ACTA SCIENTIFIC DENTAL SCIENCES (ISSN: 2581-4893)

Volume 2 Issue 12 December 2018

Review Article

Techniques of Rigid Internal Fixation for Mandibular Fractures

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Received: October 12, 2018; **Published:** November 26, 2018

Abstract

Proper application of rigid internal fixation (RIF) is a highly technical procedure during which correct technique must be followed to keep complications to a minimum. Many different systems for maxillofacial rigid fixation are currently available and most employ the same basic principles. AO/ASIF (Arbeitsgemeinschaft fur Osteosynthesefragen, Swiss study group in 1958/ Association for the Study of Internal Fixation, German study group) system is used as a model to describe the application of rigid fixation and compression osteosynthesis.

Keywords: RIF; Compression Osteosynthesis; Mandibular Fractures

Introduction

Internal fixation of fractures has been the subject of much discussion over the past twenty-five years. For centuries surgeons have attempted to provide satisfactory treatment for fractures of the skeleton. All attempts, both early and recent have focused on the time-honored and proven principles of reduction, immobilization and rehabilitation. The most basic variable in the implementation of these principles have been and still is whether the fracture should be treated open (i.e. Operatively exposed to provide means for reduction and/or immobilization) or closed. Rigid Internal Fixation is "Any form of fixation applied directly to the bones which is strong enough to permit active use of the skeletal structure during the healing phase and also helps in healing". Internal fixation for maxillofacial surgery was developed initially for mandibular fractures, and then was applied to mid and upper face fractures, continuity defects, and subsequently to facial osteotomies [1]. In 1949, Davis put forth three basic aims of RIF as immediate active movement of muscles and joints in the affected region, complete restoration of body form and direct union of bony fragments without the formation of visible callus. RIF has improved the total care of multiple trauma patients. Early reduction of fractures with RIF decreases the number of days on a ventilator and the stay in an ICU and contributes to reduced morbidity due to metabolic disturbances which accompany trauma and its treatment. RIF for facial fractures allows restoration of occlusion and the bony architecture while eliminating or minimizing the period of maxillomandibular fixation. Thus, RIF improves airway management, nutrition, and oral hygiene while hastening the patient's return to full function. Speaking and communication obviously are improved if the patient does not have the teeth wired together. RIF has also increased our understanding of the mechanisms of osseous healing. Experience has shown that callus formation at the fracture site is not a necessary step in bone healing. Use of RIF has resulted in the evolution of the concept of primary bone healing.

Techniques of RIF

Many different systems for maxillofacial rigid fixation are currently available and most employ the same basic principles.

Compression osteosynthesis

The goal of the AO or ASIF is rigid internal fixation with primary bone healing, even under functional loading. To achieve this goal, four basic principles must be achieved:

Citation: Kanwaldeep Singh Soodan., *et al.* "Techniques of Rigid Internal Fixation for Mandibular Fractures". *Acta Scientific Dental Sciences* 2.12 (2018): 153-159.

1. Accurate reduction of the bone fragments
2. stable fixation of the fragments
3. preservation of the adjacent blood supply, and
4. Early functional mobilization.

Unless compression is achieved across a fracture, the stability of the fracture is dependent on the rigidity of fixation system, without the benefit of friction between the bony surfaces. If after fracture reduction a space exists between the ends of the fracture, the fixation device will be under great force, possibly leading to deformation of the plate, fracture of the plate, or loosening of screws. Additionally, instability of the bony fragments promotes bone resorption and infection. The goal of compression osteosynthesis is a condition called absolute stability in which no movement occurs at the area of interfragmentary contact or between the bone and the fixation device [2]. Compression of the fractured bone segments enhances the likelihood of successful primary bone healing in two ways;

Generation of the preload, which is the force generated across the fracture by the fixation system. Preload provides absolute stability in the loaded mandible as long as the dynamic traction forces produced by loading do not exceed the forces of interfragmentary compression.

Friction produced by compression of the fractured bone segments. The amount of friction produced is the product of the force of compression and the coefficient of friction.

