blade held in front of the pupils of the eyes will incline away from a horizontal plane if one eye is lower than the other.

When a maxillary fracture is suspected, several signs should be looked for before proceeding with manual examination as just described.

1. Bleeding from the ears. This requires differentiation between a middle cranial fossa fracture, a fracture of the mandibular condyle, and even a primary wound in the external auditory canal. A neurosurgical consultation is necessary to help differentiate these conditions. Other neurological signs are present with the cranial fracture. However, the experienced oral surgeon can diagnose the condylar fracture and thereby facilitate the neurological examination. The patient with a suspected or diagnosed cranial fracture is the responsibility of the neurologist or neurosurgeon. Fractures or other wounds are treated only when he considers the patient to be out of danger, which in some cases may be a week or two later.

2. Cerebrospinal rhinorrhea. If the cribriform plate of the ethmoid bone is fractured in a complicated maxillary fracture, cerebrospinal fluid will leak out the external nares. Quick diagnosis can be made by placing a handkerchief under the nose for a moment and then allowing the material to dry. Mucus associated with a head cold will starch the handkerchief, whereas cerebrospinal fluid will dry without starching. If doubt exists, test the collected material for glucose. A commercial paper reagent test will identify sugar in normal cerebrospinal fluid; it is not accurate, however, in the presence of significant amounts of blood.

Movement of the maxilla of any type in the presence of cerebrospinal rhinorrhea is dangerous. Infectious organisms can be pushed up into the dura, and a meningitis may result. A few years ago the neurologist insisted that time be allowed for a granulation tissue covering to form over the distracted bone ends so that infection could not enter the meninges when maxillary fracture reduction was attempted. Complete reduction often was not possible by that time. With antibiotics, the reduction is now allower earlier. Properly reduced bones allow earlier and better soft tissue healing over them with less bridgings of voids between distracted bone ends.

3. Neurological signs and symptoms. Lethargy, severe headache, vomiting, positive Babinski reflex, and a dilated and widely fixed pupil or pupils are signposts that point to possible neurological trauma. Neurological consultation should be sought.

Radiographic examination. A patient should be examined radiographically if indications suggest that a fracture exists. Three extraoral are films routinely made: posteroanterior jaw and right and left lateral oblique jaws. The films should be examined immediately with particular attention paid to the bone borders, where most fractures appear.

If a fracture is suspected in the vertical ramus or in the condyle, the oblique lateral view on that side can be remade to concentrate on the suspected area. A lateral temporomandibular radiograph can also be made. If necessary, the x-ray beam can be directed posteriorly through the orbit to a cassette held to one side of the back of the head to obtain a proximolateral view of the condyle head.

In suspected maxillary fractures, a Waters view (nose-chin position taken from a posteroanterior exposure) should be made. If a zygomatic fracture is suspected, a "jug-handle" view is made with the tube near the patient's umbilicus and the cassette at the top of the head. Maxillary fractures are difficult to diagnose on the radiograph even by the trained oral surgeon or the radiologist. When a definite conclusion cannot be reached, a lateral skull radiograph should be made. If the frontonasal suture line is opened on the radiograph, the possibility is strong that a maxillary fracture exists. The absence of this sign, however, does not eliminate the possibility of maxillary fracture.

In cases in which a fracture is demonstrated, intraoral radiographs should be made at fracture sites before definitive treatment is given. Extreme trismus or a severly injured patient would preclude this. Intraoral views generally provide excellent definition because of the proximity of bone to the film. They sometimes show fractures that are not seen on the standard views, notably alveolar process, midline maxilla, and symphyseal fractures. The condition of adjacent teeth and detailed information about the fracture can be obtained by this procedure.

The diagnosis of a double fracture at one site, particularly in the mandible, should be made guardedly. A lateral jaw radiograph is not often so made that the fractures of the lateral cortex and the medical cortex superimpose exactly. The two fractured cortical plates may be interpreted mistakenly as two fractures through the body of the bone.

From a medicolegal point of view, a permanent record in the form of radiographs is necessary. In any case in which a fracture might be suspected, it is better to err on the safe side and make the minimum extraoral radiographs, that is, the posteroanterior jaw and right and left lateral oblique jaw films. In children or young adults in whom consideration of the total amount of radiation is a factor, a leaded rubber sheet can be used to cover the gonads and neck.

First aid

The primary consideration is to have a live patient. Accordingly, immediate measures should be taken to assure that his general condition is satisfactory. Specific treatment of fractures in the severely injured patient is given anytime from hours to weeks later.

If the airway is not patent, the fingers should be placed at the base of the tongue and the tongue pulled forward. Dentures, broken-off teeth, and foreign objects should be removed carefully if the finger can reach them. Suction should be employed for secretions and blood. A rubber airway can maintain a patent airway temporarily, or a suture can be placed through the midline of the tongue and tied to the clothing or affixed to the chest wall with adhesive tape. Mandibular fractures may involve the muscular attachment of the tongue with attendant posterior displacement and resultant asphyxia. If serious consideration is given to performing a tracheostomy, it should be done. An emergency tracheostomy may be needed, or, if time and facilities are available, an elective tracheostomy can be done.

However, in a surprisingly large number of cases of temporary airway embarrassment, an intratracheal tube will provide adequate relief until the fracture can be reduced, thus making a tracheostomy unnecessary. Usually, the tube is placed first, and then a tracheostomy is performed only if the tube is found to be inadequate.

Shock is treated by placing the patient in shock position, with the head slightly below the level of the feet. Warm blankets are placed over him. Excessive heat in the form of hot-water bottles is as dangerous as cold. Whole blood is given for definitive treatment of major shock.

Hemorrhage is rarely a complication of jaw fractures unless deep vessels in the soft tissues (for example, maxillary artery, facial vessels, lingual vessels) are involved. Even if the inferior alveolar vessels are severed in the bony canal, the hemorrhage is not severe. Hemorrhage from other wounds, however, demands immediate attention. In most cases the proper pressure point can be held with finger pressure until the vessel can be clamped and tied.

Patients with head injury should not receive morphine, except possibly in case of severe pain. Morphine may complicate further the function of the respiratory center. Tetanus antitoxin is given after a sensitivity test if the skin is broken, provided the patient has not been immunized. If the patient has been previously immunized, then a 1 mL booster dose of tetanus toxoid is given. This is done in the emergency room.

The possibility of spinal cord injury concomitant with cervical fracture or dislocation should be considered. Movement of the head in this instance can cause permanent injury to the spinal cord. Cervical radiographs should be made first if pain is present in the neck or if muscle weakness is present in the extremities.

The best treatment for jaw fractures is immediate intermaxillary fixation. Ideally, the permanent fixation that will be used to treat the fracture should be placed within hours after the injury. In a good many large hospitals the resident is instructed to place intermaxillary fixation immediately after clinical and radiographic examination, regardless of the time of day or night. The patient then is sedated further, given antibiotics and other necessary supportive measures, and ice packs are placed on the face. If these procedures are done soon after admission, the patient is more comfortable. The broken ends of bone are not moving or in malposition, and therefore, the nerve is not traumatized. The organization of the blood clot, which takes place in the first few hours, will not be disrupted by further manipulation in the majority of instances. Intraoral wiring is more difficult to apply the next morning when edema and the trismus associated with reflex spasms of the muscles have occurred. If further treatment is necessary, it is discussed after the immediate measures have been instituted and adequate postoperative radiographs are available for interpretation.

Temporary fixation should be placed if definitive fixation is not feasible. Some type of fixation should always be placed to keep the patient comfortable and to keep the fragments in as good as position as possible. A head bandage is the most simple form of fixation. The four-tailed bandage is one method that can be used. Ivy loops can be placed as temporary measures. A method that has been valuable is to string No 4-0 dress clamps on thin, 28-gauge stainless steel wire. Four of these can be placed in as many minutes, and elastics are stretched between them.

Treatment

The treatment of fractures is directed toward placing the ends of the bone in the proper relation so that they touch and maintaining this position until healing occurs. The term used for positioning the bone is *reduction* of the fracture. The term used for maintaining the position is *fixation.*

Closed reduction. Several methods of reduction are available. The simplest method is closed reduction, that is, manipulation without surgically exposing the bone to view. In closed reduction of long bones, the orthopedic surgeon pulls or manipulates the bone under the intact skin until the fracture is in proper position. The story is told of an old Scottish physician who had a bucket of sand in the corner of his office. A patient suffering a wrist fracture would be directed against his will to pick up the bucket. In so doing, the fractured parts would align themselves perfectly, and a plaster cast was applied.

Most early jaw fractures can be reduced manually. In older fractures in which the bony segments are not freely movable, traction supplied by rubber bands between the jaws exerts a powerful, continuous force that will reduce an obstinate fracture in 15 minutes to 24 hours. The elastic traction overcomes three factors: the active muscular pull that distracts the fragments (the main cause for malposition), the organized connective tissue at the fracture site, and the malposition caused by the direction and force of the trauma. A maxillary fracture often is pushed back by force, and it must be brought forward by manual manipulation or elastic traction. Rarely do the bones require surgical separation except in the case of delayed treatment when a fracture has healed in malposition (malunion).

Open reduction. It is not feasible to reduce all fractures satisfactorily by closed procedures. The often-encountered fracture at the angle of the mandible is difficult to reduce because it is difficult to counter the powerful pull of the masticatory muscles in that area. In the case of the angle fracture, however, open reduction is done more for fixation that for reduction. When the bone is surgically exposed, holes are drilled on either side of the fracture, wire is crossed over the fracture, and the bone ends are brought into good approximation. Besides good fixation, the fracture can be reduced exactly by direct vision. Perfect approximation is not always present after closed procedures. It might be stated in passing, however, that jaw fractures occurring within the dental arch are reduced to a fraction of a millimeter by the action of the dental facets of one arch guiding the other arch into the preexistent occlusion. This is not so likely to be true in fractures in other parts of the body, where manipulation is necessarily done through large muscle masses. Reduction in these latter instances need not be as critical as in jaw fractures, which must present an exact occlusion.

Another advantage of open reduction, particularly in a late fracture, is the opportunity for the surgeon to clean out the organizing connective tissue and debris between bone ends that would delay healing in the new position if left interposed.

Disadvantages of open reduction are: (1) the surgical procedures removes the natural protective clot at the site, and the limiting periosteum in incised; (2) infection is possible even with extreme aseptic procedures and antibiotics; (3) a surgical procedure is necessary, which increases time in the hospital and other hospital costs; and (4) a skin scar is present.

Fixation. The orthopedic surgeon reduces a simple fracture of the long bones by a closed procedure and then employs a plaster cast for fixation. The oral surgeon frequently combines the two procedures by the use of one apparatus. When the bones of the jaws contain teeth, the occlusion of the teeth can be used to guide the reduction. By placing wires, arch bars, or splints on the teeth and then extending elastic bands or wires from the mandibular to the maxillary arch, the bones are held in proper position through proper and harmonious interdigitation of the teeth. Plaster casts are not necessary or feasible.

The fixation of jaw fractures is approached in graduating steps. Usually intermaxillary fixation by means of wires, arch bars, or splints is the first step. In many cases that is all that

is needed. If this is insufficient, however, direct wiring through holes in the bone is done by an open procedure. This is done in addition to the intermaxillary fixation.

Methods other than open reduction and direct bone wiring have been employed to manage the angle fracture. Distal extensions from intraoral splints and external extensions from plaster headcaps to a hole in the proximal fragments have been discarded by and large. Fixation by medullary pins is used sometimes. The parts are reduced, and a long, sharp, stainless steel pin is drilled into the length of the bone, crossing the fracture line. The pin is used more often in mandibular symphysis fractures and rather infrequently in mandibular angle fractures.

Skeletal pin fixation is used often. In simplest form, a screw pin, 8 cm long with a diameter of 2 mm, is drilled into the lateral aspect of the jaw through the skin and subcutaneous tissues, through the outer bone cortex, the spongiosa, and just through the inner bone cortex. Another pin is drilled on the same side of the fracture. Two pins are drilled on the other side of the fracture. The pins are attached to each other by a connecting apparatus, and the two connecting units are united across the fracture by a stout metal rod. This is a closed procedure that is simple, but many failures are associated with it. If it is performed by an inexperienced person, the pin will not engage the inner cortex, and the entire assembly will become loose at an inopportune time.

Maxillary fractures must be maintained against the base of the skull. A plaster headcap with extensions has been used for years. Recently, internal wiring has been used more often. Wires are suspended over the intact zygomatic arches or holes are drilled into an unfractured bone superior to the fracture, such as the infraorbital ridge or the bone just above the zygomaticofrontal suture line. Wires are passed then beneath the skin, and the maxilla thereby is supended. Since this suspension is not visible, the patient can go about his business during recovery. Less chance exists for movement of the fracture during healing than with the plaster headcap.

It is interesting to note changes in the thinking of the profession over the years regarding open reduction. In the years before World War II, open operations on bones frequently resulted in osteomyelitis. Complicated jaw fractures were treated by all manner of gadgets. Bicycle spokes, fancy castings, and "man-from-Mars" outfits were used. In the years since the beginning of World War II, the popular procedure has been the open reduction. Antibiotics, the introduction of metals tolerated by the tissues, and more predictable results were largely responsible. The gadgets had been uncomfortable to the patient and sometimes inefficient in approximating the bony segments, and the surgeon never knew when one would slip at a crucial moment.

The trend is beginning to regress a bit at present. Largely responsible are the occasional infection of the open wound that is resistant to many antibiotics and the fact that results are not always that much better despite the increased amount of surgery. A tremendous backlog of experience with open procedures can be compared now with conservative procedures. The fractured mandibular condyle is an exmaple. A few years ago almost every fractured condyle was considered for open reduction. Now only a selected few are done. However, many indications exist for open procedures if no other method will give a comparable satisfactory result. Open reduction is still preferable to most of the modern gadgets.

Healing of Bone

Healing of bone can be divided into three overlapping phases. *Hemorrhage* occurs first, associated with clot organization and proliferation of blood vessels. This nonspecific phase occurs during the first 10 days. *Callus formation* occurs in the next 10 to 20 days. A secondary callus in which the haversian systems form "in every which way" forms in 20 to 60 days. *Functional reconstruction* of the bone is the third phase. Mechanical forces are important here. The haversian systems are lined up according to stress lines. Excess bone is removed. The shape of the bone is molded to conform with functional usage so that bone may be added to one surface and removed on another side. It takes 2 to 3 years, for example, to completely reform a fracture of the human femur.

