CONTENTS

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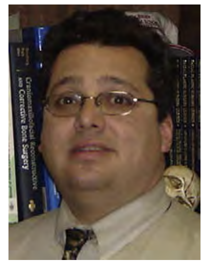
Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) vii

Atlas of the
Oral and
Maxillofacial
Surgery Clinics

Preface



Vincent B. Ziccardi, DDS, MD
Guest Editor

Mandibular fractures are one of the most frequent traumatic injuries treated by oral and maxillofacial surgeons. These fractures result from a multitude of causes, including sports injuries, motor vehicle accidents, falls, and interpersonal violence. Training in the management of mandibular fractures includes various techniques, depending on the surgeon's specialty and training, location, and geographical preferences. Oral and maxillofacial surgeons have a unique perspective in the treatment of these injuries due to their dental training and intimate knowledge of the occlusion and stomatognathic system.

This issue reviews the relevant anatomy and decision making for the multitude of techniques utilized in the contemporary treatment of these injuries, ranging from closed reduction to open procedures. Due to the popularity and widespread acceptance by surgeons and patients for the intraoral monocortical techniques, two articles are included that discuss the versatility and limitations of this method. Indications for extraoral approaches and bicortical plating techniques are reviewed in another article. Special techniques that have been reemerging with commercially available dedicated systems for extraoral pin fixation are reviewed in another article. Newer techniques, including the endoscopically assisted management of condylar fractures, are introduced as well. Finally, an article on special considerations in the treatment of children and a review of the common complications occurring with the management of mandibular fractures is presented.

It is the hope of the authors and myself that this issue of *Atlas of the Oral and Maxillofacial Surgery Clinics of North America* will become a resource for residents in training and practicing surgeons treating patients with mandibular trauma. I would like to thank all my colleagues who participated in this project and, of course, my wife Nicea for her endless support and tolerance.

Vincent B. Ziccardi, DDS, MD
Department of Oral and Maxillofacial Surgery
University of Medicine and Dentistry of New Jersey
110 Bergen Street
Room B-854
Newark, NJ 07103-2400

E-mail address: ziccarvb@umdnj.edu

1061-3315/08/$ - see front matter
doi:10.1016/j.cxom.2008.11.003

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Ghali E. Ghali, DDS, MD, *Guest Editor*

March 2010

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Dale A. Baur, DDS, and Henry Rowshand, DDS, *Guest Editors*

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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 1–13

Atlas of the Oral and Maxillofacial Surgery Clinics

Closed Reduction of the Mandibular Fracture

Meredith Blitz, DDS[a,b,*], Kurt Notarnicola, DDS[a]

[a]Department of Oral and Maxillofacial Surgery, University of Medicine and Dentistry of New Jersey, New Jersey Dental School, 110 Bergen Street, Room B-854, Newark, NJ 07103-2400, USA
[b]Division of Oral and Maxillofacial Surgery, Department of Dentistry, Seton Hall University, South Orange, NJ, USA

Definition

Closed reduction of mandibular fractures can be defined as the treatment of fractured segments without visualization through skin or mucous membranes. There are many differing methods to achieve closed reduction; however, all of these techniques share the common application of materials that ideally prevent movement of bony segments during the healing phase. The most critical and necessary factors in management of any fracture are reduction and stabilization of the fracture, which should be accomplished by the simplest means possible to achieve optimal results. Considering these statements, ‘‘closed reduction’’ continues to be used extensively in the successful management and treatment of all types of mandibular fractures.

When treating mandibular fractures, surgeons must attempt to return patients to as close to a state of normal function and appearance as possible. Considering the anatomic and functional relationship of the maxilla and mandible, the thin soft-tissue covering of the bony structures, the dentition and its bacterial exposure, and the essential need for the oral cavity with regard to caloric intake and survival necessity, fracture management of this area of the body remains unique among all other bones of the body.

History

Any academic discussion of mandibular fracture treatment should include an historical review. When we consider that open reduction techniques are relatively new (only used within the past few decades), we should consider that management of mandibular fractures using closed reduction techniques has occurred for centuries. Mandibular fractures have been traced back by paleontologists to the age of Neanderthals; however, the ancient Egyptians (circa 1700 BC) were the first to detail the diagnosis and prognosis of the mandibular fracture. At that time, fracture management was considered impossible. Hippocrates, the ‘‘father of medicine’’ (circa 430–370 BC), wrote on the subject of mandibular fractures in the *Corpus Hippocraticum,* a collection of approximately 70 writings detailing his teachings. Hippocrates' writings included extensive descriptions of the need for stabilization of fractures to lead to consolidation. He is said to be the first to advocate the use of gold wire—or linen thread if wire was unavailable—to maintain proper position of the fractured segments. Fracture management at that time most often involved bandaging techniques, which Hippocrates noted were suboptimal without adequate reduction of fractured segments.

* Corresponding author. Department of Oral and Maxillofacial Surgery, New Jersey Dental School, University of Medicine and Dentistry of New Jersey, 110 Bergen Street, Room B-854, Newark, NJ 07103-2400, USA.
E-mail address: blitzgme@umdnj.edu (M. Blitz).

1061-3315/08/$ - see front matter
doi:10.1016/j.cxom.2008.10.002

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Throughout the past centuries, many surgeons, such as John Bernhardt Erich, Harold Gillies, Thomas Gilmer, Stout, Robert Henry Ivy, Varaztad Kazanjian, T.B. Gunning, Norman W. Kingsley, and many others attempted, to successfully treat fractures with wiring, splints, and intraoral and extraoral appliances (Figs. 1, 2). Each person contributed innovative and cutting edge methods of treating mandibular fractures for his or her era. The use of intermaxillary fixation (IMF), which became popular in the mid-1800s, led to the development of our current methods of treating mandibular fractures. The ideal of returning the patient to the proper occlusal relationship was—and still remains—the basis for all mandibular fracture treatment in the dentate patient.

Classification as favorable versus unfavorable

The classification of mandibular fractures into a favorable versus unfavorable category is a product of muscular force and potential displacement of the segments. The muscle groups that may impact the favorability of a fracture include the retractors, protrusors, elevators, and depressor-retractors groups (Fig. 3). Each muscle group exerts specific and significant force patterns that can displace segments and make closed reduction techniques obsolete if the segments cannot be reduced and stabilized against the forces of the muscular pull.

Although the mandible can fracture essentially in any area, each with unique anatomy and potential muscular action displacing segments shown in Fig. 3, a discussion of angle fractures helps to review the concept of favorable versus unfavorable and the associated terminology. The unique anatomy in the area of the ramus/angle includes the insertion of the muscles of mastication, the temporalis, masseter, lateral, and medial pterygoid muscles, and the mylohyoid. The muscles continue to exert forces on the fractured segments to which they attach. In situations in which muscle action displaces the segments, the fracture is considered "unfavorable." If muscle action tends to the pull the segments together, it is considered "favorable." Because of the differential muscle action, further consideration must be given to horizontal or vertical favorability. In general, the pterygomasseteric sling displaces the segments in an angle fracture medially and superiorly in an unfavorable fracture pattern (Fig. 4 A–D). Closed reductions in the case of the unfavorable angle fracture may be complicated because the fixation method may not be rigid enough to counteract the medial and superior pull of the muscle sling, leading to proximal segment displacement, malunions, and nonunions. When angle fractures are

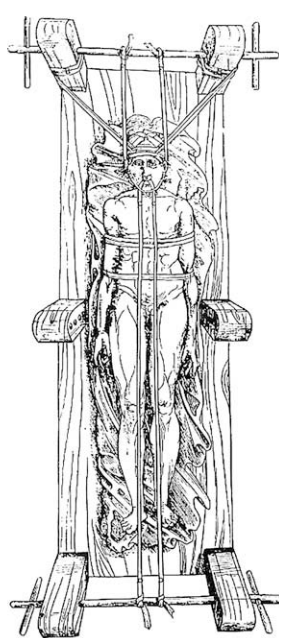

Fig. 1. Early attempt at closed reduction using an extraoral apparatus.

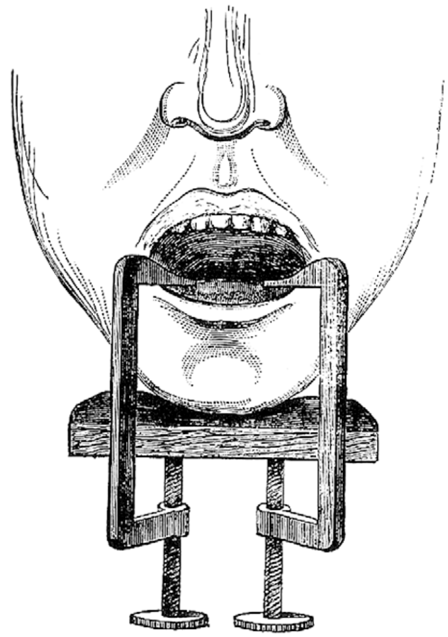

Fig. 2. Early attempt at closed reduction using an intra/extraoral apparatus. (*From* Stener RD. Treatment of fractures of the lower maxilla. British Journal of Dental Science 1877;20:660.)

classified as and considered to be favorable, muscle action actually helps to bring the segments into contact, and these fractures are more amenable to closed reduction techniques.

Techniques for closed reduction

Erich arch bars are the most commonly used devices in closed reduction techniques; closed reduction is often considered synonymous with arch bar application. Arch bars provide a means

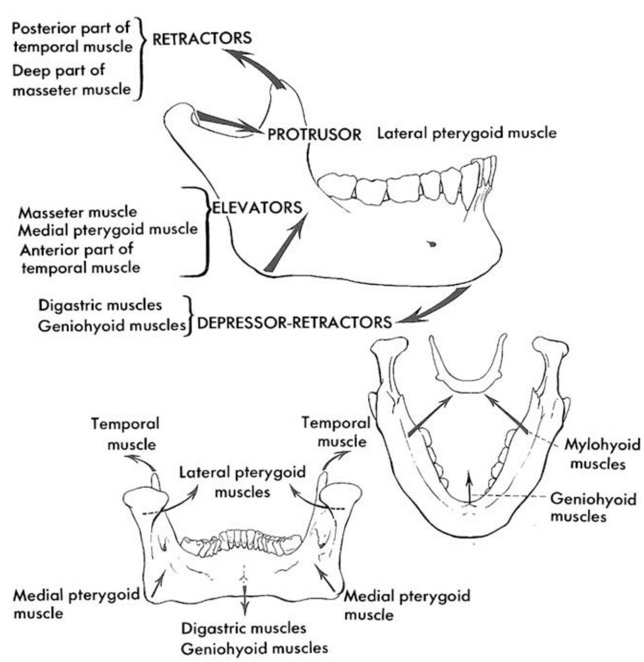

Fig. 3. Muscle action by group. (*From* Dingman RO, Natvig P. The mandible. In: Dingman RO, Natvig P, editors. Surgery of facial fractures. Philadelphia: WB Saunders; 1964. p. 140; with permission.)

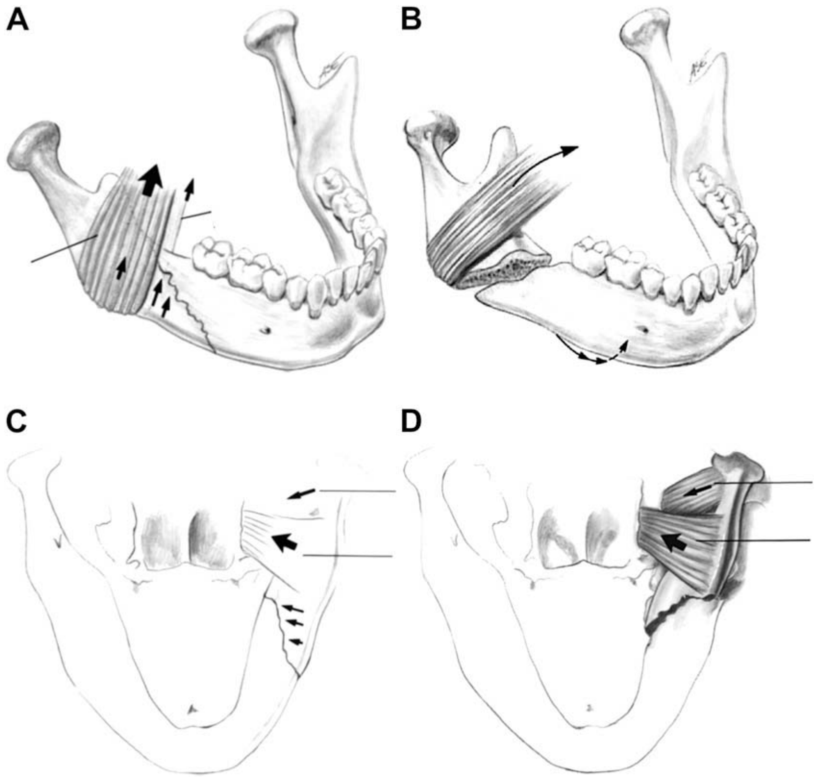

Fig. 4. (*A*) Vertically favorable angle fracture. Muscle action brings segments into contact. (*B*) Vertically unfavorable angle fracture. Muscle force displaces segments. (*C*) Horizontally favorable angle fracture. Muscle action brings segments into contact. (*D*) Horizontally unfavorable angle fracture. Muscle force displaces segments. (*From* Barber HD, Bahram R, et al. Mandibular fractures. In: Fonseca RJ, Walker RV, Betts NJ, et al, editors. Oral and maxillofacial trauma. 3rd edition. St. Louis: Elsevier Saunders; 2005. p. 488; with permission.)

of securing a stable, preinjury occlusion and allow for different force vectors to be applied if necessary to reduce the fracture and achieve the most stable position for healing.

Arch bar application is relatively fast and easy. It can be performed with local anesthesia, which makes it possible to use in the emergency department, clinic, or office setting. The procedure should begin with a measurement of the length of the arch bar for the mandibular and maxillary arches. Arch length ideally should be from first molar to first molar but may deviate based on fracture location, stability, reduction, and posterior occlusion. Once ideal arch bar length has been determined and the arch bars cut to length, they are secured with stainless steel wires to the maxillary and mandibular facial/buccal cervical levels of the teeth. Stainless steel wires are traditionally 24 or 26 gauge wire and are often prestretched. Maxillary and mandibular lug position on the arch bars should be checked before passing and securing wires. The occasional inverted arch bar can significantly lengthen the procedure when it requires removal and replacement in the correct position. The wire space between the lug and the base of the arch bar should be open toward the apices of the teeth (Fig. 5).

Circumdental wiring can be accomplished with one or two practitioners. Skilled practitioners passing to each other work quickly and efficiently. The wires are passed below the interdental contacts and heights of contour of the teeth, and attempts should be made to keep the periodontium intact. The wires are placed circumferentially around the cervical level of the tooth with one end above the arch bar and one end below. The free ends are then twisted together until they tightly bind the arch bar to the arch buccal surface (Fig. 6). The twisted wire is then cut to approximately 5 to 10 mm in length and rosetted against the tissue. Rosettes allow for little irritation of the mucosa caused by the cut end of the wire twist. Once in place, arch bars must be checked for stability. Even minimal movement of the arch bars can allow for micro-movement at the fracture site and failure to heal. When arch bars are secure, intermaxillary wires or orthodontic rubber bands are used to obtain preinjury occlusion and fixation

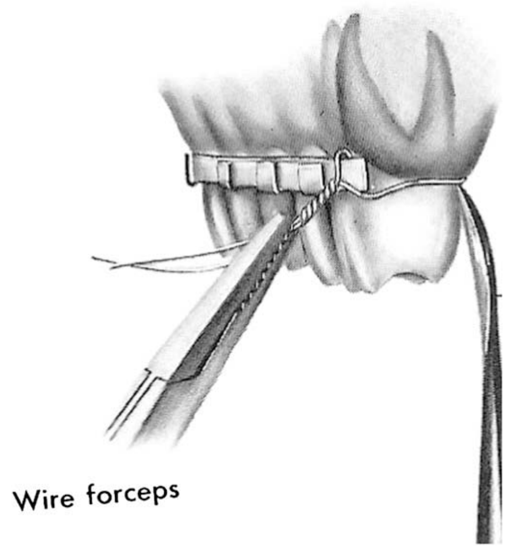

Fig. 5. Lug position and arch bar application. Note that circumdental wire is below height of contour. (*From* Dingman RO, Natvig P. Occlusion and intermaxillary fixation. In: Surgery of facial fractures. Philadelphia: WB Saunders; 1964. p. 127; with permission.)

(Fig. 7). For cases of preoperative skeletal malocclusion, such as angle classes II and III, adequate occlusion may be difficult to obtain. Patients always must be questioned about their preinjury occlusal relationship before the procedure. Preinjury photographs and evaluation of dental wear facets can be useful in such instances.

Ivy loops provide a rapid means of closed reduction that, like arch bars, can be done using local anesthesia in an emergency department, office, or clinic setting. This procedure can be done quickly with few risks. This wiring technique is a useful technique for practitioners who are working alone and need a quick and effective means to secure preinjury occlusion. It requires only six 24- or 26-gauge wires. As a result, cost remains minimal. The technique is difficult to

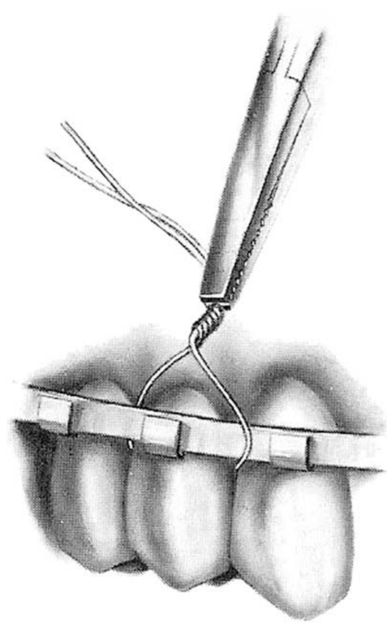

Fig. 6. Circumdental wiring technique. Note one end above and one end below arch bar. (*From* Dingman RO, Natvig P. Occlusion and intermaxillary fixation. In: Surgery of facial fractures. Philadelphia: WB Saunders; 1964. p. 127; with permission.)

Fig. 7. IMF using Erich arch bars.

describe and best learned by direct observation; however, it is briefly described here. A 24-gauge wire, approximately 4 to 6 in long, is twisted into a 2- to 3-mm loop directly in the middle of the wire. The free ends of the twisted wire are passed together from the direct facial to the palatal/lingual region from an interdental position in the premolar/molar region (Fig. 8A). There is traditionally one Ivy loop per quadrant (although additional Ivy loops may be placed for stabilization), and the upper and lower Ivy loops should be directly opposing each other in the premolar/molar areas.

Once both free ends of the wire are passed to the palatal/lingual aspect, one free end is then passed back to the facial aspect around the cervical level of the tooth on the distal side of the wires. The other free end is then passed to the facial aspect around the cervical level of the tooth on the mesial aspect of the mesial tooth (Fig. 8B). The distal wire should be passed through the small loop that remains on the facial surface when the free ends are passed (Fig. 8C). The distal wire, which is through the small loop, is twisted with the mesial wire down to the gingival, cervical level of the tooth. The Ivy loop should be circumferentially around the necks of two teeth in the premolar/molar area (Fig. 8D). With at least four Ivy loops in place, 26-gauge wire is then passed from maxillary to mandibular buccal small loops on the left and right sides. The 26-gauge intermaxillary wires are tightened to secure the preinjury occlusion (Fig. 8E).

This technique, although easy and cost efficient, has some inherent problems that must be mentioned. Because of the minimal number of wires, this technique may allow for some dynamic movement. Mobility and loosening of the wires during the postoperative phase are common. Close monitoring of the clinical condition should continue throughout treatment, with tightening and replacement of wires as deemed necessary. If the small facial interdental loop is too large or mobile, upon tightening the IMF wires, the loops may be pulled in the occlusal direction. If the loops touch or overlap, stability may be compromised. In this situation, the wires should be replaced with smaller diameter loops.

With the surge of orthodontic treatment in recent decades, using orthodontic brackets for IMF is yet another technique available to the surgeon treating mandibular trauma. Easily placed and tolerated, they have a high rate of patient acceptance. Brackets are bonded to the facial surfaces of the teeth in the same manner they would be applied for orthodontic treatment. These brackets are then used to reduce and stabilize the fracture with intermaxillary wires or elastics (Fig. 9). For the operator, ease of use and application allow brackets to be an excellent alternative to traditional wiring techniques. The risk of contaminated wire stick injuries is no longer a threat, and the ease of placement makes fracture treatment less difficult for the operator. The benefits of this procedure also include the possibility that local anesthesia may not be needed. No actual penetration of tissues occurs with the wires, and the potential for not having to inject before placement makes it acceptable to patients. In the event that a patient feels pain with manipulation of the segments involved, local anesthesia may be administered for pain control. The difficulties with this technique include the loss of brackets during the postoperative period and ease of removing the wires/elastics by the patient. Occasionally, adequate stabilization can be difficult to achieve. This technique is best used with an easily reduced, nondisplaced, or immobile fracture with adequate stability of the segments in a compliant patient. This technique is useful when treating injuries in younger patients. The removal of orthodontic brackets is also

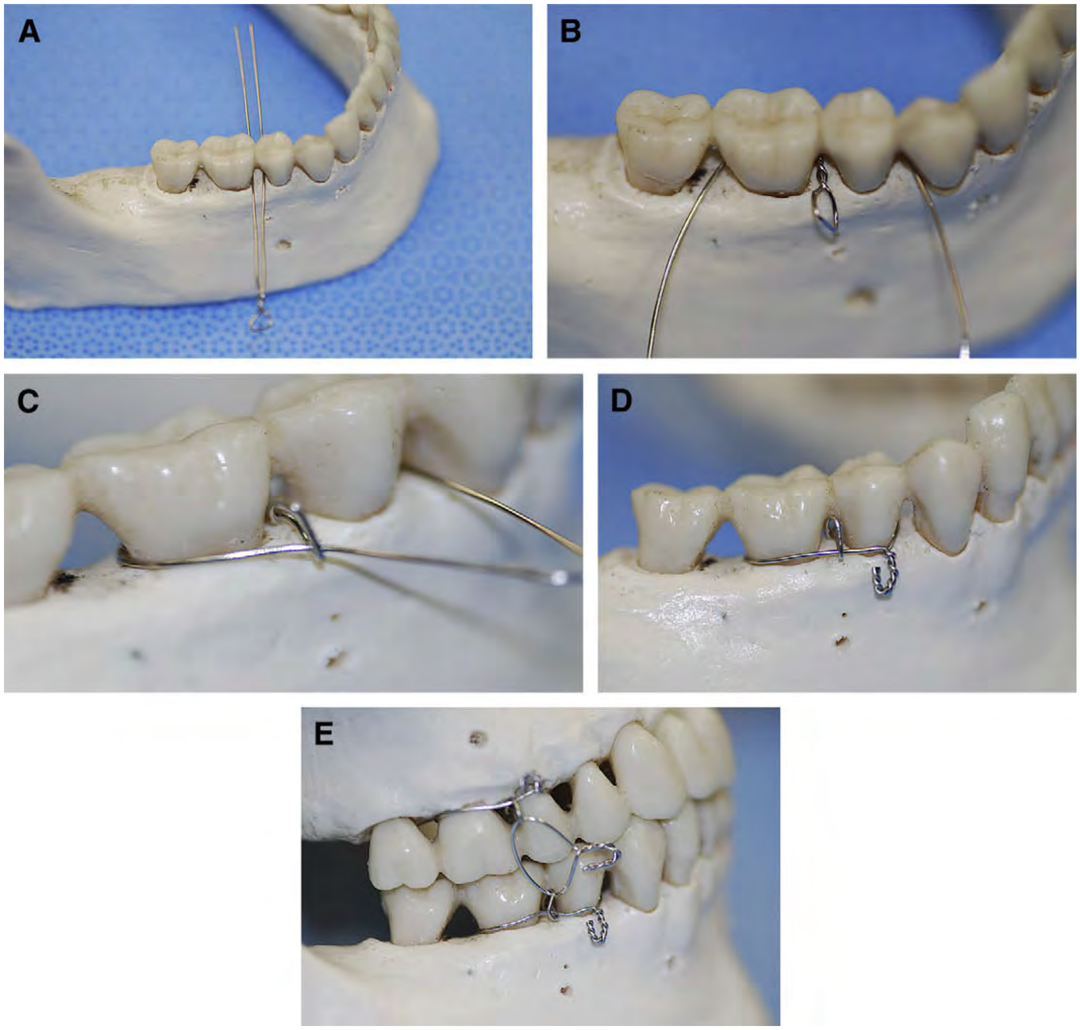

Fig. 8. (*A*) Initial step in Ivy loop placement. (*B*) Free ends pass around adjacent teeth at cervical level and below height of contour. Note that loop placement remains facial. (*C*) Distal wire is passed through loop anteriorly on facial aspect of tooth surface. (*D*) Ivy loop in place. (*E*) IMF using Ivy loop technique.

easier than removal of arch bars and circumdental wires. It can be done without local anesthesia in minutes.

IMF screws can be considered a method of closed reduction. Although the screws are transmucosal, because direct visualization of the fracture does not occur, by definition it is a closed reduction technique. This procedure also can be performed with local anesthesia but

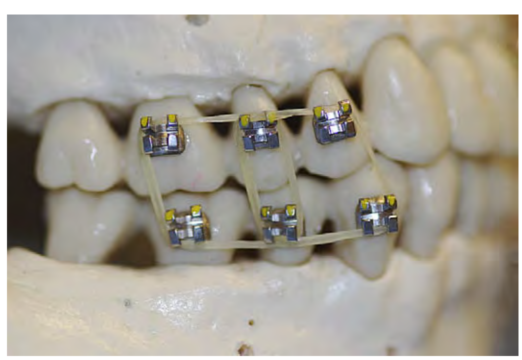

Fig. 9. IMF using orthodontic brackets and elastics.

requires specialized instrumentation and may not be performed in the outpatient setting if the appropriate set for placement is not immediately available. The benefits of this particular technique include its ease of placement with little risk for wire injury and decreased amount of time for placement. They are easy to remove at the end of the healing period and can be removed in minutes with minimal local anesthesia. IMF screws are machine manufactured and are available in the self-drilling and traditional drilling styles. They typically have an opening in the actual head of the screw through which a wire is passed securely and cannot become separated from the screw itself (Fig. 10A). If true IMF screws are not available, screws from bone plating systems can be used.

Placement of screws should be in areas that avoid the apices of the dentition and all vital structures. The mental nerve, inferior alveolar nerve, maxillary sinus, nasal aperture/floor, and infraorbital nerve must be considered when placing screws in these areas. If there is any risk of compromise to the teeth or anatomic structures, an alternative method of reduction and fixation must be considered. Placement of screws, such as Ivy loops, should be opposing in the arches to secure the occlusion with no mobility. Screw placement is relatively easy. A small 2-mm incision can be made in the mucosa and down through periosteum. Using a drill guide, an osteotomy can be performed with the appropriate drill bit when using the self-tapping type of screw. For the self-drilling screws, after initial incision, the screw is immediately placed into the osseous structures via screwdriver. The screws should be as close to perpendicular to the occlusal plane and bony cortex as possible. When screws are placed in the upper and lower jaws, a 24- or 26-gauge wire is passed through both heads and tightened into occlusion (Fig. 10B).

This technique also requires mention of the difficulties encountered. IMF screws may become loose during the post-operative phase. Monocortical in nature, they may not be able to resist the forces of the tightening of the intermaxillary wire. Once a screw loosens, it must be removed and replaced, or an alternative method of reduction of the fracture should be considered. IMF screws do not allow for any dynamic movement, and occlusal discrepancies may not be adjusted as with arch bars and elastics. Occlusion should be easy to reproduce and stabilize if this technique is be used. Closed reduction techniques using IMF screws also include the disadvantage of possible instability of the fracture segments when placed in IMF and inadequate reduction leading to nonunion or malunion. In some instances in which IMF screws are placed deep in the vestibule, soft-tissue overgrowth may occur. This may be an area of chronic inflammation for the patient, and infections do rarely occur. If infection occurs, close management of the screw/bone interface and involvement of underlying osseous structures should occur. In most cases of localized soft-tissue involvement, the area can be managed until the completion of the IMF period. At the time of removal, however, an incision may be necessary to adequately access the submerged screw head.

In edentulous patients, Gunning splints and dentures are routinely used to reduce and stabilize fractured segments. When a patient who is edentulous with significant mandibular atrophy sustains a traumatic injury to the mandible, open reduction can result in complications related to loss of blood supply to the segments when the periosteum is stripped. As a result, surgeons should be able to perform closed reduction techniques using lingual splints, Gunning

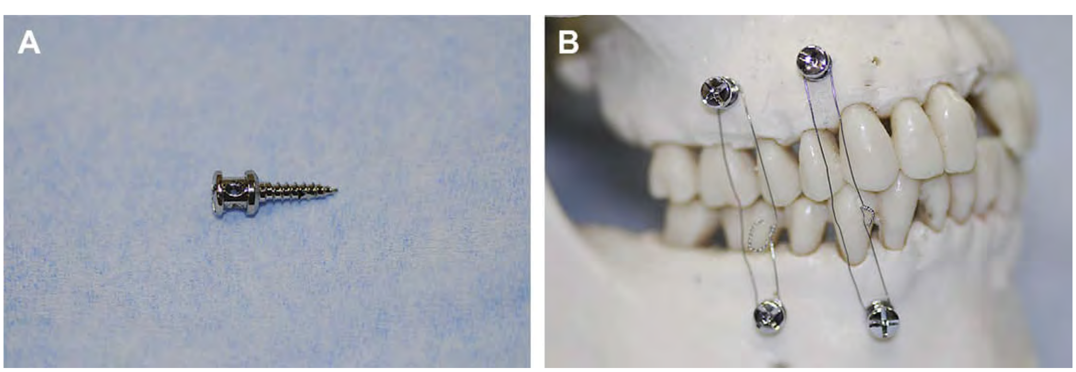

Fig. 10. (*A*) IMF screw. Note machined head with hole for wire passage. (*B*) IMF using IMF screw technique.

splint therapy, or the patient's own denture prosthesis wired into place to secure the fractures and allow for healing. In the case of the patient's own denture, the surgeon must evaluate the fit of the dentures preoperatively to ensure immobility and appropriate tissue forces. The patient also must be informed that the denture may be irreparably damaged during the placement of circumandibular wires or screws. If the fit is not ideal or the patient is averse to damage or surgical alterations to the dentures, Gunning splints should be fabricated.

When we consider splint therapy for closed reduction, we are most often discussing Gunning splints. For fractures that are minimally displaced and cases in which there is no occlusion with the maxilla, a simple lingual/labial splint can be fabricated to reduce and stabilize the fracture. With a more displaced fracture that is difficult to stabilize, it is necessary to fabricate an upper splint to aid in the final mandibular segment position. An impression should be taken of the upper and lower jaws. After pouring the impressions, the mandibular models should be sectioned at the fractured site. Once sectioned, the segments should be reduced on the model and waxed together in the ideal position. Using the upper and lower models, the Gunning splints can be fabricated on the reduced models. Care should be taken to relieve the acrylic in the area of the fracture in the event of pressure on the mucosa. If necrosis of the tissue occurs, healing of the fracture is compromised. It is critical that the splints be evaluated for such complications; once wired into place, removal of splints and evaluation of the affected area is difficult. Pressure-indicating paste is helpful in the operating room to evaluate for possible problematic areas. A soft reline material should be added to the splint/denture immediately before wiring the prosthesis into place. The soft reline allows for better tissue adaptation and fewer complications at the tissue support level.

When closed reductions are performed with splint therapy, the sequential steps leading to adequate splint fabrication require a significant amount of time. This disadvantage must be acknowledged when considering closed versus open techniques; however, if the most appropriate treatment would include splint therapy with either Gunning or lingual splints, this modality should be used regardless of the time needed to produce an adequate prosthesis.

Skeletal wiring can be a useful technique for achieving closed reduction in patients who are edentulous or partially dentate. In also can be considered for children with primary or early mixed dentition, in whom conventional wiring techniques may be difficult, if not impossible, to achieve. In these patients, the dentition is inadequate either by sheer number or structure to accommodate circumdental wiring. Skeletal wiring can be used in conjunction with a patient's denture or with Gunning/lingual splints to provide a means of stable fixation. Circummandibular wiring is a technique that is most commonly used to secure a splint or denture into place. Although originally used to stabilize the fractured segments themselves, currently it is rarely used for this purpose. A small skin incision is made directly inferior to the area to which the splint needs to be secured, allows for passage of the Obwegeser awl. The awl is passed into the floor of the mouth in close proximity to the lingual cortex to avoid injury to the vital structures, including the lingual nerve and submandibular duct. The end of a 24-gauge wire is placed into the "eye" of the awl and gently bent to prevent dislodging during passage. The awl is withdrawn with attached wire into the floor of the mouth but not out of the skin incision. The awl is then passed below the inferior border of the mandible and passed in a similar fashion into the buccal vestibule, again hugging the buccal cortex. The wire end in the awl "eye" is then removed, leaving a free wire end on the lingual surface and a free wire end on the buccal surface of the mandible. With a gentle "sawing" motion, the free ends are grasped and pulled back and forth until the inferior border of the mandible is tightly contacted with the wire. Any soft tissue between the wire and the inferior border may cause loosening of the splint over time and failure to achieve stability through the healing phase (Fig. 11).

Once complete contact with the inferior border of the mandible is achieved, the lingual wire end may be passed through a drilled hole in the splint or an occlusal groove. The two free ends are twisted into position to secure the denture into place. This wire can be used to secure the maxilla to the mandible when IMF occurs (Fig. 12). Additional skeletal wiring techniques include circumzygomatic and frontal suspension wiring. These techniques can be used in conjunction with many mandibular closed reduction techniques in dentate and edentulous patients. They are most frequently used when panfacial trauma or complex wounds, including fragmented gunshot injuries, occur.