This friction between the fracture segments is beneficial in that it helps reduce fracture mobility produced by torsional forces. The effects produced by interfragmentary compression (preload and friction) help stabilize the fracture, minimizing complications such as osteomyelities and nonunion. Multiple studies suggest that there is no inherent osteogenic effect from compression, but the benefit is an increase in fracture stability, results in primary bone healing. The forces of compression dissipate as one move away from the plate. In addition, the forces achieved during compression osteosynthesis are not static. There is a variable loss of compression over time. The greatest loss occurs during the first few days. After this initial loss of compression, the residual compressive forces diminish gradually over several months. The AO principles of rigid fixation are based on the principles of beam mechanics. Ideally, one would like to place a plate at the superior border of the mandible where tensile forces dominate. Because of the roots of the teeth and the inferior alveolar canal, insertion of a plate in this location is associated with unacceptable morbidity. When considering adjacent anatomic structures, the most acceptable location for mandibular plate placement is at the inferior border. A standard fracture plate placed at the inferior border of the mandible is capable of providing compression to the bone fragments, but it fails to control the tensile forces at the alveolar surface. Several methods of fixation have been developed to provide compression of the fracture segments while minimizing tensile forces at the alveolar surface.

Dynamic compression plates (DCP)

In 1977, Luhr adapted the principle of dynamic compression to maxillofacial region for treatment of mandibular fractures; however, Spiessl was first to apply the AO/ASIF principles to the management of mandibular fractures [3]. The ingenious design of the dynamic compression plate is based on a screw head that, when tightened, slides down an inclined plane within the plate. The compression hole is elongated in a direction parallel to the axis of the plate, with the highest portion of the inclined plane located at the outer aspect of the hole.

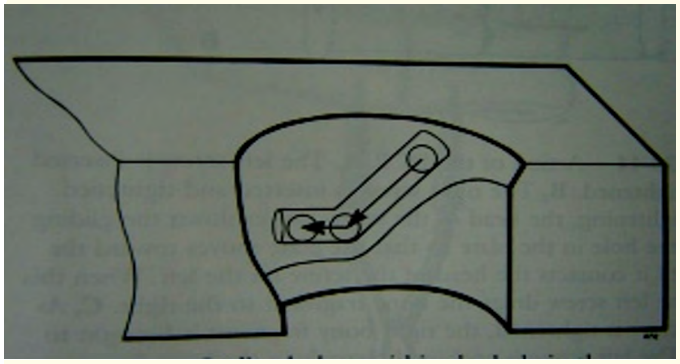

Figure 1: Inclined plane within the hole in the plate. As screw is tightened, it moves down the inclined plane, causing the underlying bone to translate toward the fracture site.

If the screw is initially drilled in the outer or most elevated portion of the hole, it will tend to move in the direction of the least resistance as it is tightened. This movement results in the screw, and the bone in which it is fastened, moving toward the fracture until the screw is completely seated and has reached the lowest point of the inclined plane. If a screw is placed at the height of the inclined plane so that it will move as it is tightened, it is called a compression screw. If the screw is placed at the lowest point in the hole so that it will not create compression as it is tightened, it is termed a static or passive screw. For the plate to be a dynamic compression plate, one compression hole should be located in each fragment of the fracture; these holes are usually placed most proximal to the line of fracture. Screw movements produced from the inclined planes of these holes oppose each other, the fracture ends will move toward one another relative to the plate (compression or active screw). This movement of the bony segments relative to the plate produces compression across the fracture. In the AO/ASIF plating system, each compression hole will produce 0.8mm of the bone movement. Thus, if compression is used on both sides of the fracture, a total of 1.6 mm of bone movement may be achieved (0.8 mm on each side). If no compression is desired, compression holes may be used for screw placement as long as placement is at the low point of the inclined plane, which corresponds to the side of the hole toward the fracture (static or passive screw) [4]. In order to eliminate rotational movements of the plate, at least two screws are necessary on each side of the fracture. Therefore, positional screws are placed passively in the outer holes after the compression screws have been activated in the holes adjacent to the fracture.