Weinmann and Sicher divide the healing of fractures in six stages:

1. Clotting of blood of the hematoma. When a fracture occurs, blood vessels of the bone marrow, the cortex, the periosteum, the surrounding muscles, and adjacent soft tissues rupture. The resultant hematoma completely surrounds the fractured ends and extends into the bone marrow as well as into the soft tissues. It coagulates in 6 to 8 hours after the accident.

2. Organization of blood of the hematoma. A meshwork of fibrin is formed in the organizing hematoma. The hematoma contains fragments of periosteum, muscle, fascia, bone, and bone marrow. Most of these fragments are digested and removed from the scene. Inflammatory cells, which are so necessary for the hemorrhagic phase of bone healing, are called forth by this diseased tissue rather than by bacterial organisms. Capillaries invade the clot in 24 to 48 hours. Fibroblasts invade the clot at about the same time.

The proliferation of blood vessels is a characteristic of the early organizing hematoma. A good blood supply is important. The capillary beds in the narrow, cortex, and periosteum become small arteries to supply the area of fracture. As they become more tortuous, a slower flow results in a richer blood supply. At this stage, proliferation of capillaries occurs throughout the hematoma. The hyperemia associated with the slow flow of blood through tortuous vessels is responsible for mesenchymal proliferation. Protein building blocks created by the richer blood supply form the basis for mesenchymal proliferation.

Resorption of bone is a characteristic of an older hematoma. The torrents of blood running through the area of active hyperemia, and not disuse atrophy, cause resorption of bone. When the blood gets into the actual site of fracture where the capillary bed lies (which Johnson likens to a "swamp"), the flow is slowed. This area of passive hyperemia is associated with proliferation of bone. Calcium ion level is increased in this swamp area by the capillary bed.

3. Formation of fibrous callus. The organized hematoma is replaced by granulation tissue ordinarily in 10 days. The granulation tissue removes necrotic tissue primarily by phagocytic activity. As soon as this function is completed, the granulation tissue develops into a loose connective tissue. The end of the hyperemic phase is characterized by a decrease in the number of white cells and partial obliteration of the capillaries. The fibroblasts are now most important. They produce numerous collagenous fibers, which are termed fibrous callus.

4. Formation of primary bony callus. Primary callus forms between 10 and 30 days after fracture. Structurally it has been compared to a crudely woven burlap. The calcium content is so low that primary callus can be cut with a knife. It is for this reason that primary

callus cannot be detected on the roentgenogram. It is an early stage that serves only as a mechanical prop for the formation of secondary callus.

Primary callus has been considered in different categories, depending on location and function.

Anchoring callus develops on the outside surface of the bone near the periosteum. It extends some distance away from the fracture. Young connective tissue cells of the fibrous callus differentiate into osteoblasts, which produce this spongy bone.

Sealing callus develops on the inside surface of the bone across the fractured end. It fills the marrow spaces and goes out into the fracture site. It forms from endosteal proliferation.

Bridging callus develops on the outside surface between the anchoring callus on the two fractured ends. This callus is the only one that is primarily cartilaginous. The question has been raised whether true bridging callus forms in the healing of mandibular fracture, since the mandible is one of the bones formed originally in membrane rather than by replacement of cartilage. However, cartilage cells have been identified in such areas of healing in the mandible.

Uniting callus forms between the ends of bones and between areas of other primary calluses that have formed on the two fractured parts. It does not form until the other types of callus are well developed. It forms by direct ossification. Extensive resorption of the bone ends has occurred by this time. Therefore, rather than merely ossifying the interposed connective tissue at the fracture site, the uniting callus forms in the area of resorption as well. A well-united fracture is the result.

5. Formation of secondary bony callus. Secondary bony callus is mature bone that replaces the immature bone of the primary callus. It is more heavily calcified, and therefore it can be seen on the roentgenogram. It differs from other skeletal bone, however, by the fact that the pseudohaversian systems are not formed in any uniform pattern. It is composed of laminated bone that can withstand active use. Therefore fixation can be removed when secondary callus is seen on the roentgenogram. Formation of secondary callus is a slow process, requiring from 20 to 60 days.

6. Functional reconstruction of the fractured bone. Reconstruction proceeds over months or years to the point where the location of the fracture usually cannot be detected histologically or anatomically. Mechanics is the major factor in this stage. As a matter of fact, if a bone is not subjected to functional stress, true mature bone will not form. True haversian systems that are oriented by stress factors replace the non-oriented pseudohaversian systems of secondary callus. The secondary callus that is formed in abundance is sculptured to conform with the size of the remainder of the bone. The entire bone is molded by mechanical factors if the healing has not taken place in exact alignment. Steps are reduced on the one side, and deficiencies are filled in on the other side. This process seems to take place in alternative waves of osteoclastic activity and osteoblastic activity.

Fractures of the Mandible

Causes

Two principal components are involved in fractures of the mandible: the dynamic factor (blow) and the stationary factor (jaw). Common causes for setting in motion the dynamic factors have been discussed at the beginning of the chapter. Physical violence and automobile accidents lead the list in a municipal hospital administering to a preponderance of indigent patients. However, in studies conducted in private hospitals, industrial accidents rate as a close second to automobile accidents. In these hospitals the incidence of physical violence is extremely low, usually about 10%.

The dynamic factor is characterized by the intensity of the blow and its direction. A light blow may cause a greenstick or simple unilateral fracture, whereas a heavy blow with "follow through" may cause a compounded, comminuted fracture with traumatic displacement of the parts. The direction of the blow largely determines the location of the fracture or fractures. A blow to the right of the chin may result in a fracture of the mental foramen region on that side and a fracture of the angle of the mandible on the other side. Force applied to the point of the chin might result in symphysis and bilateral condylar fractures. Severe force may push the condylar fragments out of the glenoid fossa.

The stationary component has to do with the jaw itself. Physiological age is important. A child, with his growing bones, can fall out of a window and experience a greenstick fracture or no fracture at all, whereas an elderly person, whose heavily calcified skull can be compared to a flower pot, can trip over a rug and suffer a complicated fracture.

Mental and physical relaxation prevents fractures associated with muscular tension. A bone that has severe tensions placed on it by all-out contractions of its attached muscles requires only a slight blow to fracture it. On the other hand, intoxicated persons have fallen from rapidly moving vehicles only to suffer bruises. The muscle masses serve as tissue cushions when relaxed, but the same muscles under tension form strain patterns in the bones.

Vulnerability of the jaw itself varies from one individual to another and from time to time in the same individual. A deeply impacted tooth will make the angle of the jaw vulnerable, as will physiological and pathological conditions such as osteoporosis or a large cyst. Heavier deposition of calcium in the trained athlete will reduce jaw fractures. Jaw fractures in boxers are almost nonexistent because of increased calcification, the use of padded boxing gloves and rubber mouthguards, and a training factor.

Location

In the series quoted previously, the following incidence of fracture, by sites, occurred in the mandible.

Angle	31%	Symphysis	8%
Condyle	18%	Cuspid	7%
Molar region	15%	Ramus	6%
Mental region	14%	Coronoid process	1%.

The most common bilateral fracture was in the angle-mental regions.

Displacement

The displacement of a fracture of the mandible is a result of the following factors.

Muscle pull. The intricate musculature attached to the mandible for functional movement distracts the fragments when the continuity of the bone is lost. The action of balances between sets of muscles is lost, and each muscle group exerts its own force unopposed by another muscle group. The "sling of the mandible", that is, the masseter and medial pterygoid muscles, displaces the posterior jaw fragment upward, aided by the temporal muscle. The opposing force, that is, the suprahyoid muscles, displaces the anterior fragment downward. These forces would balance themselves if attached to an intact bone.

The posterior fragment usually is displaced medially, not because of lack of muscular balance as much as because the functional direction of pull is medial. The medial pterygoid muscle is largely responsible. The superior constrictor of the pharynx exerts medial pull from its multicentric origin on the mylohyoid ridge, pterygomandibular raphe, and hamular process to its insertion on the occipital bone. The lateral pterygoid muscle attached to the condyle will help, and in the case of the condylar fracture, it will tend to displace the condyle medially.

Fragments situated in the anterior portion of the jaw can be displaced medially by the mylohyoid muscle. Symphysis fractures are difficult to fixate because of the bilateral posterior and slight lateral pull exerted by the suprahyoid and digastric muscles.

Direction of line of fracture. Fry anmd associates classified fractures of the mandible as "favorable" and "unfavorable", depending on whether or not the line of fracture was in such direction as to allow muscular distraction. In the mandibular angle fracture, the posterior fragment will be pulled upward if the fracture extends forward toward the alveolar ridge from a posterior point on the inferior border. This is termed unfavorable fracture. However, if the inferior border fracture occurs further anteriorly and the line of fracture extends in a distal direction toward the ridge, a favorable fracture is present. The long angle of the anteroinferior portion will lock the posterior fragment mechanically to withstand upward muscular pull.

These distractions are in a horizontal plane, and so the terms horizontal unfavorable and horizontal favorable are used. Most angle fractures are horizontal unfavorable.

Medial displacement can be considered in similar fashion. Oblique fracture lines can form a large buccal cortical fragment that will prevent medial displacement. If the mandible could be viewed directly downward from the upper jaw so that the occlusal surfaces of the teeth are seen in button fashion, a vertical unfavorable fracture line extends from a posterolateral point to an anteromedial point. No obstruction to medial muscular pull is present. A vertical favorable fracture extends from an anterolateral to a posteromedial point. Medial muscular displacement is prevented by the large buccal cortical fragment.

Force. Factors such as the direction of the blow, the amount of force, the number and location of fractures, and the loss of substance as in gunshot wounds are not as important in displacing mandibular fractures as they are in maxillary fractures except insofar as they form the basis for later muscular distraction. Force on itself can displace fractures by forcing the bone ends away, impacting the bone ends, or pushing the condyles out of their sockets, but secondary displacement by muscular pull is stronger and more significant in mandibular fractures.

Force that compounds a fracture or comminutes it serves to complicate the treatment. Events that follow the initial fracture can also complicate it. An initially undisplaced fracture may be displaced by trauma (such as rolling) in the same accident. Placing the patient face down on a stretcher or injudicious and unskilled examination may displace bone segments. Lack of temporary support of the jaw, particularly in the case of a fractured skull, often leads to functional and muscular displacement, which is painful and difficult to treat later.

Signs and symptoms

1. *History of injury* is invariably present, a possible exception being a pathological fracture.

2. *Occlusion indirectly* offers the best index of recently acquired bony deformity.

3. *Abnormal mobility* with bimanual palpation of the mandible is a reliable sign of fracture. By this procedure, separation between mandibular fragments is differentiated from mobility of teeth.

4. *Pain* with movements of the mandible or on palpation of the face often is a significant symptom. When condylar movements are restricted and painful, a condylar fracture should be suspected.

5. *Crepitus* with manipulation or mandibular function s pathognomonic of a fracture. However, this is elicited with considerable pain to the patient in many cases.

6. *Disability* is manifested by the patient's inability to masticate because of pain or abnormal motility.

7. *Trismus* is seen frequently, especially in fractures through the angle or in the ramus region. This is a reflex spasm mediated through the sensory pathways of the disrupted bone segments.

8. *Laceration* of the gingiva may be seen in the region of the fracture.

9. *Anesthesia* may be noted, especially in the gingiva and lip up to the midline, when the inferior alveolar nerve is injured.

10. *Ecchymosis* of the gingiva or mucosa on the lingual or buccal surfaces may be suggestive of a fracture site.

11. *Salivation* and *foetor of breath.*

Treatment methods

Treatment of the fracture consists of reduction and fixation. In the case of long bones, this is often done in two stages, particularly if much manipulation is necessary for reduction. In simple mandibular fractures, reduction and fixation are accomplished together. The apparatus that is used to keep the jaws together during healing will often reduce the fracture as well. If multiple-loop wiring is placed, no attempt is made to reduce the fracture until the wiring on each jaw is complete. When the jaws are brought together and intermaxillary elastic traction is placed, the occlusion of the teeth will help to orient the fractured parts into good

position. Exceptions occur, of course. Fractures that occur beyond the tooth-bearing portion of the mandible, such as the angle, will not be reduced if initially displaced. Other examples are edentulous jaws and old fractures that are partially healed, which require continuous elastic traction for reduction.

Intermaxillary fixation, that is, fixation obtained by applying wires or elastic bands between the upper and lower jaws to which suitable anchoring devices have been attached, will successfully treat most fractures of the mandible. The main methods for such fixation are wiring, arch bars, and splints.

Wiring

Multiple-loop wiring. The armed services and many civilian institutions use this method almost exclusively. The four posterior quadrants are wired.

Preparation. Local anesthesia with sedation or sedation alone is used. General anesthesia is used occasionally when further treatment is necessary after the wiring. Even then it is better to have the interdental wiring completed the day or night before the operation so that the time of the operating room personnel and prolonged general anesthesia are not needlessly required. The wiring is done in a dental chair if possible.

A local anesthetic can be given by two pterygomandibular blocks in the mandible and simple infiltration in the maxilla. Bilateral block anesthesia combined with sedation in a patient who later will be put on his back in bed can be dangerous because of lingual anesthesia. The patient should sit in a chair until the anesthesia has disappeared.

If the contact points of the teeth are not too tight and broad, and if the interdental gingival tissue is not too close to the contact points, no anesthesia is necessary. Sedation alone is adequate if care is taken that the fracture zone is not traumatized by undue movement. Premedication with either meperidine hydrochloride (Demerol), 50 to 100 mg, or pentobarbital sodium (Nembutal), 100 to 200 mg, parenterally is adequate generally. For severe pain or to render the patient almost completely insensible to manipulative pain for 20 minutes, 75 to 100 mg of meperidine hydrochloride can be given intravenously to an average adult. This must be administered slowly over a 2-minute interval.

Armamentarium. The materials used for multiple-loop wiring are as follows:

Wire, 26-gauge stainless steel, cut into lengths of 20 cm and placed in a cold-sterilizing solution 20 minutes before use; wire cut on a bevel so that the bevel can act like a needle point if it must go through tissue.

Solder, soft No 20 resin core.

Hegar needle holders (two).

Wire cutters.

Blunt-nosed crown and bridge pliers.

Discoid dental instrument.