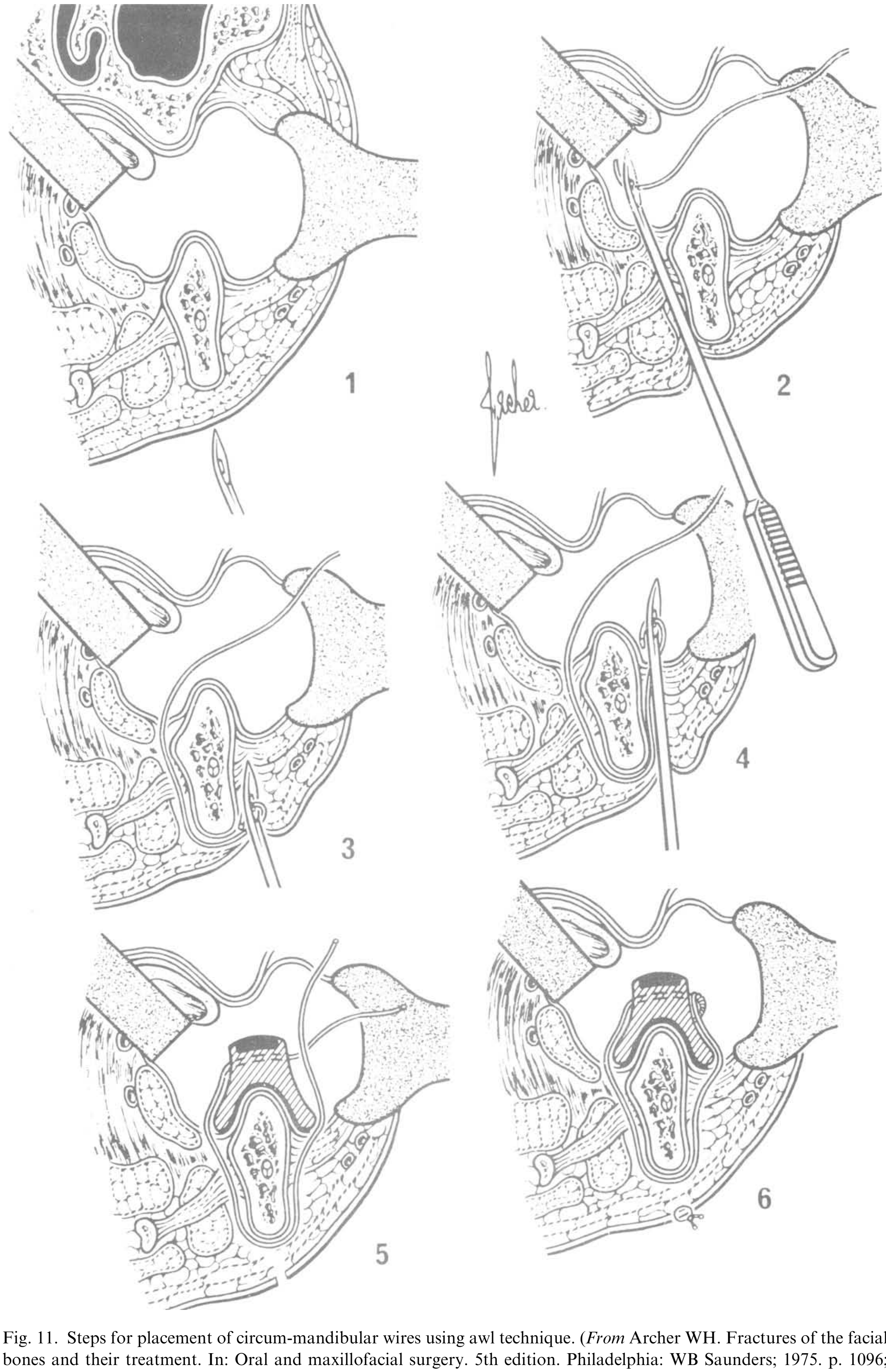

Fig. 11. Steps for placement of circum-mandibular wires using awl technique. (*From* Archer WH. Fractures of the facial bones and their treatment. In: Oral and maxillofacial surgery. 5th edition. Philadelphia: WB Saunders; 1975. p. 1096; with permission.)

Fig. 12. Circum-mandibular wire in place using additional skeletal wiring/fixation techniques.

Fracture locations and types and period of immobilization

When considering the location and type of fracture, it is generally accepted that most mandibular fractures can be treated with closed reduction. If adequate reapproximation of bony segments allows for callous formation and bony union, a closed reduction technique should be used. The amount of displacement and mobility is not an indication for open reduction techniques. If the segments are reduced and stable in a closed reduction technique, this should be used. In the case in which stability is questionable, open reduction techniques for fixation should be used. Fractures of the symphysis, parasymphysis, body, angle, ramus, subcondylar, and condylar areas can be treated with IMF. If absolute stability and adequate bony contact are questionable, however, a surgeon should consider the addition of—or replacement with—open reduction internal fixation.

Fractures with an unfavorable pattern of muscle force on them may require open reduction techniques to ensure that segments are stable and fixated in preinjury position throughout the healing period. Unfavorable fractures, with the pull of the musculature, may be adequately reduced on immediate postoperative radiographs, only to be displaced over time from muscular force. This muscular force can lead to nonunion or malunion at the fracture site. Significant muscle pull may make stability or reduction impossible, as may be the case in the anterior mandibular segmental fracture with the posterior displacement caused by the genial musculature. The force of the muscular action should be considered when choosing an appropriate reduction and stabilization technique. In the case of grossly comminuted fracture (ie, gunshot wounds), the loss of blood supply from periosteal stripping of comminuted fragments should be considered before open reduction occurs. These complicated fractures are often treated with closed reduction techniques in an attempt to save the fragments and allow for bony healing across the injury without damaging the blood supply.

The period of immobility traditionally has been 6 weeks for uncomplicated mandibular fractures treated with closed reduction. Research has shown, however, that for healthy, young adult patients, a period of 3 to 4 weeks is adequate. Children require even shorter periods of immobility, and satisfactory healing occurs in most fractures within a 2-week period. Elderly patients were shown to require slightly longer periods—5 or more weeks. Age-related changes in healing capacity and concomitant medical conditions may impact this age group. Fracture site has no significant relationship with regard to healing time and period of immobility necessary, with the exception of the ramus area. When considering the anatomy and thick muscle envelope in this area, it is unlike other areas of the mandible, which is most likely the contributing factor to the slightly shorter immobilization period for ramus fractures.

Advantages and disadvantages of closed reduction treatment

Closed reduction techniques offer many advantages over the use of open reduction techniques. The low cost, shorter length of procedure, and ability to achieve preinjury occlusion with some dynamic adjustment allow these techniques to be used routinely in private practice settings, hospital operating rooms, and emergency room treatment areas. Most techniques are relatively easy to learn and maintain in the surgeon's repertoire. Additional advantages include the lack of opening of tissues with incisions or dissection and placement of foreign body materials.

Although the listed advantages are appealing to most clinicians, there are certain disadvantages, which have led to the development of many different closed and open reduction techniques. The disadvantages can be profound, leading to failure of treatment and loss of preinjury function. The most obvious disadvantage is the length of time in which the patient is maintained in IMF. Traditionally a period of 6 weeks has been implemented, which is a difficult period for patients to complete successfully. Noncompliance is common because patients are faced with altered dietary regimens and weight loss, inability to perform adequate hygiene, wire trauma to the soft tissues, which causes pain and ulceration, fear of suffocation, and choking. Patients who struggle with these issues may elect to remove wires and are often lost to follow-up, only returning when a problem arises. Loosening of wires over time and inability to obtain complete rigidity may lead to nonunion and possible infection in the postoperative period.

The more serious disadvantages should be discussed. Fortunately, most patients do not have long-term negative sequelae because of closed reduction techniques. The temporomandibular joint is a site of alteration that may lead to permanent changes of structure and function. These changes include—but are not limited to—stiffness of the joint and limited opening, atrophy/denervation of muscles, loss of bite strength and range of motion, and change in cartilage structure internally in the joint. Although rare, these complications can be debilitating to patients and difficult to manage and correct. For surgeons, the looming risk of wire penetration injuries to fingers and hands must be considered. The risk of transmission of infectious organisms is low. With good technique and careful placement, wire injuries can be avoided. Even using open reduction with internal fixation techniques, closed reduction techniques to obtain preinjury occlusion before rigid fixation placement put operators at risk of injury.

There are certain situations in which closed reduction techniques are not possible to maintain because of the concomitant medical status of the patient. For patients who have severe seizure disorders, sleep apnea that requires continuous positive airway pressure or bi-level positive airway pressure, anorexia/bulimia nervosa, certain psychiatric conditions, certain endocrine diseases (brittle diabetes), or coagulopathies or bleeding tendencies and in whom a second procedure to remove the IMF may be undesirable and for certain patients with altered pulmonary function who may not be able to tolerate the period of IMF, open reduction techniques should be implemented.

Summary

The search for the ideal method of treatment for mandibular fractures has continued for thousands of years. These injuries have unique and problematic features for adequate reliable wound healing. Oral and maxillofacial surgeons must learn and master several techniques for mandibular fracture treatment. The age-old successful management of these injuries using closed reduction techniques always should be considered when mandibular trauma presents. The closed reduction remains a mainstay of mandibular fracture treatment. An adequate knowledge of anatomy, multiple closed reduction techniques, and the physiology of fracture healing must be adequately understood and technically mastered by the oral and maxillofacial surgical team for the present and future of mandibular fracture management.

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Teeth in the Line of Mandibular Fractures

Gaetano Spinnato, DMD, MD*, Pamela L. Alberto, DMD

Department of Oral and Maxillofacial Surgery, University of Medicine and Dentistry of New Jersey, New Jersey Dental School, Newark, NJ, USA

Many mandibular fractures occur through tooth sockets. The treatment plan for teeth in the line of fracture has evolved through the years because of the development of new antibiotics and fixation techniques. In this article we review the history and current studies and discuss treatment protocols for teeth in the line of mandibular fractures.

History

Opinions differ regarding removal of teeth in the line of mandibular fractures. In 1975, Canaro agreed with Kruger, Archer, and Rowe that each case should be decided on its own merit; however, Clark, Ivy, and Thoma recommended the removal of teeth within a fracture line [1]. Proponents for removal of teeth adjacent to a fracture line believe that these teeth can potentially become a source of infection and be detrimental to a successful outcome of mandibular fracture treatment. Many surgeons hold the opinion that the only complication with leaving these teeth is infection; however, many of the teeth can be retained with the proper use of antibiotic therapy [1,2]. Canaro described the prophylactic removal of teeth leading to other problems, including allowing greater communication of the fracture site with the oral cavity and further distraction of the fracture segments (Fig. 1A). Extraction of these teeth also could lead to secondary displacement of the fractures, problems with immobilization of fragments, and the need for intraosseous fixation. Canaro's reason, along with the opinions of other surgeons, for maintaining these teeth is that they may allow easier methods of treatment. This would avoid the need for an open reduction and the potential complications associated with this surgery.

Many surgeons agree that teeth that are hopelessly mobile or fractured or complicate the reduction of the fracture should be removed (Fig. 1B). Canero believes that if certain conditions are met, teeth in the line of fracture can be preserved. The conditions for maintaining teeth in the line of fractures include maintaining antibiotic therapy, strict oral hygiene, radiologic and clinical monitoring for evidence of periapical infection and pulp necrosis, and endodontic therapy for teeth that require treatment (Fig. 2A, B) [2]. De Amaratunga stated that teeth in the line of fracture could be salvaged if proper fixation techniques were used along with antibiotic coverage [3].

Review of current studies

In 2000, Spina and Marciani listed the following pitfalls in making decisions regarding leaving teeth in the line of fracture [4]: (1) not treating teeth with pulpal involvement or periapical pathology, (2) maintaining teeth that can become symptomatic and necrotic and can infect

* Corresponding author.
E-mail address: spinnaga@umdnj.edu (G. Spinnato).

doi:10.1016/j.cxom.2008.10.006
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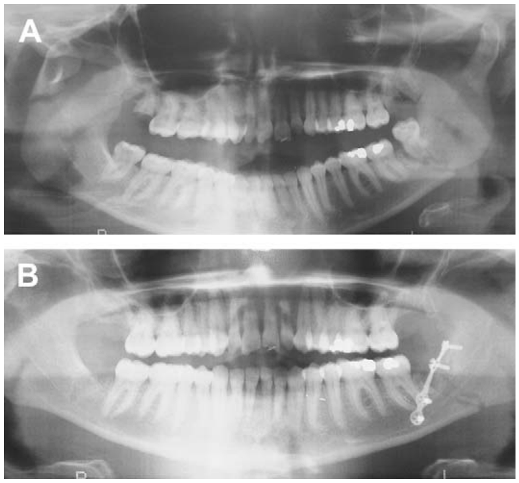

Fig. 1. (*A*) Tooth #17 in the line of fracture was decayed and required extraction for reduction. (*B*) The execution of tooth #17 with an intraoral open reduction of the fracture.

the fracture site, and (3) routinely extracting teeth in the fracture line to reduce fracture repair morbidity. They advocated considering the retention of teeth with a guarded prognosis if they are useful for reduction or stabilization of the fracture (Fig. 3A, B). Ellis found virtually no difference in the incidence of infection when teeth were left in the line of fracture or extracted [5]. Similar conclusions were made by Chuong and colleagues [6] during their studies.

Indications for removal of teeth in the line of fracture

In 1989, Shetty and Freymiller [7] reviewed indications for removal of teeth in the line of fracture. They recommended the following indications:

1. Significant periodontal disease with gross mobility and periapical pathology
2. Partially erupted third molars with pericoronitis or cystic areas
3. Teeth preventing the reduction of fractures (Fig. 4)
4. Teeth with fractured roots

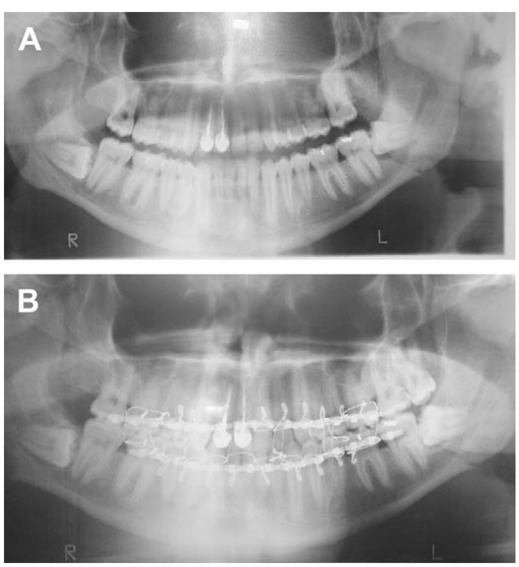

Fig. 2. (*A*) Fracture of the left mandible with horizontal impacted #17 in the line of fracture. (*B*) The tooth was not extracted from the fracture site to avoid displacement of the segments.

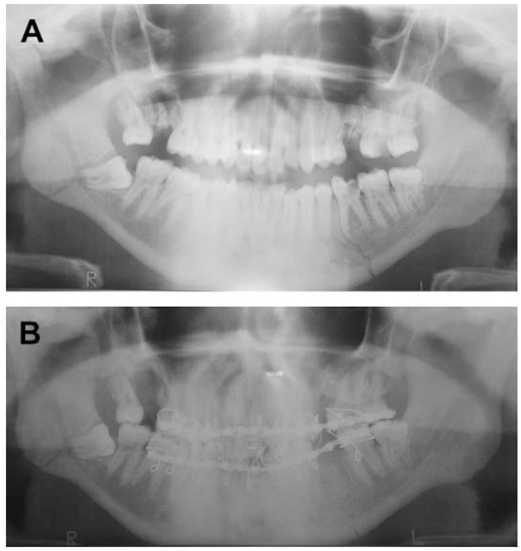

Fig. 3. (*A*) Bilateral fractured mandible with two teeth in the line of fracture. (*B*) A closed reduction was performed after the extraction of the abscessed tooth #19. Tooth #32 was retained so as not to displace the segments.

5. Teeth with exposed root apices or teeth in which the entire root surface from the apex to the gingival margin is exposed
6. Excessive delay from the time of fracture to the time of definitive treatment

In addition to these indications, another indication that requires extraction of teeth in the line of fracture is an acute, recurring abscess at the site of the fracture despite antibiotic therapy [8].

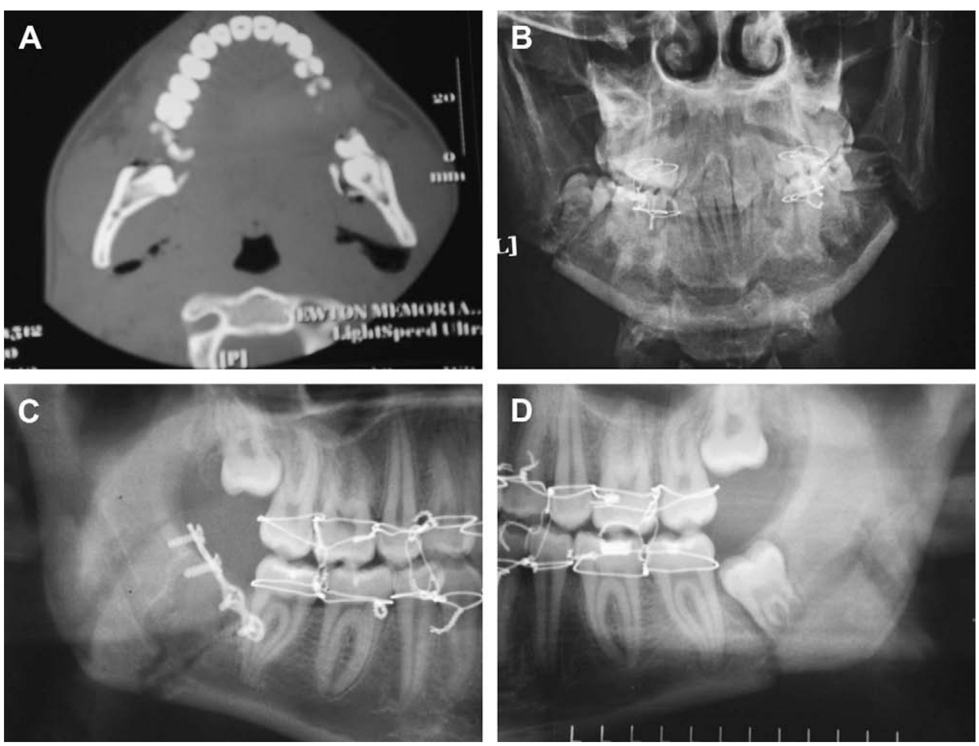

Fig. 4. (*A*) CT scan of a bilateral fractured mandible with teeth #17 and 32 in the line of fracture. (*B*) After a closed reduction, it was noted that tooth #32 displaced the fracture segments. (*C*) Tooth #32 was extracted and an intraoral open reduction was performed. (*D*) The tooth #17 was left in the line of fracture so as not to displace the segments with extraction.

Use of antibiotics

It is generally accepted by most surgeons that antibiotic therapy should be administered when teeth are left in the line of fracture because of open nature and contamination of the oral cavity. Penicillin is still considered the drug of choice. Many practitioners recommend a 5-day course of antibiotics; however, one author advocated antibiotics preoperatively and 24 hours after reduction, which may be as effective as a 5-day course of antibiotics [9].

Summary

Current studies reinforce the idea that each fracture case should be treated on its own merits. The routine prophylactic removal of teeth in the line of fracture should be avoided to reduce potential fracture repair morbidity [10,11]. Strong consideration should be given to retaining teeth, especially impacted third molars not communicating with the oral cavity, which can prevent the displacement of a posterior segment or help register the occlusion accurately in the symphyseal area [12]. Finally, some studies have shown an increased rate of infection by 50% in fracture cases treated without antibiotics, whether treated with a closed or open reduction. Antibiotics should be considered prophylactically in the treatment of all compound/open mandibular fractures [13,14].

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Atlas of the Oral and Maxillofacial Surgery Clinics

Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 19–25

Use of Monocortical Miniplates for the Intraoral Treatment of Mandibular Fractures

Thomas A. Chiodo, DDS*, Maano Milles, DDS

University of Medicine and Dentistry of New Jersey, New Jersey Dental School, Department of Oral and Maxillofacial Surgery, 348 East Main Street, 1st Floor, Somerville, NJ 08876, USA

Fixation of mandibular fractures using rigid hardware has gained wide acceptance over the past 3 decades. The goal of rigid internal fixation is to allow for fracture healing with limited, or no, time in maxillo-mandibular fixation (MMF). Originally internal fixation of mandibular fractures was accomplished with stainless steel plates. These plates were thick because of lack of material tensile strength and were combined with maxillo-mandibular fixation to prevent failure. There has been a significant evolution in plate and screw materials and design over the past 30 years. Today there are numerous companies offering a myriad of plates and instrument design for application in the craniomaxillofacial region.

The term miniplate is commonly used to describe a fracture plate with a screw diameter of 2.0 mm or less. These thin plates were originally reserved for treating facial fractures in low or non–load-bearing areas such as the mid-face. As experience with smaller fixation hardware evolved, miniplates gained increased use in the mandible. This led to research both "in vitro" and "in vivo" models of mandibular fractures widening the application of the small plates. With correct diagnosis and understanding of the forces affecting mandible fractures, miniplates can be applied transorally in a variety of situations. This allows for less invasive treatment with open reduction of mandible fractures.

Anatomic and physiologic considerations

When considering the use of miniplates for fixation of mandibular fractures, several factors must be considered. The first factor is the location and nature of the fracture. Mini-plates may be used for ramus, angle, body, or symphyseal fractures. Fractures with minimal comminution are the best suited for miniplate application and large intact bone segments provide the optimal situation for a successful result (Fig. 1). Although miniplates can be used to secure smaller bone segments, excessive stripping of periosteal tissues compromises blood supply and can cause bone necrosis and sequestra in the mandible.

The fracture orientation in relation to the tension and compression forces of the mandible is another important variable. Under function, the mandible develops compressive forces at the inferior border while tension forces are located at mid body and the superior border. In addition, the anterior mandible has a double tension band in the symphysis region because of suprahyoid muscular pull. These factors must be considered when deciding on a treatment to avoid excessive mobility and potential splaying of fracture segments resulting in nonunion or malunion of the fracture.

Another consideration is the presence of teeth in the line of the fracture. Teeth may sometimes prevent adequate fracture reduction or may become a source of infection when

* Corresponding author.

E-mail address: chiodota@umdnj.edu (T.A. Chiodo).

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doi:10.1016/j.cxom.2008.10.008

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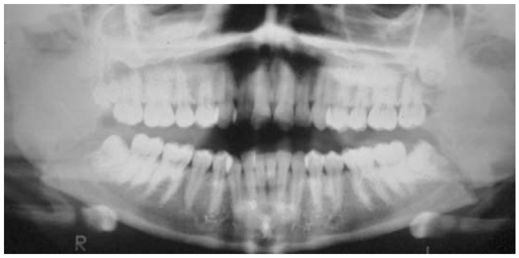

Fig. 1. Panoramic radiograph showing bilateral fractures of mandibular angles. Note impacted teeth in both fracture sites.

luxated from their original alveolar position (Figs. 2 and 3). This may require removal of the affecting tooth, leaving a thin residual cortical plate in the fracture area with inadequate strength to maintain fracture hardware. Also, teeth may limit the options for optimal placement without root damage.

Finally, infection is a known complication of all fracture repair modalities. Because mandibular miniplates are generally placed via intraoral approaches, some fractures may not be amenable to this technique. Mini-plates should not be used where access is not available for proper placement. Surgeons must also decide if it is prudent to place small hardware in an area of active infection. Because miniplates will allow for additional fracture flexure compared with larger fixation hardware, chronic infection may persist, resulting in nonunion.

Techniques

Mandibular angle fracture

The most popular use of miniplates for the mandible has been the use of the superior border plating technique for mandibular angle fractures. This technique was described by Michele Champy in 1986 and has become widely accepted as a preferred method of treating angle fractures. Since its inception, the technique has been the subject of multiple studies by many different authors giving the evidence-based data required to validate any surgical technique.

The superior border plate technique offers many advantages. First, it allows for a relatively rigid internal fixation of a mandibular angle fracture that prevents the proximal segment from displacing superiorly yielding a malunion. Second, it is placed via an intraoral approach

Fig. 2. Close-up cropped view of right angle fracture.

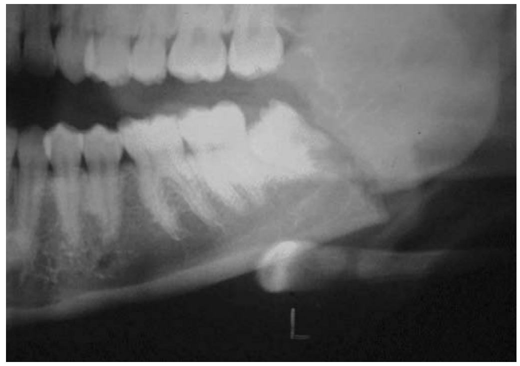

Fig. 3. Close-up cropped view of left angle fracture.

avoiding any external facial scar, and possible damage to the facial nerve. Finally, it allows for early mobilization of the mandible avoiding the approximately 6 weeks of maxillo-mandibular fixation required of closed reductions.

When considering the monocortical superior border plating, the surgeon must first examine the patient to assess for the fracture criteria discussed earlier. The ideal fracture will have minimal comminution with little displacement and an intact mucosal surface. Examine intraorally for steps, bony prominences, and any lacerations. An imaging study is done to correlate the clinical findings. Computed tomography is readily available today, however is not required in the case of isolated mandibular fracture injuries. Plain radiographic films with views in two planes/or an orthopantogram will generally give the required diagnostic information.

The surgical procedure is typically performed in the operating room under general anesthesia. Nasal intubation avoids interference of an oral tube during the surgical procedure and application of MMF. A moist gauze throat pack will protect the airway from any foreign bodies such as screws or wires during the procedure. The authors prefer to perform a preop irrigation with Peridex to decrease the intraoral bacterial load to aid in reduction of postoperative infections. The first step in the procedure is to manually reduce the fracture to ensure the patient can be placed into a correct central occlusal relationship. Once this is confirmed, one can commence with the placement of arch bars secured using 24- to 26-gauge wires. It is very important to examine the mucosa in the area of the angle to visualize any lacerations that may be present. These lacerations may be incorporated into the incision to prevent additional tissue trauma and necrosis of small tissue islands with compromised blood supply. If the mucosa is intact, the mouth is propped open and an incision is created in the posterior vestibule paralleling the external oblique ridge. The incision may be created with a blade, or a needle-tip cautery device to reduce intraoperative bleeding. An incision is created through mucosa, muscle, and down to bone by angling the scalpel or cautery toward the mandible. It is important to place the incision lateral to the mandible to help prevent postoperative plate dehiscence and ensure it is long enough for adequate exposure (Fig. 4). In addition, the lateral placement facilitates suturing when the patient is released from MMF. A periosteal elevator is used to expose the mandible distal and proximal to the fracture line and free any entrapped tissue present in the fracture line. Any old blood clot, fibrous tissue, or unsupported bone fragment area is debrided. If a third molar is present in the fracture area that may compromise reduction or healing, it should be removed at this time. Bone should be removed judiciously from the third molar area when removing teeth. Overaggressive bone removal may result in inadequate bone quantity or quality and compromise screw placement for fixation.

The fracture is now manipulated into reduction and the patient placed into maxillo-mandibular fixation. Right angle and ramus retractors are placed to allow for visualization of the surgical site. A 2.0-mm mandibular fracture plate is then contoured to fit passively along the superior border of the body/ramus. In certain cases it is necessary to place a slight twist of the plate to secure passive placement on the distal fracture segment. In these cases a portion of the plate is bent slightly toward the lateral surface of the mandible (Fig. 5). Certain manufacturers have

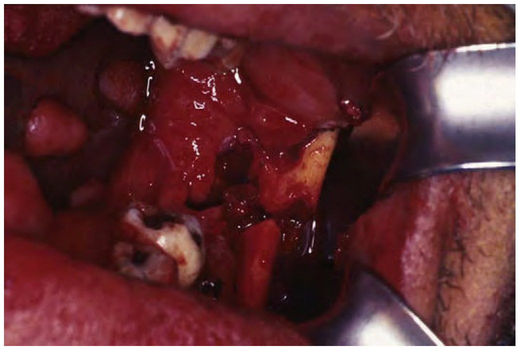

Fig. 4. Reduction of left angle fracture before plate adaptation.

available prebent miniplates for application in this angle region. The plate is held in place and a drill is used to make a monocortical hole through the lateral cortex. A monocortical screw is placed that will secure the plate for the completion of the other drilling and screw placement. In some cases, it is necessary to release the MMF to access the location of the most proximal screw. Once the plate is completely secure, the fixation is released and the throat pack is removed. The mandible is mobilized to check the occlusion. Once occlusion is confirmed, the patient may be placed back into MMF using wire fixation or guiding elastics for the postoperative period. The patient is placed on recall visits every 1 to 2 weeks and monitored with periodic panoramic radiographs (Figs. 6 and 7). The fracture will be stable at 4 to 6 weeks and mature at about 12 weeks. There is no need to remove the miniplates unless there are complications.

Miniplate trocar technique

The trocar is a useful adjunctive instrument for fracture access in the mandible. A transoral approach alone does not always provide adequate access to posterior fracture sites. This is particularly true if the surgeon wishes to fixate a posterior body or ramus fracture and wants to avoid a facial incision. This procedure is initiated like other cases with maxillo-mandibular fixation and reduction of the fracture. A standard transoral approach as previously described is created and the fracture is visualized. The fracture segments are reduced, and the trocar is then inserted percutaneously. To insert the trocar, attention is first directed extraorally. A scalpel is used to create a small incision (4 to 5 mm) through the skin of the cheek over the fracture area. The incision should be placed parallel to skin tension lines to minimize the possibility of scarring. A mosquito hemostat is then used to bluntly dissect through the cheek to create a pathway for the trocar. The trocar is then placed through the incision and dissection track with the stylette locked into the working channel. The stylette is removed and the retractor

Fig. 5. Miniplate fixated to left angle fracture after reduction. Note maxillo-mandibular fixation.

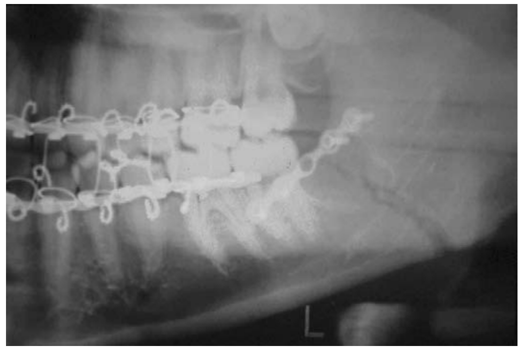

Fig. 6. Cropped panoramic radiograph showing reduction and fixation of left angle fracture with miniplate. Note removal of impacted third molar #17 and maxillo-mandibular fixation.

portion of the trocar can be attached for better visualization while leaving the trocar in place. The plate is then passively adapted across the fracture and a long drill bit is maneuvered through the trocar to create the fixation holes. Similarly, the screws are inserted and secured through the trocar with the appropriate screwdriver.

Double miniplates for symphysis and body fractures

Another area where miniplates are commonly used for open reduction of mandibular fractures is the symphysis and body region. Following the principles of mandibular tension and compression forces, double monocortical plates may be used to repair fractures. This technique may also be useful when treating fractures in close proximity to the inferior alveolar or mental nerves. As in other types of mandible fractures, reduction and MMF are initially required. When securing dental wires around teeth adjacent to the fracture, the surgeon must be careful not to damage any compromised teeth or excessively distract the mobile segments. This may result in securing the segments into poor alignment with the arch bars or lingual splaying. A bridal wire is a useful adjunct to add additional stability of the segments during arch bar placement. With the fracture reduced, a wire is looped around the teeth one position away from the fracture site and tightened. Arch bars can then be placed in the usual manner using manual pressure to maintain the reduction and correct occlusal relationship.

When performing a transoral open reduction in the symphysis area, a scalpel or needle-tip cautery is used for the incision. The lip is rolled out and retracted to expose the vestibule. The

Fig. 7. Cropped panoramic radiograph showing reduction and fixation of right angle fracture with miniplate. Note removal of impacted third molar #32 and maxillo-mandibular fixation.

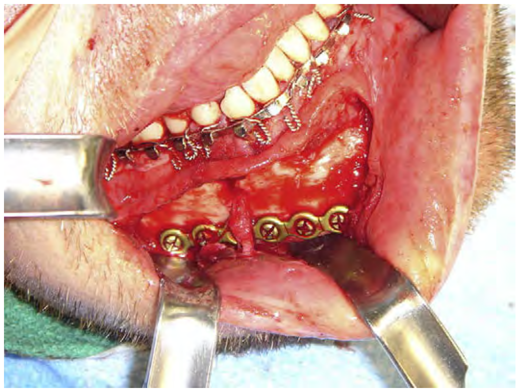

Fig. 8. Miniplate used to fixate right parasymphysis fracture. Note skeletonization of mental nerve to allow for placement of plate below nerve exiting from foramen. Also note mandibular arch bar to help control tension zone forces.

incision is made through the mucosa approximately 5 mm from the depth of the vestibule toward the lip. Once the orbicularis oris muscle is encountered, the incision is angled toward the mandible to prevent transection of the lip and button-holing of the skin. The dissection is carried sharply down to the mandible and a periosteal elevator can then be used to completely expose the fracture. The surgeon must be cognizant of the width and depth of the incision to avoid the mental nerve as it exits mandibular foramen (Fig. 8). If encountered, the nerve branches may need to be skeletonized using blunt dissection to identify, isolate, and protect them during fixation. Freeing the nerve also aids in preventing permanent nerve injury with increased mobility for additional exposure during plate placement.

After adequate exposure is achieved, the plates are passively adapted to the mandible. One plate is placed at or near the inferior border with the other plate usually in the midbody region. The position of the superior plate is usually dictated by tooth position. It is necessary to place the plate just below the root apices in dentate areas to avoid tooth damage (Fig. 9). If the fracture is in an edentulous area, the plate position may be moved more superiorly. Meticulous closure of symphyseal fractures is essential. The dissection must be closed in layers and the mentalis muscle needs to be reapproximated to avoid a ptotic chin deformity. Generally, the incision is closed in two or three layers. Resorbable sutures may be used to close the periosteal, muscle, and the superficial mucosal layer. A short period of maxillo-mandibular fixation is generally required depending on the degree of stability achieved.

Fig. 9. Two miniplates used to fixate left parasymphysis fracture. Note skeletonization of mental nerve to allow for placement of plate below nerve exiting from foramen. Also note mandibular arch bar to help control tension band forces.

Complications of mandibular miniplate fixation

Complications of mandibular fractures are discussed in detail in a different article of this issue. However, some basic complications of using miniplates will be discussed. The most commonly seen complication is wound dehiscence. Because of the thin nature of the mucoperiosteum that is present in the oral cavity, the plates can easily erode through the tissue. A second common complication is plate fracture or screw failure. Overbending of the plates or patient noncompliance exerting excessive early mandibular force may lead to plate fracture. Because these plates are secured with short monocortical screws placed from difficult angles, screws may loosen and fail. This may be a result of overdrilling of a hole or overheating of bone during drilling leading to bone necrosis around the screw. In any of these cases, treatment is removal of the loose or broken hardware. The other common complication is infection. Infection will often accompany loose or fractured hardware. When infection is present, the patient will require debridement of the area and an appropriate course of antibiotics in addition to hardware removal. If a nonunion results, placement of larger fixation hardware is usually required.

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Atlas of the
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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 27–34

Mandible Fracture: Transoral 2.0-mm Locking Miniplate plus 1 Week Maxillomandibular Fixation

Stewart K. Lazow, MD, DDS, FACS[a,b,*], Igor Tarlo, DDS, MD[a,b]

[a]Department of Dental and Oral and Maxillofacial Surgery, Kings County Hospital Center, Brooklyn, NY, USA
[b]Oral and Maxillofacial Surgery, State University of New York Downstate Medical Center, Brooklyn, NY, USA

Treatment of the mandible fracture is basic to the treatment of maxillofacial trauma. Successful treatment of the mandible fracture results in an anatomic bony union with restoration of normal occlusion and function. Although there is universal agreement as to the basic therapeutic principles of reduction and stabilization, a plethora of currently accepted treatment modalities indicates a lack of consensus.

History

Suggested treatment of mandible fractures has evolved significantly over the last three decades. Two open reduction techniques, rigid internal fixation (RIF) and adaptive miniplate fixation, have replaced the use of wire osteosynthesis and prolonged maxillomandibular fixation (MMF). The advantages of both RIF and miniplate fixation with minimum periods of MMF include early mobilization and restoration of jaw function, airway control, nutritional status, improved speech, better oral hygiene, patient comfort, and an earlier return to work.