Technique. One end of the wire is placed on the buccal side of the teeth, starting at the midline (stationary wire). The other end goes around the last tooth in the arch (for example, the second molar) and into the mesial interproximal space and emerges under the stationary wire. Then it is bent back above the stationary wire into the same interproximal space. It is delivered to the lingual side and bent around the next tooth (first molar) and into the interproximal space between the molar and the premolar. The wire that goes around each tooth and over and under the statonary wire is called the working wire.

To make uniform loops on the buccal side, a piece of solder is placed on the buccal surfaces of the teeth over the stationary wire. It can be pressed against the teeth with the finger. The working wire therefore emerges under the stationary wire as well as under the solder, and then it is turned back and passed over the wire and solder to re-enter the same interproximal space.

Each time the wire emerges on the buccal side it should be grasped with the needle holder and pulled firmly to reduce slack. The left hand should provide counterpressure on the buccal surfaces of the teeth. The discoid instrument is used to move the wire under the height of contour of the teeth on the lingual side.

When the arch segment has been wired, the working wire and the stationary wire are crossed at the mesial side of the canine or first premolar. They are crossed 1 cm away from the tooth; the needle holder is placed over the cross and twisted clockwise until the wire almost touches the tooth. With the discoid instrument, the wire is pushed beneath the cingulum of the cuspid. The wire is then grasped with the needle holder at the turn nearest the tooth and turned until the tooth surface is contacted. Backward pressure always is placed on the needle holder when wires are tightened.

The solder is cut midway between the last two buccal loops, bent outward, and twisted gently out of the last loop. The wire loop then is given a three-fourths turn in a clockwise direction with the needle holder or pliers. Another cut is made in the solder between the next two loops, and the small distal piece is withdrawn. The loop is tightened with a three-fourths turn. This is continued untill all of the solder has been removed. Then, starting in the back, each loop is given another half turn. The multiple-loop wiring should be firm by this time.

The same procedure is followed in the other three quadrants of the mouth. If elastic traction will be used, the loops should be bent away from the occlusal plane so that hooks are formed. If wire will be used between the jaws, the loops are bent toward the occlusal plane.

It is desirable to use elastic traction routinely. This overcomes muscular distraction so that reduction is accomplished more easily, and it serves as a positive force to overcome muscular spasm when the jaw first tires of its forced closed position. If the mouth should have to be entered in the immediate postoperative period for relief of vomiting or the placement of an endotracheal tube for subsequent operation, the removal of the elastic bands is a simple matter. As an emergency procedure, particularly if the patient will be transported later, a wire can be placed on the buccal side under the elastics, bent back on itself over the elastics, and the two ends tied to clothing over the chest. If actual vomiting (not retching) occurs, the patient can jerk the wire and remove the elastic fixation immediately. This procedure is used rarely in civilian hospitals.

Elastic traction is obtained by stretching small or large Angle orthodontic elastics from an upper to a lower wire loop. A 14- or 16-gauge rubber catheter can be cut into bands that

provide stronger traction. If the fracture does not position itself properly, elastics can be placed in different directions rather than straight up and down. If the chin fragment is too far forward, several strong elastics can be placed from the lower cuspid region to the upper second bicuspid region. Often the angled elastics can be replaced by straight elastics in one day, thereby eliminating a possibility of overreduction.

Ivy loop wiring. The Ivy loop embraces only two adjacent teeth, and it provides two hooks for elastics. An individual Ivy loop is applied more quickly than multiple-loop wiring, although several Ivy loops are necessary in a dentulous arch. If many teeth are missing, adjacent teeth can be used satisfactorily by this method. If a wire should break, it is simpler to replace a single Ivy loop than it is a multiple-loop wire.

The armamentarium is the same as in multiple-loop wiring. The wire is 26 gauge cut in 15 cm lengths. A loop is formed in the center of the wire around the beak of a towel clip and twisted once. These wires can be stored in an emergency room in cold-sterilizing solution.

The two tails of the wire are placed in the embrasure from the buccal to the lingual side. If difficulty occurs, a piece of dental floss can be doubled through the loop. The floss then is carried past the contact point and the wire pulled through the embrasure from the lingual to the buccal side. The floss is removed. One wire tail is carried around the lingual surface of the distal tooth, pushed through the embrasure on the distal side of that tooth, and bent around the buccal surface. It is threaded through the previously formed loop or just under the loop. The other wire tail is carried around the lingual surface of the mesial tooth, passed through the embrasure on the mesial side of that tooth, and meets the first wire. The two wires are crossed and twisted together with the needle holder. The loop is then tightened and bent toward the gingiva. The crossed wires are cut, and a small rosette is made to serve as an additional hook. The rosette is wound clockwise below the greatest circumference of the tooth for two turns and then flattened toward the tooth. One or two of these Ivy loops are placed in each quadrant. Elastic traction then is placed between the jaws.

Risdon wiring. A wire arch bar tied in the midline is especially indicated for symphysis fractures. A 26-gauge stainless steel wire 25 cm long is passed around the most distal strong tooth so that both arms of the wire extend to the buccal side. The two wires, which are of equal length, then are twisted on each other for their entire length. The same procedure is followed for the other side of the arch. The two twisted strands are crossed in the midline and twisted around each other. A rosette is formed. Each tooth in the arch then is ligated individually to the wire arch. One wire is passed over the arch wire, and the other is passed under the arch wire. After tightening, a small hook is formed with each twisted strand. Intermaxillary traction is obtained by stretching elastic bands between the hooks in each arch.

Arch bars

Arch bars are perhaps the ideal method for intermaxillary fixation. Several types of ready-made arch bars are used. The rigid type requires either an impression and a stone cast to which the bar can be adapted carefully by a two-plier technique or a person skilled in the bending of prosthetic bars who has sufficient time to adapt it in the mouth. A soft type is available that can be bent with the fingers. It must be remembered that teeth lashed to any type of bar can be moved orthodontically if the bar has not been fitted skillfully.

The soft bar can be fitted, using two large needle holders, although wire-bending pliers are better. In an unfractured maxilla the bending should be started at the buccal side of the last tooth. The bar is adapted accurately to each tooth. The pliers or needle holder should be kept close together so that previously adapted portions are not bent again. By starting at one end of the bar, progressing past the midline, and finishing at the other end, the bar can be adapted readily and quickly without producing bulges. The bar should be shortened properly and the end filed smooth with a gold file. An overextended bar will cause soft tissue necrosis and severe pain. The midline of the jaw should be marked on the bar during bending so that it will be reseated accurately. As a general rule, the bar should not cross a fracture line except in a greenstick fracture. The bar is cut and adapted to each segment of a fractured jaw.

Wiring the bar to the teeth is relatively simple. Thin 30-gauge wire is used. Before seating the bar, wires are placed on the anterior teeth to seat tightly under the cingulum to resist displacement of the bar to the incisal level. A small loop of wire is placed by "jumping" the contact point or by threading through the two embrasures. The wires are crossed and grasped with a needle holder close to the labial enamel surface. Three fourths of a turn is given to the wire after the wire has been pushed below the cingulum. This is done to each anterior tooth.

The bar then is placed between the open ends of the wires. The midline mark is adjusted, and care is taken that the hooks on the arch bar project upward in the maxilla and downward in the mandible. The individual anterior wire ends are crossed over the bar, grasped, and twisted. The posterior teeth are then ligated individually to the bar. One end of a 7 cm long wire is passed from the buccal side under the bar through one embrasure, circled around the lingual side of the tooth, and then pushed back from the lingual side through the next embrasure to pass over the bar.

The crossed wires are grasped 2 mm away from the bar, and backward pressure is placed on the needle holder before a turn is made. This pressure is maintained during any tightening operation. When the turns approach the bar, the wire is again grasped with the needle holder further away from the bar, and turns are made until the previous turns are reached. The turned strand is cut 7 mm away from the bar while the holder still has the wire in its beaks so that the cut strand will not be lost in the mouth. The strand is grasped close to the bar and given a final turn. The end is turned under the bar so that the lips and cheeks will not be traumatized.

All teeth should be ligated to the bar. This rule has few exceptions.

Perhaps the main failings of the bar technique are improper adaptation of the bar, ligation of an insufficient number of teeth, and inefficient tightening of the wires. Advantages associated with arch bars include less trauma, because of the thin wire, and greater stability in an arch that has many missing teeth, because the edentulous gaps can be spanned by a rigid appliance. If one wire should break during healing, the fixation will not suffer. The hooks on the bar also seem to be less irritating to the soft tissues.

Splints

Splints are used when wiring of the teeth will not provide adequate fixation or when horizontal splinting across a fracture zone is necessary, as well as in some cases in which immobilization of the fractured parts is indicated without closing the mouth by intermaxillary fixation. At one time, splints with distal metal extensions were used to control the posterior

fragment in angle fractures, but pain and unsatisfactory results have made it necessary to generaly discontinue this procedure.

The acrylic splint is made from an impression so that it covers a minimum of the occlusal surfaces of the teeth and as much of the labial and lingual surfaces as do not form an undercut. The gingival margins are not encroached. The lingual surface is continuous. The buccal surface is attached to the lingual portion behind the last molar either by continuous acrylic material or by a wire connector. A vertical cut is made in the midline of the labial flange through a large acrylic button. The splint is placed over the reduced fractured mandible, and the acrylic button is drawn together and held by wire.

The cast cap silver splint requires impressions of the opposing arches. The lower cast is sawed through the line of fracture. The cast is reassembled in proper occlusion and fixed in this position by pouring a base for the cast. The splint is formed to the gingival margins in 28-gauge sheet wax. Occlusal relations are established in the wax-up by bringing it into proper centric relation with the opposing casts while the wax is soft. The cast is sprued with inlay wax. When the sprues are in place, the wax-up is drawn from the stone cast in an occlusal direction while the wax is warm to eliminate undercuts. The wax-up is mounted in a large crucible former in a single investment technique, with an asbestos liner in the ring. It is cast in coin silver at $1.000°$ to $1500°F$ ($538°$ to $816°C$) and finished.

The splint is cemented to the reduced fractured jaw. If the splint will be needed for weeks rather than months, it is sometimes better to use zinc oxide and eugenol for cementation rather than crown and bridge cement, since these splints are often difficult to remove. The splints can be made of gold, and projections or hooks for intermaxillary fixation can be formed on them. Some gold splints are made in sections for specific purposes.

The splint is generally indicated for the very simple or the very complex case. If an oral surgeon suffered a simple mandibular fracture within the area of dentition, he or she probably would prefer a cast cap silver splint so that the jaws would not be wired shut. In bone graft cases or in delayed union cases, the splints are indicated, since they provide long-term fixation in the presence of function.

Except for these general indications, the use of splints is not great. The acrylic splint has fallen largely into disuse, except for children with deciduous teeth, which are difficult to wire sometimes. The average fracture with good teeth is well on the way to good healing if wired immediately. The splinted patient requires impressions, temporary immobilization, delay of various degrees during construction of the appliance, and then later reduction and cementation. If a tooth should become acutely infected under a splint, a real problem is presented.

Orthodontic fixation is used more often for elective surgery and long-term procedures than for traumatic surgery. It is especially indicated for alveolar fractures.

Circumferential wiring

Circumferential wiring ("wiring around") usually refers to the procedure of placing wires around a mandibular denture and around the mandible so that the fractured mandible is held firmly into the denture, which serves as a splint. The fracture must be situated within the area covered by the denture base unless secondary procedures for the control of the other segment are contemplated. If the denture is fractured at the time of the accident, it can be

repaired satisfactorily sometimes with quick-cure acrylic.

The mouth is rinsed with an antiseptic solution to reduce the bacterial count. The skin is prepared in the usual manner. General or local anesthesia is satisfactory, although skin infiltration is necessary to supplement a local block procedure.

The simplest procedure consists of threading a long, straight skin needle with thin 28-gauge steel wire, which has been sterilized previously. The needle is bent into a slightly concave form with the fingers. It is passed through the floor of the mouth close to the mandible to emerge through the skin directly beneath the mandible. The needle is brought out of the skin, turned, and redirected into the same skin puncture hole. It is passed upward on the buccal side of the mandible close to the bone to emerge in the mucobuccal fold. The wires are cut near the needle. The two lingual and the two buccal wires are twisted over the denture, cut short, and formed into a rosette on the buccal side. At least three circumferential wires are placed, one near the distal end of the denture on each side and one at the midline. Occasionally two wires are placed in the anterior region. One side of the denture may have a wire placed anterior and another posterior to the fracture line.

The wires are sawed back and forth several times before tightening, to move them through the tissues to the inferior border of the mandible. Care is taken that a dimple does not persist at the skin wound. The skin around the wound should be released from the subdermal structures after the wires are tightened around the denture. A No 11 surgical blade is used to release the skin, and a single skin suture is placed.

Several variations in technique are possible. A long, No 17 hypodermic needle can be used. It is bent to a concave form and passed on the lingual side from the skin through the floor of the mouth. A single 26-gauge wire is introduced into the lumen from the skin side and grasped in the mouth with a hemostat. The needle then is removed. The same needle is introduced intraorally through the buccal fold to emerge through the same skin hole, and the other arm of the wire is threaded through the lumen from the skin side into the mouth.

If the hub of a second needle is cut off so that it can be removed from the wound, it can be introduced from the skin into the buccal vestibule. The advantage of this method is the introduction of the two needles and the two arms of the wire from the skin surface into the more septic oral cavity, which will enhance the possibility of a noninfected skin wound.

Other variations have to do with the preparation of the denture. Holes for the wires can be drilled in the acrylic buccolingually between the teeth, just above the ridge. Danger of slipping is lessened, and the occlusal surfaces are not separated by the thickness of the wire. These holes also can be used for ligating the maxillary and mandibular dentures together for intermaxillary fixation after reduction, or hooks can be placed on the dentures for this purpose. The anterior teeth of the mandibular denture can be removed to provide better feeding and to eliminate the fulcrum created by the wire when it is tied over the teeth away from the ridge. Edentulous acrylic baseplate splints can be constructed if dentures are not available.

Skeletal pin fixation

Skeletal pin fixation is used in cases in which the management of a fractured bone segment is not satisfactorily accomplished by intermaxillary fixation. Fractures of the mandibular angle can be immobilized by skeletal pin fixation without surgically exposing the

fracture. Fragments bridged by a bone graft are immobilized by skeletal pin fixation. Fractures in edentulous jaws can be treated in similar fashion.