Principles and techniques of RIF were developed and popularized as a result of the research conducted by the Arbeitsgemeinschaft fur Osteosynthesefragen (AO/ASIF) in Europe in the 1970s. The basic principles of the AO were outlined by Spiessl and call for primary bone healing under conditions of absolute stability. Rigid internal fixation must neutralize all forces—tension, compression, torsion, shearing—developed during functional loading of the mandible to allow for immediate function without MMF (Fig. 1). This is accomplished by interfragmentary compression at the mandibular angle by application of a dynamic compression plate (DCP) or reconstruction plate to counter compression at the inferior border, and a smaller tension band plate at the superior border of the mandible to counter tensile forces (Fig. 2).

There are several disadvantages to this method of open reduction, internal fixation (ORIF) of mandible fractures that is usually performed transcutaneously, including increased operating room time, risk of facial nerve paresis, and risk of hypertrophic scar formation. Of perhaps greater significance is the reported high infection rate, ranging from 6% to 32%, associated with this technique. That RIF of mandible fractures is highly technique-sensitive and demanding is confirmed by Assael's report of a 24% complication rate during in vitro application of plates in a RIF laboratory study.

At approximately the same time that Spiessl was expounding the AO doctrine, Michelet and colleagues and Champy and colleagues in France were developing the concept of adaptive miniplate osteosynthesis. Champy advocated transoral placement of small, thin, malleable stainless steel miniplates with monocortical screws along an ideal osteosynthesis line of the mandible (Fig. 3). Champy and Lodde and colleagues presented biomechanical investigations that sought

* Corresponding author. University Hospital #76, 445 Lenox Road, Brooklyn, NY 11203.
E-mail address: skloms@aol.com (S.K. Lazow).

1061-3315/08/$ - see front matter
doi:10.1016/j.cxom.2008.10.009

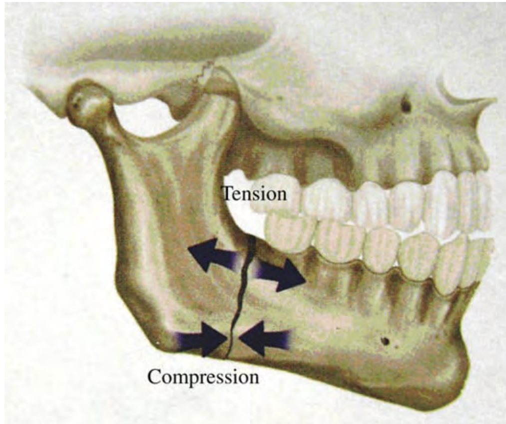

Fig. 1. Compression at the inferior border of the mandible; tension at the alveolar crest.

to confirm the concept of a functionally oriented miniplate adaptation and fixation. Miniplates achieve the goal of osteosynthesis by neutralizing undesirable tensile forces while retaining favorable compression forces during function. Champy believed that compression plates were unnecessary because of masticatory forces that produced a natural strain of compression along the inferior border of the mandible.

The advantages of adaptive miniplate fixation of mandible fractures are numerous: transoral procedure without risk of facial nerve paresis or hypertrophic scar, decreased operating time, ease of adaptation of miniplates, ability to confirm occlusion during the procedure, and early mobilization of the patient. Miniplates are less palpable because of their lower profile than DCPs, and less thermal sensitivity is reported by the patient.

There are limitations to the use of miniplates in the treatment of mandible fractures. They are not as rigid as DCP or reconstruction plates, which may lead to torsional movements of the fracture segments under functional loading. Therefore, miniplate fixation should be avoided in comminuted or infected fractures, or those fractures without adequate bone buttressing. In these cases, a load-bearing fixation device (DCP or reconstruction plate) is indicated, rather than the load-sharing miniplate.

Several studies have been conducted by Ellis and others in the use of adaptive miniplate fixation of mandible fractures without postoperative MMF. Complication rates range from 16% to 28%. Therefore, a brief period of postoperative MMF is recommended to reinforce the tension band, allow reattachment of the soft tissue drape, and stabilize the occlusion.

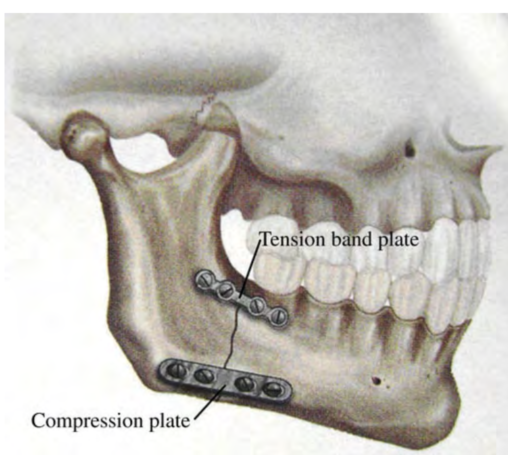

Fig. 2. DCP at the inferior border; tension band plate at the superior border of the mandible.

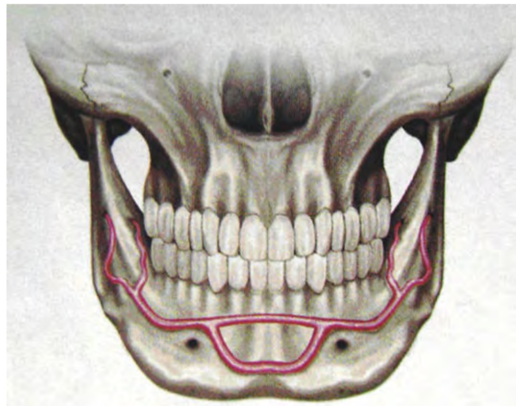

Fig. 3. Champy's line of ideal osteosynthesis.

Evolution of Kings County Hospital fracture protocol

In the 15 years from 1992 to 2007, the Oral and Maxillofacial Surgery Service at Kings County Hospital/SUNY Brooklyn has treated 2,311 mandible fractures in 1,490 patients. Of these, 54 cases required reoperation or readmission, for an overall complication rate of 2.4%. Bone healing was satisfactory in 99% of cases. The hospital continues to evolve our mandible fracture protocol to remain efficient and cost effective.

From 1993 to 1998, four prospective DCP clinical trials were conducted at Kings County Hospital/SUNY Brooklyn. All four trials involved a transcutaneous extraoral approach for ORIF of mandible fractures. Results of all four clinical trials were presented at successive Poster Sessions of the American Association of Oral and Maxillofacial Surgeons Annual Meetings. In 1993, a 2.7-mm DCP system with 3 weeks of MMF was studied; a 1% infection rate that required plate removal and a 99% satisfactory bone healing was cited. In the second study in 1994, a 2.7-mm DCP with 2 weeks of MMF yielded a 1.8% infection rate and 98.2% bone healing. In the third study in 1995, a lower profile 2.3-mm DCP with 2 weeks of MMF was used; one complication of a fibrous union (3.3%) and 96.7% bone healing were noted. In 1998, the fourth study investigated the 2.3-mm DCP with 1 week of MMF; four complications (12%) and a 96.7% bone healing rate were documented.

With the increasing interest in adaptive miniplate fixation of mandible fractures, investigators at Kings County Hospital/SUNY Brooklyn conducted a prospective clinical trial of transoral 2.0-mm miniplate fixation of mandible fractures plus 2 weeks MMF. The results of this miniplate study were published in the Journal of Oral and Maxillofacial Surgery (JOMS), 2002. In this study, 44 mandible fractures in 31 subjects were treated via a transoral 2.0-mm nonlocking miniplate placed along Champy's line of ideal osteosynthesis plus 2 weeks of MMF. The results of this data showed two minor complications of intraoral wound dehiscence(4.52%) and 100% satisfactory bone healing.

With the advancement of the more stable construct of the 2.0-mm locking miniplate (LMP) system (Synthes Maxillofacial, Paoli, PA) (Fig. 4), the authors postulated that they could reduce the period of postoperative MMF from 2 weeks to 1 week. From 2002 to 2004, the authors treated 50 mandible fractures in 34 patients with the 2.0-mm LMP plus 1 week MMF (published in JOMS, 2005). Three complications (6%) were observed: a wound dehiscence that required local wound care and oral antibiotics, a minor malocclusion that required occlusal adjustment, and a fibrous nonunion that required three additional weeks of MMF. Primary bone healing was achieved in 98% of cases. The fibrous nonunion was a result of poor case selection in a bilateral flailed mandible fracture without adequate bone buttressing. This complication could have been prevented by the use of a load-bearing fixation device (DCP or reconstruction plate) rather than the load-sharing LMP.

At Kings County Hospital/SUNY Brooklyn the authors have continued their transoral 2.0-mm LMP plus 1 week MMF prospective clinical trial from 2004 to 2008 (Table 1). In this secondary phase of the study, the authors have treated 159 mandible fractures in 93 subjects;

Fig. 4. The 2-mm LMP system with threaded screw head and plate holes.

92 angle fractures were included in this cohort. Exclusions included condylar fractures that required 2 weeks MMF, comminuted or infected fractures, and subjects in whom a brief period of MMF was medically contraindicated (epilepsy, severe asthma, psychiatric condition). Subjects were observed for complications: plate dehiscence, soft tissue infection, nonunion, malunion, malocclusion, osteomyelitis, osteolysis of plate or screws, iatrogenic nerve injury, tooth damage. All subjects were followed for at least 6 weeks until removal of arch bars with biweekly panoramic radiographs.

The results of the ongoing clinical trial are summarized in Table 2. Fifteen minor complications (9.4%) were recorded. Ten fractures developed wound dehiscences or soft-tissue infection requiring wound care and oral antibiotics. Dehiscence of the anterior vestibular incision was most commonly observed and prevented with a two-layered muscle/mucosal closure. Two fractures required hardware removal because of osteolysis of the screws. Two cases developed minor malocclusions treated by a brief period of elastic MMF and occlusal adjustment. One patient was readmitted for incision and drainage and intravenous antibiotics. Of the 159 fractures, 100% healed satisfactorily.

Transoral 2.0-mm LMP technique

Whenever possible, all mandible fractures are treated within 48 to 72 hours of injury. Surgery is conducted under general anesthesia via nasoendotracheal intubation. Either maxillary and mandibular arch bars, Ivy loops, or perialveolar screws are applied for intraoperative and postoperative MMF for 1 week. An intraoral mucoperiosteal incision is made along the external oblique ridge for angle fractures, and a vestibular mucosal incision extending halfway onto the lower lip is made for symphyseal and parasymphyseal fractures. Extraction of teeth in the line of

Table 1
Transoral 2.0 mm LMP plus 1 week MMF mandible fracture study 2004 to 2008

Demographics	
Number of fractures	159 (see Fracture site, below)
Number of patients	93
Number fx/pt	1.7
Age range	16–52
Mean age	24
Number of males	78
Number of females	15
Fracture site	
Angle	92
Parasymphysis	50
Symphysis	6
Body	9
Ramus	2
TOTAL	159

Table 2
Transoral 2.0-mm LMP plus 1 week MMF mandible fracture study 2004 to 2008

Results	
Complications	Number
Wound dehiscence/soft tissue infection	11
Hardware removal	2
Malocclusion	2
Iatrogenic V3 paresthesia	0
Tooth damage	0
Osteomyelitis	0
Total	15 (9.4%)
Readmission	1
Healed fractures	159 (100%)

fracture, including impacted third molars, is performed if indicated: caries, periodontal disease, two-thirds involvement of the periodontal ligament, tooth fracture, risk of pericoronitis. The fracture is conservatively debrided and anatomically reduced after establishment of ideal occlusion and application of MMF. One 2.0-mm four-hole LMP is adapted along Champy's line of ideal osteosynthesis and fixated with four 8-mm by 2-mm monocortical locking screws. A drill guide is used to insure the perpendicular nature of the drill hole to the plate, thereby allowing the screw to lock into the threaded plate hole and bone. Occasionally in angle fractures, a nonlocking screw is indicated in the anterior-most plate hole as determined by the tangential nature of the plate to the distal lateral cortex along the external oblique ridge. In fixating angle fractures, care must be taken to place the screws lateral to the roots and superior to the neurovascular bundle (Fig. 5). At the symphysis/parasymphysis/body regions of the mandible, the plate and screws are placed inferior

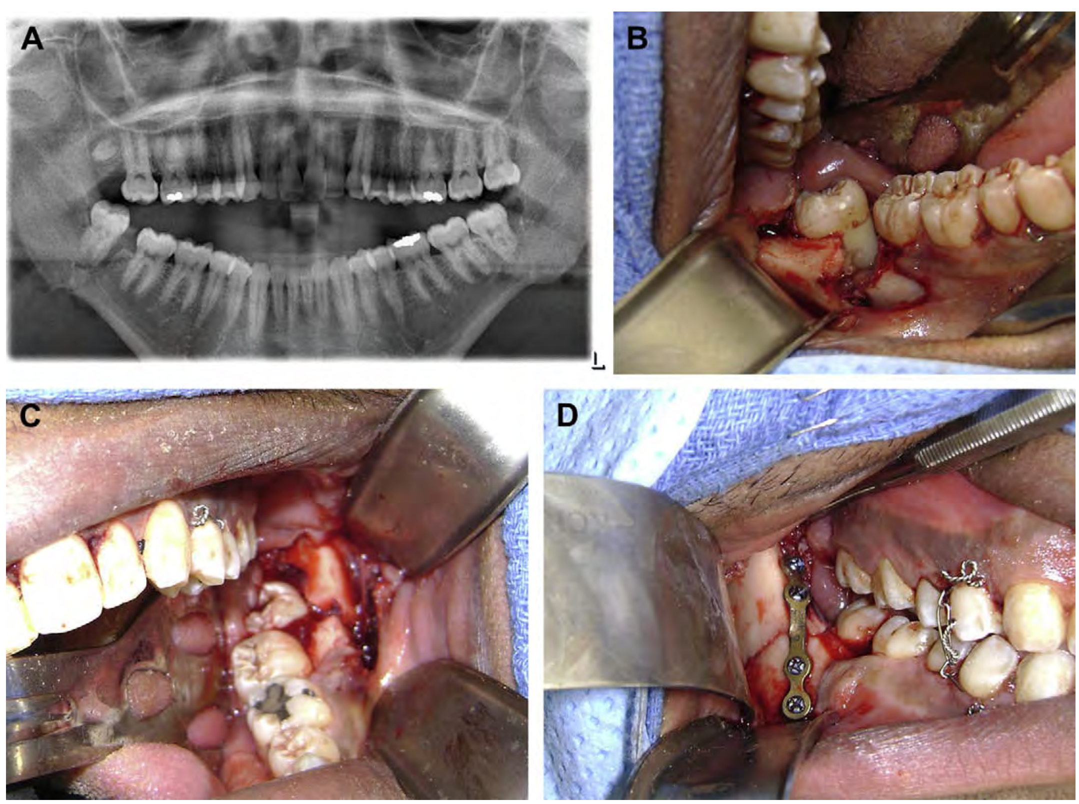

Fig. 5. (*A*) Preoperative panoramic radiograph shows bilateral mandible angle fractures. (*B*, *C*) Partially impacted mandibular third molars in line of fracture. (*D*, *E*) After extraction of third molars and anatomic reduction, each fracture is stabilized with a 2-mm LMP and four 8-mm by 2-mm locking screws placed along the external oblique ridge. (*F*) Postoperative radiograph shows good reduction and fixation with screws superior to the inferior alveolar canal. (*G*) Posteroanterior (PA) radiograph confirms screw placement lateral to roots of the mandibular second molar.

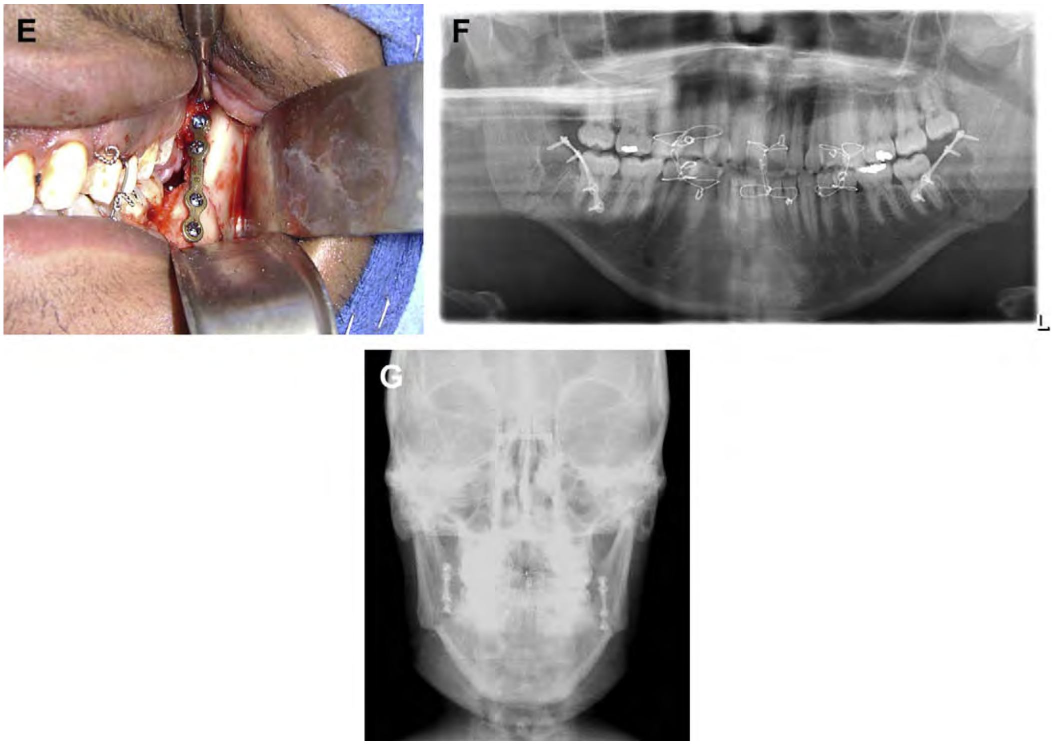

Fig. 5. (*continued*).

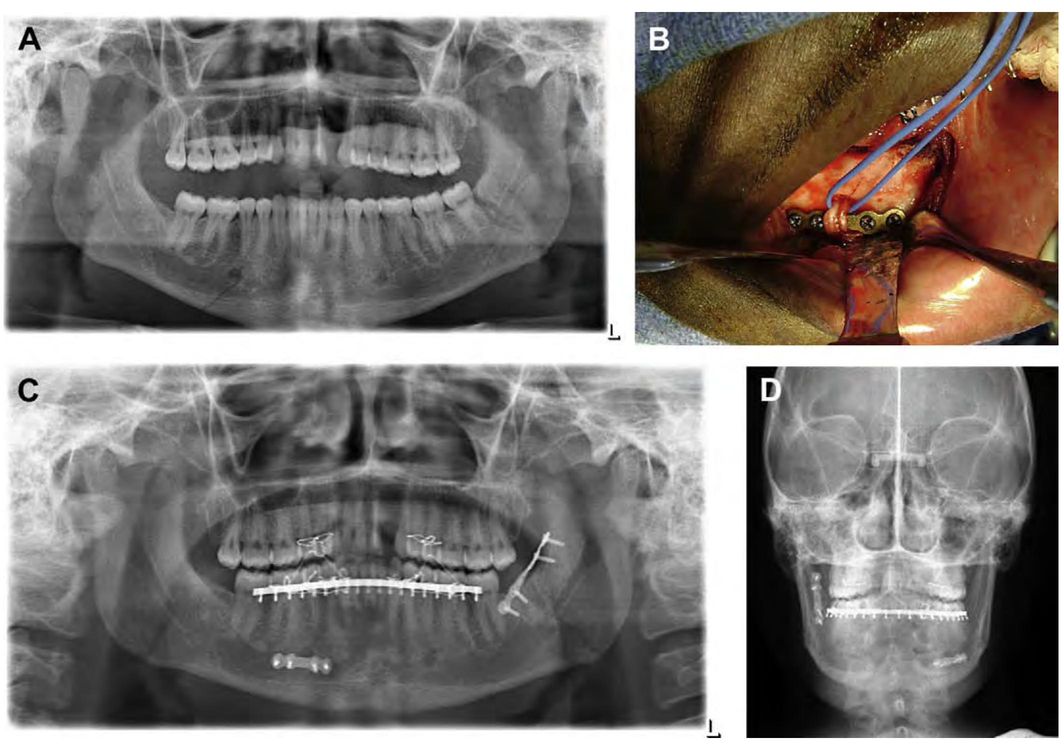

Fig. 6. (*A*) Preoperative panoramic radiograph reveals left angle, right body of mandible fractures. (*B*) Intraoperative photo shows placement of the 2-mm LMP and screws inferior to the retracted mental nerve. (*C*, *D*) Postoperative panoramic and PA radiographs confirm anatomic reduction and fixation with 2-mm LMP and four 8-mm by 2-mm locking screws at the left external oblique ridge and inferior to the right mental foramen.

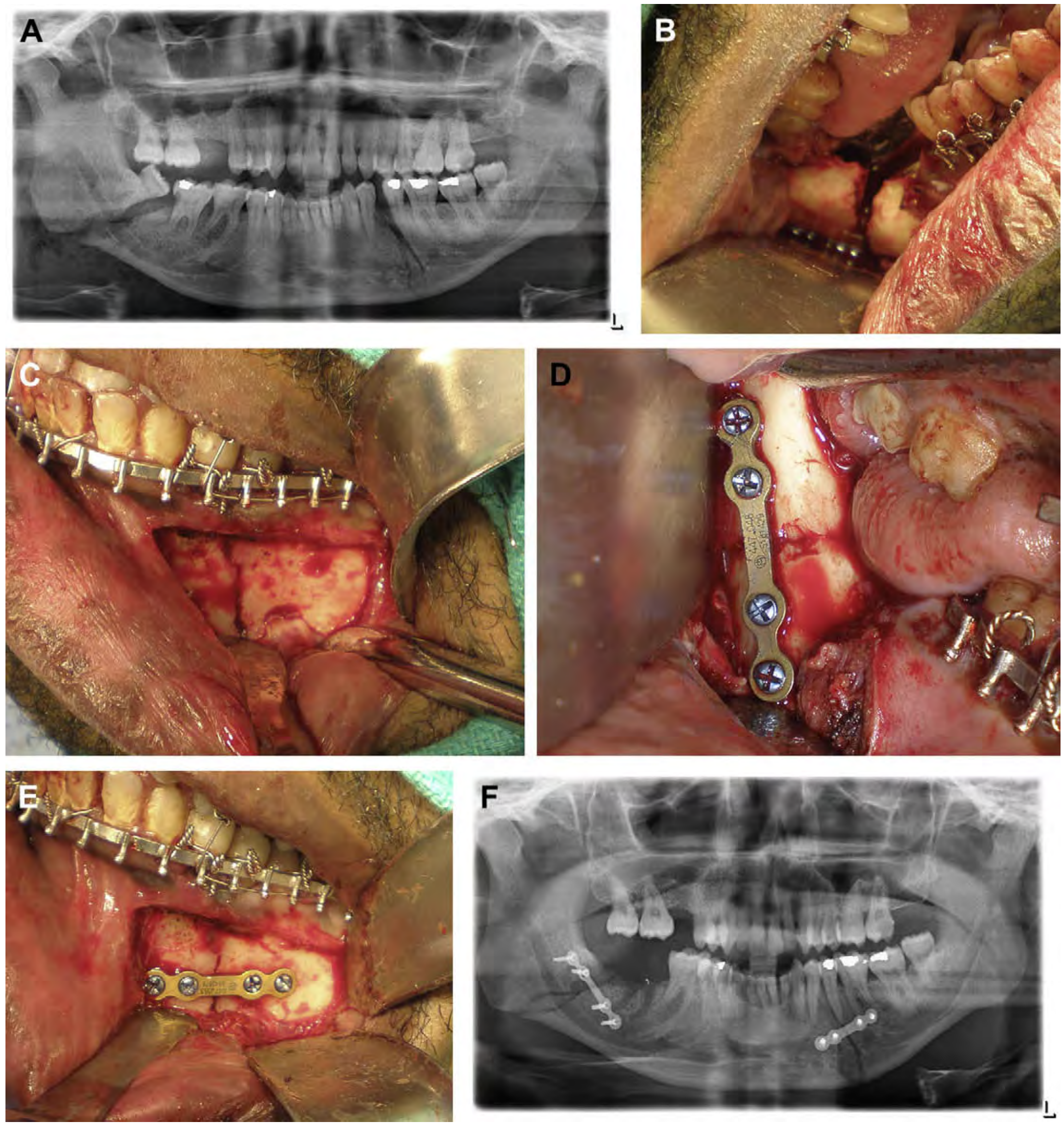

Fig. 7. (*A*) Preoperative panoramic radiograph of right angle, left body of mandible fractures. (*B*) Intraoperative photo of right angle fracture after extraction of tooth #32 in line of fracture. (*C*) Intraoperative photo of the left body of mandible fracture with the mental nerve isolated. (*D*) Intraoperative photo of 2-mm LMP after satisfactory reduction of the right angle fracture. (*E*) Intraoperative view of 2-mm LMP and four 8-mm by 2-mm monocortical locking screws placed superior to the low-exiting mental nerve to stabilize the reduced left body fracture. (*F*) Postoperative panoramic radiograph confirms 2-mm. LMP and screws placement at the left body fracture, inferior to the short bicuspid and first molar roots and superior to the low riding inferior alveolar canal.

to the roots of teeth and inferior alveolar canal, with care taken to isolate and retract the mental nerve as it exits the mental foramen (Figs. 6 and 7). The incisions are closed with resorbable sutures; no drains are placed. A two-layered muscle and running mucosal closure is required to close the anterior vestibular incision to minimize dehiscence.

Table 3
Comparison of LMP and non-LMP

	LMP	Non-LMP
Stiffness (N/mm)	33.68 ± 5.22	28.54 ± 8.20
Yield displacement (mm)	8.25 ± 1.06	8.88 ± 4.12
Yield loading (N)	290.0 ± 3.6	245.7 ± 100.0

Based on incisal edge loading of mandibular angle fractures.

Patients are maintained on perioperative intravenous antibiotics during their hospital stay (average length of stay: 48 to 72 hours) and discharged home on oral antibiotics for 7 days until closure of the intraoral incision. After 1 week the MMF is released, wounds irrigated with normal saline, and the occlusion checked. Patients are advised to remain on a soft diet. Biweekly panoramic radiographs are taken until the arch bars are removed at the 6-week mark after clinical and radiographic evidence of satisfactory fracture healing.

Locking miniplate versus nonlocking miniplate

Adaptive miniplates provide functionally stable fixation, unlike rigid fixation that prevents micromotion of the bone fragments under function. Functionally stable fixation applies to internal fixators that allow bone alignment and permit osteosynthesis during function.

The 2.0-mm LMP has conical threaded holes that lock the corresponding threaded screw head to the plate. The screws, plate, and bone form a solid framework with higher stability than the traditional non-LMP system. The 2.0-mm LMP has demonstrated higher stability across the fracture/osteotomy gap (Table 3) compared with conventional 2.0-mm non-LMPs in laboratory bench studies. It is postulated that the LMP requires less precise adaptation of the plate to the underlying bone and decreases the chance of screw stripping. Noncompression decreases the risk of necrosis of the fracture segments and produces less stress shielding.

It is, in fact, the greater stability of the 2.0-mm LMP construct that has enabled a reduction of the period of MMF from 2 weeks down to 1 week, while maintaining an acceptable minor complication rate (9.4%) with 100% satisfactory fracture healing.

Summary

The use of a single 2.0-mm LMP adapted along Champy's line of ideal osteosynthesis and fixated with four 8-mm x 2-mm locking monocortical screws plus 1 week MMF is a viable treatment modality for most mandible fractures. The authors have recorded a low minor complication rate of 9.4% and 100% primary bone healing. The cost of the hardware is under $500 for the LMP and four locking screws. The average operating time, including application of MMF, is less than 60 minutes for a unilateral case and 90 minutes for a bilateral case. The average length of stay is under 3 days.

Case selection is the key to a satisfactory outcome. Current mandible fracture treatment protocol at Kings County Hospital-SUNY Brooklyn and affiliate hospitals includes the 2.0-mm LMP plus 1 week MMF for uninfected, noncomminuted mandible fractures for those patients in whom a transoral approach is indicated and a brief period of MMF may be tolerated.

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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 35–43

Atlas of the Oral and Maxillofacial Surgery Clinics

Bicortical Extraoral Plating of Mandibular Fractures

Lawrence Gorzelnik, MD, DMD[a,b,*], Edward Kozlovsky, DMD[a,c]

[a]University of Medicine and Dentistry of New Jersey, New Jersey Dental School, Department of Oral and Maxillofacial Surgery, 110 Bergen Street, Room B-854, Newark, NJ 07103-2400, USA
[b]Private Practice, 100 Kings Road, Madison, NJ 07940, USA
[c]Private Practice, 15 School Road East, Suite #1, Marlboro, NJ 07746, USA

The goal of bicortical fixation of mandibular fractures is to provide for undisturbed healing and immobility of fragments to facilitate primary bony union. This type of fixation should provide sufficient rigidity for fracture segments to resist any movement along the fracture line during normal function of the mandible. The decision of which technique to use for fixation of a particular mandible fracture depends on multiple factors, such as fracture location, favorability of fracture vectors, anatomic location of fractures, systemic health of the patient, timing of surgery, experience of the surgeon, age of the patient, and patient compliance. In this article, the authors discuss the indications and techniques of bicortical fixation of mandible fractures.

Patient assessment

Age and gender are important factors in evaluation and treatment selection for patients with mandible fractures. Younger patients have improved postoperative healing compared with older patients. Many elderly patients have decreased osseous density because of age-related osteopenia or various disease processes. Young men generate greater biting forces than women or elderly patients. Patients with chronic medical conditions, such as epilepsy, psychiatric disorders, and alcoholism, may not tolerate maxillomandibular fixation and may require open reduction with rigid fixation for fracture treatment.

Indications for open reduction and internal fixation of mandibular fractures

Fractures that may require open reduction and internal fixation (ORIF) include open fractures, displaced fractures, severely comminuted fractures, multiple fractures (mandibular fractures in combination with condylar/subcondylar fractures), infected fractures, fractures in medically compromised patients, atrophic mandible fractures in edentulous patients, and patients for whom maxillomandibular fixation is contraindicated. The type of fracture and its location play a primary role in selecting the surgical approach and type of fixation required for proper reduction and stabilization of the fracture. Restoration of proper occlusion should be the primary goal; application of maxillomandibular fixation should be achieved as a first step. In edentulous patients, existing dental prostheses or fabricated splints should be used for proper alignment of the maxilla relative to the mandible. They can be used as an intraoperative guide for rigid fixation or be held in place during the entire bone-healing period.

Fractures located along the ascending ramus and posterior to the second molar are considered mandibular angle fractures. In many cases, these fractures traverse through partially or completely

* Corresponding author. University of Medicine and Dentistry of New Jersey, New Jersey Dental School, Department of Oral and Maxillofacial Surgery, 110 Bergen Street, Room B-854, Newark, NJ 07103-240.
E-mail address: gorzellm@umdnj.edu (L. Gorzelnik).

1061-3315/08/$ - see front matter
doi:10.1016/j.cxom.2008.10.007

impacted third molars. These types of angle fractures pose several challenges for surgeons. If a third molar is partially impacted or comes into contact with the second molar, the fracture is considered to be an open fracture. Removal of an impacted third molar may displace fracture segments, which could potentially hamper adequate reduction and increase potential for inferior alveolar nerve injury. Angle fractures that require bicortical fixation are significantly displaced and occur in combination with other mandible fractures. Types of approaches and hardware used for fixation of these fractures are dictated by the location, displacement of fracture segments, comminution of fracture segments, position of third molar, and experience of the surgeon. A severely displaced left mandibular angle fracture is demonstrated in Figs. 1 and 2.

If the fracture line transverses the capsule of the temporomandibular joint, the fracture is considered intracapsular. Intracapsular fractures are treated with short periods of immobilization followed by physical therapy. Fractures below the capsule are condylar neck fractures, which are situated inferior to the capsule. Condylar neck fractures are further subdivided into low and high fractures based on proximity to the capsule. Condylar fractures generally do not require fixation and can be treated conservatively with full liquid diet or short-term maxillomandibular fixation. Subcondylar fractures originate from the area of the sigmoid notch and extend posteriorly. Treatment of subcondylar fractures depends on severity and vector of dislocation, patient dentition, and systemic medical condition. It is important to point out the potential risk of necrosis of the proximal segment caused by loss of vascular supply during dissection in open reduction treatment. Intra- and extraoral approaches have been described for the treatment of subcondylar fractures; however, both approaches may be required to allow for adequate visualization, reduction, and fixation for the fractures.

Fractures located between the mandibular canine teeth are designated as symphyseal (mandibular midline) fractures and parasymphyseal (lateral to the mandibular midline) fractures. In most cases, these types of fractures are considered open because of involvement of the mandibular alveolus and teeth. The treatment challenge in these types of fractures is to avoid a lingual gap and splaying during reduction and fixation, which would inevitably lead to malocclusion. Widening of facial projection can occur when angle fractures are present. Other important factors to consider when treating these types of fractures are the vectors of compressive, tensile, and torsion forces present at the symphyseal region of mandible. These forces must be taken into account when planning reduction and fixation of fracture segments.

Fractures located between the mandibular canine and second molar are considered mandibular body fractures. If the fracture travels through the alveolus in the dentate patient, it is considered an open fracture. Special consideration should be given to treatment planning, surgical approach, and options for fixation of these types of fractures. Specifically, attention

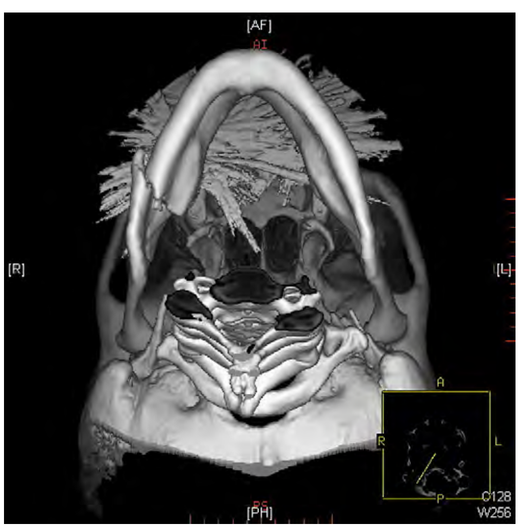

Fig. 1. Submental three-dimensional CT scan of laterally displaced mandible fracture secondary to motor vehicle trauma in a 44-year-old woman.

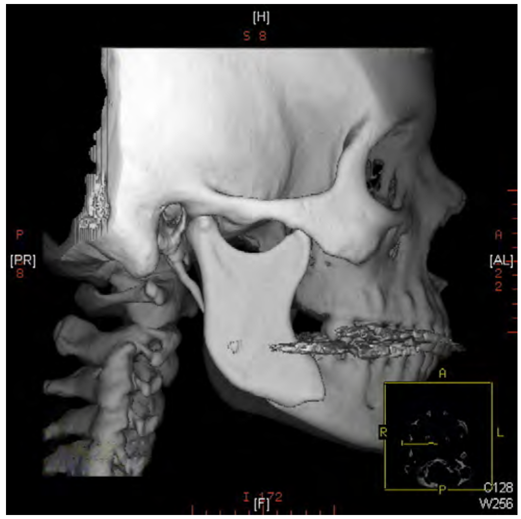

Fig. 2. Lateral three-dimensional CT scan of laterally displaced right mandibular angle fracture shown in Fig. 1. The fracture is displacing superiorly because of masseter, internal pterygoid, and temporalis muscle forces.

must be given to the location of the inferior alveolar and mental nerves. During the intraoral approach the mental nerve should be dissected and protected at all times. With the extraoral approach, attention must be given to the protection of the facial nerve during dissection and the location of the inferior alveolar nerve during fixation of fractures when using bicortical screws. Plate placement at the inferior border of the mandible via an extraoral approach can be done to avoid the path of the inferior alveolar nerve.