At the time of World War II, skeletal pin fixation became popular for several reasons. The armed services and the British treated simple as well as complicated fractures by this method, without supplementing it with intermaxillary fixation, so that the transported patient who suffered from motion sickness was not endangered by drowning in vomitus, and limigted duty was made possible without liquid-diet restrictions. Men practing in as well as out of the armed services could treat complicated fractures without having training in open procedures.

Skeletal pins can be placed while the patient is under general anesthesia or local block anesthesia or local block anesthesia supplemented by skin infiltration. It can be done in the dental chair or preferably in the operating room, where greater safety and convenience are possible. Strict asepsis is necessary. The skin must be prepared thoroughly, the field must be draped, and the operating team must be scrubbed and wear gloves and gowns.

After skin preparation, the inferior and superior borders of the mandible are palpated and marked on the skin with a dye such as gentian violet on an applicator stick. The line of fracture is marked, and the general location of the inferior alveolar canal is marked after reference to the radiograph. Intermaxillary fixation should be placed beforehand if used.

The pins are positioned usually by an egg-beater-type drill. Two are placed at a 40-degree angle to each other on one side of the fracture, and two are placed similarly on the other side. If each pin is started 20 degrees from the vertical plane, a 40-degree divergence betweeen them will result. The pins should not be placed closer to the fracture line than 1 cm. The skin is tensed directly over the bone. The pin in the drill is placed on the skin and pressed directly down to bone. The drill is rotated slowly under moderate pressure. The revolving point will be felt to penetrate the outer cortex, transverse the softer spongiosa, and then enter the inner cortex. It should penetrate the entire inner cortex, but it should not be lodged more than 1 to 2 mm in the medial soft tissues. The drill then is removed carefully from the pin. The pin should be tested for stability. If not stable, it has not penetrated the medial cortex and should be rotated deeper with a hand attachment.

Two pins are placed in the anterior fragment parallel to the inferior border. The two pins in the posterior fragment can be placed parallel to the inferior border also, provided that the location of the fracture is not so far back that the most posterior pin will be located in the thin bone at the angle of the jaw. If the most posterior pin location is at the angle, it is better to locate the second pin further up on the vertical ramus at the posterior border or in the retromolar area near the anterior border. The pins should be located halfway between the mandibular canal and the inferior border, and care is taken that they do not transverse the facial artery or vein.

A bar assembly is attached to the two anterior pins. A similar assembly is placed on the two posterior pins. A large bar is selected and placed in the attachments on the short bars so that it crosses the fracture. The fracture is manually reduced so that the inferior border is continuous to palpation and the lateral border is continuous. All attachments are then tightened securely with a wrench. A drop of collodion is placed around the pin entrances into the skin. Roentgenograms made in the operating room or later will demonstrate the accuracy of the reduction.

Properly placed pins will remain tight for several months in the absence of infection.

Many variations exist in the design of skeletal pin apparatus. The Thoma bone clamp is useful in cases in which infection makes pins or transosseous wiring uncertain or in long-range treatment cases in which a bone graft is used.

Some operators make use of an electrical drill to place pins rather than the manually operated eggbeater-type drill.

Open reduction

Open reduction with interosseous wiring is a definitive method for anchoring bone segments at the fracture site. Wire is placed through holes on either side of the fracture, reduction is accomplished under direct vision, and immobilization is obtained by tightening the wires. This procedure usually is reserved for fractures that cannot be reduced and immobilized adequately by closed methods. However, fractures that have soft tissue or debris interposed between the fragments and fractures that have healed in malposition are treated by open reduction.

One advantage to this method is direct visualization of the fractured parts, and consequently better reduction is possible. Oblique fractures, particularly those that present a short fracture on one cortical plate and a long one on the other plate (usually the lingual), are reduced with more precision. Complicated fractures are treated in this manner. It should be noted, on the other hand, that a severely comminuted fracture is not treated by open reduction if it can be avoided. The many small fragments may lose their vitality and be sloughed after an open procedure because the surrounding periosteal and soft tissue attachments and the traumatic hematoma and its binding, nutritive, and protective functions have been removed, and infection may be introduced.

Another advantage is firm fixation. Teeth can loosen, wires and appliances can slip, but the bone ends are still held close to each other. If teeth are present, open reduction should be supplemented by intermaxillary fixation for additional stabilization. Experience has shown that direct interosseous wires cannot be relied on for complete immobilization of the fragments if unrestricted use of the jaws is permitted.

Open reduction is done almost always under general anesthesia in the operating room. Intermaxillary wiring should be in place. For that reason, nasoendotracheal anesthesia is indicated. The most common site for open reduction is at the angle of the mandible, and the description will be for that procedure. Preparation of the site of surgery, draping, and the surgical approach through the skin and soft tissues have been described in Chapter 2. The basic armamentarium is supplemented with the following instruments necessary for interosseous wiring:

2 Periosteotomes, dull and sharp
1 Bone rongeur
1 Mallet, metal, small
3 Chisels
1 Pliers, cutting, wire
4 Forceps, bone, Kocher's
1 Retractor, malleable, narrow
1 Pistol drill, key, and drill points
  Wire, stainless steel, 24 and 30 gauge.

Infiltration of the skin with a local anesthetic solution containing 1:50.000 epinephrine or another vasoconstrictor will eliminate clamping and tying the skin blood vessels, resulting in a smoother postoperative skin wound.

The bone is exposed, and the fracture is visualized (see Chapter 2 for technique). The posterior fragment usually will be malplaced in a superior and medial position. Examination should be made of the cortical plates, particularly on the medial side. If the medial cortex is missing for some distance on one fragment, the location of the bur holes will have to be moved back until both cortical plates of the fragment can be traversed by one hole.

A flat ribbon retractror is placed under the medial side of the bone from the inferior border to protect the underlying soft tissue structures. The second assistant holds the superior soft tissue retractor across the face with the right hand and the ribbon retractor at the inferior border of the jaw with the left hand. The first assistant holds a syringe of normal saline solution in the right hand and the suction (if it is used) in the left hand. The operator holds the drill in both hands. Occasionally secondary tissue retraction by the right hand of the first assistant is necessary near the drill bit.

An electrical drill is used more commonly than a mechanical eggbeater-type drill. The first hole should be started on the anterior fragment, near the inferior border, 0.5 cm from the fracture site. The drill point should be sharp. Rotation is started at slow speed until the hole is started, and then the speed may be increased, taking care that burning of the bone does not occur. The operator will feel the penetration of the outer cortex, the spongiosa, and the inner cortex. Saline solution is sprayed on the site during drilling. The drill is removed. Another hole is placed above the first one in the anterior fragment. It should not go through the inferior alveolar canal being slightly below it. Usually it is well to place a 24-gauge wire in this hole immediately after the drill is removed and clamp the two ends with a hemostat outside the wound.

The ribbon retractor is repositioned under the posterior fragment. One hole is placed near the inferior border 0.5 cm from the fracture site. Another hole is placed as high as possible above the first one and still just below the inferior alveolar canal. A wire is placed through this hole and clamped outside the wound.

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The medial arm of the wire in the anterosuperior hole crosses the fracture line and is threaded in the posteroinferior hole from the medial to the lateral cortex. It usually is difficult to locate the hole from beneath. Time can be saved by placing a thin 30-gauge wire in the second hole from a lateral to medial direction. This wire is doubled, and the loop is introduced into the hole first. When recovered with a small curved hemostat from the medial aspect, the medial arm of the original wire is placed through the loop and bent back 3 cm. The thin double wire then is pulled upward (laterally) with care, to thread the original wire through the hole. The two arms of the original wire then are clamped outside the wound.

The medial arm of the wire in the posterosuperior hole is threaded through the anteroinferior hole from a medial to lateral direction, using a similar thin wire loop technique. It is clamped outside the wound.

The bone fragments are grasped with bone-holding or Kocher's forceps, although two No 150 dental forceps may be employed, and the fracture is reduced by manipulating the fragments. If aberrant soft tissue and other debris are located between the bone fragments, it should be removed at this time. If necessary, major debridement should be done before the wires are placed. The wires are tightened while the assistant holds the bone ends int he reduced position. It is important to place upward traction on the needle holder while twisting the wires. After the wire has been tightened to within 3 mm of the bone surface, a small periosteal elevator is placed on the underside (medial) of the bone and the wire flattened against the bone. The needle holder grasps the strand of wire at the next to last turn, upward traction is made, and the wire is turned down to the bone surface.

The same procedure is followed for the other wire. The first wire is examined for tightnessč. The bone-holding instruments are removed, and the fracture reduction is inspected. Ordinarily no further manipulation will be necessary. The wire strands are cut off at a length of 0.7 cm, and the ends are turned carefully into the nearest bone holes.

Soft tissue closure is made by layers as described in Chapter 2. No drains are placed unless uncontrollable oozing of blood from deep areas is noted when the platysma muscle layer is being closed. After the skin sutures are placed, a small piece of sterile Teflon is laid over them. Three 10 by 10 cm gauze sponges are placed over the Teflon and held. Drapes are removed together with gloves and operating gowns. Blood and secretions are wiped from the face and neck. Skin areas adjacent to the bandages are painted with compound tincture of benzoin and allowed to dry. Many narrow strips (1 cm) of adhesive tape 20 cm long are placed over the bandages and skin with a fair amount of tension, since a pressure dressing is desired. An operating cap is placed on the head of the patient. A roll of elastic adhesive tape is wrapped around the chin, bandage, and head in modified Barton style. Last, a 10 cm strip of ordinary adhesive tape is placed on the cap over the forehead, and the words "fractured jaw" are written upside down on it. This will remind recovery room personnel that the ordinary practice of holding the chin up to maintain a clear airway must be done with care, if at all.

It is possible to place too much bulk and pressure with the elastic adhesive dressing on the anterior throat instead of under the chin. Immediate respiratory embarrassment will result, necessitating revision.

The endotracheal tube should not be removed until the elastic adhesive dressing is in place. Anesthesia should be continued in sufficient depth until that time so that the patient will not "buck" on the tube. A carefully reduced fracture can be disturbed by "bucking" on the tube, particularly if the fracture is not supported adequately by outside bandaging.

The postoperative orders should be written in the operating room. In most hospitals all preoperative orders are automatically cancelled by an operative procedure.

This basic technique has many variations. Three bone holes are adequate usually. This eliminates the need for the anterosuperior hole, with the attendant threading of the wire immediately after drilling. All three holes are drilled. The posterosuperior hole is drilled last, and a wire is placed through it. The medial arm of this wire in the posterosuperior hole is threaded into the anterior hole. Then one wire is placed from the anterior hole to the posteroinferior hole. Two wires therefore are located in one anterior hole. The horizontal wire is tightened first to impact the bone, and then the oblique wire is tightened to prevent upward muscle displacement. The first wire is examined for stability, since it often requires another

turn.

In the three-hole technique, a figure-of-eight wire in two inferior holes offers advantages in providing downward traction as well as cross fracture traction. As a matter of fact, the technique used most today employs two holes, one on either side of the fracture, connected with a figure-of-eight wire. A figure of eight is made on the inferior border, with the wires crossing near the fracture site. Both ends of the wire can be placed from the lateral side, eliminating the threading from the medial side.

Bone plates are used infrequently in new fractures of the jaws. Healing seems to be delayed in comparison with wire techniques that pull the fractured ends together during convalescence. The screws in bone plates hold the bones rigidly. The technique of fastening the plates sometimes will allow a small distraction of the fragments, and the absence of minute functional stresses at the fracture site results in slower healing. Care must be taken that the screws and the plate are made of exactly the same alloy to prevent electrolytic currents from forming, which would cause dissolution of bone around the holes. Even screws cast from the same alloy sometimes cause such currents. In the casting process the metals may have separated somewhat so that the head and point of the same screw are not a uniform alloy.

In comminuted fractures that require open reduction and occasionally in edentulous mandibular fractures that have a strong tendency to override, a metal gutter plate can be placed on the inferior border with screws or wires through bone holes. Ordinary wires without a bone plate will pull an overriding fracture together, but they will not hold an overriding fracture in proper distracted position unless other wires are placed in lateral directions. The principle of the slotted plate used by the orthopedic surgeon in fractures of the long bone is applicable here. Muscular pull across the fracture site is allowed to act to keep the fractured ends together during healing by the sliding of screws in a horizontal slot rather than in a hole in the plate.

The L splint has a right-angle bend across its top surface that is placed in a slot cut through the cortical plate across the fracture zone. Because of its horizontal stability, only two screws are necessary. The L splint is less bulky and more stable than ordinary bone plates.

Treatment of fractures of the mandible

Uncomplicated fractures

A large percentage of mandibular fractures can be treated by simple intermaxillary fixation. The fractures must be located within the dental arch, and at least one sound tooth should be present in the posterior (proximal) fragment. Although specific advantages are inherent in the use of one method over another in a specific fracture, by and large any method of intermaxillary fixation can be used. For example, multiple-loop wiring was used extensively and almost exclusively in the armed services during World War II. The beginning practitioner should be able to manage one method well. Variations can be considered with increased experience.

The question of the removal of a tooth in the line of fracture is managed often by the judgment of the operator. Before the sulfonamides and antibiotics, it was always removed. Most experienced practitioners still will remove this tooth. The following factors influence the decision: the absence of fracture or gross injury to the tooth; the absence of caries or large

restorations; the absence of periodontitis; the location of the tooth, including esthetics and the possibility of arch collapse; the nature of the fracture; and the probability of adequate response to antibiotic therapy. If serious doubt exists whether or not to extract the tooth, it should be extracted. Persistent chronic infection or an acute abscess occurring later in treatment sometimes will require opening of the fixation to extract the tooth. Delayed union or nonunion can result.

As a matter of fact, infected and grossly carious teeth that are not in the line of fracture should be extracted before placing intermaxillary fixation. This can be done while the patient is under the same anesthesia given for wiring.

Elastic traction is placed to overcome distraction and muscle spasm. With continued changing, elastic traction can be used throughout convalescence. If desired, the elastics can be replaced by intermaxillary wires after 1 week. The wires are easier to keep clean, and they seem to bother the patient less. Recalcitrant patients who desire a chicken dinner at the end of the third week sometimes require intermaxillary wire fixation supplemented by elastic traction.