Presentation

Often the best way to visualize certain concepts is to demonstrate them in a specific patient. The situation created by bilateral subcondylar fractures and a parasymphyseal fracture presents some unusual challenges to surgeons. This situation is seen on the three-dimensional volume-rendered CT scan in Fig. 3. The splaying of the lingual cortex of the symphysis is not visualized with a closed reduction and is best seen and controlled through a submental incision when possible. In the case of bilateral subcondylar fractures, early mobilization of the condyles is preferred to prevent hypomobility and ankylosis. Rigid fixation with a plate and bicortical screws allows the mandible to be mobilized early to prevent these problems. The situation of a comminuted mandibular angle and body is illustrated in Fig. 4. A submandibular extraoral approach provides full visualization of the lingual cortex and allows for anatomic reduction of the fractures despite multiple segments. In the patient seen in Fig. 4, two lag screws were used to hold a small intermediate fragment in place. This is seen clearly in the close-up view of the same patient in Fig. 5.

Edentulous or partially edentulous patients also can present some unique challenges. Use of a patient's existing removable dental prostheses can aid in fracture repair and reduce laboratory time for fabrication of specialized splints. The patient in Fig. 6 underwent bilateral open reductions of the mandible with 2.0-mm system plates placed on the inferior border of the mandible. His posterior mandible was edentulous, so his bilateral distal extension partial denture was used as a surgical splint held secured with circum-mandibular wires. This approach served to reapproximate his preoperative occlusion and establish the arch form of the mandible. The surgical exposure and plate placement can be seen in Fig. 7, and the postoperative three-dimensional CT scans, posteroanterior film, and panoramic radiographs are demonstrated in Figs. 8–11. His submental incision, which was closed with a subcuticular closure, is seen in Fig. 12 after 1 week of healing. In the case of a patient who has no dental prosthesis, a submandibular approach allows direct anatomic reduction. Frequently, such patients are elderly, and incisions

Fig. 3. An 18-year-old male patient with panfacial fractures, including a displaced symphyseal fracture and bilateral subcondylar fractures. Note the splaying of the mandible and the increased distance between the mandibular angles secondary to the fracture trauma.

Fig. 4. Intraoperative view of a comminuted left mandibular body and angle fracture.

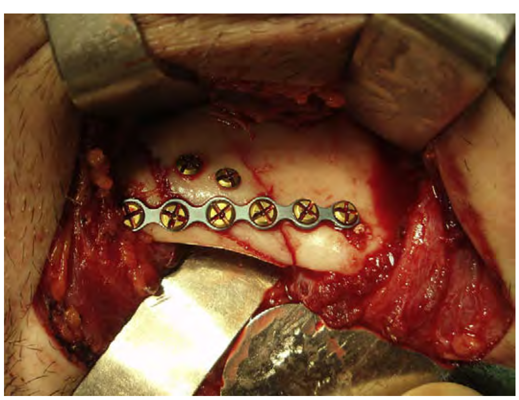

Fig. 5. Close-up intraoperative view of the left angle and body fracture shown in Fig. 4 illustrates bone plating and lag screw placement.

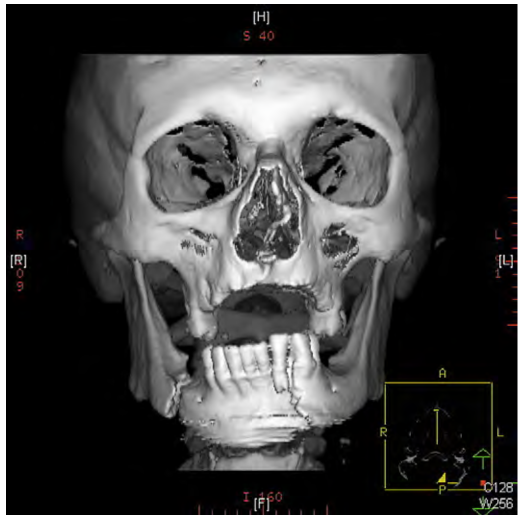

Fig. 6. A 61-year-old man with bilateral mandibular fractures secondary to trauma from being hit with a baseball while pitching at a game. Note the severe fracture displacement and patient's partial edentulous state.

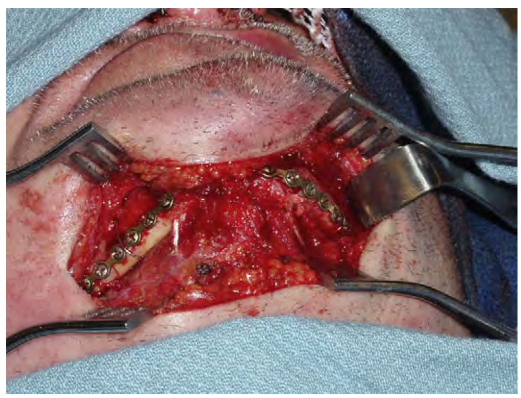

Fig. 7. Intraoperative view of the patient in Fig. 6 shows bilateral submental extraoral exposure. A circum-mandibular wire, which is visible on the patient's right side, secures the patient's bilateral distal extension partial denture. He has another such wire on the left side.

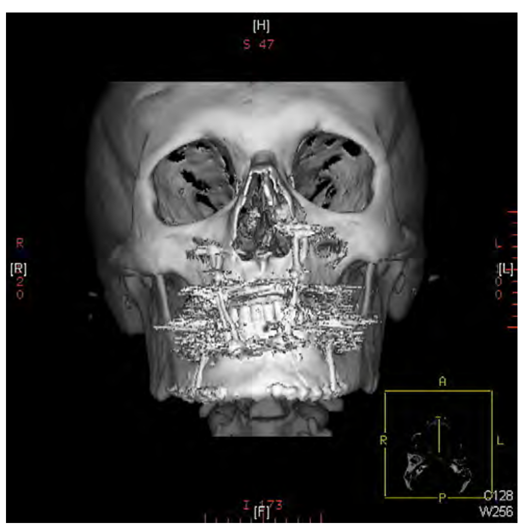

Fig. 8. Postoperative three-dimensional CT scan of the patient in Fig. 6. Note the skeletal suspension wires.

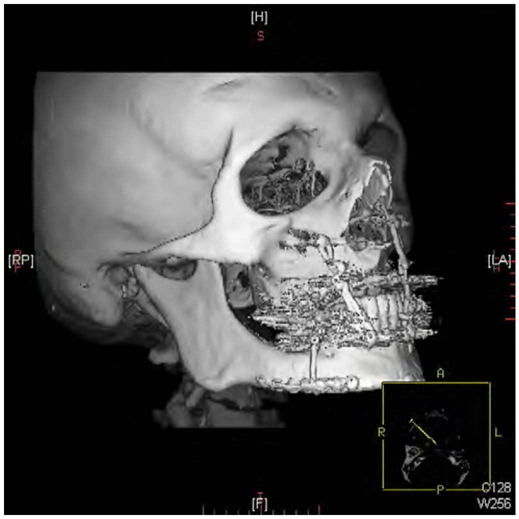

Fig. 9. Postoperative three-dimensional CT scan of the patient in Fig. 6.

Fig. 10. Postoperative three-dimensional CT scan of the patient in Fig. 6 shows reconstruction of the anatomic curvature of the mandible.

Fig. 11. Panoramic radiograph of the patient in Fig. 6 shows circum-mandibular wires on mandibular bilateral distal extension removable partial denture used as a surgical splint and maxillary partial denture in place with skeletal fixation screws and wires in the maxilla. The plates at the inferior border of mandible are Synthes 2.0-mm system plates.

Fig. 12. Postoperative healing of the extraoral submental incision of the patient in Fig. 6 at approximately 1 week.

Fig. 13. Postoperative lateral radiograph of a 70-year-old man with multiple facial fractures shows larger plate placement at the inferior border done through an extraoral approach.

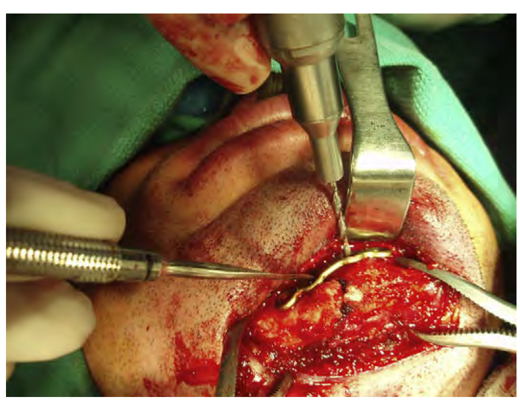

Fig. 14. Dingman bone clamps applied to the inferior border of the mandible secure fracture segments during plating.

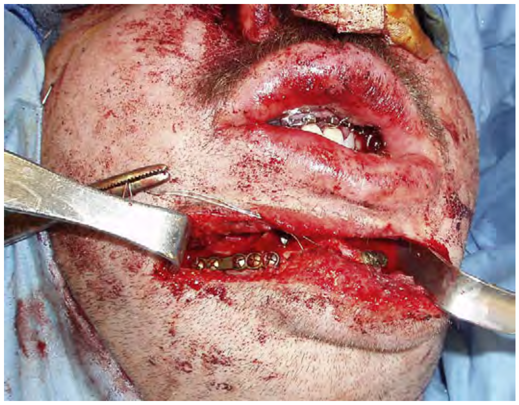

Fig. 15. A 24-gauge transosseous wire is placed through the mandible for control of the mandibular segments during plating and to counteract downward pressure from drilling procedures.

can be placed in rhytids or relaxed skin tension lines, which allows for maximal cosmesis. A larger bicortical plate can be placed via such an approach, as seen in the postoperative radiograph in Fig. 13.

Access to the mandible via an extraoral approach can be advantageous for multiple reasons. Control of the inferior border and avoidance of splaying of the lingual cortex are key advantages in multiple mandibular fractures. Kocher clamps or specialized Dingman bone clamps can be placed on the inferior border of the mandible via a neck incision to allow three-dimensional control of the fracture segments during plating procedures. These instruments also allow counterpressure to be applied in an upward direction while the operator applies downward pressure with the drill or screwdriver. This approach keeps segments in proper alignment during plating and ultimately ensures good fracture reduction. This technique is illustrated with Dingman bone clamps applied to a symphyseal fracture during drilling of a screw hole in Fig. 14. Another useful technique to accomplish this counterpressure in an upward direction involves placing a transosseous 24-gauge wire approximately 12 cm in length. One such wire placement is shown on a patient with bilateral fractures in Fig. 15. Upward traction on this wire during plating yields a similar effect of counterpressure to the use of bone clamps and may require less subperiosteal stripping in the area of the fracture. This technique is particularly useful in the types of lingually splayed symphyseal fractures represented in Fig. 3. If this counterpressure is not maintained, disruption of the dental occlusion can occur during the drilling and plate placement process. The arch bars and wires can easily shift with the forces applied to the fracture during open reduction, so the oral cavity should be inspected frequently to ensure that the occlusion is stable.

Plate size is another consideration that must be customized to the individual fracture and patient. Larger plates are indicated for cases in which maxillomandibular fixation is not used or in cases of early mobilization of fractures. Even in these cases, large reconstruction-type plates need not be used as long as the plate and the fracture are stable and resist muscular forces. Smaller plates are indicated for smaller mandibles and smaller patients, such as women and adolescents. The case illustrated in Figs. 7 and 8 demonstrates the use of a 2.0-mm plating system with a low profile placed at the inferior border using bicortical screws. This particular choice gave excellent primary fracture stability, although the patient was not kept in maxillomandibular fixation. In patients with a thin soft-tissue drape, thicker and larger plates should be avoided unless a continuity defect of the mandible is present that requires the strength of a large plate.

Summary

Bicortical fixation of mandibular fractures via a direct extraoral approach has distinct advantages. Control of the inferior border is a particular advantage in cases in which direct visualization of the fracture and control with clamps or wires can yield anatomic reduction.

Establishment of the dental occlusion is the first step in treatment of any mandible fracture. The second step involves stabilizing the fracture in cases that require an open reduction with internal fixation. Select patients require intraoral approaches for open reduction, and the trend toward minimally invasive endoscopic techniques for fracture treatment continues to grow. Careful selection and placement of submandibular incisions with careful wound closure can yield a positive cosmetic result in many patients.

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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 45–53

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External Fixation for Mandible Fractures

Hani F. Braidy, DMD*, Vincent B. Ziccardi, DDS, MD

Department of Oral and Maxillofacial Surgery, University of Medicine and Dentistry of New Jersey, 110 Bergen Street, Room B-854, Newark, NJ 07103–2400, USA

External fixation of mandible fractures is a technique in which segments are manipulated in place by pins and then fixated with some type of connectors. It is often considered a subtype of closed reduction and provides semirigid fixation to the fractured mandibular segments. Historically, the first example of splinted pins being applied to long bones was reported as early as 1853 by Malgaigne and by Rigaud in 1870. The first external fixator applied to the mandible was attributed to Ginestet in 1936. Clouster and Walker described modifying a Roger Anderson orthopedic appliance to treat comminuted mandible fractures during World War II. The first biphasic fixation device was introduced by Morris in 1949, which was a variant of older fixators intended as a temporary mean of fixation until acrylic was applied and cured to link the pins. Suddenly, external fixation became the most popular method to treat many types of facial fractures in the 1950s and 1960s until the advent of rigid internal fixation. Since then, the use of external fixators has significantly decreased but remains a useful technique in selected types of fractures, as reviewed in this article.

Indications for external pin fixators

In nonatrophic mandibles, most of the blood flow is supplied from the inferior alveolar vessels. By disturbing this central flow, mandible fractures subsequently rely on the periosteum and soft tissue envelope during the healing phase. In situations in which comminution is combined with a large amount of periosteal, muscle, or mucosal damage, an increased incidence of nonunion and infections can be expected. It is based on these biologic principles that most indications for external fixation have been developed, especially when maxillomandibular fixation is not adequate because of missing teeth on either side of the fracture or is contraindicated for concomitant medical reasons. Placing these devices does not require extensive periosteal reflection as compared with open reductions, thus preserving vascularity of bone fragments. Situations like extensive fracture comminution and severe tissue loss, such as that occurring in gunshot wounds, are well-accepted indications for external fixation. In theory, by treating these fractures in a closed fashion, the viability of the fragments is maintained without disrupting their blood supply (Fig. 1). These comminuted fractures then consolidate for 8 to 10 weeks before secondary surgery, if considered. At that time, the fractures are debrided or reconstructed. During the initial stabilization period of 8 to 10 weeks, the soft tissue is also allowed to be restored, optimizing future potential operations.

The technique of external pin fixation may also be considered when there is a large amount of bone loss in such conditions as pathologic fractures occurring through tumors, cysts, or severely atrophic mandibles. In these clinical scenarios, there may be not enough bone to adapt plates and screws reliably. Examples of pathologic fractures involving metastatic tumors, such as multiple myeloma of the mandible, are also amenable to temporary treatment with external

* Corresponding author.
E-mail address: braidyhf@umdnj.edu (H.F. Braidy).

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doi:10.1016/j.cxom.2008.10.001

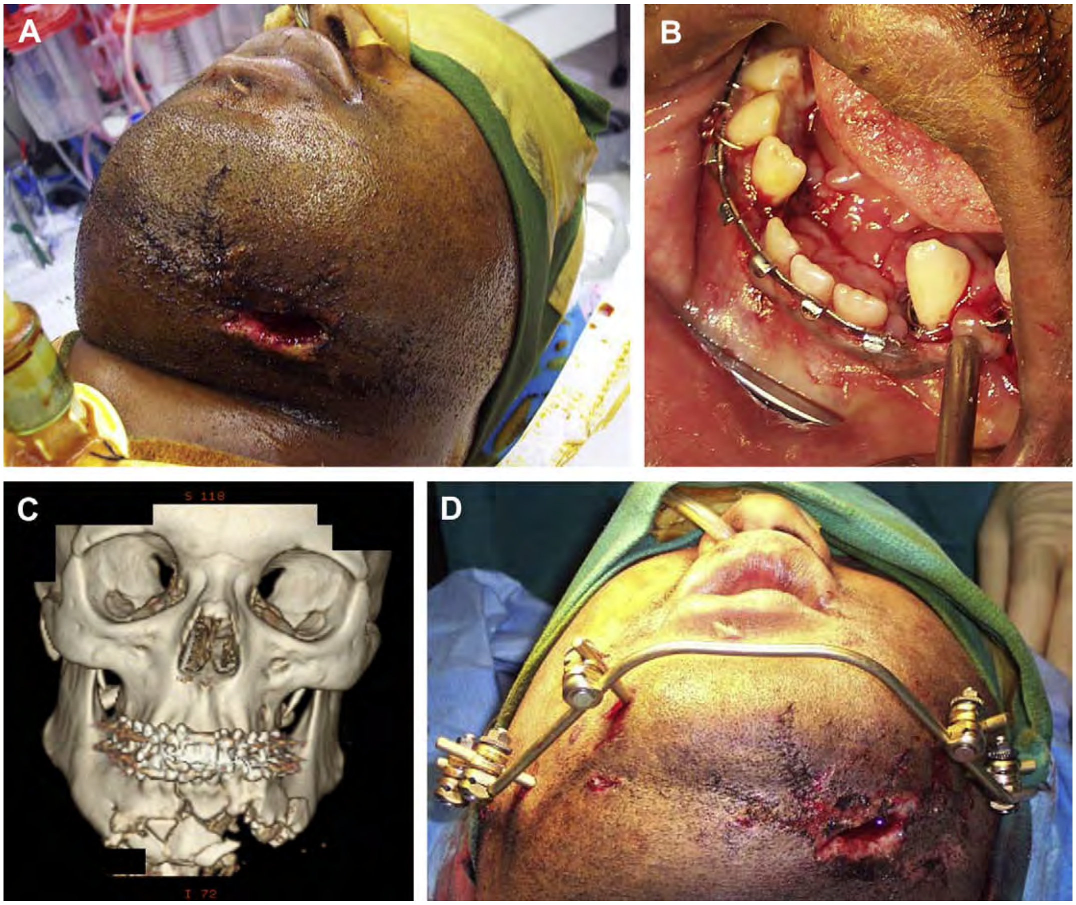

Fig. 1. (*A*) A 22-year-old male patient after a gunshot wound to the mandible. The exit wound is shown. (*B*) Intraoral soft tissue edema and displaced teeth. (*C*) Three-dimension reconstruction of the fractures. Note the extensive comminution. (*D*) External fixator in place using a titanium bar.

fixation until completion of radiotherapy and subsequent reconstruction, as illustrated in Fig. 2. Severe osteoradionecrosis of the mandible with fracture of the inferior border may also be provisionally managed with an external fixator until the conclusion of hyperbaric oxygen therapy and before definitive reconstructive procedures (Fig. 3).

Grossly infected fractures with significant soft tissue edema, cellulites, and osteomyelitis are also amenable to external fixation, thus avoiding large extraoral incisions and potentially difficult neck dissections (Fig. 4). This technique is often used as a temporary or final treatment, especially when teeth are absent proximally or when maxillomandibular fixation is inadequate. Once the infection is under control after a short period of external fixation, the fracture may be debrided and rigidly reconstructed. In addition, because the application of external fixators is rather simple and requires minimal operating time, it is sometimes used in patients with compromised health or in critically injured patients as a temporary means of fixation.

Recently, the use of external fixators has been described for the treatment of condylar fractures. This modality of treatment provides the opportunity for immediate function, and it is especially beneficial for intracapsular fractures in children. Because of limited surgical access to apply rigid fixation, it has been hypothesized that pins may be more suitable and the possible need for secondary plate removal or condylar displacement can be avoided. Because the external fixator was providing only semirigid fixation, the condyle would be under a physiologic load, improving long-term functional outcomes based on functional matrix concepts.

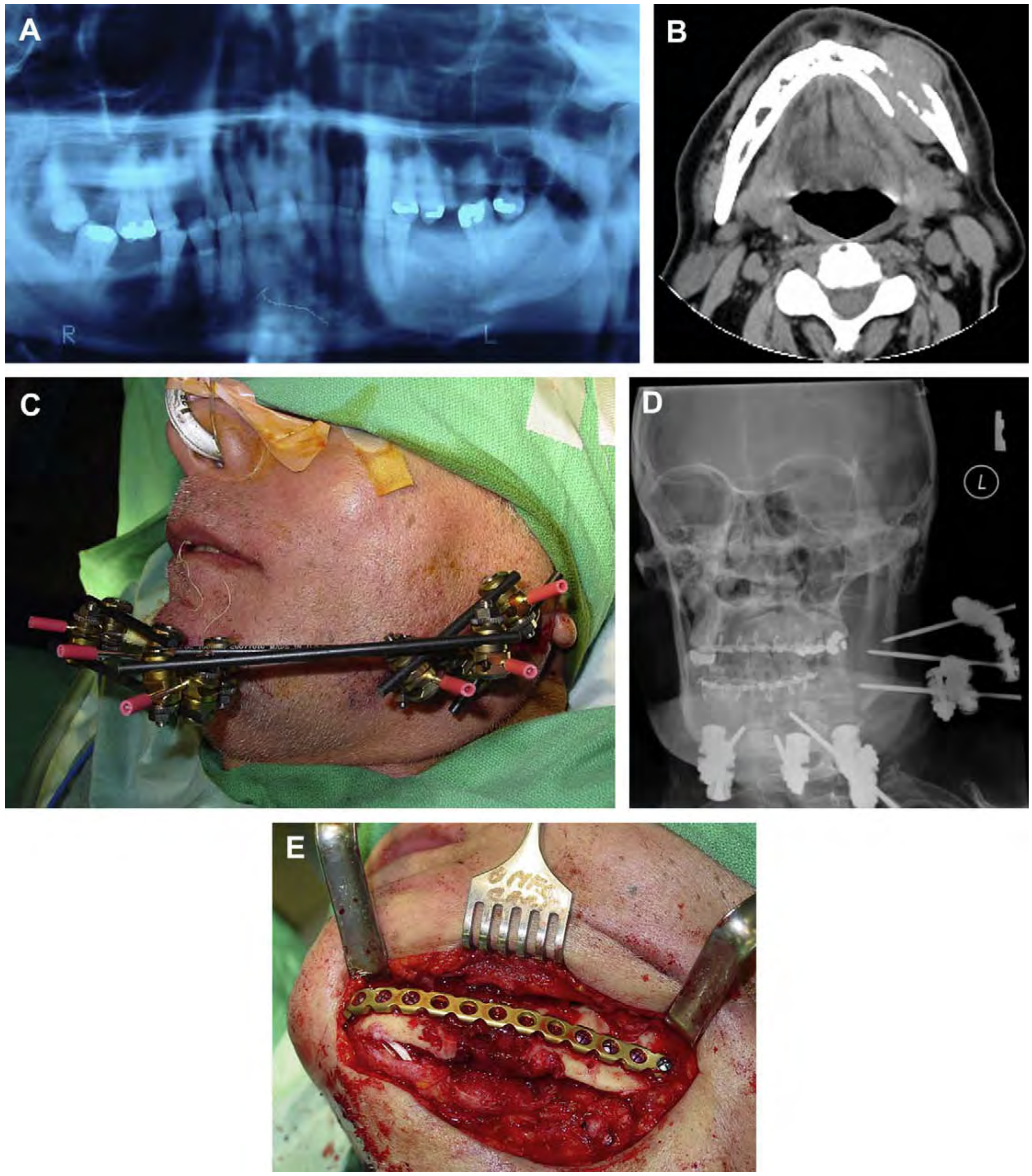

Fig. 2. (*A*) A 56-year-old male patient with multiple myeloma of the left mandible and pathologic fracture visualized on the panoramic film. (*B*) Axial CT demonstrates the extent of the tumor with the fracture. (*C*) Pathologic fracture is stabilized with external fixation until radiotherapy is completed. (*D*) Postero-anterior cephalogram demonstrates pin placement. Note that carbon rods are not radiopaque. (*E*) Debridement of the fracture, debulking of the tumor, and reconstruction plate applied at later stage.

The use of external fixation has many advantages because of its versatility and simplicity of use. Because the application of these devices does not require extensive surgical dissection and prolonged operating time, it is possible to place them with local anesthesia when general anesthesia is contraindicated or not available. In addition, control of bone fragments by manipulating the pins and connectors can be achieved after radiographic examination with or without the use of local anesthesia. Immediate function is also possible in selected situations,

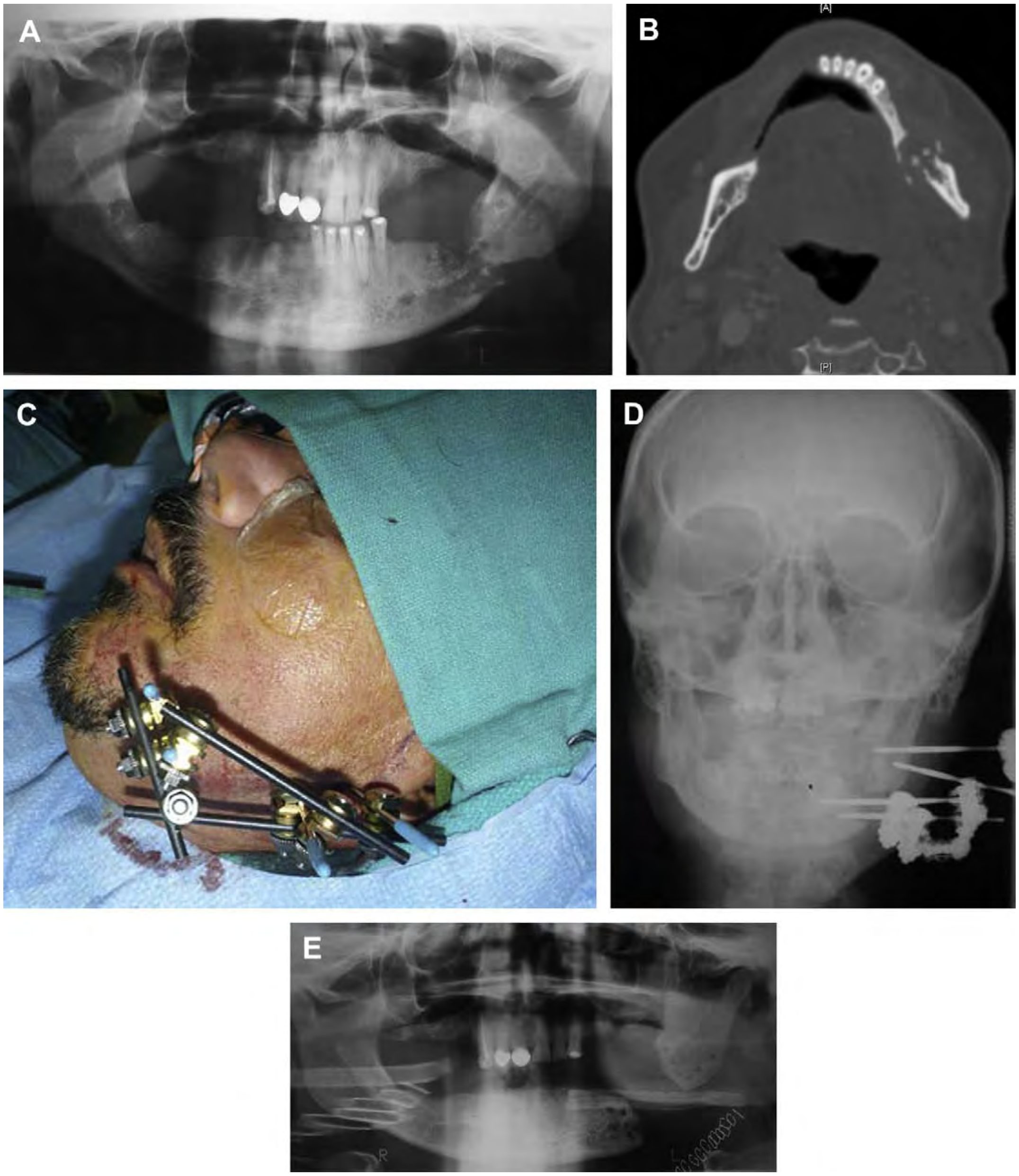

Fig. 3. (*A*) A 58-year-old male patient with osteoradionecrosis and infected pathologic fracture of the left mandibular body, as demonstrated in the panoramic film. (*B*) Axial CT demonstrates the extent of the osteoradionecrosis. (*C*) External fixation device is in place until completion of hyperbaric oxygen therapy. (*D*) Postoperative Postero-anterior cephalogram shows pin placement. (*E*) Panoramic film depicts subsequent debridement of the fracture and removal of the appliance.

yielding improved stomatognathic function, oral hygiene, and patient comfort. Unfortunately, because of the location of the hardware, external fixation devices are often cumbersome for patients. Scarring around the pins may present as dimples on the skin requiring subsequent excision or revision. In addition, it may be difficult to achieve precise bony anatomic reduction, thus occasionally necessitating the use of intraoperative fluoroscopy. When nonunion or malocclusion occurs after the healing period, a secondary open procedure is most likely required.

Fig. 4. (*A*) A 32-year-old male patient after an assault in which he sustained bilateral mandible fractures with subsequent extensive soft tissue cellulitis and abscess. Note the poor dentition proximal to the fractures on panoramic film. (*B*) Incision and drainage of the abscess was performed with external fixation of his fractures. The patient healed without complication, and the appliances were removed 8 weeks later.

Types of external fixation systems

Several types of external fixation devices exist. The oldest type is a modified Roger Anderson device, which is considered to be uniphasic and consists of two percutaneous pins on either side of the fracture linked together by a metal bar and connectors. This apparatus would remain in place for approximately 8 to 10 weeks until the fracture healed. A biphasic system, such as the Joe Hall Morris appliance, consists of a primary connector used as a reduction rig, which is temporarily placed until a secondary phase, usually self-curing acrylic, is placed to join the pins (Fig. 5A). The primary connector is then removed, leaving a light and rigid device in place.

Recently, newer versions of the uniphasic system have been made commercially available for use based on upper extremity and hand external fixators, such as those used in orthopedic surgery (Fig. 5B). Lightweight straight carbon fiber or prebent titanium rods are connected to the threaded pins or Kirschner wires with versatile snap-on titanium clamps. Wires and clamps are the only radiopaque components of this system The Shanz pins (screws), made of titanium, are 2.5 to 4.0 mm wide and are self-drilling or self-tapping. This system's simplicity of use has made it well accepted for external fixation at the authors' institution.

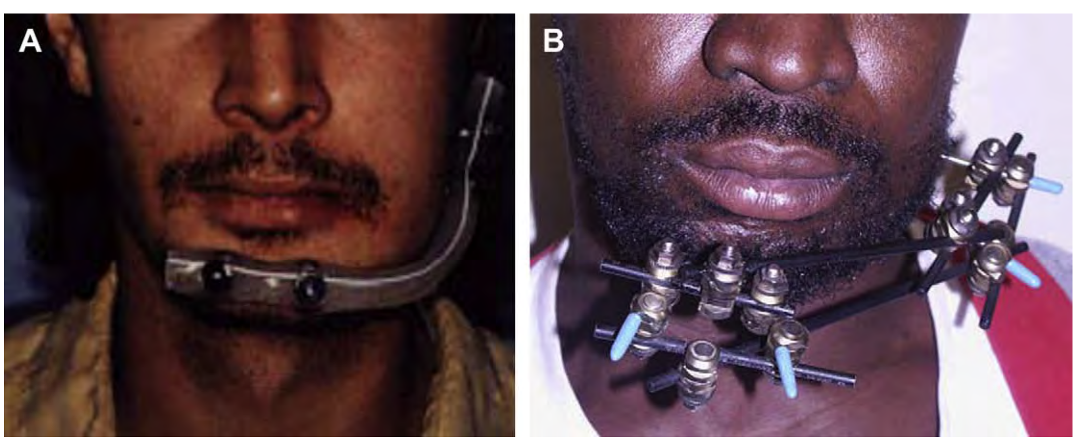

Fig. 5. (*A*) Joe Hall Morris (biphasic appliance). An endotracheal tube was used to contain the acrylic. (*Courtesy of* B. Zweig, DDS, Newark, NJ.) (*B*) Modern uniphasic device with Kirschner wires as pins and straight carbon fiber rods as connectors. Note the titanium clamps linking the pins to the rods (Synthes Maxillofacial, Paoli, Pennsylvania).

Surgical considerations for application of external pin fixations

It is recommended that at least two pins be placed on each side of the fracture. Buccal and lingual cortices should be engaged for proper fixation. It is critical to confirm the location of the fractures, because segments can be displaced or telescoped. A short cutaneous stab incision is sufficient to allow placement of the drill bits. After blunt dissection, a trochar or pediatric nasal speculum can be used to protect the skin from the drills. According to histologic studies, the optimal drill speed is 500 rpm to minimize bone necrosis.

Thicker pins tend to loosen less often. Pins are typically placed at 70° from bony surfaces in a divergent fashion (toward the operator), thereby maximizing bony screw retention. At least two pins are placed in each of the segments approximately 25 mm apart and at least 10 mm from the fracture margins (Fig. 6C). It is best to position the pins where bone is thickest to minimize hardware loosening. The inferior border of the mandible and the posterior and anterior portions

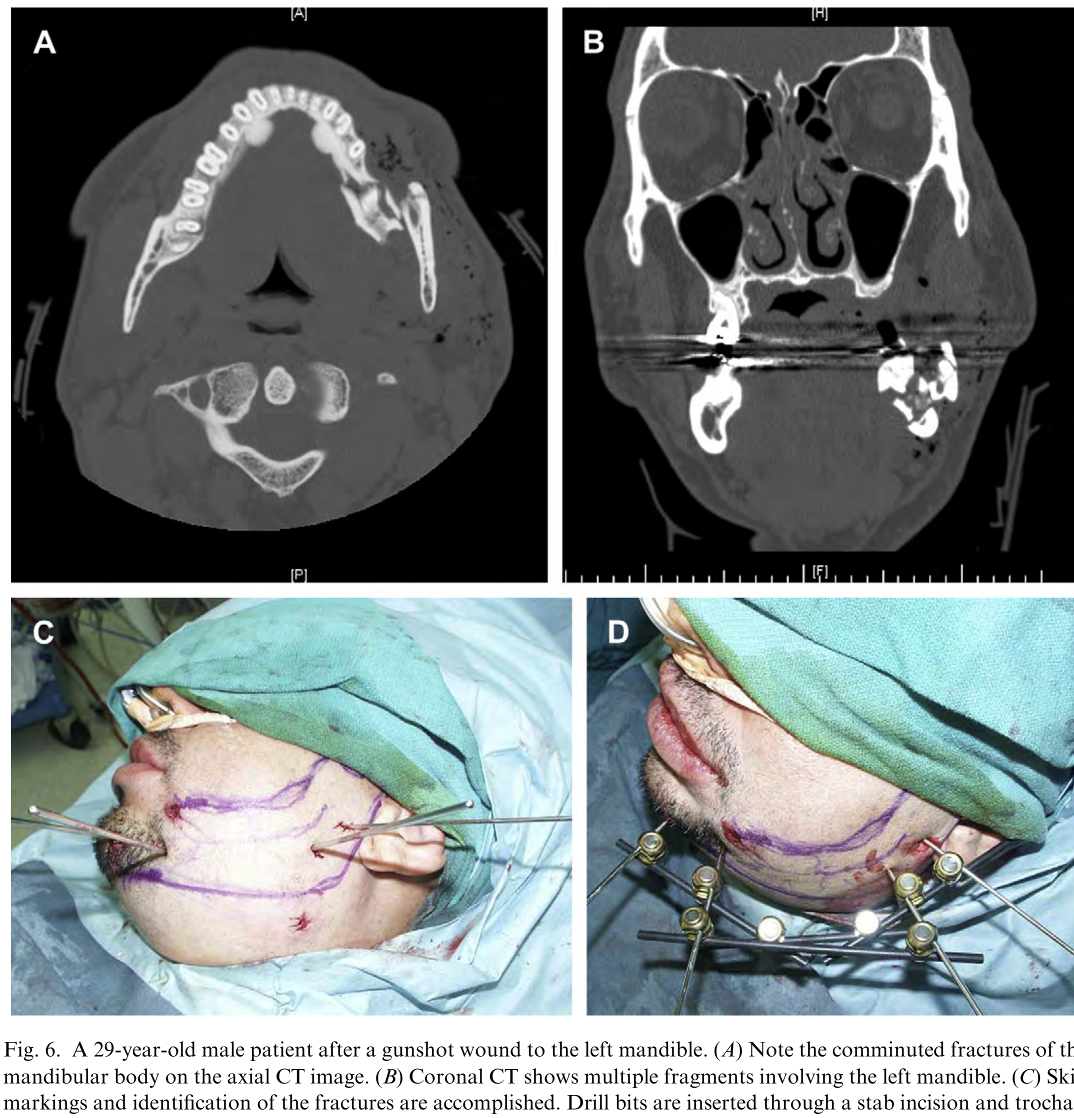

Fig. 6. A 29-year-old male patient after a gunshot wound to the left mandible. (*A*) Note the comminuted fractures of the mandibular body on the axial CT image. (*B*) Coronal CT shows multiple fragments involving the left mandible. (*C*) Skin markings and identification of the fractures are accomplished. Drill bits are inserted through a stab incision and trochar. Two pins are placed at least 10 mm from the fracture, 25 mm apart. (*D*) Pins on the same side of the fracture are joined together with one or two rods. Each set of pins is then linked across the fracture with additional rods. (*E*) Postoperative posterior-anterior cephalogram shows pin placement and reduction of mandibular fragments. (*F*) Panoramic radiograph shows consolidation of the fracture 8 weeks after external fixation. (*G*) Definitive treatment consisted of debridement of the area, bone graft, and reconstruction of the defect.

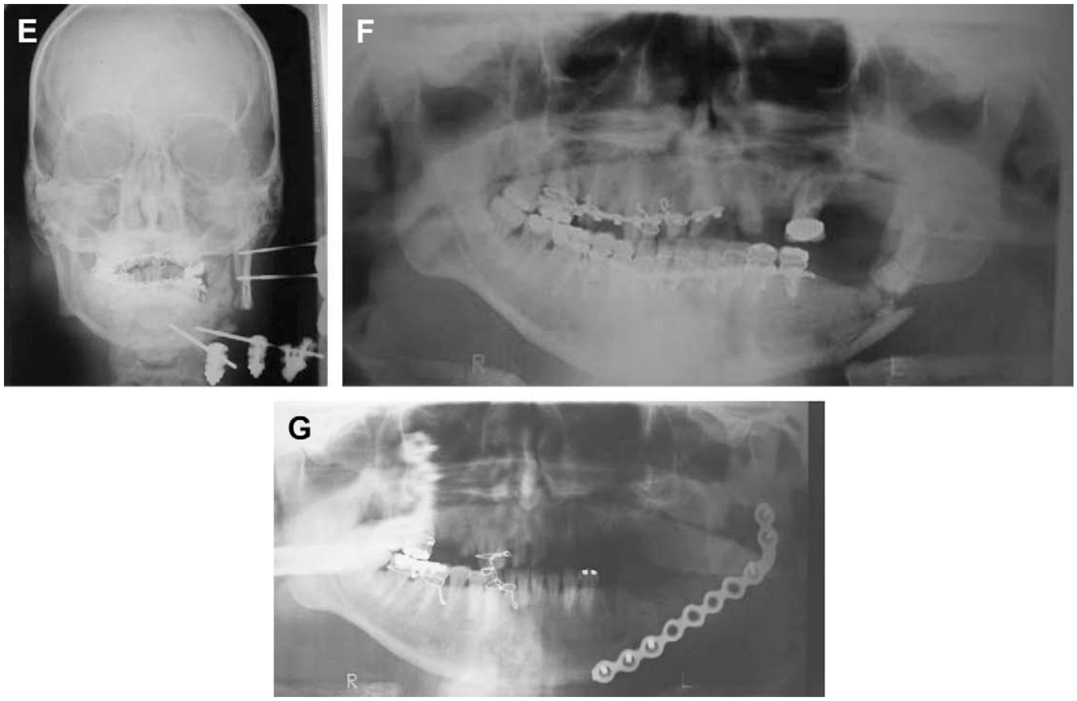

Fig. 6. (*continued*).

of the ramus are good anatomic choices. Care should be taken to place the pins away from the teeth, developing tooth buds, inferior alveolar canal, facial artery and vein, and retromandibular vein.

Connectors should be placed at a sufficient distance from the skin to allow for anticipated soft tissue edema (Fig. 6D). If they are placed too far from the skin, the device may become cumbersome for the patient. Once the reduction is confirmed, the connector's nuts and bolts may be tightened. When using a biphasic fixator, the acrylic may be injected directly into an orotracheal tube attached to the pins with wet sponges placed on the skin to minimize heat during acrylic curing. Vaseline-impregnated gauze is then placed around the pins for a few days during the early healing phase. After 8 to 10 weeks of healing, the fixation devices may be removed. Connectors are loosened, and pins are then twisted out, usually under local anesthesia. Before removal of a biphasic appliance, the acrylic may be gradually thinned out over the last few weeks so as to load the mandible functionally. When the fracture finally has healed, the acrylic must be sectioned between each pin before taking the system apart. Alternatively, newer systems allow rapid application of carbon rods or a titanium framework to be applied to pin connectors (the authors' preferred technique).

Complications of external fixation devices

Because of the general nature and severity of the mandibular fractures treated by external fixation, a high complication rate of up to 35% has been reported. Postoperative infections, cellulitis around the pins, nonunions, malocclusions, and pin loosening are potentially frequent with this fixation technique (Fig. 7). Other complications include injury to the inferior alveolar nerve, especially with atrophic mandibles. Rarely, damage to the facial vessels may occur and may require surgical ligation. A small ring of necrotic bone surrounding the pins has been reported in the literature and may require local debridement. In addition, damage to the parotid gland and subsequent mucocele and sialocele or salivary fistula formation have been reported. Skin burn from the acrylic polymerization may occur if proper precautions and technique are not followed.

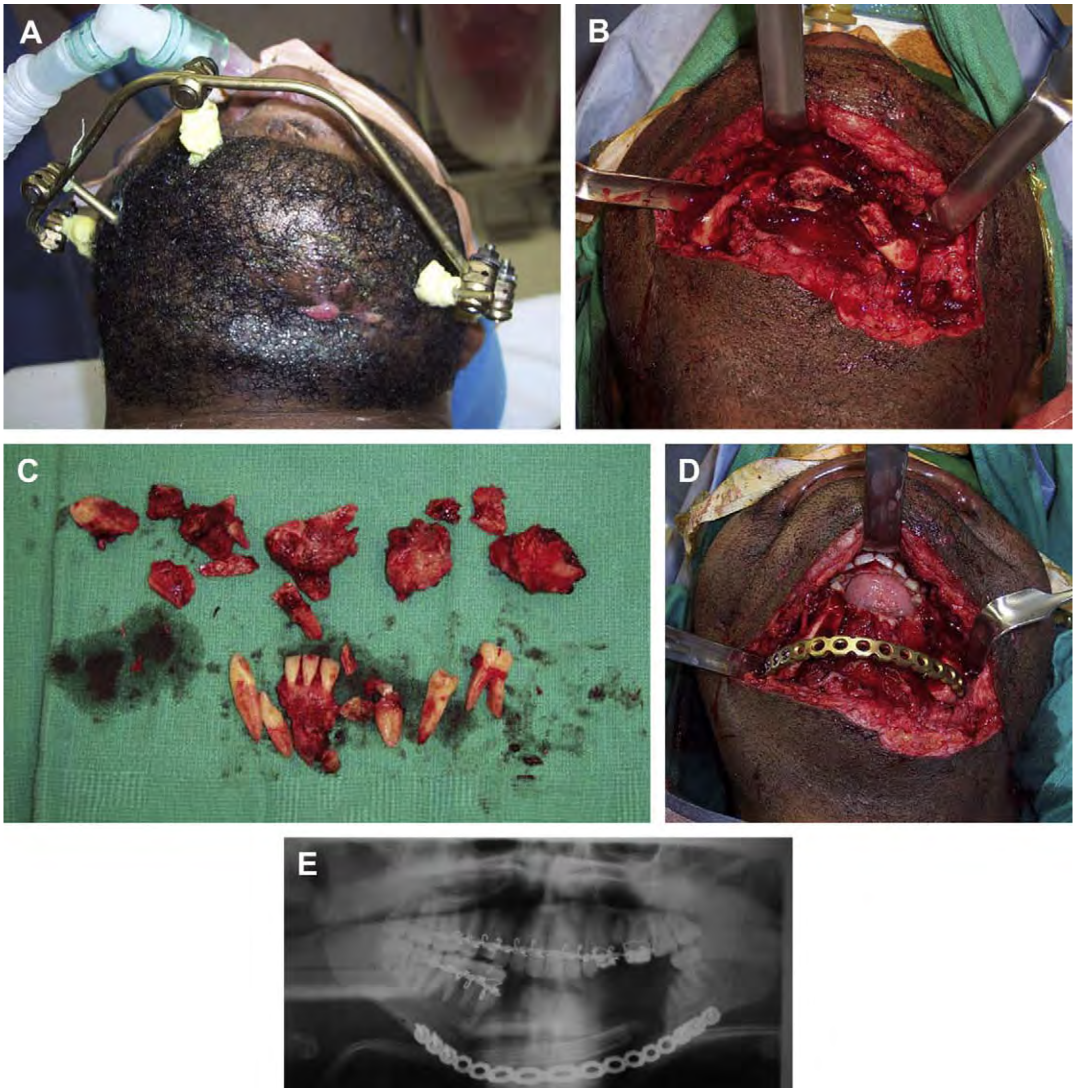

Fig. 7. (*A*) Patient in Fig. 1 (gunshot wound to the mandible), 4 weeks after external fixation, presented with extraoral purulent drainage. (*B*) Clinical exposure of the mandible fractures reveals large necrotic segments deemed unsalvageable. (*C*) Debridement of bone and teeth fragments. (*D*) Reconstruction of the mandibular defect; bone graft was delayed until resolution of the infection. (*E*) Postoperative panoramic film demonstrates the bony defect and the placement of the titanium reconstruction plate.

Summary

In summary, external fixation of mandible fractures is a useful technique when an open treatment is contraindicated because of extensive comminution, bone or soft tissue loss, and infection. This technique can also be used temporarily until definitive treatment is delivered. A uniphasic system, such as a modified Roger Anderson appliance, or a Joe Hall Morris appliance, a biphasic system, can be placed to reduce and stabilize mandibular fractures. These systems use surgically placed threaded pins and different types of connectors that can be manipulated to optimize the reduction of fractures. External fixation remains a quick, safe, and simple method to treat mandible fractures in selected clinical situations, and it should be part of the armamentarium in surgeons treating these injuries and fractures.

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Management of Condylar Fractures

André H. Montazem, DMD, MD[a,b,c,*],
George Anastassov, MD, DDS[b,c]

[a]*Division of Oral and Maxillofacial Surgery, Mount Sinai School of Medicine, New York, NY 10022, USA*
[b]*Division of Oral and Maxillofacial Surgery, The Mount Sinai Hospital, 1 Gustave L. Levy Place, New York, 10029, NY, USA*
[c]*Department of Oral and Maxillofacial Surgery, Room D3-25C, Elmhurst Hospital Center, Elmhurst, NY 11373, USA*

Condylar fractures are a unique subset of traumatic injuries to the maxillofacial skeleton. While these injuries must be managed according to the general principles of fractures management, there are a variety of special considerations that are peculiar to the condylar region that are not present in fractures of the nonarticulating maxillofacial skeleton. These additional points of consideration are due to the function of the condyle as a moving unit within the temporomandibular joint and the fact that the condylar unit serves as a mandibular growth center. As a result of the functional requirements of the condylar area, the oral and maxillofacial surgeon must balance the principles of maxillofacial fracture management with restoration of temporomandibular joint function and the potential impact of the injury on growth and development. The salient features of condylar fracture management are addressed along with illustrative cases to demonstrate certain key points.

Anatomic considerations

In order to appreciate the complexity of the temporomandibular joint it is important to understand the anatomy of this articulation and how the anatomy is altered by traumatic injuries. The condyle resides in the articular fossa and is surrounded circumferentially by the capsular ligament which is a tendinous expansion arising from the periosteum of the margins of the glenoid fossa and inserting on the most superior aspect of the condylar neck. This tightly bound capsular ligament helps to maintain the condyle within the fossa except under the most severe of forces. The function of the capsular ligament is supported to some degree by the collateral ligaments and the lateral or temporomandibular ligaments. The collateral ligaments arise off of the medial and lateral disc margins and blend with the capsular ligament onto the condylar neck. The lateral ligaments are present only on the lateral aspect of the joint space and condyle and also serve to restrict extreme movements. Of note, these ligaments all serve to prevent dislocation of the condyle from the articular fossa and also to maintain the disc–condyle–fossa relationships. When these anatomic relationships are disturbed, the effects on the condyle can become problematic.

Muscular attachments to the condylar region are limited and include mainly the lateral pterygoid muscle. The lateral pterygoid arises from the lateral aspect of the lateral pterygoid plate and from the infratemporal surface of the greater wing of the sphenoid. The lateral pterygoid is composed of two distinct muscle bellies. The inferior belly inserts onto the medial aspect of the condylar neck at the pterygoid fovea. The superior head inserts onto the disc,

* Corresponding author. Department of Oral and Maxillofacial Surgery, Room D3-25C, Elmhurst Hospital Center, Elmhurst, NY 11373.
E-mail address: andre.montazem@mssm.edu (A.H. Montazem).

doi:10.1016/j.cxom.2008.11.002 **oralmaxsurgeryatlas.theclinics.com**

capsule, and medial surface of the condyle. Owing to this unopposed muscle pull, fractures of the condylar head often exhibit displacement anteriorly in the glenoid fossa as the lateral pterygoid exerts its influence (Fig. 1A–C). For the same reasons, subcondylar fractures often exhibit anterosuperior rotation. Low subcondylar fractures may have variable muscle pull from the medial pterygoid muscle and the masseter depending upon fracture configuration.

The articular fossa is bounded by a number of vital structures. Superiorly, the glenoid fossa is bounded by the contents of the middle cranial fossa. Rarely, fractures involving the articular fossa occur through the roof of the glenoid fossa resulting in intracranial injury. Posteriorly, the articular fossa is bounded by the external auditory canal. Injuries with a significant posterior vector may cause injuries to the middle ear, disruption of the external auditory canal, and, occasionally, stenosis or narrowing of the canal.

The role of the disc or meniscus in internal derangement can be debated; however, it may play a pivotal role in preventing complications associated with these fractures. While the disc is positioned between the condyle and the articular fossa in the normal temporomandibular joint it serves as an anatomic barrier to separate the condylar head from the glenoid fossa. Although it is not clear whether abnormalities in disc position will have any impact on fractures involving the joint space, it has been suggested that the presence of the meniscus plays an integral role in preventing ankylosis of the temporomandibular joint after condylar fractures. It seems that the development of posttraumatic ankylosis is a multifactorial process whereby a number of conditions must be in place to result in this serious complication.

Anatomically, the adult condyle is composed of dense cortical bone and a variable amount of cancellous bone depending upon the age of the patient. The condylar neck is generally long and slender. This configuration results in a preponderance of subcondylar fractures in adults rather than fractures of the condylar head. This must be held in contrast to the morphology and make-up of this area in children. In the pediatric population, cortical bone is generally thinner and more elastic than in the adult population. The condyle, serving as a growth center, is composed of abundant marrow spaces. In addition, the condylar neck in the pediatric mandible is shorter

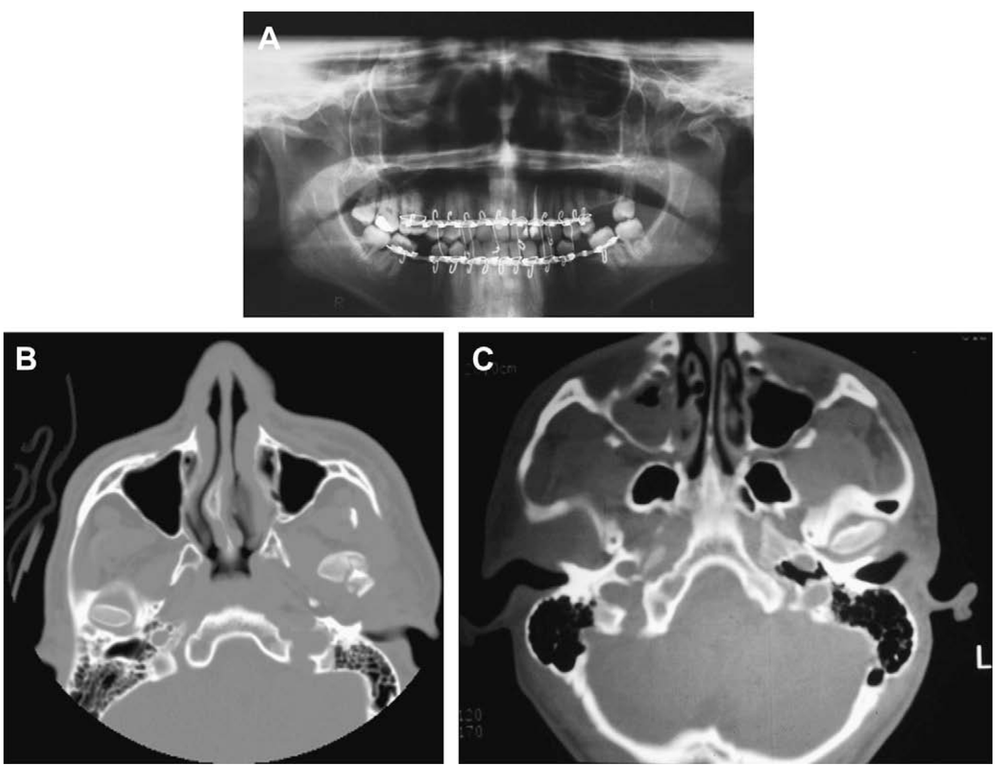

Fig. 1. (*A*) Panoramic radiograph demonstrating the anterior displacement of the condylar segment on left side. (*B*) Axial CT demonstrating anterior displacement of the condylar head. (*C*) Axial CT scan demonstrating ‘‘empty fossa’’ sign due to dislocation of condyle from right glenoid fossa.

and broader than in that of the adult. As a consequence, condylar process fractures are more common in children than they are in adults.

Classification of condylar fractures

There have been many attempts to create classification systems for fractures of the mandible. Fractures of the condylar region may be classified into intra-articular and extra-articular categories. This classification is somewhat simple but serves a useful purpose in treatment algorithms. Operative management will often depend upon whether the fracture is intra-articular or extra-articular in nature. Intra-articular fractures can be further subdivided into lateral pole fractures, medial pole fractures, condylar head fractures contained within the capsular ligament (Fig. 2A), and comminuted fractures. Since surgical treatment options are generally limited in cases of intra-articular fracture, these injuries may often be treated nonoperatively. The ability to reduce and fixate these fractures is hampered by limited access and small fragment size which can make fixation of these fractures difficult. Nonoperative techniques based upon physiotherapy and the recovery of range of motion and masticatory function are the most commonly employed modalities in these types of fractures. Avoidance of posttraumatic ankylosis is an important consideration; and physiotherapy and range of motion exercises are the most effective techniques in preventing this complication. Lateral pole fractures are fairly common and generally require nothing more than palliative treatment such as analgesics and soft diet. The lateral pole fracture typically does not affect articulation or condyloramal length which is maintained by the intact portion of the head of the condyle which remains attached to the condylar neck and ramal components of the mandible. Likewise, medial pole fractures typically do not cause disturbances in occlusion or condyloramal length. The treatment of these types of fractures remains largely symptom based.

Comminuted fractures of the condylar head remain the most problematic of the intra-articular fractures. This is due to the inability to reduce and fixate these fractures. Of all the fractures of the condylar region, the comminuted fracture type has the potential to lead to the most significant complications of all these injuries. Once multiple bone fragments are dispersed throughout the articular fossa, the potential exists for union of the scattered fragments in ectopic positions. Heterotopic bone formation may also ensue compounding the problem. In the case of the pediatric patient, with thin layers of cortical bone surrounding large marrow spaces, these types of fractures disperse an abundant supply of potent osteogenic material throughout the fossa. When this occurs in concert with guarding and immobilization, it is not difficult to understand how ankylosis can occur. The role of the meniscus in the prevention of ankylosis requires mention. If the capsular ligament is not disrupted, all of the fragments should lie within the fossa. Furthermore, the meniscus should serve to separate the condyle and its bony fragments from the articular fossa. This would likely be enough to prevent ankylosis as it would separate the condylar stump and all of the fragments from fusing to the glenoid fossa. Abnormalities in condylar morphology would still exist as the bone fragments consolidated in their aberrant position.

The management of extra-articular fractures of the condylar region is subject to a much greater debate. A variety of treatment algorithms have been proposed based upon degree of displacement, position of the displaced condylar fragment, loss of condyloramal length and angulation of the proximal fragment to the ramus. Treatment options for these injuries include observation with soft diet, functional therapy with guiding elastic traction, closed reduction and open reduction with or without internal fixation. Treatment decisions are based upon the likelihood of postoperative complications and whether the complications are more likely with or without surgical treatment. These concerns form the basis of the controversy in the treatment of these injuries.

Indications for surgical management of condylar fractures

There are well-accepted absolute indications for open treatment of subcondylar fractures. These absolute indications are as follows:

Dislocation of the condyle into the middle cranial fossa
Inability to open mouth or establish occlusion after conservative therapy

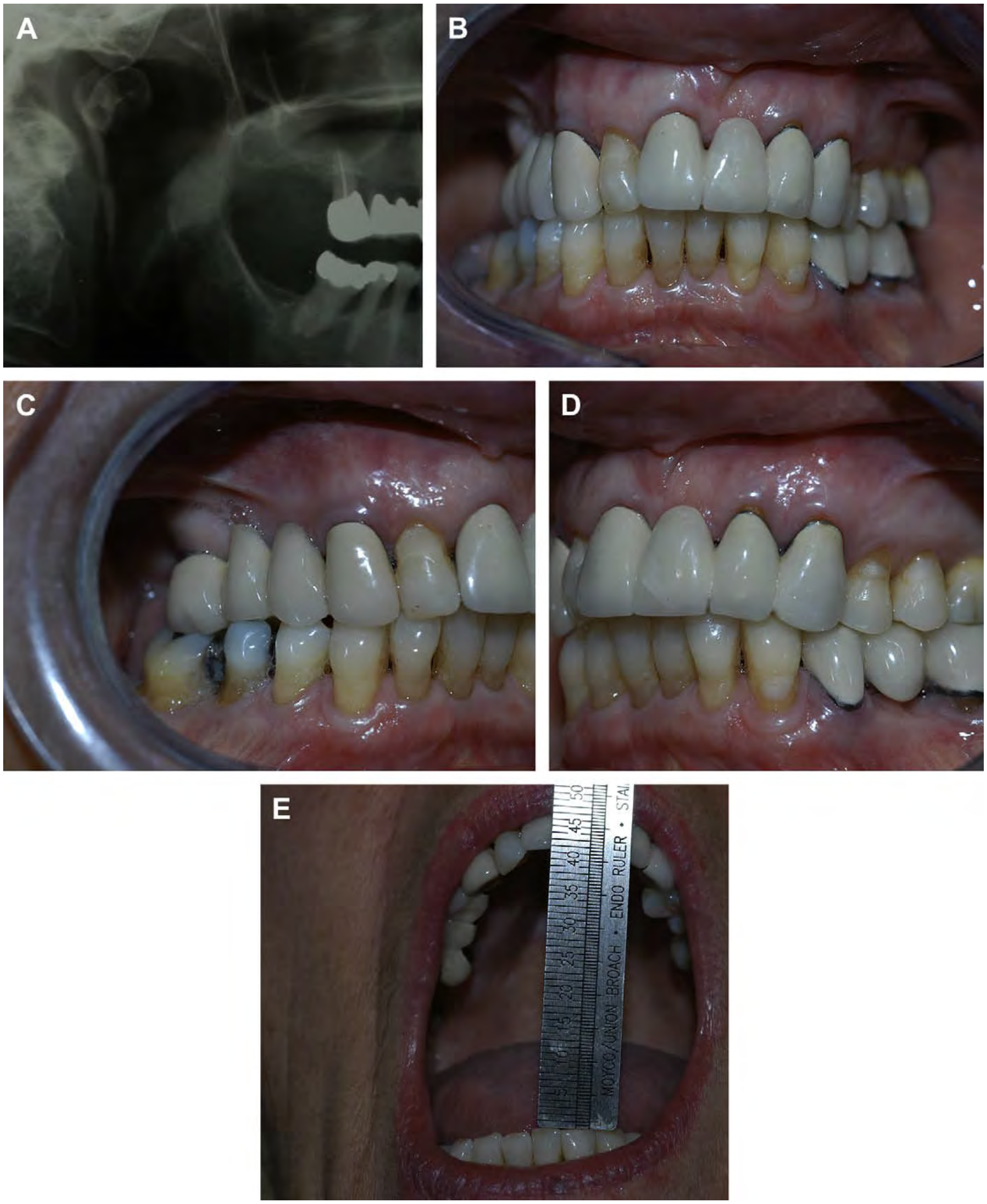

Fig. 2. (*A–E*) Pretreatment panoramic radiograph demonstrating intracapsular fracture of the right condylar head and the 1 year postoperative clinical outcome after closed treatment of the fracture and use of guiding elastics. Note the satisfactory occlusion and maximal incisal opening, but with a deviation of the mandible to the affected side which is otherwise asymptomatic.

Intra-articular foreign body
Lateral extracapsular displacement.

There are also a variety of relative indications:

Medical necessity (alcoholism, seizure disorder, bulimia, and so forth)
Displacement of the condyle out of the fossa
Bilateral mandibular fractures involving subcondylar fracture.

In addition, there are proposed absolute indications for conservative therapy which include the following

Intracapsular fractures
Fractures in small children
Fractures without dislocation.

Treatment options

Observation may be employed in cases where the occlusion is unaffected by the fracture. In these cases, symptomatic therapy is provided including soft diet, analgesics, and occasionally anti-inflammatory medications. It is important to note that occasionally edentulous patients may sustain a subcondylar fracture which does not require intervention. Fabrication of new dental prostheses may be all that is required to restore a functional occlusion in this small subset of patients. This may be the most prudent course in the elderly patient with significant comorbidities. Pain on function can typically be managed by analgesics and avoidance of functional activity that exacerbates painful symptoms. Once the symptoms begin to subside, function can be initiated by advancing the diet, as tolerated, to regular consistency. Range of motion should be monitored for progression to normal maximal incisal opening. If return to maximal opening is delayed, range of motion exercises can be initiated; however, return to normal function is usually enough to improve mouth opening without formal physical therapy. In a small minority of cases, active physical therapy may be required in the form of mouth stretching exercises. This physical therapy is generally patient directed and may include scissoring of the fingers between the incisal edges, progressive tongue blade exercises or, rarely, mechanical therapy such as a TheraBite appliance (Athos Medical AB, Hörby, Sweden).

When there is an occlusal disturbance or pain that is refractory to analgesics, some form of active treatment should be initiated. The simplest form of treatment is the application of maxillomandibular fixation which can be performed using a variety of different techniques. Immobilization of the jaw prevents joint function and mandibular movement thereby allowing symptomatic relief. This form of treatment generally allows for restoration of interdental relations while allowing for soft tissue healing by immobilization of the injured joint or mandible. The maxillomandibular fixation can be released after a short period of time to begin jaw function and assess for resolution of painful symptoms. In addition, the occlusal relations are also assessed to determine the need for additional treatment.

When the occlusal relations are not in accord with the preinjury state or a functional shift is identified, therapy should be instituted. For this reason, the application of Erich arch bars is desirable as it allows for the application of training or guiding elastics. The elastic therapy is guided by the nature of the malocclusion. In most cases of unilateral fracture, there exists a prematurity of the posterior occlusion and a variable rotation of the mandible to the affected side owing to loss of condyloramal height on the side of the fracture. The use of arch bars allows for multiple points to apply traction which can be used to exert any necessary combination of forces and vectors. Occasionally in patients with extensive or intricate restorative dentistry, alternatives such as application of orthodontic appliances may be used to avoid damage to fragile prosthetic components or the gingival tissues. Orthodontic appliances with a full complement of surgical lugs or attachments provide an excellent means for application of varying vectors of force and are much kinder to the soft tissues. The arch bars or orthodontic appliances can be removed once the occlusion has stabilized.

The temporomandibular apparatus has an amazing capacity to adapt to changes in condylar position within the fossa while maintaining occlusal relations. This is the case despite sometimes dramatic alterations in condylar morphology and condyloramal height (see Fig. 2A–E). However, in certain cases, a prematurity may persist despite a long period of elastic guidance and training. In most of these cases the occlusal irregularity is minor and is easily corrected with some occlusal equilibration with no appreciable alteration of facial esthetics. Rarely, patients may be left with a significant malocclusion which must be addressed by comprehensive orthodontic therapy or corrective jaw surgery.

The decision to perform an open surgical procedure is based upon the predicted likelihood of an unfavorable outcome with nonsurgical treatment. Unsatisfactory outcomes are typically related to a reduced height of the condyloramal unit on the fractured side. This is most often seen in cases which exhibit severely displaced fractures with marked loss of vertical dimension. When a poor functional or esthetic outcome is anticipated the decision will be made to perform a surgical procedure. Once the decision has been made to perform a surgical procedure, a decision has to be made as to which procedure will be performed. A variety of techniques are available for open reduction of fractures of the condylar region. Access will ultimately be determined in large part by the position of the fracture and operator preference. For fractures of the condylar head, any of the standard approaches to the temporomandibular joint may be performed. These include the preauricular approach, a modified endaural approach or, occasionally, a postauricular approach. The postauricular approach would be the access of choice in those cases with injury to the external auditory canal resulting in stenosis and significant air conduction deficits with diminished hearing. The modified endaural approach may be preferred as it allows for the incision line, and therefore the scar, to be hidden behind the tragus.

Approaches to the temporomandibular joint

In the preauricular approach, a skin crease is identified in front of the auricle beginning at the superior pole of the helix and continued down anterior to the tragus to a point just below the base of the tragus. A hockey stick extension into the hairline is neither necessary nor desirable in a standard temporomandibular joint approach. In the modified endaural approach, the incision begins in the same crease as described for the preauricular approach but then extends onto the posterior aspect of the tragus, rather than in a preauricular skin fold, ending at the base of the tragus (Fig. 3). At this point, the remainder of the dissection is the same for the preauricular and modified endaural approach. The dissection proceeds down through skin, subcutaneous tissues, and the temporoparietal fascia until reaching the superficial layer of the deep temporal fascia in the superior limb of the incision in the preauricular skin fold. Along the inferior limb of the incision, the dissection proceeds to the same depth anterior to the tragal cartilage. It is important to remember the inclination of the helix and the tragus so as to avoid injuring the cartilage during the dissection. Attention is then redirected to the superior portion of the incision, where the flap is reflected anteriorly with an army-navy–type retractor. An incision is then created through

Fig. 3. Outline for the modified endaural approach to the condyle.

the superficial layer of the deep temporal fascia approximately 30° to the long axis of the helix thereby exposing a layer of fat between the superficial and deep layers of the deep temporal fascia. The incision is extended inferiorly onto bone at the root of the zygomatic arch at the most posterior extent of the glenoid fossa which is identified by palpation. Care should be taken to avoid transection of temporalis muscle fibers during this portion of the dissection as this will result in unnecessary bleeding and postoperative trismus.

A subperiosteal reflection is accomplished, exposing the root of the zygoma, lateral lip of the articular fossa, and proceeding anteriorly until the articular tubercle is exposed. By performing a subperiosteal reflection from the root of the zygomatic arch, the temporal branch of the facial nerve which lies in the confluence of fascias and periosteum is protected. This plane of dissection lies along the capsular ligament providing full exposure to the joint space. The remainder of the dissection is completed along the pre-tragal limb of the incision to the depth of the capsular ligament. Access to the joint space is then accomplished by way of any of a number of techniques through the capsular ligament into the inferior joint space to gain access to the condyle. Access to the area medial to the ramal stump can be enhanced by the application of a Kocher clamp on the angle of the mandible to exert inferior displacement of the ramus.

Fixation of a condylar segment is difficult to perform because of minimal bone stock available for application of hardware. If fixation is considered necessary, supplemental incisions will likely be required to allow access down to the inferior portion of the condylar neck and the ramus. This approach is most suitable for removing displaced condylar fragments that are a risk for mechanical problems within the joint or in cases of ankylosis. It is also required for reconstructive procedures involving replacement of the condyle by way of a costochondral graft. These approaches do not provide adequate access for fractures of the subcondylar area and an alternative approach is recommended. Complications from these approaches are rare if the proper planes of dissection are followed. Facial nerve injury can occur with excessive retraction, especially inferiorly where an alternative approach would have been more suitable. Damage to the ear cartilage can also occur resulting in deformity of the tragus if the cartilage is mishandled. Infection is rare and the scars are generally well concealed and leave an excellent cosmetic result.

Endoscopic management of subcondylar fractures

Minimally invasive surgical techniques have gained popularity in recent years. This is due to a reported decrease in postoperative pain, limited incisions resulting in lesser scars, and earlier return to function and social activities. Endoscopically assisted treatment of mandibular subcondylar mandibular fractures was initially developed to improve visualization of this otherwise difficult-to-access area. The endoscope was inserted through a limited submandibular approach (Risdon). The fixation screws were applied transfacially, which was a potential drawback of the technique causing cumbersome manipulation and potential trauma to the underlying neurovascular structures and resulting in facial scarring. Eventually, improved endoscopic instrumentation was developed allowing for limited intraoral access, manipulation, and fixation. These innovations have significantly reduced the operative time, which in experienced hands approximates or is even shorter than that for standard open reduction.