Antibiotics are useful for the first week as a prophylactic measure. It is advantageous usually to admit a fracture patient to the hospital. Many patients with simple fractures are treated in the outpatient clinic or office and then allowed to go home, where they are observed. However, a 24- or 48-hour admission will allow the patient to recuperate from his trauma and operation better, his new diet and drug therapy can be introduced to him, and he can be observed more closely.

Complicated fractures

Fractures that cannot be reduced and fixed properly by simple intermaxillary fixation require further measures. Usually the dentulous cases have intermaxillary fixation placed as a starting point.

Mandibular angle. Intermaxillary fixation is placed. The horizontal and vertical favorable fractures require no further treatment. A solid, unfractured tooth in the posterior fragment with an antagonist in the maxilla will preclude further treatment. Conservatism is necessary in condemning such a tooth for extraction. Many experienced practitioners on occasion have reatined such a tooth when one root has been fractured, but as a rule the worry during the convalescence period does not make the procedure worthwhile. The oral surgeon who enjoys life treats the fracture in definitive fashion immediately.

Many methods for controlling the posterior fragment have been advocated. Some have been abandoned, and others are not generally accepted. Skeletal pin fixation and open reduction are the two main alternatives. Individual preference is a strong factor in choice. Skeletal pin fixation is satisfactory if it is placed properly. Pin fixation can be done in the office if necessary. The fact that much external hardware is in evidence during healing and the fact that open reduction takes only about 30 minutes longer to do influence many oral surgeons toward open reduction. Open reduction, despite its drawbacks of the external scar, the loss of the original hematoma, the exposure of bone to possible infection, and the operating room procedure involved, still seems to provide more definitive treatment.

Two alternative intraoral methods are illustrated. Occasionally a circumferential wire can be placed through a hole in the posterior fragment through an intraoral incision and the

wire looped around the inferior border. The angle of the fracture line must be suitable. The other method involves placing two intraoral holes in the buccal cortex of the bone after removal of the third molar. This method is valuable in the case of mandibular fracture associated with removal of an impacted third molar. The wire should lie in a vertical plane rather than a horizontal plane. The technique is especially successful in the horizontal favorable fracture.

Symphysis. Simple wiring often provides satisfactory immobilization. Wiring of the teeth, particularly with the Risdon wiring across the fracture, will reduce the fracture adequately at the alveolar level, but separation or telescoping may occur at the inferior border. If the wiring is tight and the inferior border separation is minimal, healing will be satisfactory. However, the principal complication is collapse of the alveolar arch inward, which is difficult to prevent with dental wiring. A simple acrylic splint placed on the lingual aspect of the dental arch before wiring will prevent arch collapse.

Wide separation or other malposition requires further treatment. Skeletal pins can be used. A Kirschner wire or Steinmann pin can be driven across the chin by an electrical drill. This is done through the skin surfaces while the fracture ends are held in proper reduction. This is a relatively simple procedure that takes little time.

Open reduction in this region does not encounter large vessels, but the tissue attachments are difficult to raise. Care must be given to locating the linear scar beneath the chin within the skin creases if practicable. More exact reduction and closer fixation are made possible by open reduction. This method is valuable, especially in the grossly telescoped fracture.

In symphysis fractures uncomplicated by condyle fracture, force of the blow has traumatized the temporomandibular joint, and ankylosis can occur if the jaw is not opened occasionally during the treatment period to free the joint. This maneuver is accomplished better if a lingual acrylic splint stabilizes the symphysis fracture.

Edentulous fracture. Circumferential wiring around a denture or acrylic splint is adequate in most cases. All fragments must be covered by the denture base, and they must be held adequately to preclude auxiliary treatment. Fractures occurring distal to the posterior border of the denture, old telescope fractures, and cases of severe trauma require skeletal pin fixation or open reduction. Some oral surgeons do not place dentures and intermaxillary fixation in edentulous jaws when skeletal pin fixation or open reduction is done, although others feel that all jaw fractures should have intraoral stabilization.

In the case of the angle-third molar region fracture that is not distal to the posterior border of the denture, the circummandibular wires should be placed around the anterior fragment. Muscular pull on the posterior fragment will elevate it so that further wires are not necessary in this area.

Keeping the maxillary denture in is often a problem. If the maxillary denture fits wells, and particularly if it has one or more minor undercuts, the two dentures connected by intermaxillary fixation may stay in place. Older women with resorbed alveolar ridges will carefully slip the maxilla out of the assembled dentures when the surgeon has gone, turn to the next bed, and start to jaber incessantly. This is an eerie sight with the dentures closed and still moving in unison over fast speech. If the surgeon does not drop in unexpectedly he or she will find the jaws always fixed in position and will wonder why the fracture heals slowly,

if at all.

A head bandage worn continuously is uncomfortable. The cooperative patient can wear an elastic support over the head and chin at night or even during the day. The uncooperative patient will require further stabilization. A simple method consists of direct wiring to the piriform fossa margins. With the patient under local anesthesia or general anesthesia supplemented by infiltration anesthesia, an incision is made high in the labial fold next to the midline of the maxilla. The bone is exposed by blunt dissection. The inferior border of the piriform fossa is followed laterally until the lateral border is reached, where a small hole is placed with a bur. Thirty-gauge wire is placed through the hole and brought out untwisted through the incision. The incision is closed with No 3-0 catgut. The same procedure is carried out on the other side. The denture is removed from a cold-sterilizing solution and placed in the mouth. The wires are threaded through previously drilled holes in the labial flanges of the denture and tightened moderately. Dental compound is placed over the rosette, and a pressure bandage is placed over the lip.

Pernasal wiring is another method for fixing a denture to the maxilla. A heavy awl is passed just inside the external nares directly through the mucosa and bone of the nasal floor and palate with simple pressure and rotation. A wire is looped through the eye of the awl at its point of emergence on the palatal side. The instrument is withdrawn upward through the palate, but only to a point just beneath the nasal epithelium. It is then guided anteriorly and inferiorly through the labial mucosa into the height of the vestibule. The wire is removed from the eye of the awl, the awl is withdrawn completely, and the two free wire ends (one palatal and the other vestibular) are drawn together around the prosthesis, drawn through a palatal bur hole in the appliance, and tightened on the labial surface.

Circumzygomatic wires are useful also. A long, sharp instrument with a hole near the tip is introduced at the height of the buccal fold just distal to the maxillary first molar region and is pushed upward and posteriorly. A finger on the skin over the zygomatic arch guides the point medial to the arch to emerge on the skin. A wire is threaded into the eye of the instrument, and the instrument is withdrawn into the mouth. The wire is disengaged. The instrument is introduced into the same oral wound and pushed in the same upward direction, this time to pass on the lateral side of the zygomatic arch and emerge through the same skin wound. The other arm of the wire is threaded into the eye of the instrument, and the instrument is withdrawn. The two arms of the wire are sawed back and forth until they contact bone, and they are attached to the maxillary denture flange in the molar region. A similar circumzygomatic wire is placed around the opposite zygomatic arch. The wires can be looped around the mandibular circumferential wires that secure the mandibular denture to the lower jaw.

Open reduction of an edentulous fracture is done best with four holes, using heavy wire. If a triangular segment of bone is found on the inferior border (a not uncommon occurrence in edentulous fractures) and telescoping has occurred, a gutter bone plate on the inferior border will support the segment.

Skeletal pin fixation is excellent. The thinness of the bone makes placement difficult at times.

Multiple fractures

Multiple fractures, in which four or more jaw fractures are present in the same person, occurred in 17% of the fractures in the District of Columbia General Hospital series. When multiple fractures occur in both jaws in the same patient, it is difficult sometimes to find a starting point for treatment. Many fragments at different occlusal levels require the establishment of a baseline, which is usually the mandible. The rule is "bottom up and inside out". After the parts of the mandible have been reduced to a satisfactory plane of occlusion, other segments are fitted to it. If many mandibular segments are present, and if the maxilla is severely fractured so that it cannot be used to establish a plane of occlusion, impressions of the teeth are made and casts are poured. The casts are cut at the fracture lines and reassembled in normal occlusion, and a cast splint that has proper indentations on its superior surface to support the maxillary teeth is made for the mandible.

Multiple fractures that occur solely in the mandible often can be assembled by fixing the teeth of the individual segments to the intact maxillary arch. Wiring or divided arch bars are used. However, many teeth often are lost in this type of fracture. A splint may be used for greater stability, but the splinted mandible in this case is wired to the maxilla to obtain and maintain good occlusion. Oblique fractures and horizontal fractures appearing on the inferior border are treated by circumferential wiring around the splint. Skeletal pins are difficult to place in many small fragments. Open reduction is a last resort. It is definitive treatment, but many small pieces are difficult to wire, and surgical exposure will deprive them of any last vestiges of mechanical and physiological support afforded by the surrounding soft tissues.

Fractures of the coronoid process (2% of the District of Columbia General Hospital series) often are not treated if no displacement has occurred. Tendons of the temporal muscle frequently are inserted low on the ramus, which will prevent displacement. If upward displacement does occur, open reduction can be done through an intraoral approach. An incision is made on the anterior border of the ramus, and direct wiring utilizing two holes is done. If reduction is not possible and impairment of function is present, the coronoid process is removed.

Condyle

The fractured mandibular condyle has been treated for many years by a closed procedure. Intermaxillary fixation is placed that immobilizes concomitant fractures and corrects the displacement of the jaws associated with the condyle fracture, that is, a shift of the midline toward the side of the fractured condyle and a slight premature posterior occlusion on that side. The fractured ends of the bone in the condylar region thereby are placed in a somewhat better relationship.

Because of muscular pulls and the stress of the blow, the condylar head often is dislocated forward or tipped medially out of the glenoid fossa. Often the fractured neck of the condyle remains close to the fractured ramus portion. In a subcondylar fracture the fractured segment remains upright in a position lateral to the ramus. Attempts at intraoral as well as extraoral manipulation, the latter including lateral pressure by a sharp instrument through the skin ("ice-pick technique") and various pressure pads on the skin, are usually unsuccessful.

Because of trauma to the joint structures, an ever-present danger exists of ankylosis of the condyle to the glenoid fossa. Healing in proper occlusion under intermaxillary

immobilization is allowed to progress for 1 week. At that time, with the patient in the dental chair, the jaw is opened carefully once by the operator rather than the patient, care being taken that other fractures do not move, and fixation is again applied. This is done several times in the following weeks.

The effect of this procedure is to ensure motion in the condylar area. Joint surfaces are mobilized so that hemorrhage and edema fluid brought into the joint by trauma are not allowed to organize into a bony ankylosis. The objective is to move the joint without moving the lower fractured bone surfaces, which would lead to nonunion. Such manipulation during healing will create movement in the joint rather than in the fracture zone if it is done carefully, and primary healing of the fractured parts will occur with no ankylosis in the joint.

If the fracture occurs inside the joint capsule, weekly movement of the parts (sometimes more frequently) is especiallhy necessary to prevent ankylosis. In this case, because joint and fracture are together, movement may disrupt the condinuity of the fibrous callus in the condylar fracture area. Fibrous tissue rather than bone forms at the junction. The fractured condylar head treated in this manner is nonfunctional. Because of this factor, together with a traumatic hematoma and the damaged synovial membranes, it ankyloses to the base of the skull. The ramus articulates on the edge of the condylar fragment by a fibrous joint. The functioning of the contralateral joint, together with the stability afforded by the fibrous joint, allows satisfactory functioning in good occlusion. The patient can bite as hard on the side of injury as on the other side without experiencing pain.

The head of the condyle that is displaced medially out of the glenoid fossa will ankylose if it touches bone. It is held in place by the soft tissues. Years later it seems to disappear. Fibroous tissue fills the joint cavity.

The occluding dental arches attached to a normal contralateral joint will not allow the ramus to move further upward to form an open bite, whether or not an ankylosed condylar fragment is present in the fossa. Evidence suggests that an attempt is made over the years to re-form the missing condyle from the remaining ramus portion.

Open reduction of condylar fractures has become popular since World War II. The condylar head is placed back in its original position in the glenoid fossa and wired to the ramus. Healing of the fracture takes place by direct bony union, and the healed member functions on the true joint rather than on an artificial fibrous joint.

The surgical procedure for the preauricular approach is made according to the description given in Chapter 2. Dissection is carried down to the articular capsule. Manual movement of the jaw at this time will demonstrate the joint structure. The capsule is incised horizontally if the fracture is intracapsular or if the condyle has been displaced medially out of the glenoid fossa. This is necessary for access. It is advantageous not to incise the capsule if possible, since the lateral side of the capsule is stronger than the medial side, and the intact capsule stabilizes the condylar head.

A hole is placed in the fragment that lies most superficial. Special retractors such as those designed by Thoma are placed beneath the fragment to protect the maxillary artery. The ramus of the jaw may be pushed upward into the wound to visualize the inferior fragment better and distracted downward to gain access to the superior fragment. A hole is then placed in the other fragment.

The condylar fragment is repositioned carefully in the glenoid fossa. The management of this fragment is a delicate procedure. The fragment is difficult to find if it is displaced deeply to the medial side. It must be placed in its properly oriented position in the fossa with as little damage to surrounding structures as possible. It must be held firmly while the whole is drilled. Any excessive pulling will bring the fragment completely out of the wound.

A wire is placed through the two holes, threading it from the lateral surface of the condylar fragment first and recovering it from the medial surface to the lateral surface of the inferior fragment by means of a thin wire loop. The wires are twisted over the reduced fracture. It is well to remove the attachment of the lateral pterygoid muscle to prevent redislocation of the condyle. Thoma immobilized the severely displaced condyle that has few if any attachments by means of a catgut suture through holes to the glenoid fossa or by skeletal pin fixation between the condylar head and the eminentia articularis.

The wound is closed in layers, with particular attention to good closure of the articular capsule. A pressure bandage is placed over the wound, and a head bandage made with elastic adhesive tape is placed before the anesthesia is lightened. The endotracheal tube is removed before the patient "bucks" on it.

The submandibular approach is used if the fracture is situated outside of the capsule at the base of the condylar neck. As a matter of fact, this approach is recommended for most cases of open reduction of the condyle. For a description of the surgical approach see Chapter 2. The fracture site can be exposed well with long, narrow-angle Army-Navy retractors. It may be necessary at this stage to administer curare, 60 to 90 units, or succinylcholine hydrochloride, 20 mg, intravenously to provide muscular relaxation.