Typically, 30° and 45° endoscopes are used. Angulated drilling handpieces and screwdrivers have been developed for application of the fixation hardware (Fig. 4). A high-intensity xenon light source is used for illumination of the optical field. Even though the surgical instrumentation and techniques have greatly improved, some concerns still remain. These concerns are mainly related to the difficulty of manipulation of the anteromedially displaced proximal segments, limited surfaces available for application of adequate rigid fixation (two miniplates or specialized three-dimensional plates), and the need for plating along the posterior border of the ascending ramus. In cases of inadvertent hemorrhage from branches of the internal maxillary artery the control of the bleeding may be difficult. Numerous reports presenting excellent results have been published, which is encouraging. The benefits of the endoscopic technique for treatment of subcondylar fractures are mainly the avoidance of visible facial incisions for access and improved and magnified visualization of the fracture site. Due to the limited dissection, less edema and pain are anticipated and, hence, earlier return to function. The drawbacks

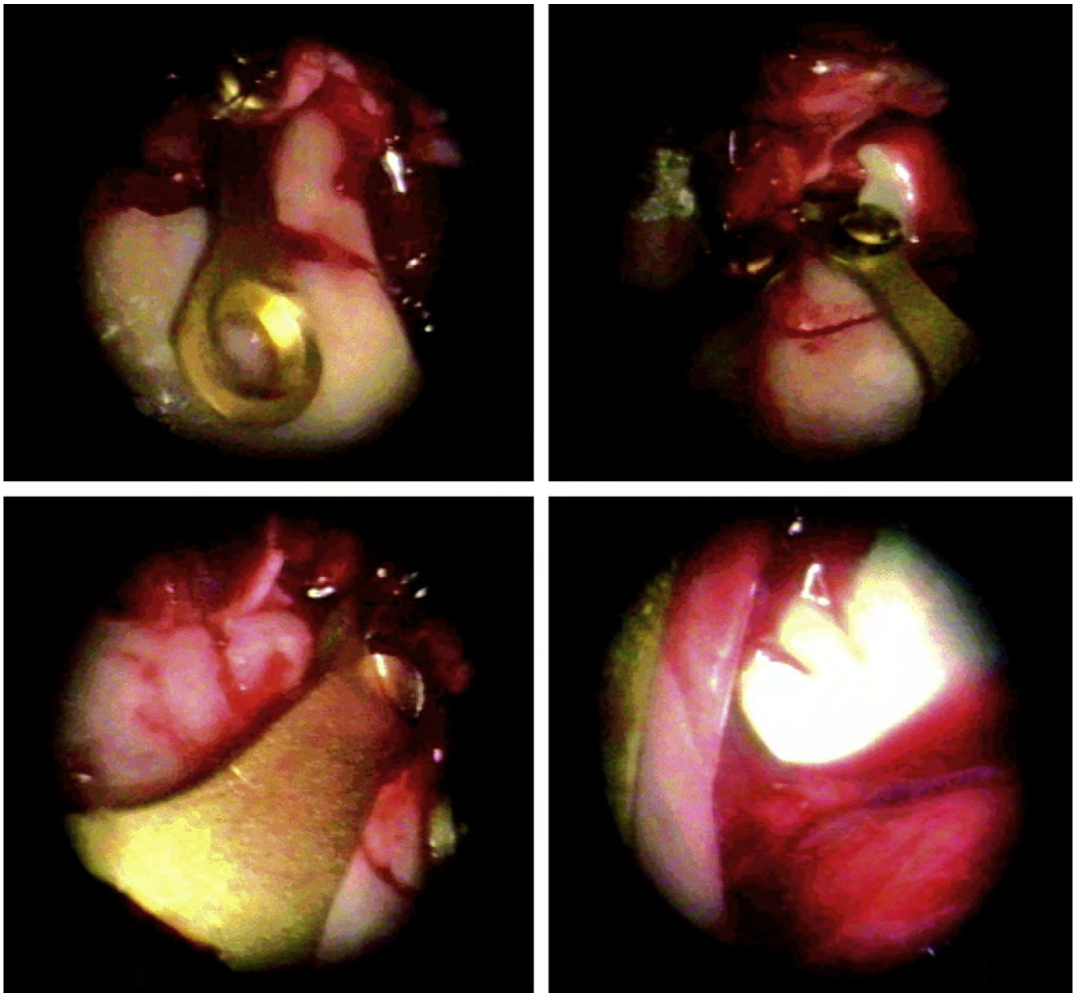

Fig. 4. Endoscopic view of a dislocated left condylar fracture after exposure of the fracture site and following plate fixation at the cranial aspect of the fracture with one screw in the condylar fragment (*above, left*). The fracture was reduced by pulling the plate caudally, and fixation was performed with only two screws at the cranial aspect (*above, right*). The result of fracture reduction is controlled endoscopically before the second plate is placed parallel to the posterior aspect of the mandibular ramus. Anatomic reduction of the fracture and placement of the second plate parallel to the posterior border of the mandibular ramus are controlled endoscopically (*below, left*). Note the precise fracture reduction at the posterior border of the mandibular ramus (*below, right*).

to the endoscopic technique are the need for specialized, expensive instrumentation and a steep learning curve.

The role of arthroscopic assisted reduction of condylar fractures has yet to be determined. A number of successful cases have been reported; however, the indications for this procedure appear to be limited to a select subset of cases involving fractures of the condylar head which has been determined to require repositioning. In this technique, the disc–fossa relationship must be preserved as the reduced condylar position is stabilized by anchorage of the disc posteriorly to the lateral capsule.

Risdon approach

The Risdon approach, which provides access to the ramus and subcondylar areas of the mandible, is suitable for reduction and fixation of all but the high subcondylar fractures. Access is limited to the condyle and neck of the condyle regions. A curvilinear incision approximately 4 to 5 centimeters is marked onto the skin with a marking pen at the region of the angle of the mandible approximately one finger-breadth inferior and posterior to the angle of the mandible.

The dissection proceeds through skin, subcutaneous tissue, and down to the platysma. A nerve stimulator is employed to identify branches of the facial nerve, most commonly the marginal mandibular branch which can be found below the inferior border of the mandible in this area. Branches of the facial artery and vein are usually identified, ligated, and divided during the dissection. The submandibular gland may be identified at the anterior extent of the incision and is not disturbed. The tendinous insertions of the masseter are identified and divided allowing a subperiosteal dissection with wide exposure to the ramus and subcondylar areas (Fig. 5A–C).

Of note, manipulation of the fracture segments is greatly enhanced by deferring the application of maxillomandibular fixation until reduction is accomplished. Reduction of the fracture can be aided by inferior traction on the ramus with the use of a Kocher clamp applied to the angle of the mandible which allows easier manipulation of the proximal segment. Once satisfactory reduction is accomplished, maxillomandibular fixation can then be applied and fixation can be accomplished according to the operator's preference. Bicortical fixation with application of at least two well-engaged screws on each side of the fracture is recommended. Due to the high functional load in this area, care must be taken in plate selection for risk of fractured hardware. A rigid mandibular fracture plate or two adaption-type plates are suggested in this area.

Complications from this approach include injury to the marginal mandibular branch of the facial nerve with resultant paresis or paralysis of the depressor anguli oris. Recovery of function is common as most of the nerve injuries are due to forces of retraction rather than true nerve damage. Additional complications include hypertrophic or unsightly scarring, failure of hardware, malocclusion, and malunion.

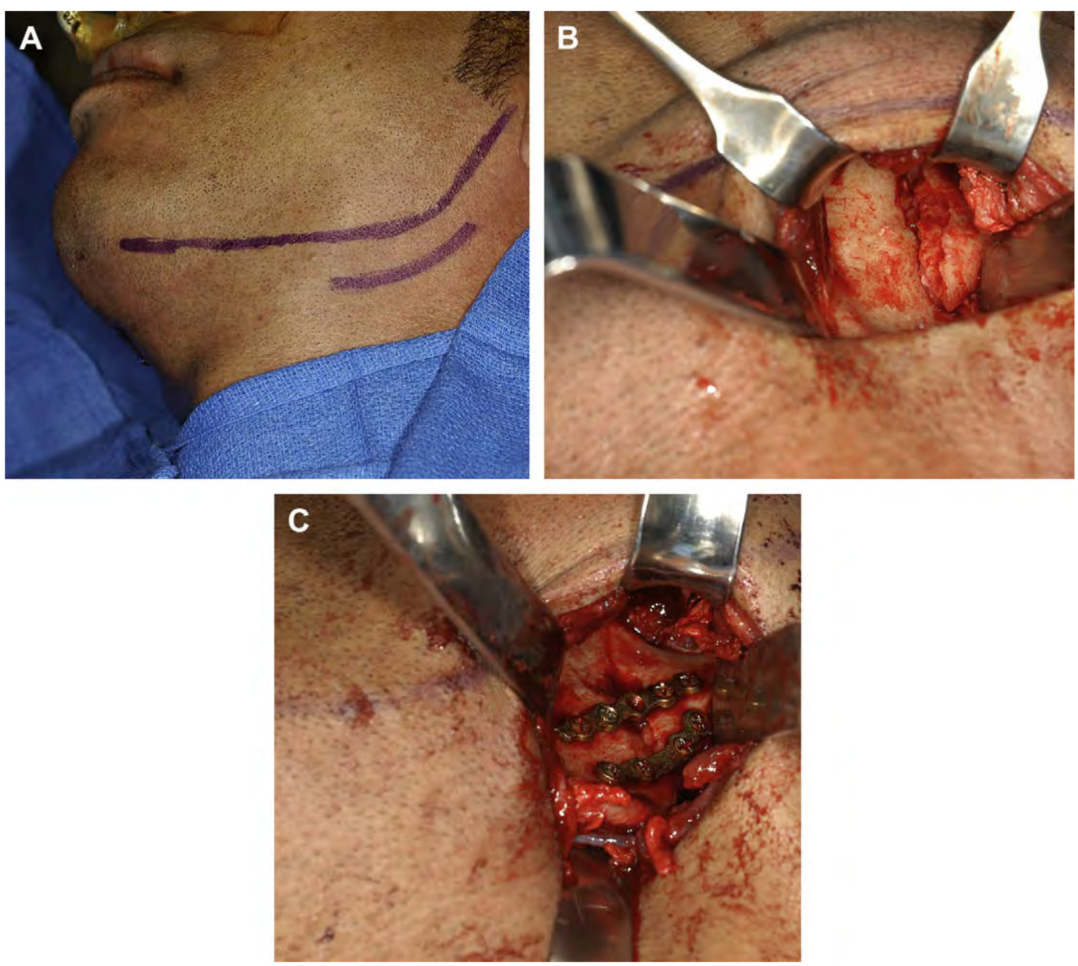

Fig. 5. (*A*) Outline of mandible and proposed Risdon type incision. (*B*) Exposure of low left subcondylar fracture prior to reduction. (*C*) Demonstration of anatomic reduction and internal fixation using a two plate technique.

Retromandibular approach

The retromandibular, or Hinds approach, is another alternative to the exposure and fixation of subcondylar fractures. In this technique, the incision is designed parallel to and behind the posterior border of the mandible beginning approximately 1 cm below the earlobe. It is continued inferiorly as long as is necessary depending upon the position of the fracture. The dissection proceeds through skin, subcutaneous tissue, and the superficial musculoaponeurotic system (SMAS) until reaching the parotid capsule. The parotid gland is retracted superiorly and anteriorly exposing the pterygomasseteric sling which is divided along with the periosteum to provide direct access to the ramus and subcondylar areas. Nerve testing should be performed for the marginal mandibular and cervical branches of the facial nerve. The retromandibular vein may be encountered but rarely requires ligation. Complications for this approach are similar to those described for the Risdon approach.

Facial rhytidectomy approach

The facial rhytidectomy approach results in the least noticeable postoperative facial scar while allowing increased exposure for direct visualization for reduction and fixation of subcondylar fractures. While operating through an open approach there are numerous anatomical considerations. In the parotideomasseteric region the nerves to be protected are the auriculotemporal, greater auricular, spinal accessory, and the very important facial nerve. The vascular structures in the area are the superficial temporal, transverse facial and facial arteries and veins. In the lower face, below the zygomatic arch the branches of the facial nerve are deep to the SMAS (Fig. 6).

The correct plane of dissection (ie, below the SMAS) provides for clear visualization and protection of the branches of the facial nerve. There are two main divisions of the facial nerve: the frontotemporal and cervicofacial. In management of subcondylar fractures by way of the facial rhytidectomy approach, the buccal, marginal mandibular and the cervical branches are identified. The buccal branch is located in the sub-SMAS plane approximately 5.5 to 6 cm anterior to the earlobe in a line parallel to the zygomatic arch. The zygomatic branch is 3 cm anterior to the tragus on the tragal-canthal line. The marginal mandibular branch is located below the platysma immediately under the mandibular angle 4 to 4.5 cm inferior to the lower pole of the earlobe. The cervical branch of the facial nerve is located approximately 1 to 2 cm below the marginal mandibular branch. The branches of the facial nerve emerge above the SMAS 2 to 2.5 cm lateral to the labial commissure. Therefore, if the dissection is extended under the SMAS anterior to this landmark, transection of the facial nerve branches is possible. The

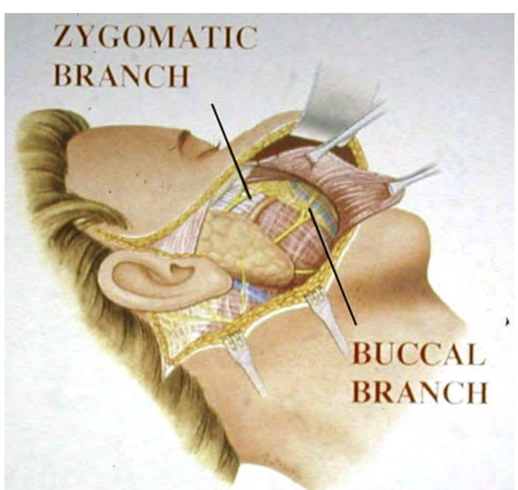

Fig. 6. Branches of the facial nerve below the zygomatic arch and deep to the SMAS.

parotideomasseteric fascia is deep to the SMAS and envelopes the parotid gland and the masseter muscle. The facial artery and vein are located at the intersection of the anteroinferior border of the masseter and the inferior border of the mandible. The retromandibular vein joins the facial vein anteroinferiorly and the external jugular vein posteriorly.

The incision follows a classic facial rhytidectomy design starting at the superior pole of the helix of the ear and then continues in a preauricular skin crease inferiorly extending onto the posterior aspect of the tragus and then in front of the earlobe. Posteriorly, the incision continues onto the conchal skin, taking care to place the incision anterior to the postauricular sulcus to avoid possible posterior migration of the scar, which may be visible later. The incision is extended superiorly behind the ear to the hear-bearing mastoid skin for approximately 5 cm. A short skin flap is elevated approximately 2 cm anterior to the tragus. The SMAS layer is then identified and elevated (Fig. 7A–D).

The sub-SMAS dissection continues anteriorly until reaching the anterior border of the parotid gland, where the branches of the facial nerve are identified and protected. The inferior pole of the parotid gland is dissected from the stylomandibular ligament and the lateral pharyngeal wall. The gland is retracted superoposteriorly, thus exposing the pterygomasseteric sling. The sling is sharply divided and the masseter muscle reflected superiorly thus exposing the fracture site. This dissection provides an unobstructed view of the posterior mandible from the posterior body to the condyle. Even severely displaced subcondylar fractures are amenable to anatomic reduction and stable, adequate rigid fixation via this approach (Fig. 8A–F).

There is no need for vacuum drains postoperatively and meticulous hemostasis is paramount to avoid hematoma formation. The main advantages of the facial rhytidectomy approach for treatment of displaced and dislocated subcondylar fractures are the wide exposure of the posterior mandible, easy accessibility with minimal retraction, hence causing less tissue trauma, versatility of treatment modalities (lag screws, plates, condylar lag screws, etc), predictable identification and protection of vital structures and no visible facial scars.

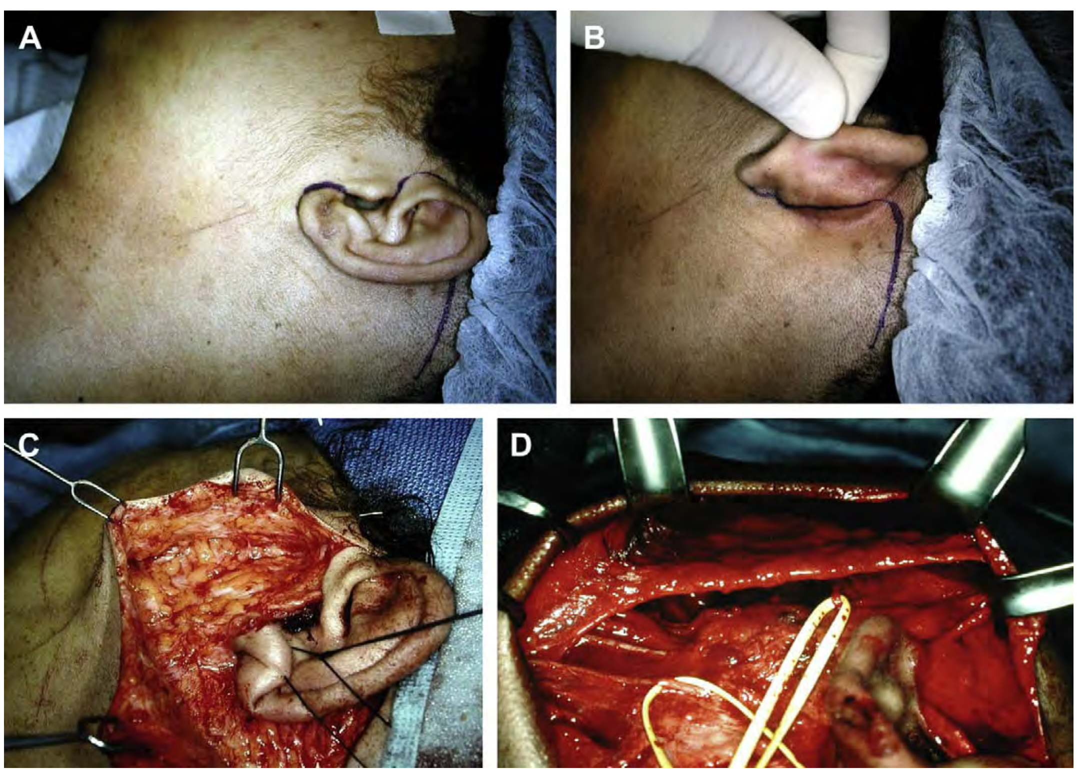

Fig. 7. (*A, B*) Outline of the facial rhytidectomy incision. (*C, D*) Elevation of a short skin flap and SMAS flap. Note the branches of the facial nerve identified (buccal, marginal mandibular and cervical).

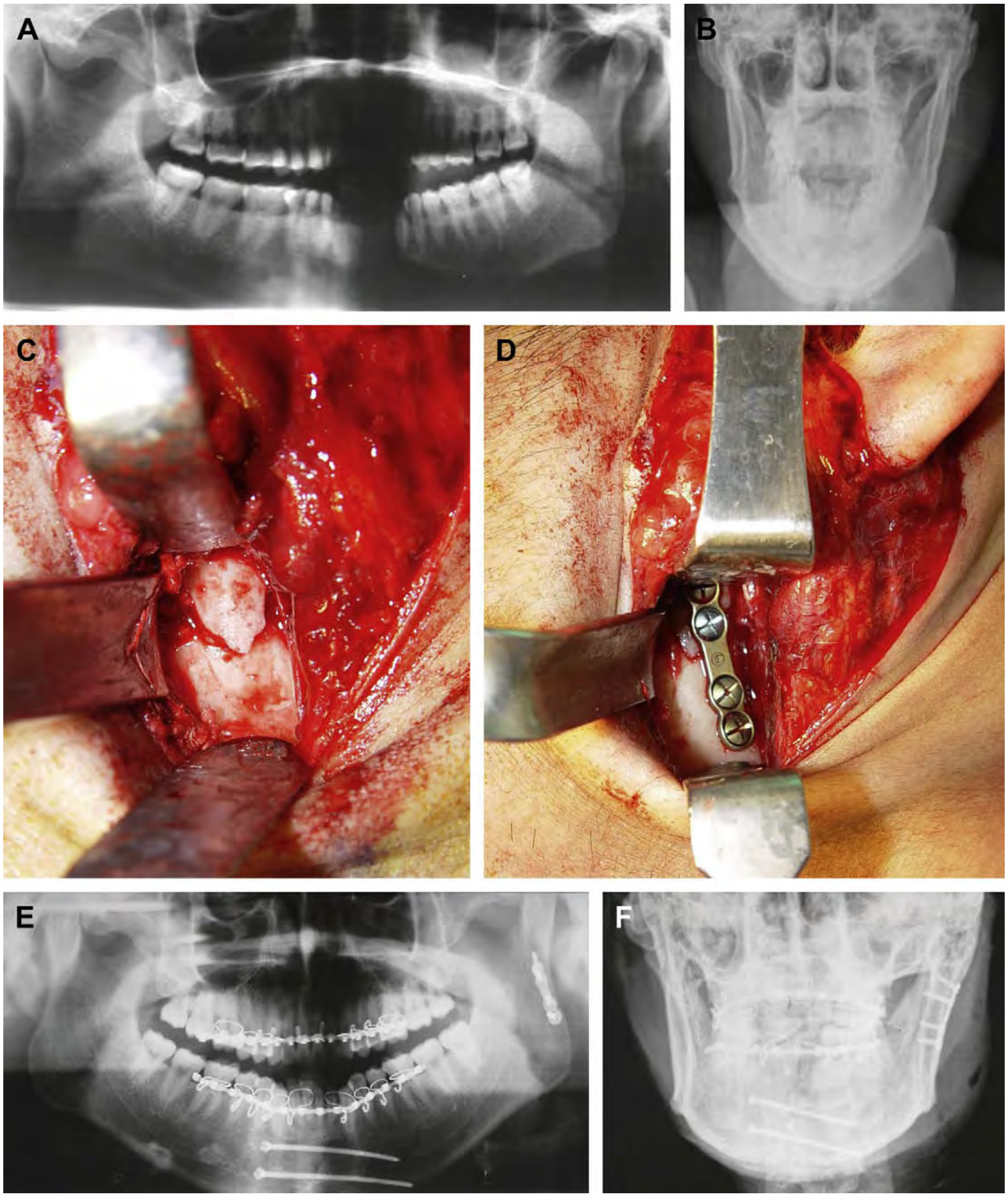

Fig. 8. (*A–F*) Preoperative and postoperative radiographs and intraoperative photographs showing open reduction and internal fixation of left subcondylar fracture by way of the facial rhytidectomy approach.

Complications

A variety of short- and long-term complications may result from both the injury and attempts to treat the injury. General risks related to fracture management apply to condylar fractures and all fractures of the dentate maxillofacial skeleton. These risks include pain, swelling, bleeding, bruising, infection, delayed healing, nonhealing, malunion, and malocclusion. Late risks include the development of symptomatic internal derangement, limited mouth opening with decreased lateral excursion, temporomandibular joint arthropathy, degenerative joint disease, and condylar resorption. Ankylosis is the most dreaded of complications related to condylar process fractures. The etiology of ankylosis is unclear; however, it appears to be a multifactorial process. It is not surprising to note that ankylosis is more common in the pediatric population than in adults. It appears that ankylosis is generally associated with fractures of the condylar process rather than the subcondylar areas. It is unlikely that fractures in the subcondylar area will result in fusion of the condyle to the articular fossa even when the patient is subjected to long periods of maxillomandibular fixation. As discussed earlier, the anatomic and biomechanical features of the pediatric ramus-condyle unit favor intracapsular fractures, more so than in adults, because of the generally thinner cortical bone lining over the condylar head, larger marrow spaces with abundant osteopotent cells, and a thicker, broader condylar neck in the mandibles of pediatric patients. Intuitively, it is not hard to imagine that the dispersion of large amounts of osteocompetent cells throughout the glenoid fossa would lead to the formation of exuberant bone formation and set the stage for the development of ankylosis.

A number of investigators have experimentally attempted to induce ankylosis and it appears that a variety of conditions must be encountered to result in ankylosis. Some of those conditions include the following: intracapsular fracture, prolonged period of immobilization, position of the meniscus as a barrier between the condyle and fossa, failure to diagnose decreasing mouth opening, and failure to institute or comply with physical therapy regimens. Still it remains unclear as to why some patients will develop ankylosis despite proper evaluation and management and others will not despite failure to follow postinjury treatment recommendations.

The best way to avoid ankylosis is by close monitoring and follow-up by the oral and maxillofacial surgeon. Physical therapy regimens can be initiated once the initial painful symptoms begin to subside. The type of therapy instituted will depend entirely upon the

Fig. 9. (*A, B*) Clinical photographs and CT scan of a 7-year-old boy after conservative treatment of bilateral subcondylar fractures resulting in bilateral osseous ankylosis. Note the inability to open the mouth and the severe retrognathia. L, left; R, right.

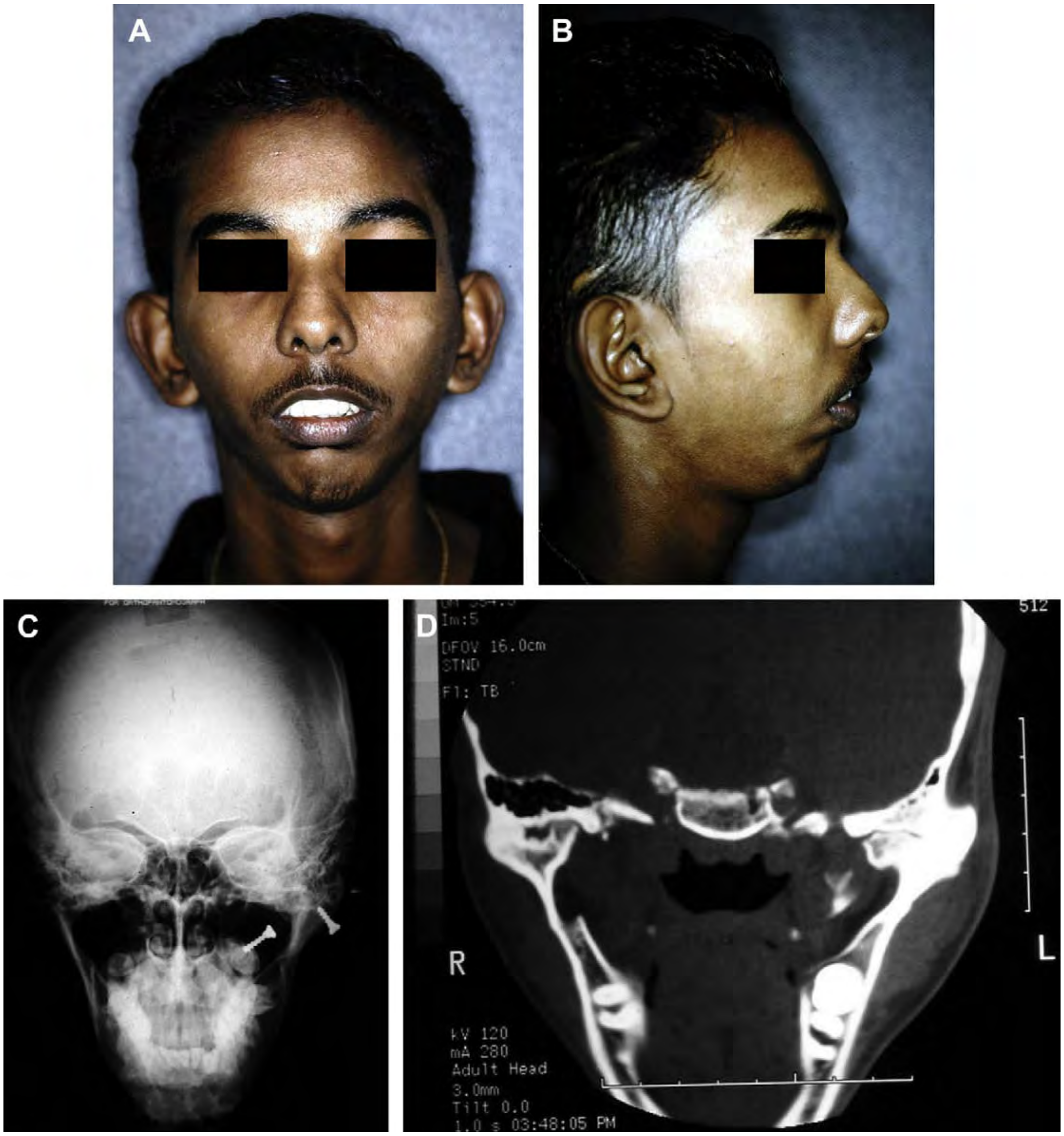

Fig. 10. (*A–D*) Clinical photographs and radiographs of a 16-year-old male patient with bilateral bony ankylosis secondary to inadequately treated bilateral subcondylar fractures. Note the pronounced retrognathia due to disruption of the condylar growth center. The patient required bilateral arthroplasties, bilateral costochondral graft reconstruction, and temporalis myofascial flaps to line the newly created glenoid fossae. L, left; R, right.

patient's response, so a variety of techniques should be familiar to the oral and maxillofacial surgeon. Since patient understanding and compliance with treatment is paramount to success, unsupervised and loosely monitored programs are potentially problematic. Frequent follow-up is recommended until it is certain that the patient is making progress at sequential visits. Should ankylosis occur despite optimal care, it may be managed by a variety of surgical techniques that are beyond the scope of this article (Fig. 9).

Growth disturbances

The pediatric patient is also subject to an additional complication that is not seen in the adult population. Since the condyle serves as a growth center, it stands to reason that damage to the condyle may result in alteration of growth in this subset of patients. Growth disturbances following disruption of the condylar growth center are somewhat unpredictable but it is generally accepted that the younger the patient, the more likely the chance for growth disturbance. When fractures disrupt the condylar growth center in patients less than 3 years of age, growth disturbance is highly likely. When the injury occurs in patients from ages 3 to 12 years, growth disturbance is variable. When the injury occurs in patients 12 years of age or greater, growth disturbance is not likely as the majority of growth has already been completed. It should be noted that unilateral injuries may result in marked asymmetries with resultant effects on the entire craniofacial skeleton. Bilateral injuries lead to less asymmetry but may result in dramatic hypoplasia of the mandible with a resultant retrognathia (Fig. 10). The severity of the retrognathia may be so severe that it results in obstructive sleep apnea in some cases. When a growth disturbance is encountered, it may be treated in a variety of ways depending upon the oral and maxillofacial surgeon's experience and preference.

Summary

Management of condylar fractures remains a source of ongoing controversy. The goals of treatment include restoration of function and esthetics. Satisfactory outcomes can be achieved using a variety of treatment paradigms. In order to avoid the myriad of complications that may arise, it is important to follow these patients closely and institute appropriate therapy based upon the clinical situation. While it appears that many condylar fractures can be managed nonsurgically, recognition of cases that require surgical intervention and selecting an appropriate procedure are paramount to success in treating these injuries. Careful consideration and attention to the principles of fracture management, and the role of the condyle as an articulating unit and growth center, must be taken into account for the successful management of these injuries.

Further readings

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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 71–74

Atlas of the Oral and Maxillofacial Surgery Clinics

Endoscopically Assisted Management of Mandibular Condylar Fractures

Shahid R. Aziz, DMD, MD, FACS*, Vincent B. Ziccardi, DDS, MD

Department of Oral and Maxillofacial Surgery, University of Medicine and Dentistry of New Jersey, New Jersey Dental School, 110 Bergen Street, Room B854, Newark, NJ 07103, USA

The mandibular condyle is a unique area of the facial skeleton. It is an integral part of the temporomandibular joint (TMJ)—a ginglymoarthrodial joint (rotation/translation joint) found bilaterally in the face [1–5]. Fractures of the mandibular condylar apparatus are common and account for about 25% to 30% of all mandibular fractures. Complications of fractures of this area include malocclusion, such as apertognathia, loss of posterior mandibular vertical height resulting in a facial asymmetry, loss of chin projection in the sagittal plane, and loss of function/mobility of the TMJ. Management of fractures of the mandibular condyle and subcondyle has historically been debated in the maxillofacial surgical literature. Many advocate simple closed reduction of these fractures, whereas others feel that open reduction is the appropriate treatment modality. Closed reduction, while minimally invasive, may not adequately reduce the fracture, resulting in long-term TMJ dysfunction or mobility issues. In general terms, fractures of this area of the jaw can be classified into fractures of

- Condylar head (intracapsular)
- Condylar neck
- Subcondylar/high ramus fractures
  1. Medially displaced (medial over-ride)
  2. Laterally displaced (lateral over-ride)

There is a general consensus that isolated fractures of the condylar head (intracapsular) are best treated via a closed approach, including soft diet or maxillo-mandibular fixation for 2 to 3 weeks followed by intensive physical therapy. Subcondylar and condylar neck fractures may be amenable to rigid fixation; however, traditional open reduction has certain risks, including facial nerve injury and preauricular scarring. Advantages of open reduction include immediate function, restoration of facial symmetry, and improved jaw motion (Fig. 1A–D).

Minimally invasive endoscopy was originally developed by general surgeons and gynecologists and has evolved over the past decade. It was a technique initially well suited for the abdomen, as this area of the body creates an anatomic ‘‘optical cavity’’ for visualization with an endoscope. Advantages of endoscopic surgery are based on its ability to provide excellent visualization of the surgical field via a small incision and include acceptable minimal scarring and decreased tissue manipulation and dissection, resulting in decreased postoperative morbidity and faster recovery with shorter hospital stay and quicker return to normal function.

The facial skeleton anatomically is not as well suited for endoscopy because the optical cavities created are significantly smaller than those of the abdomen. Smaller endoscopy instruments have been developed, allowing for use in facial skeletal surgery. A small optical cavity is created in the lateral aspect of the ramus allowing for endoscopic reduction of

* Corresponding author.
E-mail address: azizsr@umdnj.edu (S.R. Aziz).

1061-3315/08/$ - see front matter
doi:10.1016/j.cxom.2008.10.003

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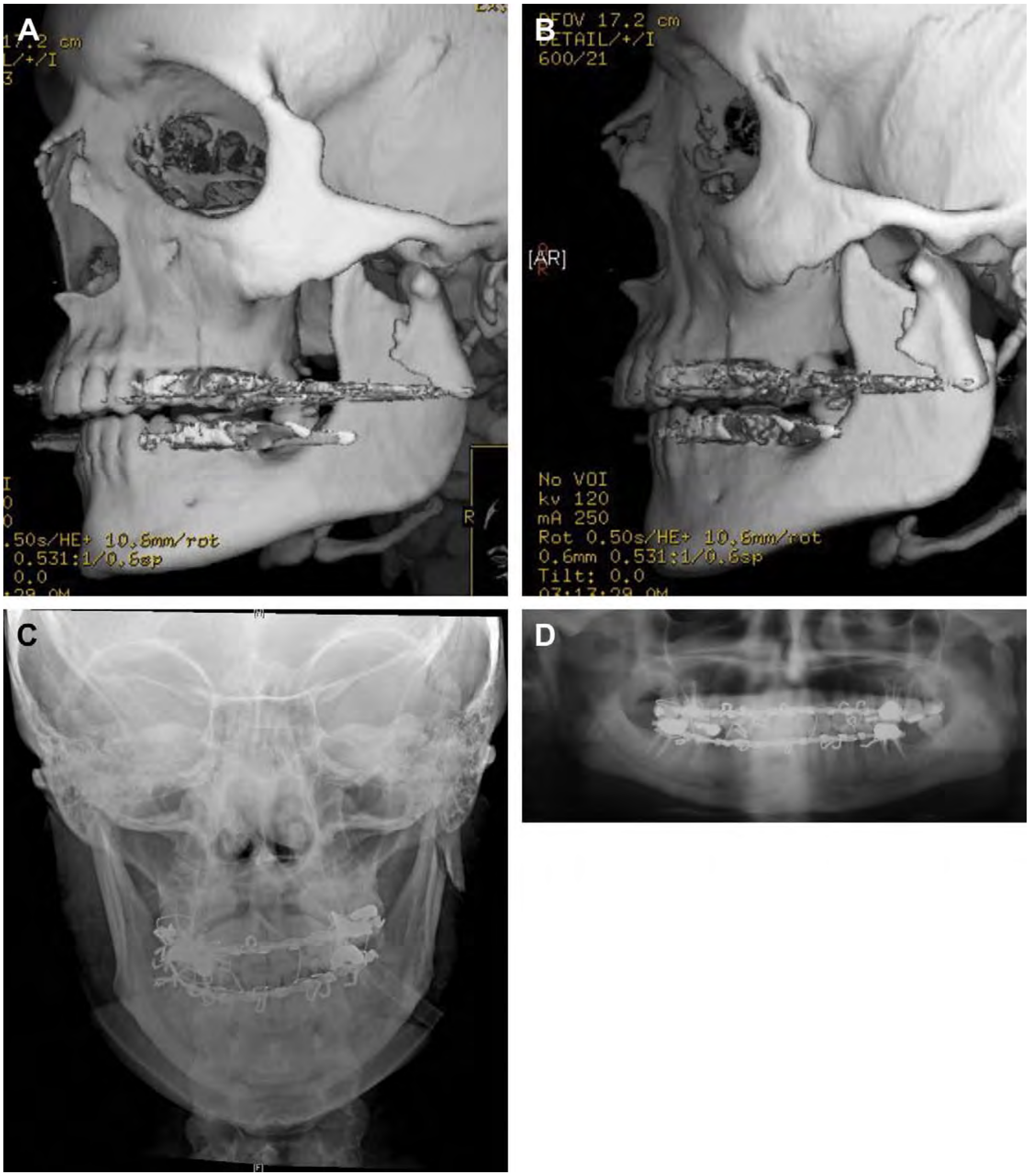

Fig. 1. (*A*) Left subcondylar fracture with lateral displacement, condyle anterior to articular eminence. (*B*) Lateral view. (*C*) Posterior-anterior cephalogram post closed reduction of fracture, demonstrating inadequate reduction/lateral displacement of condyle. (*D*) Post-reduction panorex. Note left subcondylar fracture is not well reduced, in spite of adequate maxillo-mandibular fixation. (*Courtesy of* Lawrence Gorzelnik, DMD, MD, Madison, NJ.)

subcondylar fractures. By using an endoscopic technique, the advantages of open reduction are met, while minimizing the risk of facial nerve injury.

Indications for endoscopically assisted open reduction and internal fixation (EAORIF) of mandibular condylar fractures include

- fractures limited to the subcondyle or condylar neck in which there is enough bone stock to stabilize a bone plate
- malocclusion and/or decreased range of motion (edentulous patients with subcondylar fractures can be treated endoscopically; however, splints or dentures to stabilize the maxilla and mandible should be used)
- loss of chin projection or facial asymmetry

Contraindications to the endoscopic approach include

- comminuted condylar fractures or intracapsular fractures
- medially displaced condylar fractures that cannot be reduced
- condylar fractures older than 2 weeks on which fibrous union has started to develop
- medically compromised patients who are not healthy enough to undergo general anesthesia required for surgical procedures

There are two surgical approaches used in EAORIF of the condyle: an intraoral approach and a submandibular approach. Advantages of the intraoral approach include the lack of a skin incision, whereas its disadvantage is a smaller optical cavity to work within. The submandibular approach requires a 1.5-cm skin incision at the angle of the mandible, similar to a Risdon incision, placing the facial nerve at minimal risk; however, the optical cavity created has a larger working space with better endoscopic orientation.

Instrumentation for this technique includes

- endoscopic equipment: monitor, endoscope with irrigation sheath (usually 2.7 to 4.0 mm in diameter with 30-degree or 45-degree angles)
- subcondylar/ramus fixation set (Synthes Maxillofacial, Paoli, PA)

In either surgical approach, placing the patient into maxillo-mandibular fixation is necessary, typically using Erich arch bars. At this point, the optical cavity is created via an intraoral or extraoral approach as previously discussed. Once down to the lateral ramus, a periosteal

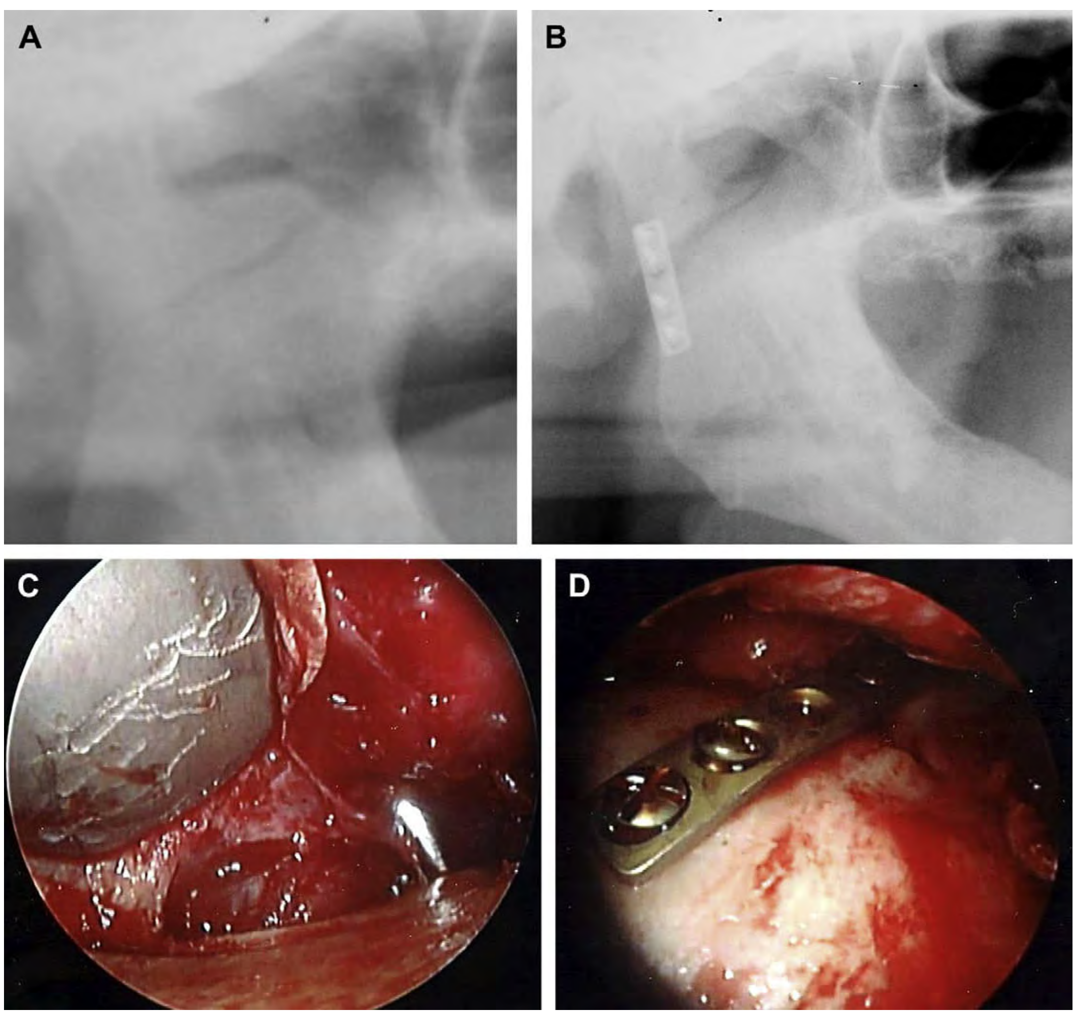

Fig. 2. (*A*) Minimally displaced right subcondylar fracture. (*B*) EAORIF of fracture using six-hole 2.0-mm rigid fixation plate. (*C*) Endoscopic view of fracture before reduction. (*D*) Endoscopic view of fracture post EAORIF.

elevator exposes the mandible in the subperiosteal plane from subcondyle to angle, creating the optical cavity. Once the optical cavity is created, the endoscope is placed and the fracture is visualized. Manual reduction of the fracture is then completed via manipulating the teeth or distracting the mandible in the angle region. Once reduced, a six-hole 2.0-mm noncompression miniplate is inserted using a right-angle screwdriver/drill or a trocar. Angled elevators and reduction-manipulation forceps in the Synthes fixation set facilitate reduction and fixation of these fractures. Once reduced, the patient is allowed to function—typically placed into guiding elastics for 1 to 2 weeks (Fig. 2A–D).

Summary

Endoscopic-assisted open reduction/internal fixation of mandibular condylar fractures is a viable alternative to traditional closed or open reduction techniques. However, case selection is important. Ideally, the fracture undergoing EAORIF should be easily manipulated into reduction and have enough stable bone on either side of the fracture to support a bone plate. It is important to note that in all reprinted studies, authors note a steep ‘‘learning curve’’ with the EAORIF technique. Identical procedures took the novice surgeon two to three times as long when compared with an experienced surgeon. EAORIF is a technique that should be included in the armamentarium of the maxillofacial trauma surgeon when treating mandibular condylar fractures.

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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 75–79

Atlas of the Oral and Maxillofacial Surgery Clinics

Management of the Edentulous/Atrophic Mandibular Fracture

Shahid R. Aziz, DMD, MD, FACS*, Talib Najjar, DMD, MDS, PhD

Department of Oral and Maxillofacial Surgery, University of Medicine and Dentistry of New Jersey, New Jersey Dental School, 110 Bergen Street, Room B854, Newark, NJ 07103, USA

Edentulous or atrophic mandible fractures are rare and potentially problematic for the oral and maxillofacial surgeon. With the loss of teeth, atrophy of the alveolar bony apparatus ensues, creating a mandible more prone to fracture. Approximately 8% of the American population is considered completely edentulous [1]. Most of these patients are elderly, although in certain states (Kentucky, Louisiana, and West Virginia) the incidence of edentulism is significantly higher (West Virginia has a 40% edentulism rate) [2]. As a result, edentulous/atrophic mandible fractures may be seen in the nonelderly as well. In addition, the American population is growing older—US Census data noted that people older than 65 years will represent 13.6% of the American population; people older than 80 will represent 6.2% of the population in 2004 [3].

Tooth-bearing alveolar bone is stimulated to maintain its quality and quantity of bone secondary to the occlusal forces/load generated by the teeth. Loss of teeth results in a loss of this stimulus, leading to a loss of bone volume—atrophy. It is this decrease in bone volume that makes the atrophic mandible less resistant to traumatic forces, and more prone to fracture.

Overall, the incidence of atrophic mandible fractures is rare compared with other types of facial fractures. A recent study of mandible fractures over a 17-year period at an urban level-one trauma center revealed an average of 2 atrophic mandible fractures per year out of 200 total mandible fractures, or 1% [4]. Another study by Mugino and colleagues [5] noted 11 (3%) of 335 fractures were edentulous/atrophic. In addition, most of these patients were elderly with comorbid diseases, most commonly hypertension, diabetes, and coronary artery disease, which in turn made medical and surgical management more complicated. The elderly also have delayed bone regeneration, and atrophic bone is often sclerotic with a compromised blood supply.

Luhr and colleagues [6] developed a classification for fractured atrophic mandibles, based on bone height at the fracture site. A fracture in bone of less than 20 mm of height is considered atrophic. Class I fractures are those fractures in which the bone height is 16 to 20 mm, Class II fractures are 11 to 15 mm in height, and Class III fractures are less than 10 mm in height (Table 1).

There remains some controversy in treating the edentulous/atrophic mandible fracture. Many surgeons advocate conservative closed treatment, while others advocate more aggressive open reduction of these fractures. The crux of this debate centers on the concerns over comorbid disease in the elderly patient resulting in an increased general anesthesia risk as well as the compromised vascular supply of the atrophic jaw bone [7]. Obviously, patients who are deemed by an anesthesiologist to be a poor candidate for general anesthesia require closed reduction of the fracture via the use of existing dentures or Gunning splints; in situations where the patient is too unstable and the fracture posses no airway threat, no treatment may be an option. On the other hand, advances in trauma care and anesthetic management have decreased the risk of surgery in the elderly (Fig. 1).

* Corresponding author.
E-mail address: azizsr@umdnj.edu (S.R. Aziz).

doi:10.1016/j.cxom.2008.10.004 ***oralmaxsurgeryatlas.theclinics.com***

Table 1
Luhr's classification of edentulous mandible fractures

Class	Mandible height at fracture site
I	16–20 mm
II	11–15 mm
III	<10 mm

The controversy regarding the quality of blood supply to the atrophic mandible stems from a 1975 article by Bradley [8]. Using angiography, he documented that the inferior alveolar artery provided inconsistent supply to the atrophic mandible. As such, he felt that the primary blood supply in the atrophic mandible arises from the periosteum. He wrote that "elevation of the periosteum … may seriously impair the vascular supply to the bone resulting in nonunion of fractures treated by open reduction and direct osseous fixation [8]." Multiple studies in the past 15 years, however, have shown that open reduction does not increase the incidence of non-union in atrophic fractures. In fact, many authors have advocated open reduction of atrophic mandible fractures as superior to closed techniques, because open reduction provides direct visualization and rigid fixation provides stability. In addition, these same studies have shown that a supraperiosteal dissection provides no significant advantage in healing compared with subperiosteal dissection.

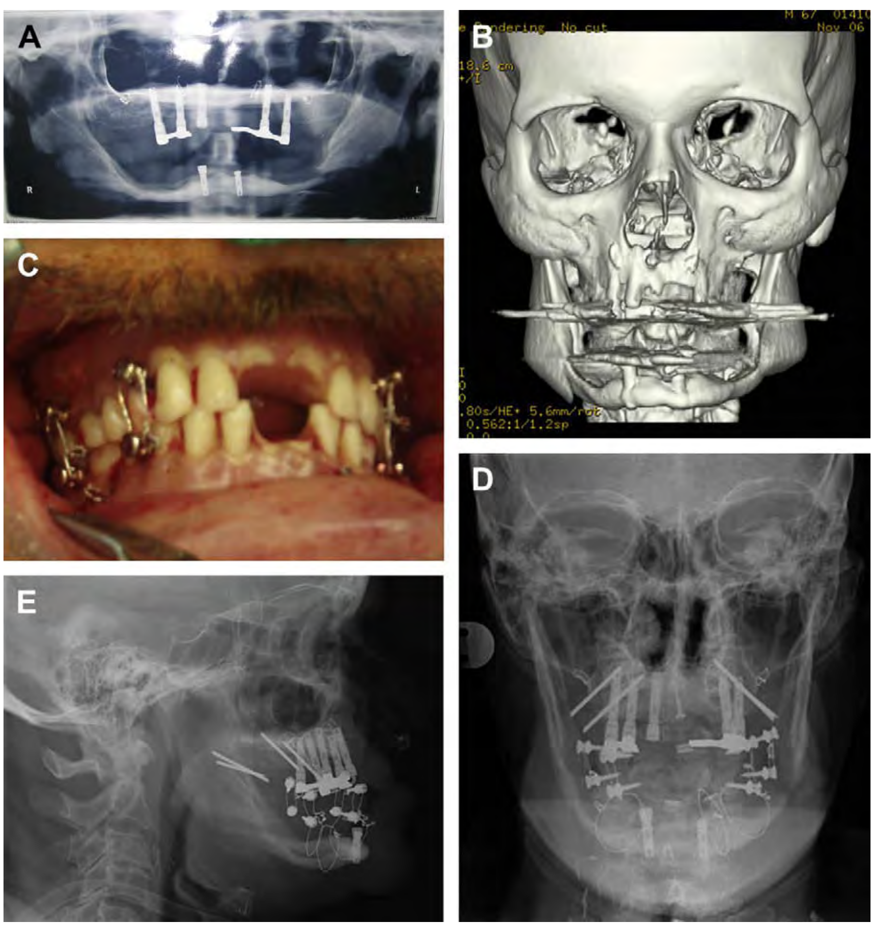

Fig. 1. (*A*) Panoramic radiograph of left body fracture of edentulous mandible. (*B*) Three-dimensional CT scan of left body fracture of edentulous mandible. (*C*) Use of existing complete dentures for closed reduction. (*D*) Postoperative reduction film. (*E*) Postoperative reduction film, lateral view. (*Courtesy of* Lawrence Gorzelnik, DMD, MD, Madison, NJ.)

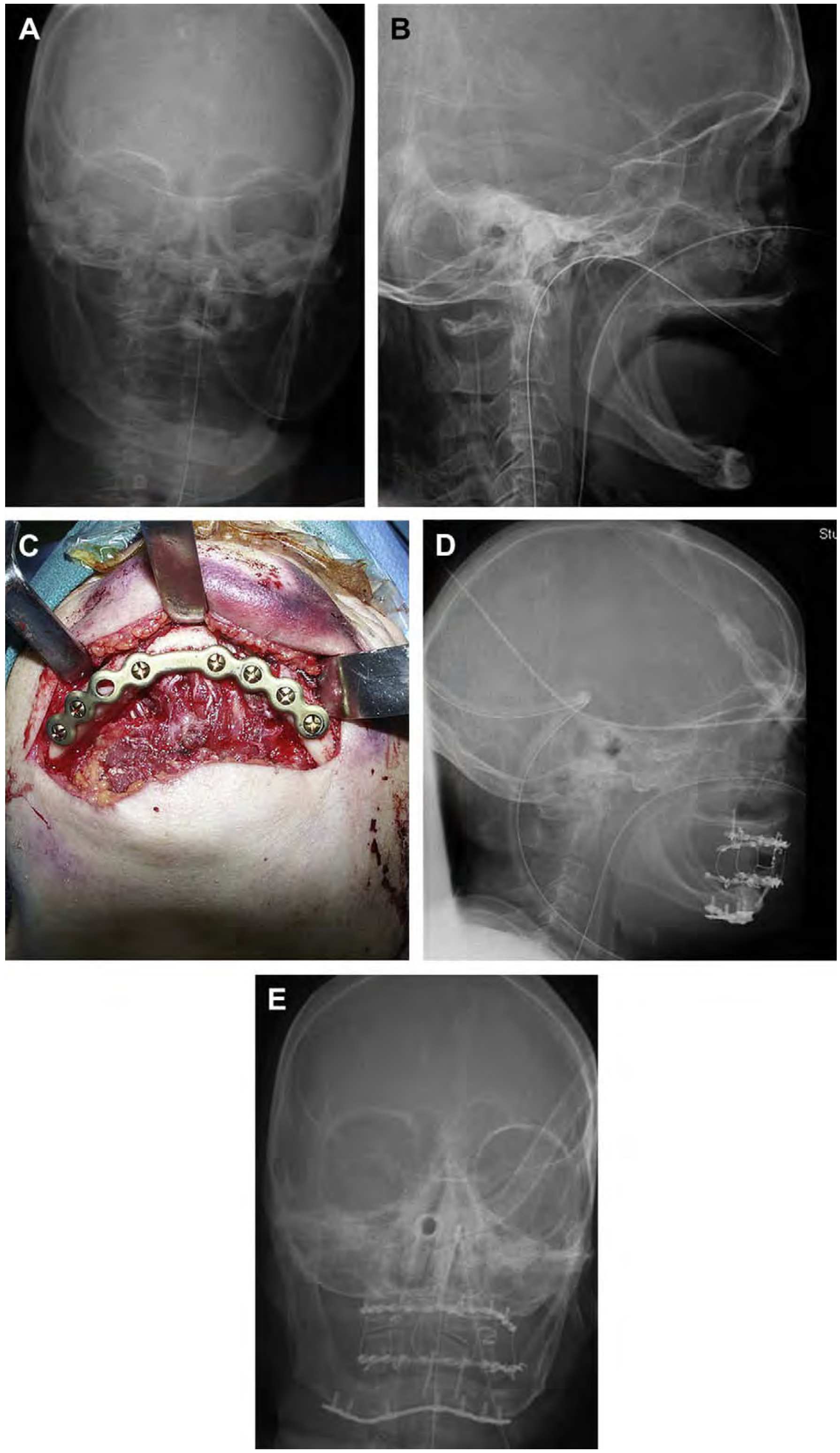

Fig. 2. (*A*) Bilateral mandibular fracture, edentulous mandible. (*B*) Lateral view. (*C*) Large reconstruction plate placed. (*D, E*) Postoperative films; note dentures used in combination with rigid fixation.

There has been further discussion in the literature about an intraoral versus extraoral approach to open reduction. Advantages of an intraoral approach primarily focus on the ease and speed of dissection and closure. Disadvantages of the intraoral approach include salivary contamination and visualization difficulties. In addition, in some cases, the mandibular neurovascular bundle/mental foramen may actually lie close to the crest of the alveolar ridge in a severely atrophic fracture; an intraoral incision may inadvertently traumatize this nerve.

An extraoral route has the advantage of providing for excellent visualization and manipulation of the fracture as well as ease of hardware application. Disadvantages include a facial scar and risk to the facial nerve; however, often in the elderly the scar can be hidden in a well-placed incision in a facial rhytid. Ultimately, the approach to access the fracture must be tailored to the patient's case. The approach selected must allow the surgeon to adequately visualize the fracture easily and allow for easy hardware application. Although this is true in all facial fracture open reductions, this principle is more important in treating the edentulous/atrophic mandible fracture. Stabilizing the occlusion via maxillo-mandibular fixation often reduces the fracture before placing rigid fixation plates. In the edentulous fracture, an anatomic reduction is necessary, as there is no occlusal guidance. This requires the surgeon to reduce the fracture manually, which requires excellent unhampered access.

As rigid fixation has evolved over the past several years, multiple authors have suggested different protocols for rigid fixation of the edentulous/atrophic mandible. Wittwer and colleagues [9] noted in a recent study that the treatment of atrophic mandibular fractures should be based on the degree of atrophy. They found that Luhr Class I and Class II mandibles had a much higher incidence of complications, including hardware failure, infection, or nonunion. In their review of 36 atrophic fracture patients, they concluded that more rigid fixation is indicated in mandibles with atrophy of 15 mm on bone height or less. In addition, whereas some studies have advocated using the smallest plate available in treating these fractures [10], the current recommendations include using larger plates. Ellis noted that rigid fixation bone plates in edentulous mandibles are subjected to repeated muscle loading as well as deformation [4]. As a result, these plates will often fracture. In addition, the bone along the fracture line in an atrophic mandible does not share any of the occlusal load; most of the load is placed on the bone plate.

As such, larger bone plates are advocated. Locking plating systems provided plates with greater stability as well as easier plate adaptation. Currently available are 2.0-mm, 2.3-mm, 2.4-mm, and 2.7-mm locking plate systems. The 2.0 locking system is an excellent option in rigidly fixating the atrophic fracture: it is easily adapted, provides excellent stability across the fracture, and has significant increased strength compared with a conventional 2.0 miniplate. Ellis recommended this plate with six holes, three bicortical screws on either side of the fracture,

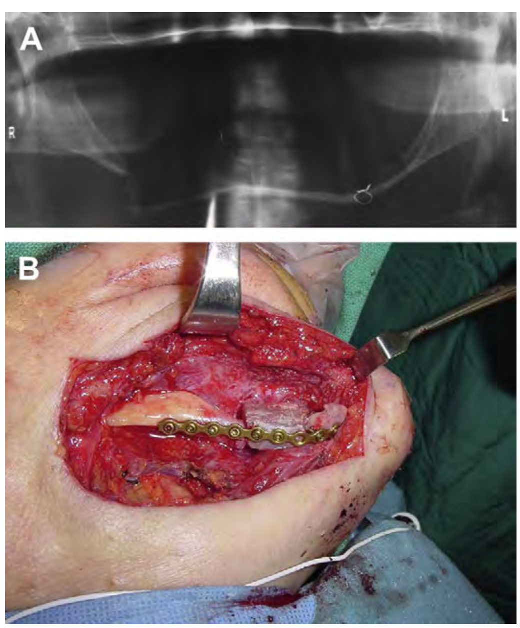

Fig. 3. (*A*) Right body fracture, edentulous mandible; note old left body fracture reduced via intraosseous wire. (*B*) Open reduction, internal fixation of right body fracture with interpositional bone graft from anterior ileum.

located at the inferior border of the jaw, to provide strong and stable reduction [4]. Although this plate is exceedingly small, another advantage is its lower profile, compared with larger-caliber plates, allowing for easier closure and more comfort in wearing dentures (Fig. 2). Immediate bone grafting at time of repair of the atrophic mandible fracture has historically been advocated in the literature, often in situations where there was a nonunion of the fracture and the bone was used as a method of fixation. This provided the fracture with fixation as well as promoted fracture healing by providing osteocompetent cells to the fracture site. With the advent of rigid fixation, bone grafting is often not indicated. However, bone grafting is still used in the situation of continuity defects or to add alveolar height to a severely atrophic fracture. This additional bone height is hoped to facilitate dental reconstruction post fracture repair. Ultimately, bone grafting as part of the repair of the atrophic fracture should be limited to situations in which a continuity defect requires reconstruction, there is a possibility of prosthetic rehabilitation, and the donor site (rib or ileum) has minimal morbidity associated in an elderly patient (Fig. 3).

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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 81–91

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Fractures of the Growing Mandible

George M. Kushner, DMD, MD[a,b,c,d],
Paul S. Tiwana, DDS, MD, MS[a,b,c,e,*]

[a]*Department of Surgical and Hospital Dentistry, School of Dentistry, The University of Louisville, Louisville, KY 40292, USA*
[b]*Department of Surgery, School of Medicine, The University of Louisville, Louisville, KY 40292, USA*
[c]*Pediatric Oral and Maxillofacial Surgery, Kosair Children's Hospital, The University of Louisville, Louisville, KY 40292, USA*
[d]*Oral and Maxillofacial Surgery, The University of Louisville, Louisville, KY 40292, USA*
[e]*Department of Pediatrics, School of Medicine, The University of Louisville, Louisville, KY 40292, USA*

Oral and maxillofacial surgeons have a long history of providing care for the trauma patient. This care for the maxillofacial trauma patient is one of our specialty's greatest contributions to society as a whole. Countless residents have honed their surgical skills and patient management techniques caring for the trauma patient while providing an immense service to our patient population. The specialty of oral and maxillofacial surgery has also been responsible for trauma care in our most precious patient population, our children.

Management of maxillofacial trauma has undergone tremendous change over time. These changes have been mandated by the evolving complexity of injuries of this age as well as advances in modern imaging, instrumentation, and techniques such as rigid fixation. Perhaps the greatest impetus for change in the approaches of the surgical management of maxillofacial trauma originated through the conflicts of the World Wars. The pioneering efforts of surgeons such as Kazanjian, Converse [1], Gillies and Millard [2] are examples of these advancements. Their triumphs were then moved forward and further refined by surgeons such as: Thoma, Blair, Ivy, Curtis, Dingman, Natvig, and Rowe and Killey [3–8]. However, in the surgical management of pediatric craniomaxillofacial disease and deformity perhaps the greatest influence came from the contribution of Paul Tessier [9] in his principles of cranio-orbital surgery first introduced in 1967. Gruss and colleagues [10] and Manson and colleagues [11] provided many of the operative principles of maxillofacial trauma employed today such as sequencing of panfacial injuries, autogenous bone grafting, and the important role of open reduction and rigid internal fixation in re-establishing facial height, width, and projection. These principles have provided the fundamental underpinnings of modern facial fracture treatment. More recently, these principles, which work so well in the adult patient, have been applied in the management of pediatric maxillofacial trauma. Posnick [12–14] and Kaban [15] have more clearly described the epidemiology and further clarified the advantages of rigid internal fixation for these injuries.

The term ''pediatric'' must be defined to assure that the discussion is about similar age group populations. Many health care providers consider patients under the ages of 18 or 21 as still falling within the pediatric population. Management of facial fractures in an 18-year-old patient generally follows adult principles and should not be considered pediatric management. For the sake of this discussion, the authors will follow the guidelines of the American Association of Oral and Maxillofacial Surgeons and define pediatric patients as 12 years old and younger.

* Corresponding author. The University of Louisville, Louisville, KY 40292, USA.
E-mail address: paul.tiwana@louisville.edu (P.S. Tiwana).

doi:10.1016/j.cxom.2008.11.001

Fundamentally, understanding of complex facial injuries evolved through experience, both good and bad, with adult patients. However, children are not simply "small adults" and the application of adult-type treatment can be inappropriate in many circumstances. There is still a place for conservatism in treatment of craniomaxillofacial injuries in the child.

General considerations

Craniofacial growth & development

The role of the human face is significant for reasons other than purely aesthetic considerations. Highly evolved and specialized functions of the face include vision, breathing, mastication, speech, smell, and hearing. Indeed, it is the culmination of an extremely complex process of growth and development that provides the functional and aesthetic framework of the human face. Interruption of this process, such as insult from maxillofacial injury or surgical treatment, may produce deleterious alterations of the facial framework resulting in aesthetic and functional deficits which are apparent and hard to ignore. For the surgeon who treats pediatric facial fractures, an understanding of this process becomes crucial in developing and exercising sound surgical judgment [16–18].

The mandible has both a component of endochondral ossification at the temporomandibular joint regions bilaterally, and remodeling and apposition of bone everywhere else. The mandibular body and alveolus follow the downward and forward vector of movement of the midface, but the rami and condyles grow upward and backward to maintain contact with the skull base. Vertical height is gained at the condyle through endochondral replacement and length is added though an active remodeling of the ramus. Skeletal maturity of the maxilla and mandible is reached by approximately 14 to 16 years of age in females and 16 to 18 years of age in males [19,20].

The functional matrix concept of growth first proposed by Moss has gained general acceptance [21]. The theory, in essence, postulates that growth occurs as a result of expanding functional requirements of the cranial, nasal, and oral cavities; and that these requirements are transmitted to the bone and cartilage from the soft-tissue envelope of the face. The bones grow in response to the expansion of the cranial and facial capsule. Thus the nasal septum and mandibular condyles react to growth requirements and should not be considered the primary centers of growth as they were once professed to be. Therefore, surgical attention in managing injuries of the mandibular condyle should be directed at preserving as scar-free an envelope of soft tissue as possible and promoting function of the joint. Extending this theory to a myriad of other craniofacial problems leads to similar conclusions. A classic example of the influence of the soft-tissue envelope on growth are patients with cleft palate. Maxillary growth restriction in these patients is the result of scarring from palatal surgery. The cleft palate itself, if not operated on until skeletal maturity, would have little to no effect on maxillary growth [22]. The importance of understanding the deleterious effects of scar tissue, traumatically or surgically induced, and restricted function on growth and development cannot be overstated when managing the child with facial fractures.

Surgical anatomy

Critical examination of the stages of gross anatomic craniofacial development leads to several particular issues that have an impact in both the epidemiology and management of facial bone injuries in children. During the early years of development, the bone itself has a very high osteogenic potential and is characterized by thick medullary space and thin bony cortices resulting in a greater likelihood of greenstick fracture. The greenstick fracture is defined as a fracture through one cortex and is almost exclusively seen in the pediatric age group. Thick periosteum allows for rapid consolidation and remodeling at the site of fracture. Comminution of fractures is rare in the pediatric population except in injuries such as gunshot wounds. The teeth in the primary dentition have particularly short, bulbous crowns that can make it difficult in achieving stable maxillomandibular fixation (MMF) during fracture reduction and stabilization using traditional techniques.

The development of the craniofacial skeleton during the later childhood years into the mixed dentition period also yields further insight. During this time, the lower two thirds of the face become more prominent as a result of the forward and downward growth of the face thus exposing these bones to more injuries. This stage of development also is characterized by the development of the permanent tooth buds which occupy space in the maxilla and mandible (Fig. 1). These unerupted teeth also create areas of structural weakness in the bone with a greater probability of sustaining a fracture through them. In addition, the eruption of the permanent teeth in conjunction with loose, exfoliating primary teeth make maxillomandibular wiring, and thus fracture reduction and stabilization, more difficult. The bone itself still has excellent, although decreasing osteogenic potential and elasticity during this time. The sinuses of the face also continue their development and their presence changes fracture patterns secondary to different areas of strength and weakness in the bone. As the permanent dentition becomes fully erupted at about 12 years of age, and growth continues through the early teenage years, the craniofacial skeleton becomes more adult like in its form and its surgical management [23].

Epidemiology

Children have a lower incidence of facial bone injury. For the most part they reside in a very protective social environment. In the early years of life, parental supervision and a child-friendly environment mitigate the likelihood of serious injury. Although falls during these years are common, their low center of gravity ensures that little harmful force is generated which might cause injury. As they reach the later childhood years, children become involved in activities such as school and play with other children. Participation in athletic activity later in life is also a cause of facial injury proximate to a developing neuromuscular coordination system and decreased situational awareness. Balls of all sorts, hockey pucks and sticks, lacrosse sticks, bats, elbows, knees, are very common in the cause of pediatric facial injuries during athletic events, especially when the appropriate protective equipment is not worn.

While there have been several excellent studies regarding the epidemiology of pediatric facial trauma, Posnick and colleagues [24] provided the most significant recent description of this problem. In their review of 137 pediatric patients with facial fractures, the majority was male and the largest group of patients was found in the 6 to 12 years age range. The most common cause of trauma was motor vehicle-related, followed by falls, sports injuries, and interpersonal violent altercation. Mandibular fractures comprised 55% of the injuries, orbital fractures 30%, dentoalveolar fractures 23%, midface fractures 17%, nasal fractures 15%, zygomaticomaxillary complex fractures 14%, and cranial fractures 6%. Among the reported mandibular fractures, condyle fractures are the most common, followed by the symphyseal region, body, and, last, the angle of the mandible. However, from a rational standpoint, actual incidence may vary across geographic locations depending on many factors including the absence or presence of a level I pediatric trauma facility. In addition, many minor injuries such as nasal and dentoalveolar fractures are likely underreported as they can be commonly managed on an outpatient basis. There were no cervical spine injuries in this study.

Fig. 1. Panorex of 6 year old. Note developing permanent dentition within jawbones. Mandibular plates and screws must be placed at inferior border to avoid damaging dentition.

Evaluation

The evaluation of the injured pediatric patient can be challenging. A thorough, systematic approach such as the advanced trauma life support protocols is valuable to insure that significant injury is not overlooked and to prioritize treatment. Standard questions in evaluating maxillofacial trauma regarding the presence of a malocclusion or inferior alveolar nerve dysfunction are not well understood by the pediatric age group and may lead to incorrect answers or no answers at all. The diagnosis of maxillofacial trauma is primarily made by clinical and radiographic examination. Practitioners must remember that any fracture in a child is generally an indicator of significant force as children tend to ''bounce'' and not ''break.'' The practitioner must have a high index of suspicion of associated injuries whenever a fracture is diagnosed.