The same general technique of direct wiring, using two holes, can be employed as described previously. The thin fragments in the condylar neck are usually telescoped. Therefore the ordinary placement of wires will further telescope the fragments rather than hold them distracted in correct position. A small amount of telescoping of the fragments does not seem to affect correct function, particularly in the presence of poor dentition. Lateral contact of the bone ends is important to healing, although the healing is slower. Several methods to overcome telescoping are employed. A figure-of-eight wiring offers some advantage. If one cortex is longer than the other, one hole is drilled through both fragments and the fragments are wired together. A rounded gutter plate can be placed around the posterior border and wired into place, or a flat, three-pronged plate can be screwed into the lateral surface. The lateral pterygoid muscle attachment often is removed surgically to prevent subsequent dislocation through muscle spasm. Surgical closure of the wound and the immediate postoperative treatment are similar to the procedures described previously.

The Chalmers J Lyons Club in 1947 reviewed the postoperative results of 120 cases of fractured condyles. They found that fractures treated by closed procedures healed satisfactorily without accurate alignment of the fragments, that ankylosis occurred infrequently, that disturbances to epiphyseal growth did not appear among the younger or skeletally immature patients, and that conservative methods of closed reduction and intermaxillary fixation were simple and effective.

In a 5-year survey of 540 jaw fractures at the District of Columbia General Hospital, 115 cases of condylar fracture were found with a total of 123 condylar fractures (8 being bilateral). Of these, 16 were intracapsular, 64 were extracapsular, and 43 were subcondylar (a total of 107 extracapsular fractures). Thirteen cases were in children. Condyles were

fractured in 21% of all cases of jaw fracture. Treatment was as follows: no treatment, 14 cases; conservative treatment, 96 cases; and open reduction, 12 cases. One case of postoperative ankylosis developed in a conservatively treated case.

The general consensus today in the management of the condyle fracture is toward conservative (that is, closed) treatment. This is particularly true in the unilateral case. No figures are available to indicate the percentage of ankylosis after open reduction of the condyle, which would necessitate later resection of the condyle. This seems to be an infrequent complication. However, function after the open procedure does not seem to be better than that after the closed procedure, in spite of the rather time-consuming procedure in a hazardous location.

The bilateral case presents a different problem. If proper ramus height is afforded by a nondisplaced condylar fracture on at least one side, open bite may not result. If ramus height is collapsed on both sides, consideration should be given to an open procedure on at least one side. If a low extracapsular fracture occurs on one side, that side should be opened through a submandibular approach. True temporomandibular joint function then will be made possible through direct bone healing on the one side. Both sides can be wired directly if the fractures demand it.

Smith and Robinson presented an interesting case of bilateral joint fracture. The fractures occurred several years apart. Repeated intermaxillary wiring for a total of 3 years and 6 months was followed in each instance by open bite when the wires were removed. When the patient was presented to them, they performed a bilateral joint reconstruction by placing in each glenoid fossa a piece of bone that was designed to ankylose to the fossa and to the ramus. Later the two sides were resected at the graft-ramus junction and preformed metal guide plates were placed to form joint surfaces. Function was excellent.

Observation is continuing on condyle fractures in children. The main growth center of the jaw is located in the condylar region. A study conducted elsewhere was said to show that portions of the growth center in rats extended some distance down the posterior border of the ramus. For this reason, the separation of the growth center from the rest of the jaw is being studied.

The mandibular growth that is associated with the condylar growth center occurs between 1 and 5 years of age in the human. A period of quiescence occurs from 5 to 10 years of age, followed by another period of active mandibular growth from 10 to 15 years of age. This latter growth is associated with muscular function more than with the growth center, which is not so important at this age. By this reasoning the most critical period for a condylar fracture would be from 1 to 5 years of age. Perhaps the most critical situation is a fracture-dislocation in a child 2.5 years old or less.

Numerous clinicians have presented radiographs showing re-formed rami after closed treatment of condylar fractures. Such reconstruction takes place in conformity with Wolff's law that the shape of the bone conforms to the stresses placed on it during function. The process takes years to accomplish the end result.

Fractured jaws in children

Two considerations are primary in the management of fractured jaws in children. Deciduous teeth are difficult to wire, and growing jaws heal exceedingly fast.

Deciduous teeth have a bell shape. The widest portion of the tooth is at the neck, where the wires are placed. For this reason, many oral surgeons did not attempt to wire deciduous teeth in the past, turning to the use of acrylic splints instead. The splint has the advantages of stability and the elimination of time spent in wiring the patient under general anesthesia. However, often the splint requires the use of circumferential wires. The main disadvantage is the time needed for construction, although if several sizes of preformed acrylic splints are available, one can be selected and adapted with dental compound for immediate insertion. Healing usually is complete in 3 to 4 weeks. If nearly a week is required for impressions and laboratory construction of the splint, the preliminary organization at the fracture site is broken up during reduction and placing of the splint.

The use of a finer wire (28-gauge) makes the wiring of deciduous teeth possible. If the permanent first molar and anterior teeth have erupted, retention is made easier.

Malpositioned angle fractures occurring in children are treated by open reduction. Condyle fractures are treated conservatively in most instances. Intermaxillary fixation is placed while the patient is under general anesthesia or heavy sedation. It is maintained for 2 weeks, and the fracture then is examined. No fixation has been used in isolated instances, with apparently satisfactory results.

Feeding problems

The diet is a high-protein, high-caloric, high-vitamin diet in liquid or semiliquid form. A successful sample diet* containing 2.100 calories is as follows:

Breakfast
      Fruit juice - 1/2 cup
      Cereal - 1/2 cup cooked, thinned with 1/2 cup milk, sugar to taste
      Milk - 1 cup
      Coffee or tea as desired

Midmorning
      Milk shake (4 level tbsp of protein-vitamin-mineral supplement in 1 cup whole milk)

Lunch
      Meat - 6 tbsp thinned with 1/2 cup broth or bouillon
      Vegetable - 1/4 cup thinned with 1/4 cup vegetable juice
      Potato - 1/4 cup mashed potato thinned with 1/4 cup milk
      Fruit - 1/4 cup thinned with 1/4 cup fruit juice
      Cocoa - 1 cup
      Coffee or tea as desired

Midafternoon
      Milk shake (4 level tbsp of protein-vitamin-mineral supplement in 1 cup whole milk)
Dinner
      Same as lunch, but substitute 1/2 cup strained cream soup for potato
Bedtime
      Milk shake (4 level tbsp of protein-vitamin-mineral supplement in 1 cup whole milk)

Food selections

Beverages: Milk, cocoa, and milk shakes; fruit and vegetable juices; coffee, tea, etc, only if they do not interfere with schedule

Cereals: Cocoa Wheats, Cream-of-Wheat, Farina, Malt-o-Meal, Cream-of-Rice, corn meal - *thinned with milk*

Fruits: Applesauce, apricot, peach, pear - *strained and thinned with fruit juices*

Fruit juices: Apple, apricot, grape, grapefruit, orange, pineapple, tomato

Meat: Beef, lamb, pork, veal, liver - *strained and thinned with broth or bouillon*

Vegetables: Beets, carrots, wax beans, green beans, peas, asparagus, spinach, mashed squash - *strained and thinned with vegetable juice*

Vegetable juice: Can be the water used in cooking, or liquid from canned vegetables, or commercially prepared vegetable juices

Cream soup: Make with strained vegetable and milk, or use commercial soup thinned with milk

Seasoning: Sugar may be added to tart juices or any seasoning used in any foods to suit your taste

Instructions to patient: Follow the feeding schedule above, selecting foods from the accompanying list. Larger amounts may be taken, but be certain to follow the basic meal plan. For the strained foods you can use prepared baby foods or you can liquefy common table foods in a mechanical blender. Potatoes can be mashed or strained by hand. **Important:** The three protein-vitamin-mineral nourishments ensure nutritional adequacy in this liquid diet and must be taken. Additional liquids and beverages may be taken, provided they do not interfere with feeding schedule.

* Courtesy Dietene Co, Minneapolis, Minn.

The patient should be fed six times a day. He is unable to obtain enough nourishment in the ordinary regimen of three meals a day. Perhaps this is associated with the small particle size, which eliminates bulky pieces in the diet.

A calorie chart is important to the fracture patient. He should know how many calories are present in each ounce of the special mixture and how many are in supplementary foods and beverages. He should know also how many calories are necessary to maintain his weight at his present level of activity. The decision then is made whether he should maintain his present weight, gain, or lose weight. Some individuals will lose weight when loss is not indicated, and attention should be given to supplements that will make the diet as attractive as possible. Other persons will gain a tremendous amount of weight, especially with ice cream soda supplements. Some individual who are overweight will use this situation to lose weight deliberately. This should be encouraged if the amount of loss each week is not too drastic and the patient receives adequate nourishment.

Many modern food advances have a place in this program. Milk and egg powders and protein supplements make nourishment possible without great quantity. The electric food blender makes possible a balanced diet of the same foods that the rest of the family eats rather than the monotonous dairy food diet. The meal is made more palatable by the electric blender because the individual vegetable and meat can be served as separate servings rather than as a nonspecific conglomeration. A soup preceding and a liquid dessert after the meal constitute a normal fare, except for particle size. The importance of meat in the diet is emphasized by faster healing, especially if the meat is not over cooked. Meats canned for babies are excellent if a food blender is unavailable, although they are expensive.

Intravenous feeding with a supplement of 5% protein hydrolysate and vitamins is the method of choice for the first 24 hours after the treatment of a fracture with intraoral complications or for a severely injured patient. This method keeps food out of the mouth until preliminary healing can take place, and it keeps food out of the stomach. A Levin tube placed into the stomach through the nose will allow feeding into the stomach and still keep food out of the mouth. It is a good method of feeding in the first few days after operation if oral wounds are present.

The patient who has an uncomplicated fractured jaw usually is better off to start with the diet for fractured jaw as soon as possible rather than to be fed intravenously. Ordinary spoon-feeding or a large-bore glass straw is satisfactory. Most patients have one or more teeth missing, and through these spaces the food material can be placed. If no teeth are missing, the food material is brought by means of a straw into the oropharynx through the space existing behind the last molars. When the patient is recuperating well, usually he will want separate blenderized fods by spoon. The larger the entrance space the larger the particle size and the more bulk admissible, which avoid constipation.

An old adage states that as soon as the hospitalized fractured jaw patient complains about his food, he has recovered enough to go home.

Time for repair

Most mandibular fractures heal well enough to allow removal of fixation in 6 weeks. Occasionally the young adult will require only 4 or 4.5 weeks. Children require 3 to 4 weeks.

Oral hygiene is difficult to maintain during immobilization. During hospitalization the mouth should be sprayed by means of a 10-pound pressure spray on a dental unit at least once each day. The patient must irrigate the mouth after every meal with saline solution, preferably with a Water Pil. The use of a soft brush is excellent. Failure to keep the mouth clean in a patient who is lying down will permit material to enter the eustachian tubes and allow a middle ear infection to start. The outpatient can have his mouth irrigated with a power spray once or twice each week. Elastics should be changed weekly.

Wires that irritate the lips and cheeks should be turned and the ends protected by dental compound, gutta percha, wax, or quick-cure acrylic.

Pain during healing is not common. For the first few days a satisfactory analgesia level is obtained by giving one 300 mg tablet of aspirin each hour for 4 consecutive hours to obtain a satisfactory level and one tablet every fourth hour to maintain the level. Eacg day that analgesia is needed, the aspirin level should be built up by taking 1.2 g of aspirin in 4 hours and then maintained as just outlined. Some patients may not be able to tolerate this amount

of salicylate. However, this method has been found by pharmacologists to be as equally effective as 30 mg of codeine. Because of the possibilities of nausea and addiction, codeine should be used only if absolutely necessary. Then it is ordered in 60 mg doses every 4 hours with salicylates.

At the optimum time for healing, callus formation should be seen on the radiograph. However, the surgeon should be guided by clinical signs of union in determining the length of time immobilization is necessary, since bone healing in the form of secondary callus takes place sometimes before it is demonstrable clearly on the radiograph. The intermaxillary elastics or wires are removed, and the fracture is tested gently with the fingers. If clinical movement occurs, the elastics should be replaced for another week. Reexamination is carried out at weekly intervals until healing has occurred. Even with the best of treatment, some fractures will take several months to heal. In instances in which an unusual delay has occurred, a cast cap splint can be cemented over the fractured member so that the jaws can be opened. Function stimulates healing at this stage. If nonunion is inevitable, all fixation is removed, and the patient is allowed to rest for several months so that the bone ends may round off preparatory to a bone graft. It is not an isolated occurrence to find that the patient has bony union when he returns after moderate functional use of the jaw during the interim.

After removal of the elastics the patient is seen daily for 3 days. If the occlusion and the fracture site remain satisfactory, the wiring or arch bars can be removed at that time. The patient should eat a soft diet for a week, until muscle and joint function have returned. Scaling and polishing of the teeth should be done, and minor occlusion disharmonies should be corrected by grinding.

Complications

Delayed healing in the properly reduced fracture occurs in the presence of inadequate or loosened fixation, infection, or a fault in the vital reparative effort.

Loosened fixation usually is associated with poorly placed wires. Wires that have not been placed under the cingulum in anterior teeth or those that have not been tightened properly so that they stay under the cingulum will not hold. The multiple-loop wiring technique fails if the strand of wire bridging an edentulous area is not twisted so that it fits the space exactly. For that reason the eyelet wire for double teeth or a thin wire wound twice around a single tooth is preferable in areas of missing teeth. Arch bars should be wired to every tooth in the arch.

The occasional patient who removes his elastics for a small chicken dinner should be strongly advised of the serious consequences. He should be warned that a bone graft is an interesting operation for the oral surgeon and that the patient himself will request such an operation when he tires of a flopping jaw.

Infection caused by bizarre and resistant organisms is becoming more frequent. A routine blood culture and organism sensitivity test should be done in all cases of postoperative infection. If pus forms, it should be cultured. Systemic and metabolic disease will cause delayed healing. In some instances the cause for dealyed healing is not apparent even after a general medical survey, and healing takes months instead of weeks.

Nonunion is an aftermath of delayed healing if the cause is not corrected. A bone graft is necessary. Sometimes freshening of the area through open reduction is sufficient. A

technique for an intraoral approach, freshening, and the placing of homogenous bone chips has been successful.