Radiographic exams are crucial to evaluate maxillofacial trauma in the pediatric patient. Most oral and maxillofacial offices are equipped with panoramic radiograph capability and, therefore, orthopantograms are commonly used to diagnose fractures of the mandible. However, in the hospital setting, there appears to be a trend to rely on CT imaging. Most emergency room facilities use the rapid CT scans to evaluate for central nervous system trauma. The scan can easily be carried through the maxillofacial region to diagnose facial fractures and give detailed three-dimensional information about fracture morphology and displacement. The CT scan is especially valuable when evaluating midface trauma. Additionally, the polytrauma patient or patient with questionable spinal injuries or long bone fractures cannot sit or stand for the traditional panoramic radiograph (Fig. 2). The information obtained from the CT scan is more detailed and valuable than information obtained from the traditional panoramic films. Finally, the standard mandibular series of plain radiographs has very limited use when compared with the information gained from CT imaging (Fig. 3).

Symphyseal and parasymphyseal mandibular fractures

Pediatric mandibular fractures require thoughtful consideration in management to avoid further injury to the developing dentition and significant growth disturbance. Most pediatric mandible fractures are amenable to closed reduction with MMF and the use of splints with skeletal fixation. With rapid healing and remodeling characteristic of the growing pediatric patient, even significant alterations of the occlusion and discrepancies in alignment are rapidly resolved. Indications for the use of rigid fixation are not common but do exist. Infants (less than 1 year of age) with mandibular fractures should be treated with observation. Diet modification is usually not necessary in this age group (Fig. 4).

For anterior mandibular fractures, closed reduction is the preferred treatment plan. However, in fractures where proper alignment cannot be gained with MMF alone or condyle fractures require jaw function and physiotherapy, two alternative options exist. Construction of a lingual splint from dental models is an elegant but time-consuming technique for reduction and fixation. It requires taking dental impressions, a dental lab for fabrication, and yet another

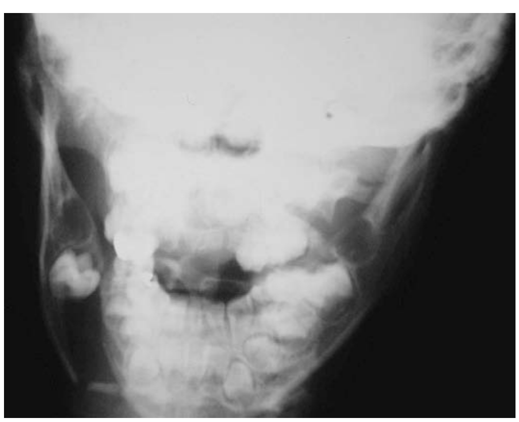

Fig. 2. Plain film of pediatric mandibular fracture.

Fig. 3. Three-dimensional CT scan reconstruction of same patient. Note better information obtained about fracture morphology and locations obtained from CT scan.

procedure to wire it on to the teeth (Fig. 5). In addition, circumandibular wires are sometimes required to further secure the splint. This type of fixation allows for anatomic stabilization of the fracture and facilitates movement of the mandible, encouraging rehabilitation of condyle fractures if present. The second treatment alternative calls for placement of MMF and a transoral monocortical miniplate placed at the very inferior border of the mandible (Fig. 6). This combination of internal fixation and arch wire or bar across the involved teeth allows adequate stability for postoperative function with guiding elastics for the closed management of condylar fractures. The importance of placing the plate at the very inferior aspect of the mandible is emphasized. In the young child, the risk of screw placement in the developing dentition is high unless this principle is followed (Fig. 7).

Mandibular body and angle fractures

Mandibular body and angle fractures have a lower incidence than anterior fractures of the mandible, and can be treated in a similar fashion. The vast majority of these injuries can be managed with closed reduction techniques and some form of MMF. Sagittal fractures of the mandibular body may also benefit from placement of a circumandibular wire to aid in fracture reduction as well as fixation. The circumandibular wire has the advantages of semiclosed placement and simple removal. Otherwise, the use of monomaxillary fixation such as with a lingual splint or open reduction of the unstable fracture and placement of a monocortical plate at the inferior border remain options.

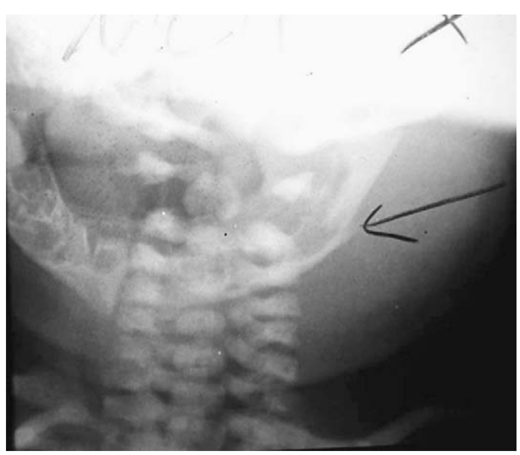

Fig. 4. Neonate with mandible fracture from forceps delivery. Treatment was observation only.

Mandibular condyle fractures

Condyle fractures are insidious in children for two reasons. First, a relatively significant number of these injuries remain undiagnosed and second, whether diagnosed or not, condyle fractures can cause significant lower facial asymmetry as growth continues. The mandible is the last bone in the face to reach skeletal maturity and is vulnerable to growth-related injury because injuries are more likely in late childhood and adolescence. Classically caused by a fall and commonly heralded by a laceration in the submental region, condyle fractures are characterized by shortening of the ramus on the affected side causing deviation of the chin to the affected side. On the unaffected side, open bite and flattening of the body of the mandible are seen. In bilateral fractures of the condyle, posterior displacement of the mandible is seen with anterior open bite. Occasionally, despite condyle fracture, the child will be able to hold projection, symmetry, and occlusion in the mandible without difficulty. In such cases, observation with diet modification is usually sufficient for treatment. These immediate sequela of condyle fracture are not different in the child or adult. However, the type of condyle fracture can be substantially different. Children have a propensity to fracture through the condylar head rather than the low neck pattern seen in adults. This is secondary to the pediatric mandible having a relatively thick and short condylar neck. In addition, compression injuries of the fossa and condylar head as well as medial pole fracture are also commonly seen in children.

While some surgeons see the treatment of condyle fractures in adults in terms of open versus closed as somewhat controversial, in children it would be a rare instance when open reduction is necessary. Closed treatment of the condyle fracture in children remains the standard for treatment today. Advocacy for closed treatment is biologically based on Walker's [25] primate study and is further documented in the work of Lindahl, Lund, and Gilhuus-Moe [26–28]. Whereas in the adult patient closed treatment results in forced adaptation to the altered anatomy, in children rapid and progressive remodeling of the condylar unit is common. Dramatic evidence of this extensive remodeling is seen when careful examination of long-term postoperative CT scans is performed. Although closed reduction of condyle fractures with a very brief period of MMF followed by physiotherapy and training elastics is not time consuming or technically demanding, the long-term follow-up required for these injuries is. Although ankylosis following condylar fractures is rare in North America (compared with the significant incidence in the Third World), children with these injuries should be followed at regular intervals until the completion of mandibular growth. The assistance of an orthodontist who is familiar with functional appliance therapy for growth modification is invaluable should asymmetry begin to develop in the early post-injury phase. If the asymmetry is not or cannot be corrected with growth modification, surgical correction using conventional facial osteotomies can go forward

Fig. 5. Lingual splint. Adjunct to managing pediatric mandible fracture.

Fig. 6. Postoperative three-dimensional CT scan reconstruction showing inferior border plate and Risdon cable. Note excellent reduction.

once growth is complete. Proffit and colleagues [29] reported that up to 10% of patients in the dentofacial deformity population have evidence of previously undiagnosed condyle fractures.

The amount of time that children with condyle fractures stay in tight elastic MMF before being allowed to function with elastic guidance has been decreasing over time. This is secondary to the realization of therapeutic value during functional movement of the condyle as the bone reacts to the soft tissue forces surrounding it. Previously, the timeframe for tight elastic MMF was set for approximately 14 days to allow for a decrease in swelling and pain before begin function. However, in our experience only a few days are more than adequate for the discomfort associated with the injury to decrease to where function of the joint is possible. Given the well-documented capacity for rapid bone healing, the highly osteogenic potential of the facial bones, and the important relationship of the functional soft-tissue envelope on bone in the growing patient, this approach has much to recommend it. In instances where there are accompanying fractures of the mandibular corpus, ideal treatment with a lingual splint for monomaxillary fixation would still allow for almost immediate mandibular function. Alternatively, closed reduction with wire MMF can be performed for a brief period of time, usually 7 to 14 days, before elastic guidance is instituted to promote function of the joint. The advantage of monocortical plate and screw fixation at the inferior border, as discussed previously, would also allow for immediate mandibular function. For the surgeon managing pediatric maxillofacial trauma, an in depth understanding of these fractures is essential for good outcomes. The maintenance of mandibular projection, symmetry, and a functional occlusion through closed technique remains the cornerstone in the treatment of condyle fractures in children.

Special considerations

The role and use of rigid internal fixation in children

For the most part, as detailed extensively in this article, there is little indication for the generalized use of plate- and screw-type internal fixation in the pediatric population as used in adult maxillofacial trauma. However, there are some key considerations if internal fixation is employed for fracture stabilization.

The advent of biodegradable bone plates and screws has been regarded by some as an excellent material for pediatric facial bone surgery [30,31]. In addition, the use of these systems has been documented extensively for orthognathic surgery in the mandible and maxilla by Turvey and colleagues [32]. However, like distraction osteogenesis of the facial skeleton, biodegradable plates and screws remain a tool in the surgeon's arsenal and should not be considered a panacea. The systems remain too bulky and oversized to maintain rigidity in the bones of the pediatric facial skeleton. During primary or mixed dentition placement, avoiding unerupted teeth with screws becomes very challenging—especially in the mandible. In addition, aggressive degradation of the plates and screws has been noted causing sterile abscess that can further complicate healing. Several factors must be carefully considered before employing this type of fixation. First, has the bone that requires fixation reached skeletal maturity? If not, the argument regarding plate and screw migration is no longer valid. Second, especially in the mandible, does the plate and screw system employed offer the expected rigidity of the stabilized fracture that prompted the surgeon to perform open reduction with internal fixation as the treatment plan? If the use of the biodegradable system does not offer the appropriate amount of rigidity for stabilization and a period of closed reduction is necessary, then the advantage of using rigid internal fixation to allow immediate function has been negated. These concerns should not be construed to imply that the authors are suggesting that biodegradable systems have no role in the management of pediatric maxillofacial trauma—just a more limited role as technology continues to develop. Certainly for cranial vault fractures in the growing child, the advent of biodegradable systems has been very useful. Although titanium plate and screw migration has not been shown to cause neurologic injury, resorbable plates and screws have eliminated this concern and there is less concern overall for rigidity in fixation in the cranial vault. In other areas of the facial skeleton, judicious use of these systems, understanding of facial growth, and achievement of fracture rigidity that necessitated open reduction with internal fixation should guide the pediatric maxillofacial trauma surgeon. If titanium fixation systems are used, adequate stabilization of the fracture can be most commonly achieved with low-profile plates and monocortical screw placement. Consideration can be given to removal of the internal fixation hardware once union has been achieved. For most young children, a return to the operating room is usually required for removal of the wire fixation, and the plates or screws may be removed at this time. Again, every effort should be made to avoid damaging the developing dentition with screw placement.

The Risdon cable in pediatric maxillofacial trauma

The primary and early mixed dentitions have numerous anatomic challenges associated with placement of MMF devices. The crowns of the teeth are short, squatty, and bulbous, and can be loose. In addition, replacement of teeth as a normal process of the succedaneous dentition leads to edentulous areas awaiting full eruption. Various types of arch bars are universally used in the application of MMF during trauma and elective reconstruction of the maxillofacial skeleton. Unfortunately, the design and bulk of these arch bars do not fit the pediatric dentition very well. As a result, the circumdental ligature wires loosen and slide off, often not even surviving emergence ‘‘struggling’’ in the recovery room. To overcome these shortcomings, many surgeons advocate the use of skeletal fixation such circumandibular, circumzygomatic, and pyriform aperture wires to hold the arch bars in place. This only adds further steps to achieve solid MMF

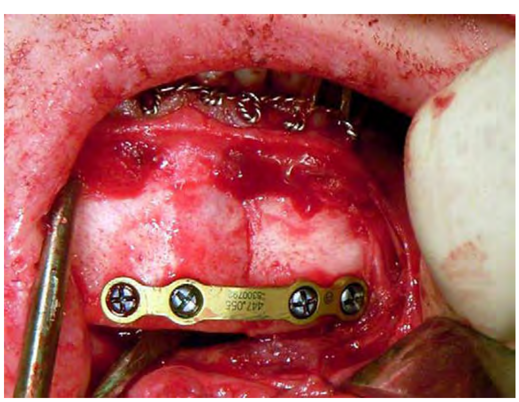

Fig. 7. When ORIF is indicated in pediatric mandible fracture treatment, keep hardware low to avoid damaging developing permanent dentition.

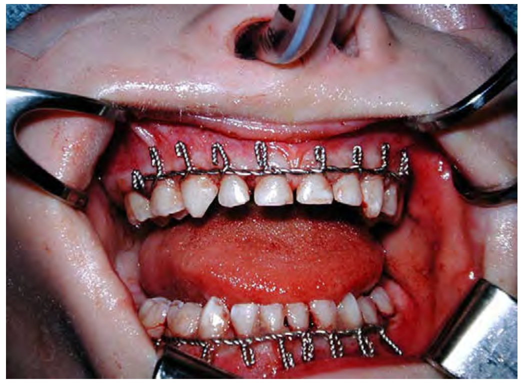

Fig. 8. Risdon cable. Twenty-four—gauge stainless steel wire is braided and acts as archbar. Each tooth ligated to the braided arch bar in the standard fashion. Note low profile of Risdon cable.

appliances and with the soft nature of the bone in children, the wires can saw through the bone if diligence is not exercised during placement.

The use of a modified Risdon cable in the primary and early mixed dentition is efficient in its application, provides excellent stability for elastic fixation, and does not require the additional placement of skeletal fixation. As the name implies, it was first described by Risdon [33], an otolaryngologist, in 1938. In essence, the bar is replaced by a cable of twisted 24-gauge stainless steel wire taken from one side of the dental arch to the other and secured to each tooth with a circumdental 24-gauge stainless steel wire. Alternatively, the cable can be started posteriorly on both sides of the same arch and tied together in the midline for added compression of anterior mandibular fractures. The fundamental advantage is that the cable is thin enough and easily contoured to allow for adequate engagement of the circumdental wires. The circumdental wires are then twisted into loops for holding elastics for MMF or guiding functions. Application is rapid in both arches and very tight MMF can be achieved with elastics alone. During emergence from anesthesia, the elastics ‘‘give’’ instead of the fixation pulling off the teeth, so the surgeon does not have to undergo the embarrassment of returning the child to the operating room to reapply the MMF appliances. At the University of Louisville, we almost exclusively use the Risdon cable in our pediatric patient population with excellent clinical results. The Risdon cable technique is a favorite ‘‘clinical pearl’’ in recommending clinical options to colleagues (Figs. 8 and 9).

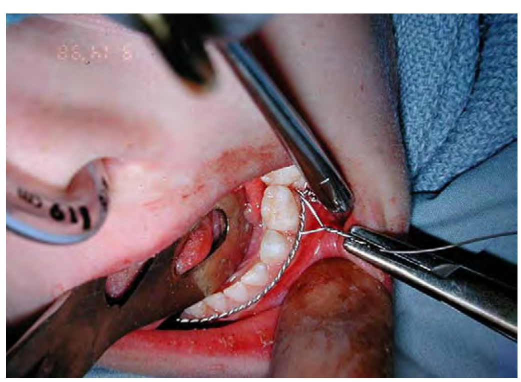

Fig. 9. Risdon cable. Twenty-four—gauge stainless steel wire is braided and acts as archbar. Each tooth ligated to the braided arch bar in the standard fashion. Note low profile of Risdon cable.

Summary

Management of pediatric maxillofacial trauma and especially mandibular trauma is both challenging and rewarding. Unfortunately, there will always be injuries to our children and we as a profession must step forward and provide the necessary care to our most valuable and vulnerable patient population. The majority of pediatric mandibular fractures can be managed with closed techniques using short periods of MMF or training elastics alone. However, there will always be reasons to perform open reductions with internal fixation. This is generally reserved for difficult fractures which are grossly displaced and are multiple in nature. When internal fixation is used, the surgeon must be cognizant of the developing permanent dentition within the jaws and position the plates and screws accordingly, generally at the inferior border of the mandible. The surgeon must constantly weigh the risks of surgical intervention against the wonderful healing capacity of children. Unlike adults, treatment of pediatric mandible fractures has a low complication rate. Once an injury has occurred, the surgeon ideally should follow the patient long-term to observe any potential growth disturbances. Often, this is extremely difficult due to the mobility of our patient population, insurance obstacles, and family dynamics. Parents should be counseled on the potential for growth disturbances in the child which may require additional treatment.

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Atlas Oral Maxillofacial Surg Clin N Am 17 (2009) 93–101

Atlas of the Oral and Maxillofacial Surgery Clinics

Complications of Mandibular Fractures

Barry E. Zweig, DDS

Department of Oral and Maxillofacial Surgery, Room C759, New Jersey Dental School, 110 Bergen Street, Newark, NJ 07103, USA

A complication is a problem that arises as a consequence of an initial condition or as a result of treatment. Because of its prominent position in the facial skeleton and the complex nature of the anatomy and environment in which it resides, the mandible is extremely susceptible, and thus frequently fractured when a traumatic insult is directed at the face. In addition, the anatomic architecture and presence of teeth create inherent areas of weakness and place the mandible at further risk for fracture. Complications involving mandibular fractures are a consequence of a myriad of factors. As such, they may be secondary to the original injury, a result of the subsequent treatment, or, in some cases, a result of failure to render treatment. Complications of mandibular fractures have an increased relevance because of the important role that the mandible plays in the establishment of occlusion, function, and facial esthetics.

Complications can present as an immediate problem at the time of injury, or they can become manifest during the operative or postoperative phase of treatment. Postoperative complications can become evident early on or some time after treatment has been instituted. In fact, some problems may not become evident for months or years after the injury. Complications of mandibular fractures can involve the entire spectrum, ranging from minor complications with little residual consequence to those having dire consequences with long-term deficits and even death.

Immediate complications

Because of the size, shape, and thickness of the mandible, any insult sufficient enough to cause a fracture of the mandible can readily result in concomitant intra-abdominal, intrathoracic, intracranial, or cervical injury (Fig. 1). In addition, it is not unusual to have simultaneous significant soft tissue injury resulting in significant edema and copious hemorrhage with the potential for airway compromise or hypovolemic shock (Fig. 2). Although in many instances of mandibular fracture, the oral and maxillofacial surgeon is consulted after the patient has been evaluated and stabilized by the trauma team or emergency department staff, it still behooves the sagacious practitioner to evaluate the patient appropriately for problems that may be life threatening, and thus take priority over the maxillofacial injury. Appropriate consultation with suitable imaging should be obtained if any of these more imperative injuries are suspected.

Airway compromise

Airway compromise may be a direct result of the mandibular fracture attributable to swelling, bleeding, foreign body aspiration, or amount of displacement, in addition to the nature of the fracture. The amount of swelling is a consequence of the severity of the injury and the degree of soft tissue involvement. Swelling can be decreased by the use of steroids immediately after trauma unless contraindicated by the patient's medical history or current condition.

E-mail address: zweig@umdnj.edu

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doi:10.1016/j.cxom.2008.10.005

Fig. 1. Fracture of C2 along with mandibular fracture.

Preliminary reduction and immobilization may be necessary in severely displaced fractures or in the situation of bilateral body fractures because of the lack of anterior support for the tongue with prolapse to the posterior pharynx and subsequent airway compromise (Fig. 3). The use of an oropharyngeal airway in the unconscious patient or bilateral nasopharyngeal airways in the conscious patient may help to alleviate airway compromise. In cases of severe compromise, intubation or tracheotomy may be required. Airway problems associated with concomitant intrathoracic or intracranial causes should be addressed by the appropriate surgical specialty before attempting any treatment of the mandibular fracture.

Bleeding

Although soft tissue or osseous bleeding is not uncommon, significant hemorrhage after mandibular fractures is a rare occurrence. If the trauma results in transection of a major vessel within the bone or the surrounding soft tissue, hemorrhage can be severe with life-threatening consequences because of the potential for hypovolemic shock or hematoma leading to airway compromise. Arrest of bleeding should be attempted by local measures initially; if such measures are unsuccessful, isolation and ligation of the offending vessel should be entertained. The application of initial reduction and temporary fixation may be helpful in stopping or

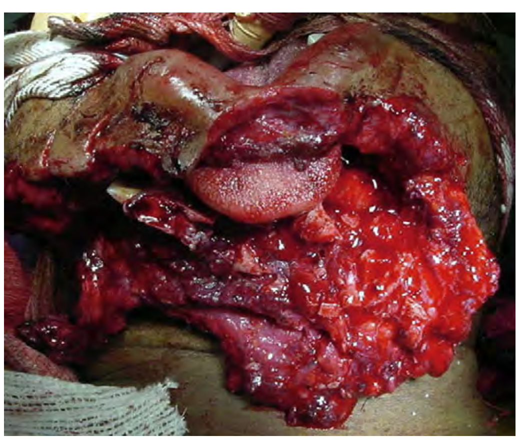

Fig. 2. Gunshot wound of the mandible with soft tissue damage and need for endotracheal intubation.

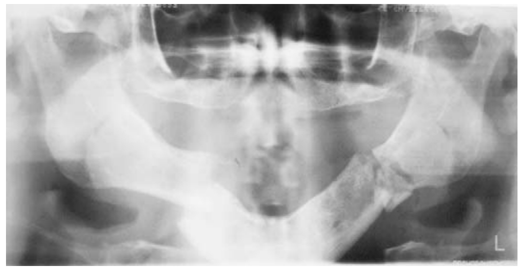

Fig. 3. Bilateral body fractures with lack of tongue support.

decreasing bleeding because of its resulting tamponade effect. In rare cases, embolization of the offending vessel or external carotid artery ligation may be required.

Loss of or damage to teeth or bone

Because of the vulnerable position of the teeth, a fracture of the mandible is frequently associated with concomitant injury to the teeth or alveolar bone (Fig. 4). Teeth can be fractured, mobilized, or avulsed when a mandibular fracture occurs. This may require debridement, fixation, extraction, or endodontic therapy. Because establishment of correct occlusion is the sine qua non to treating mandibular fractures successfully, the loss of teeth or alveolar bone fracture may compromise reduction of the mandibular fracture and may necessitate an open rather than closed procedure or construction of a surgical stent. Teeth that become nonvital during the healing phase can cause infection and interfere with fracture healing. It is suggested that all compromised teeth be treated early to lessen the chance of this occurring (Fig. 5). Questionable teeth in the line of fracture have special relevance and are addressed in another article in this issue.

Delayed complications

Nonunion

A nonunion is the lack of osseous union by two or more fracture segments after the usual 6- to 8-week healing period. Fortunately, nonunion of mandibular fractures is not a common occurrence. In some instances, no additional treatment is required because the nonunion responds to conservative management consisting only of an increased period of immobilization. This is particularly evident when there is limited bone volume or the patient has a decreased healing capacity attributable to age or concomitant medical conditions or medications. If conservative management is not successful, a second surgical intervention for correction may be

Fig. 4. Alveolar mandibular fractures.

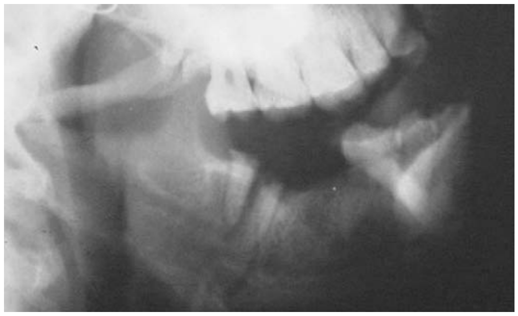

Fig. 5. Compromised tooth in the line of fracture.

required. There are many reasons why a fracture does not go on to bony union, including interference in the reduction or immobilization of the fracture and the development of infection with a resultant loss of bone (Fig. 6). Inadequate reduction with a gap between fracture segments or the interposition of soft tissue that prevents bone-to-bone contact can cause a nonunion. Excessive mobility has the propensity to prevent the initial callus formation necessary for subsequent bone formation and maturation that may go on to develop a fibrous union. In the case of closed reduction, this may result from inadequate or loose intermaxillary fixation causing macromovement of the fracture segments. For complete or partial edentulism, an insufficient number of teeth may be available for adequate immobilization and a surgical stent may be necessary for to prevent or minimize mobility. In contaminated cases or those treated by means of an open approach, infection may act as the causative agent in causing a nonunion. When rigid fixation is used, infection can result from screw loosening with subsequent fracture site mobility. Infection can also result in the destruction and loss of bone at the fracture site with a lack of bony contact, and thus the inability to form an osseous union. In addition to infection, large gaps can be caused by loss of bone because of the nature of the injury, as is frequently seen with high-energy wounds.

Additional causes of mandibular complications are impacted teeth present at the fracture site that require removal for adequate reduction and pathologic entities, such as cysts or neoplasm. The patient's age and systemic health may also play a role in the development of a nonunion. The elderly patient has a greater chance of a nonunion for two reasons. An elderly patient's reduced ability to form a bony union may attributable to a decrease in age-related healing factors, and there is often a decrease in bone height and width (Fig. 7) attributable to the normal resorptive process that occurs with loss of teeth and aging. This lack of bone quality and quantity compromises the vascularity of the bone, further complicating healing. Any concomitant medical or systemic condition or medications that the patient may be taking can result in a nonunion by altering or interfering with the natural healing potential of the body.

The treatment of nonunion depends on the cause and the resultant deformity or defect. In most cases, an open procedure is required to visualize the fracture and to remove any tissue present between segments. After all soft tissue or infected material is removed, the patient is placed in occlusion with maxillomandibular fixation while the fracture is reduced. If there is good bone-to-bone contact, the fracture segments are rigidly fixated. In the event that bone

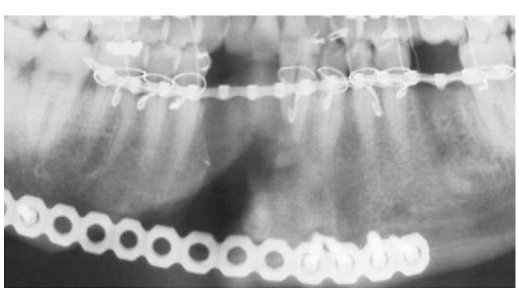

Fig. 6. Nonunion attributable to loss of bone.

Fig. 7. Lack of bone height and width.

has been lost because of infection or loss of vascularity, the ends of the fracture segments are freshened to reveal vital bleeding bone and a bone graft is placed between the segments if infection has resolved with the placement of a bicortical reconstruction plate.

Malunion

Malunion occurs when fracture segments are not properly reduced or fixated, and bony union takes place in a less than ideal position. An important way to decrease this complication is to place the patient carefully in the appropriate occlusion before any surgical intervention; at that time, the fracture is reduced and fixated. Many times, a malunion manifests clinically as a malocclusion, an inability to function normally, and, in some cases, an obvious facial deformity (Fig. 8). A malunion can occur because of a poor treatment plan; surgical error; or when there are missing or carious teeth, multiple fractures, or concomitant alveolar fractures that prevent the establishment of the proper occlusion. The correct treatment plan (ie, open versus closed reduction), external appliances, or stent construction should be based on the degree of fracture displacement, the location, the amount of bone loss or comminution, and the lack or presence of a sufficient number of teeth to establish adequate occlusion.

Once recognized, a malunion should be treated as early as possible. Minor occlusal disharmonies can be treated with occlusal equilibration, or possibly orthodontic acre. Gross abnormalities may require surgical intervention, however, in which the fracture is osteotomized, the segments are properly reduced, and the appropriate occlusion is established. Fractures involving the mandibular condyle present with separate and unique problems and are discussed in a subsequent section.

Nerve injury

Fractures involving the angle or body of the mandible frequently result in some degree of neurosensory deficit because of fracture displacement. As a result of their intrabony anatomic

Fig. 8. Malunion with resulting malocclusion.

location, resultant trauma to the inferior alveolar or mental nerve can occur. These injuries may be a consequence of the trauma itself or attributable to iatrogenic reasons, such as surgical complications; improper placement of plates and screws; or the extraction of teeth, especially third molars, that may be in the line of fracture. Most of these nerve injuries are usually temporary in nature because they are a consequence of compression or stretching of the involved nerves. In markedly displaced fractures, however, neurotmesis (complete injury) can occur, causing an injury that may result in permanent neural dysfunction. A lack of timely treatment with reduction and immobilization may cause the fracture segments to move continually, causing additional trauma to the nerves. In cases in which nerve function does not completely resolve, exploration with potential microsurgery should be considered.

The literature supports the fact that open reductions have a greater incidence of complications compared with closed reduction. This is not surprising, because surgery always carries some inherent risks. Overzealous exposure and retraction of segments, improper drilling, and inappropriate placement of plates and screws have all been implicated in postsurgical nerve dysfunction (Fig. 9). Extraoral open reductions also carry the additional risk for injury of mandibular branch of the facial nerve. This can have even greater untoward consequences because this is a motor nerve affecting function and facial esthetics. Fortunately, in most instances, this complication is transient, resulting from retraction, manipulation, or swelling and resolves in a short time. If care is not taken during the dissection process, however, the nerve can be inadvertently injured. Direct transections visualized at the time of surgery should be repaired immediately at the level of the epineurium, tagged for future repair, or tubulized to allow guided regeneration.

Infection

The most frequent complication of mandibular fractures is infection. This can involve the soft tissue surrounding the fracture site, or a more severe infection can result in osteomyelitis because of involvement of the cortical and medullary bone. There are many factors that have been implicated in the development of infection, including a delay in treatment, the lack or inappropriate use of antibiotics, teeth in the line of fracture, the type of fracture (comminuted versus noncomminuted), patient noncompliance, inadequate reduction or fixation, and concomitant medical conditions.

Treatment delay of longer than a few days may cause fracture segments to move, resulting in damage to the surrounding soft tissues, increased bleeding with hematoma formation, and contamination of the wound. This is particularly important if there was a concomitant delay in

Fig. 9. Nerve injury secondary to hardware placement.

antibiotic use, because multiple studies have demonstrated an increased rate of infection without the use of appropriate antibiotics after 72 hours.

Teeth in the line of fracture (discussed in detail in another article in this issue) can serve as a nidus of infection by allowing for contamination by way of the periodontal space or by becoming nonvital with a resultant periapical infection that can spread to the marrow spaces. Most practitioners agree that teeth in the line of fracture should be removed if they interfere with reduction, are carious or periodontally involved, have periapical pathologic findings, are fractured, or are extremely mobile.

Noncompliance by the patient can also initiate or contribute to infection development. Patients who do not follow the prescribed antibiotic protocol and dietary restrictions markedly increase their chance of infection. In addition, those patients who remove their maxillomandibular fixation prematurely can cause early movement of fracture segments with resultant infection of bone or soft tissue.

If the infection is confined to the soft tissue, incision and drainage with copious irrigation should be performed and specimens should be sent for aerobic and anaerobic cultures and antibiotic sensitivity (Fig. 10). While waiting for the results of this testing, the patient should be placed on penicillin, assuming there is no history of allergy. The area should be irrigated daily until no visible drainage is evident and the patient shows clinical signs of resolution. If it is deemed that a tooth in the line of fracture is the causative agent, it should be extracted at the time of incision and drainage.

Infections spreading to the bone can lead to osteomyelitis. This can result in ischemia, followed by necrosis and, ultimately, loss of osseous structure (Fig. 11). The decrease in vascularity can prevent antibiotic penetration, making osteomyelitis difficult to treat. Osteomyelitis treatment is by means of a multistep approach involving incision and drainage, sequestrectomy, frequent irrigations, immobilization, and prolonged antibiotics. In cases in which significant amounts of bone are lost, reconstructive surgery with bone grafting may be necessary as a secondary procedure.

Temporomandibular joint problems

Because of their anatomic location, condylar mandibular fractures can present a unique set of potential temporomandibular joint disturbances. There can be damage to the surrounding soft tissues (especially the disk), potential growth disturbances, ankylosis, malocclusion, and iatrogenic injuries as a consequence of surgical treatment (Fig. 12). Initial asymmetry during function is often seen after condylar fractures. This is a result of a deviation of the mandible to the affected side from unopposed lateral pterygoid action. This often resolves after closed reduction with a short period of immobilization, typically 7 to 10 days, and adaptive mechanisms by the body. Abnormal condylar growth can occur in the growing individual, resulting in an asymmetry or malocclusion over time. Many nondisplaced condylar fractures require no treatment provided that the patient's occlusion is reproducible. Condylar fractures are treated by

Fig. 10. Soft tissue infection after mandibular fracture.

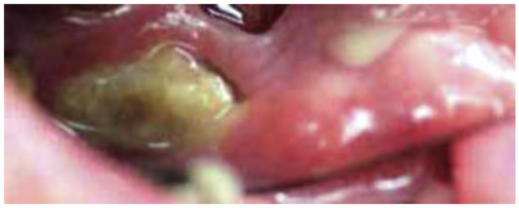

Fig. 11. Osteomyelitis of mandible with sequestrum.

Fig. 12. Open bite secondary to bilateral condylar fractures.

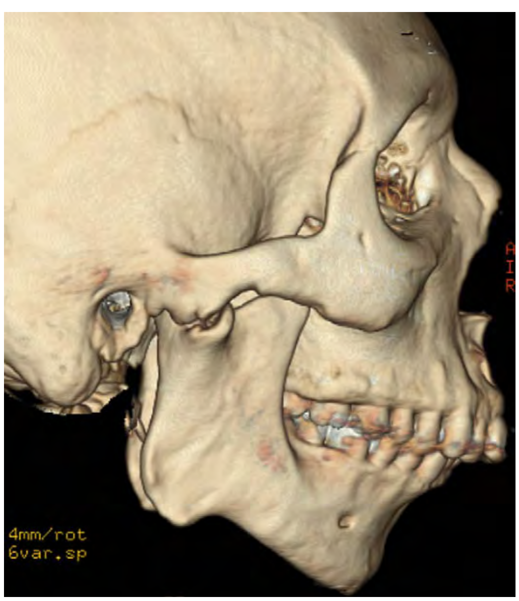

Fig. 13. Ankylosis after untreated mandibular condylar fractures.

means of a closed procedure whenever feasible because of proved successful outcomes and decreased potential problems. With the potential for ankylosis, condylar fractures should be mobilized early and function should be initiated (Fig. 13). There are significant inherent risks associated with the open procedures that may be required to treat condylar fractures refractory to a closed procedure. The potential for bleeding, infection, parotid gland fistulae, facial nerve injury, facial scarring, and decreased joint mobility can result. Because of their disadvantages, open procedures are generally used when reduction is not possible because of mechanical obstruction or displacement into the middle cranial fossa or with panfacial fractures with vertical shortening of the face that require open treatment.

Summary

The prominent position of the mandible within the facial skeleton makes it a frequently fractured structure. Before any definitive treatment of mandibular fractures, the patient needs to be evaluated for more potentially life-threatening injuries. Complications can and do occur with treatment of mandibular fractures and can occur during any of the phases of treatment. The development of an accurate diagnosis and appropriate treatment plan is vital in achieving optimal success and decreasing complications. Knowledge of the anatomy and the principles of bone healing is also an important factor in preventing complications. To limit long-term untoward effects, complications should be recognized early and the appropriate treatment should be started before a minor complication becomes a complex one that is more difficult to manage.

Further readings

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