Malunion is healing in poor position. Poor treatment, an intercurrent accident, or a lack of treatment is responsible. The bone must be refractured and immobilized. However, there is a fine line in judging whether the degree of malposition requires treatment. If the clinical position is satisfactory and the radiograph reveals a small amount of malposition, no treatment may be necessary. Repositioning in this instance is called "treating the x-ray". If facial contours and esthetics are involved as a result of malunion, cartilage or bone onlays have been used successfully.

Fractures of the Maxilla

Maxillary fractures are serious injuries because they involve important adjacent structures. The nasal cavity, the maxillary antrum, the orbit, and the brain may be involved primarily by trauma or secondarily by infection. Cranial nerves, major blood vessels, abundantly vascular areas, thin bony walls, multiple muscular attachments, and specialized epithelia characterize this region in which injury can have disastrous consequences.

Causes

Automobile injuries, blows, industrial accidents, and falls can cause such injuries. Rapid deceleration in a fast-moving vehicle can produce a typical middle face fracture known as a "dashboard injury". The force, direction, and location of the blod determine the extent of the fracture. In the District of Columbia General Hospital survey, maxillary fractures represented 6% of all jaw fractures.

Classification - signs and symptoms

Horizontal fracture

The horizontal fracture (Le Fort I) is one in which the body of the maxilla is separated from the base of the skull above the level of the palate and below the attachment of the zygomatic process. The horizontal fracture results in a freely movable upper jaw. It has been called a "floating jaw". An accessory fracture in the midline of the palate may be present, which is represented by a line of ecchymosis. The maxillary fracture can be unilateral, in which case it must be differentiated from an alveolar fracture. The alveolar fracture does not extend to the midline of the palate.

Displacement is dependent on several factors. The force of a severe head-on blow may push the maxilla backward. Muscular pull may do the same. In a low-level fracture, muscular displacement is not a factor. If the fracture is at a higher level, the pterygoid muscle attachments are included in the loose fragment, which is consequently retruded and depressed at the posterior end, resulting in an anterior open bite. Some fractures are depressed all along the line of separation. Many horizontal maxillary fractures are not displaced, and therefore the diagnosis is missed at first examination.

Evidences of trauma may be seen on the teeth, lips, and cheeks. Unless they are severely traumatized, the anterior teeth should be grasped between thumb and forefinger and a forward-backward motion made. The molar teeth on first one side and then the other should be similarly moved. A fractured jaw will move. The distally impacted jaw will not move, but

diagnosis can be made from the malocclusion.

Radiographic examination will reveal the fracture on posteroanterior, lateral jaw, and Waters views. Fractures should not be confused with cervical vertebral shadows, nor must intervertebral shadows be diagnosed as fractures.

Pyramidal fracture

The pyramidal fracture (Le Fort II) is one that has vertical fractures through the facial aspects of the maxillae and extends upward to the nasal and ethmoid bones. It usually extends through the maxillary antra. One malar bone may be involved.

The entire middle of the face is swollen, including the nose, lips, and eyes. The patient may have a reddish injection of the eyes, associated with subconjunctival extravasation of blood, in addition to the black eyes. Hemorrhage is present in the nares. If a clear fluid is seen in the nose, cerebrospinal rhinorrhoea must be differentiated from mucus associated with a head cold. An empirical test consists of collecting some of the fluid on a handkerchief or linen cloth. If it starches on drying, it is mucus; if it does not starch, it is cerebrospinal fluid that has escaped through the dura as a result of fracture of the cribriform plate of the ethmpoid bone. It is for this reason that clinical examination for suspected upper jaw fractures must be done gently with as little movement as possible. No palpation of the jaw is done in the presence of nasal fluid until cerebrospinal fluid is ruled out. Infected material can be pushed up into the dura if the cribriform plate has been fractured, and a meningitis can follow.

The neurosurgical service should be consulted if positive neurological signs are present or if a fractured skull is suspected. Discreet palpation over the vertex of the skull should be done after a head injury, even if no evidence of skull fracture are noted. Edema masks skull depression that the examining finger often will find. The possibility of a basal skull fracture should not be overlooked in the severely injured patient. More than half of all cranial fractures are complicated by basal skull fractures. A history of unconsciousness is always present, and lesions of the cranial nerves (especially the abducens and facial) are characteristic signs. Battle's sign (ecchymosis in line of the posterior auricular artery in the mastoid area) becomes evident in 24 hours after fracture of the base of the skull. Increased temperature is associated with intracranial damage.

The patient with cerebrospinal rhinorrhea is the responsibility of the neurosurgical service until that service releases him. The neurosurgeon usually will permit temporary bandaging or wiring after a satisfactory antibiotic level is obtained, and definitive treatment is sanctioned often in anticipation of faster healing of the dura on reduction of the bony walls. Only special antibiotics, such as ampicillin, that cross the blood-brain barrier are indicated. Previously no reduction was done until fibrous healing had taken place over the defect, at which time reduction of the fractures was difficult if not impossible to accomplish.

Diagnosis of all types of maxillary fractures is difficult at times. Palpation of bones through massive edema of the facial tissues is inexact. Radiographs are difficult to read. If fracture displacement is present, the radiograph will reveal steps and spaces at cortical borders that can be corroborated clinically. The many structures, including the vertebrae, that are superimposed on the maxilla make radiographic diagnosis difficult in the absence of displacement. The statement has been made that a separation of the frontonasal suture line on the lateral head radiograph usually indicates a maxillary fracture elsewhere, although its

absence does not exclude a fracture in the maxilla.

The unconscious or dazed patient should have the facets of the teeth examined carefully to verify the correct occlusion if a suspected maxillary fracture is not confirmed clinically or radiographically.

Transverse fracture

A transverse fracture (Le Fort III) is a high-level fracture that extends across the orbits through the base of the nose and the ethmoid region to the zygomatic arches. The lateral rim of the orbit is separated at the zygomaticofrontal suture line, and the bony orbit is fractured. The zygoma usually is involved either by a fracture of the arch or by a downward and backward displacement of the body of the zygoma.

Because the zygoma is involved, the transverse fracture usually is associated with other fractures. A pyramidal fracture often accompanies the transverse fracture. A unilateral transverse fracture is associated often with a unilateral pyramidal fracture on the other side. Combinations of the basic maxillary fractures are the rule rather than the exception. A severe middle face fracture includes transverse, pyramidal, and horizontal fractures, often in multiple form, zygomatic body and arch fractures, and fractures of associated structures such as the nasal and ethmoid bones.

Transverse fracture cases present a characteristic "dishface" facies because the central portion of the face is dished in. On profile the face appears spooned ou8t in the nasal area because of fracture and posterior dislocation of the maxilla.

Orbital signs are important neurological signs. If one eye is widely dilated and fixed, a 50% probability of death from intracranial damage is present, and if both eyes are involved, the probability of death is 95%. However, the neurosurgeon must differentiate this sign from other conditions such as alcoholism, morphinism, glaucoma, and previous eye operations. Cerebrospinal rhinorrhea, skull-fractures, other neurological signs, and bleeding in the ears should be looked for. Bleeding from the ears usually means a middle cranial fossa fracture. However, trauma to the external ear, scalp wounds, and a condyle fracture must be differentiated.

Palpation should be done as described previously. In all suspected maxillary fractures, the infraorbital rim should be palpated for a bony step, and the lateral orbital rim should be palpated for a separation. If the floor of the orbit is depressed, the eyeball will be lowered, resulting in diplopia. The orbital rims are reasonably easy to visualize on the radiograph, and therefore the presence or absence of a fracture in this region can be diagnosed with certainty. The normally radiolucent frontozygomatic suture line must be differentiated from a traumatic separation.

Treatment

Horizontal fracture

Treatment is directed toward positioning the maxilla in proper relation to the mandible as well as to the base of the skull and immobilizing it there. Since an exact relationship with the mandible is more important, maxillary fractures require intermaxillary fixation.

Concepts of craniomaxillary immobilization have undergone change. Formerly every maxillary fracture was immobilized by wires to a headcap or by internal wires to the nearest superior unfractured bone. These wires often were not tight enough to provide upward traction, or they soon became loose and often were not retightened. Downward positioning of the maxilla was necessary as often as upward positioning. The fractures healed without much effective aid from the craniomaxillary fixation. The intermaxillary fixation provided the effective immobilization. In one series of 116 midfacial fractures only 14% were treated by some form of cranial suspension. The remainder were treated by intermaxillary fixation only.

A simple horizontal maxillary fracture that is not displaced or one that can be positioned manually can be treated with intermaxillary immobilization alone, without craniomaxillary immobilization.

Craniomaxillary fixation is employed in cases of displacement or gross separation to supplement intermaxillary immobilization. The simplest method is that of circumzygomatic wiring. This pulls the separated upper jaw against the base of the skull, and in the case of open bite, it pulls the downwardly distracted posterior portion upward while the intermaxillary elastics pull the anterior open bite shut.

If the fracture is high and the fragment is displaced backward, considerable intermaxillary traction with the elastic bands directed downward and forward may be necessary for reduction. Occasionally extraoral traction is necessary. A plaster headcap can be used for this. A stationary post or a heavy wire is incorporated into the headcap and suspended in front of the maxilla. Elastic traction is placed from the post to the anterior arch bar. When the jaw has been moved forward, usually in 24 to 48 hours, the post is removed, and intermaxillary fixation is placed.

An old fracture that has started to heal in malposition sometimes can be separated by manual manipulation or elastic traction. If this is unsuccessful, open reduction must be performed by raising mucoperiosteal flaps and separating the bones with thin, broad osteotomes.

A few years ago a plaster headcap was placed on all maxillary fractures to position them against the base of the skull. The plaster headcap has several disadvantages. It looks and feels cubmersome, it is uncomfortable and hot, it tends to move or slide around, and it is time-consuming and messy to construct. Many modifications have been made that eliminate the plaster. Many leather headcaps have been made. The Crawford head frame developed by the Navy has three pins that make contact with the outer table of the skull in tripod fashion.

The plaster headcap is made as follows. The head is shaved to the occiput for men and women. The remainder of the hair of women is pilled high on the head. Rubber, 6 mm thick, is taped to the shaved skin over the occipital prominence. A piece of felt 6 mm thick is placed over the forehead and is removed after the plaster is dry, thereby providing space to prevent pressure necrosis and pain. A piece of stockinet 35 cm long is placed over the head to the level of the chin and pulled slightly upward to arrange the hair in an upward direction. A piece of bandage is tied loosely around the stockinet at the top of the head. A small cut is made in the stockinet above the knot, through which the remaining bandage and the knot are pushed. The upper portion of the stockinet is pulled down over the head. This leaves the crown of the head free, surrounded by the bandage, which is used as a purse string to tighten the stockinet. A pencil marks the positions of the ears and eyebrows. A piece of gauze is placed in the center to protect the hair.

Plaster-of-Paris bandage, preferably one impregnated with melamine resin (which is waterproof, porous, lightweight, cool, and stronger), is wetted with water and wrapped around the head over the stockinet to the penciled lines. Two or three layers are placed. A half roll is laid out on a table so that a piece nine layers thick and 22 cm long is formed. This is placed over the back of the head so that it is closely adapted to the region of the mastoid processes. The excess is cut off. A ready-made appliance such as the Erich attachment or a contrivance previously formed of coat hanger wire is placed. Another roll of plaster is placed around the appliance. The lower border of the stockinet is folded up to the penciled line all around to form a smooth border on the cast, and another layer of plaster bandage is placed over it. A wad of dry gauze is bandaged over the mastoid processes by bandaging around the cast. This provides pressure adaptation to this important area for 18 hours while the cast is drying, after which the gauze is removed. The gauze over the hair at the top of the cast is removed.

The headcap can be attached to the maxillary arch bar by two wires passed through the cheek on a straight needle, one on each side lateral to the infraorbital foramen. Today, however, the wires rarely are passed through the cheek. Internal wiring or circumzygomatic wiring has replaced this technique in many cases. The headcap is used mostly as a traction appliance.

The unilateral maxillary fracture is immobilized by intermaxillary fixation. If satisfactory manual reduction cannot be accomplished, elastic traction is placed. A laterally displaced fracture is treated by an elastic band placed across the palate on attachments anchored to the lingual surfaces of the molars. A medially displaced fracture can be pushed outward by a jackscrew placed across the palate or by a bar attached on the labial and buccal surfaces of the arch and bent away from the displaced fragment. Elastic traction between the bar and the attachments placed on the teeth of the fragment pull the fragment laterally. When correct position has been obtained, the apparatus is replaced by a conventional bar and intermaxillary fixation is placed all around or on the contralateral side only.

Pyramidal fracture

Treatment of the pyramidal fracture is directed toward the reduction and fixation of a downward displacement of the maxilla frequently seen in this injury and reduction of concomitant nasal fractures.

Intermaxillary wires or arch bars are placed. Manual or elastic traction usually reduces the fracture, and intermaxillary immobilization is accomplished. The pyramidal fracture that is severely displaced backward may require manual separation of the lateral portions to disimpact the central pyramidal portion and bring it forward with specially designed forceps. Craniomaxillary fixation then is placed. A head bandage or a headcap may be necessary for extraoral upward traction, particularly in a delayed case, before intermaxillary immobilization is possible. However, internal wiring is used more often. The first intact bone above the fracture is used for suspension on each side. The lateral portion of the infraorbital rim may be used on one side. The lateral margin of the supraorbital rim may be used on one or both sides. Circumzygomatic wiring can be used occasionally, although one or both zygomatic complexes can be involved in this injury.

The nasal fractures are managed by the otolaryngologist or the plastic surgeon. They are reduced by manipulation and shaping, followed by support. The procedure is accompanied by much hemorrhage, which must be managed effectively in the presence of wired jaws.

Some clinicians prefer to wait until the maxillary fracture has healed and then perform a submucous resection to reshape the nose. Others prefer to reduce the nasal fractures immediately after the maxillary fractures are reduced. The immediate reduction is done more frequently.

Transverse fracture

Because the zygoma and possibly the zygomatic arch are fractured, the treatment of the transverse fracture is complicated. The circumzygomatic wire cannot be used except in cases of unilateral transverse fracture, in which it can used on one side. If internal wiring is used, the maxilla is fixed to the first solid bone above the fractures.

A recent fracture that is not complicated by a skull fracture precluding the use of a headcap can be suspended by means of wires through the cheeks.

If the zygoma is depressed, a small skin incision is made on the face at the anteroinferior border. A small hemostat is used for blunt dissection to the bone. A large Kelly forceps is placed under the zygoma and the zygoma lifted upward and outward. The frontozygomatic suture line and the infraorbital rim are examined for position. The zygoma ordinarily will stay in the reduced position. The wound is closed with a silk mattresses skin suture. Some type of craniomaxillary fixation is placed.

If the reduction is not satisfactory or if the zygoma does not stay in place, as determined by examination of the lateral and infraorbital rims, open reduction at one or both of these sites is done.

After the usual preparation, the palpating finger locates the frontozygomatic separation at the lateral rim of the orbit. The eyebrows are never shaved. In addition to the general anesthesia, 1 mL of a local anesthetic containing epinephrine 1:50.000, is injected into the skin for hemostasis. A skin incision 2 cm long is made under the eyebrow, curving toward the external canthus. It is never carried below the external canthus because the facial nerve branches to the eyelids may be severed. Blunt dissection is carried to bone. A small periosteal elevator is placed medial to the rim to protect the orbital contents. A small hole is drilled in each fragment, preferably directed toward the temporal fossa rather than the orbit, and wires are placed and tightened to immobilize the fracture. At this point, it is well to consider internal wire suspension of the maxilla to eliminate the need for a headcap. A long, 26-gauge wire is threaded through the same superior hole in the frontal bone. Both ends of the wire are attached to a long, straight skin needle or a Morin passer and passed into the wound medial to the zygoma to enter the mouth at the crest of the mucobuccal fold opposite the first molar. The wound is closed. The wire is attached later to the maxillary arch bar.

The same procedure is carried out on the opposite side, or if no orbital fracture is found on that side, a circumzygomatic wire can be placed.

If direct wiring on the lateral rim is not sufficient to reduce the step on the infraorbital rim, the latter also should be wired directly. The same general preparation is done. The palpating finger must press through the edema in these fractures, and the finger should be held in place during the incision. A horizontal incision is made down to bone just inside the bony rim. The periosteal elevator is placed to protect the orbit. Two small holes are made and wired together. The wounds are closed.

Since oral contamination associated with passing wire into the mouth may infect the higher areas, it is best to do the lateral orbital direct wiring first and then the infraorbital wiring if it is necessary. The higher areas are left open, and the infraorbital areas are closed. The suspension wire from the frontal bone then is passed downward on one side so that the assistant recovers the needle in the mouth. A new needle is used on the other side without help from the assistant who has recovered the needle in the mouth until the second needle needs to be recovered in the mouth. Closure of wounds is accomplished after the assistant has changed gloves. Then the wires are attached to the maxillary arch bars in the mouth in case the mouth has to be opened hurriedly later. If the teeth are few so that the wiring is poor, the wires are attached to the mandibular arch bar or wiring.

Maxillary fixation is maintained for 4 weeks. At that time, maxillary union has usually taken place. Some question exists as to the amount of bony union that actually takes place. The many thin walls may form fibrous unions. At least the thicker pillars of bone heal by direct bony union so that the clinical effect is satisfactory.

The internal suspensory wires are removed while the patient is under sedation or local anestheisa. They are cut from the arch bar or wiring in the mouth, and a needle holder is placed on each end. The two ends are sawed gently back and forth a few times to determine which end of the wire will move more easily. The other end of the wire is cut as high in the mucobuccal fold as possible. The remaining longer end with the needle holder attached is pulled out. Needless to say, the wires should be placed through the tissues without twisting. The intermaxillary wiring is not removed for at least 6 weeks.

Many combinations of the fractures just described are found, and special procedures for treatment are too numerous to be described here. Then, too, the bones may be comminuted. In instances in which intermaxillary fixation is not a suitable adjunct to craniomaxillary fixation, several techniques are useful. One is skeletal pin fixation between the zygoma and the mandible. Another is the use of the Steinmann pin drilled into the bone across the symphysis of the mandible. The pin is allowed to extend beyond the margins of the bone and through the skin. Traction can be accomplished by the attachment of the free margins of the pin to a headcap arm by elastics or metal attachments. Still another method is the use of a Kirschner pin drive across the maxilla.

Complications

Infection is a possible complication of direct wiring, even under antibiotic therapy.

Malunion or nonunion is not seen often if proper early reduction and fixation are accomplished.

Diplopia may be a complication if the fracture is not reduced soon enough so that proper positioning of the parts is possible. It may result from a depressed orbital floor or an injury to the inferior oblique muscle. In the latter case, cartilage under the eyeball will not correct it.

Persistent periorbital edema is a complication that arises occasionally. It may or may not resolve eventually. No treatment is known. It is speculated that this may be the result of a traumatic blockage of the lymphatic drainage of the area.

Poor occlusion, facial disfigurement, damage to the specialized antrum lining, and an

improperly functioning nose are possible complications, but they are less frequent if the fracture can be treated early and adequately.

Dimness of vision infrequently increases day by day. It may lead to blindness. This is caused by a hematoma pressing on the optic nerve. Erich decompresses it by removing a little bone from the lateral wall of the orbit.

Zygoma Fractures

The zygoma is a heavy bone of the face that is rarely fractured. However, its bony attachments and its arch are frequently fractured, often in conjunction with a fracture of the upper jaw. In a series of 134 zygoma fractures at the District of Columbia General Hospital, the zygomaticotemporal suture line on the arch was fractured most frequently, followed by fractures of the suture line on the infraorbital rim and then by the zygomaticofrontal and zygomaticomaxillary suture lines. Fractures of the zygomatic arch may occur without fracture of the other suture lines. These fractures are usually unilateral and frequently multiple, and they may be comminuted, but because of the thick protective muscle and tissue coverings they are rarely compounded. They are displaced primarily by the blow rather than by muscle forces. As a matter of fact, because of the temporal fascia attachment superiorly and the masseter muscle attachment inferiorly, the fractures rarely are displaced upward or downward. The blow usually pushes the parts inward.

Cause of fracture varies somewhat with habits and circumstances. The municipal hospital series finds the largest number (70%) results from fisticuffs and mayhem, whereas the private hospitals show the largest number to be caused by automobile accidents. Frequently, the municipal hospital history includes the following statement, "I was standing at the bar, minding my own business, when ..." Because of the difficult sidewise angle associated with sudden blows at a bar, the side of the face approach to the zygoma seems to be more prevalent than the direct punch to the nose, even though the latter is the announced purpose. The municipal hospitals report that 12% result from automobile accidents, 8% from sports, and 6% from falls.

Time of reduction is important. The man at the bar is collected at once by his friends and rushed to the hospital, where his reduction is accomplished immediately. The automobile victim frequently is fractured in many places, including the skull, and sometimes he is in shock. His zygomatic fracture reduction is delayed until more important structures are treated.

It is difficult to treat a zygoma fracture after 5 days. Earlier than that, the bones frequently snap into place with a sound that can be heard over the room, and they stay in place without fixation. After 1 week they can be reduced, but they will not stay in place. After several months it is almost impossible to reduce them, and no attempt is generally made. Rather, the surrounding structures are treated so that function and esthetics are served.

Diagnosis

The signs of zygomatic fracture are obscured often by edema and lacerations. Swelling of the tissues overlying a depressed fracture can round out the face so that the two sides will be equally full. One unfailing sign of a zygomatic arch fracture, although not always present until edema has subsided, is a dimpling of the skin over the arch. In the presence of moderate edema, any or all of the following signs may be present: flattening of the upper cheek and fullness of the lower cheek, hemorrhage into the sclera of the eye, nasal hemorrhage, antrum

hematoma, depressed level of the eye, paresthesia over the cheek, and other middle face fractures. When all four suture lines are fractured around the body, the zygoma is depressed downward. When the arch is deeply depressed, mandibular function may be hindered because of impingement on the coronoid process.

Palpation of the arch, the lateral rim, and the infraorbital rim is necessary. Radiographs include the posteroanterior jaw film to show the orbital rims and the "jug-handle" view to show the arches. A lateral oblique jaw film sometimes will show the body separations better.

Zygomatic fractures can be considered roughly in two categories: fractures of the suture lines surrounding the body of the zygoma and fractures of the arch.

Treatment

The simplest method of treating the depressed body fracture is to make a stab skin incision beneath the bone and lift upward and outward with a Kelly clamp. If this is unsuccessful, an intraoral Caldwell-Lyuc approach is made into the antrum. The anterior maxillary wall frequently will be found to be comminuted. The gloved finger or a metal urethral sound is used to push the zygoma upward and outward. To support the fragments, the antrum is packed with sterile petrolatum gauze from which most of the petrolatum has been wiped and on which bacitracin ointment has been placed. An inflatable antrum balloon or a Foley catheter can be placed into the antrum to support the reduced parts when it is inflated with air or even water. The edges of the wound are approximated with sutures, but the central portion is left open for removal of the packing materials. The end of the gauze should be brought into the buccal vestibule over a bony edge rather than in the center of a bone void to prevent formation of a persistent oroantral opening. In cases in which the external wall of the antrum is grossly comminuted, nasal antrostomy is made for removal of the gauze. Gross comminution can result in a persistent oral opening if the end of the gauze is brought out in the usual oral opening. Nasal antrostomy is easily accomplished by pushing a small hemostat from the nasal side below the inferior turbinate in the posterior nose. The packing is retained for 2 or 3 weeks, depending on the tolerance of the patient. Further fixation by direct bone wiring at the orbital rim is necessary occasionally.

An eyelet screw is screwed in the body of the zygoma occasionally and attached to elastic traction from a headcap. This is usually a last resort in delayed treatment cases in which manipulation does not succeed or the parts will not stay in place.

The old depressed zygoma can be lifted by means of considerable pull force engendered from an intraoral approach with the help of a large instrument, usually a metal urethral sound.

The simplest method of treating the zygomatic arch fracture is by reduction with a long instrument (for example, a periosteal elevator) through an incision in the mucobuccal fold opposite the second molar. The instrument is passed laterally and superiorly until it reaches the medial surface of the arch. Lateral pressure is then made, avoiding a lever action on the surface of the maxilla or teeth. The fingers of the other hand are placed on the skin over the arch to guide the reduction. Usually no fixation is required. Some operators feel that continued functioning of the mandible may result in displacement of the fragments by action of the masseter muscle. They place an eyelet wire on the teeth in each posterior quadrant, close the jaws with elastic intermaxillary traction, and maintain closure for 10 to 14 days. Clinical healing takes place in 2 weeks.

If the fracture is older and heavy manipulation can free it, reduction will not be maintained by itself in some cases. A large, semicircular needle can be placed under the arch externally. It is placed through the skin inferior to the arch, behind the arch, and back through the skin on the superior side. The attached wires are placed through the meshes of an ether mask, which has been padded on its edges and placed on the side of the face. Reduction is obtained again, and the wires are tightened around the meshes of the mask. This is maintained in place for 3 days.

The Gillies approach for reduction of the arch is an external procedure. A skin incision in the shaved temporal region is made down to the deep temporal fascia. A special instrument is introduced under this fascia in a downward and forward direction to reach the medial surface of the arch. Lateral pressure is generated for reduction.

After reduction by either method, a round gauze "doughnut" is taped to the side of the head, or a tongue blade is taped vertically over a small roll of gauze bandage that has been taped previously to the side of the temple. This is kept in place for several days until the patient becomes trained not to sleep on that side.

These simple methods are not effective after 9 days at most. Special methods may be successful up to 2 weeks, although 2-month-old fractures have responded to treatment on occasion. Fractures over 2 weeks old are commonly considered untreated fractures and are maganed as such.

Complications

The treated zygomatic fracture presents few complications. The antrum may be filled with a hematoma, which usually evacuates itself, but it can become infected. Nerve injuries usually subside. Ocular muscle balance may be impaired because of fracture of the orbital process.

One consideration in any zygoma body fracture is the possibility of orbital fat herniation through a fractured orbital floor into the antrum. Cloudines on antrum radiographs may represent hematoma, fat herniation, or both, and differentiation is difficult even with laminagrams. The level of the orbit may not be depressed at early examination because an orbital hematoma props it up. When the hematoma disappears later, diplopia and enophthalmos will be noticed. Examination includes a survey of visual fields. Diplopia may be noticed straight away or when the eyes are turned upward and outward. The possibility of entrapment of orbital muscles should be considered at this time.

If orbital fat herniation cannot be ruled out, the antrum is explored through a Caldwell-Luc opening at the time of fracture reduction. If herniation has occurred, the fat is pushed upward, and the antrum is packed with petrolatum gauze. This may be followed by the insertion of a Silastic sheet (or a piece of autogenous bone obtained from the lateral plate of the mandibular ramus) over the fractured orbital floor through an infraorbital incision, although this procedure often is not necessary. If a strong possibility exists that herniation has occurred, the Silastic sheet is placed first to protect the globe from possible injury by sharp bony spicules, followed by the antrum packing if necessary.

The untreated fracture creates a marked flatness of the face. The coronoid process may be impinged on by the depressed fracture so that mouth opening is difficult if not impossible. The coronoid process is removed. The eyeball may be depressed downward with its floor.

Rarely is an attempt made to correct an old depressed orbital floor, since it cannot be done successfully. Cartilage or bone grafts are placed over the depressed arch and inserted into the orbital floor to prop up the eyeball. Erich advocates a spongiosa paste made from fresh autogenous iliac crest bone for placing in a tunnel over the arch to build it out. It is placed through a temporal incision and molded from the outside. It is firm in 3 days.

Fractures of the facial bones, particularly the zygomatic complex, may on rare occasions be complicated by damage to the contents of the superior orbital fissure, causing the superior orbital fissure syndrome.

The clinical features, following trauma, may be caused by actual disruption of the bony margins of the fissure or by the formation of a hematoma or aneurysm within its boundaries.

Clinically there is ophthalmoplegia, ptosis of the upper lid, proptosis, and a fixed, dilated pupil. The involvement of the third, fourth, and sixth cranial nerves is responsible for the ophthalmoplegia and ptosis. The fixed and dilated pupil is caused by disturbances in the parasympathetic nervous system, and the proptosis is caused by paresis of the extraocular muscles that normally exert a retracting influence on the globe. The syndrome is completed by sensory disturbance over the distribution of the ophthalmic division of the trigeminal nerve.

Prognosis is poor if nerves have been severely damaged or severed. Gradual, complete recovery of motor and sensory function without surgical intervention is the usual case.