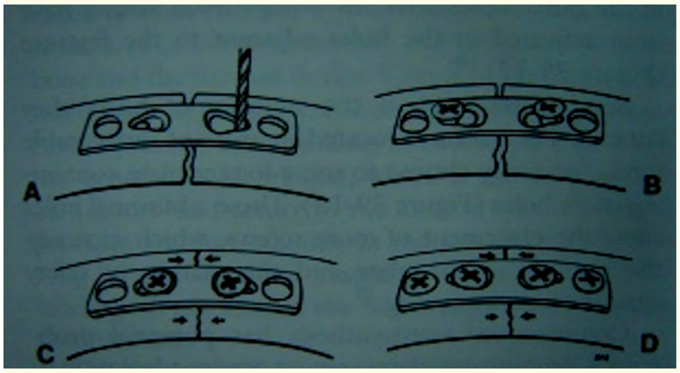

Figure 2: Sequence of screw placement when using DCP.

Bone plates vary in the number of holes they contain. For severely oblique fractures, or fractures located in the areas of unfavorable forces, longer plate containing more holes may be used. These additional holes allow the placement of mores crews, which increases stability of the plate and the margin of safety against screw loosening.

Eccentric dynamic compression plates

When the DCP and tension band cannot be applied because of anatomic constraints-such as the presence of an impacted third molar, an edentulous mandible, or avulsion of bone from the fracture, the eccentric dynamic compression plate (EDCP) may be used for plating the mandibular fracture. In 1973, Schmoker, Niederdellmann and Schilli simultaneously developed a plate incorporating the principle of eccentric dynamic compression. The design of this plate represents method of producing compression at the superior border of the fractured mandible. The design of this plate is similar to the DCP in that the inner holes are designed to produce compression across the fracture site [5]. In addition to the standard compression holes, however, the plate also contains two oblique outer compression holes. These eccentric compression holes are aligned at an angle oblique to the long axis of the plate. The activation of these outer holes produces a rotational movement of the fracture segments with the inner screws acting as the axis of rotation. This rotation of the segments establishes compression at the superior border of the mandible. In a study by the AO group, it was found that when the EDCP was applied, an initial compressive force of 200 N was observed at the inferior border of the mandible. As the outer oblique screws were activated, the compression at the base of the mandible decreased to 150 N, but compression of 150 N was now observed at the superior border. The effectiveness of superior compression also depends on the degree of the oblique hole from the long axis of the plate. When the eccentric hole is oriented at a 90-degree angle to the plate, compression at the alveolar surface is less than that generated with the eccentric hole at a 75-degree angle to the plate. The EDCP is applied using the same screws, drills, and taps as those used with the DCP. A different bone reduction forceps is used, however, and the sequence in which the screws are inserted is also different [6]. In order to achieve anatomic reduction, precompression across the fracture, and precompression at the alveolar surface, a special bone reduction forceps is necessary for the application of the EDCP. These forceps incorporate pressure rollers that are located lateral to the holding screws. Once the holding screws have been engaged, anatomic reduction and recompression are achieved as with the forceps used for DCP. The outer rollers are then tightened, which produces an occlusal directed force on the outer aspect of the fracture. These rollers rotate the fracture segments around the holding screws, creating superior border compression. The principle of the EDCP depends on the activation of compression holes in two different planes. Screws are placed in the holes closest to the fracture margin first and are placed in the outer aspect of the screw slot to achieve compression of the fracture segments. After compression has been achieved at the inferior border, screws are placed in the outer eccentric holes; these are tightened, achieving compression at the superior border. If a six hole plate is used, screws are then placed in the remaining holes in a passive fashion. If a bone reduction forceps is used, it is removed prior to the placement of these screws to permit unobstructed screw placement [7]. The goal of the EDCP is to first establish longitudinal compression across the fracture at the inferior border and then to rotate the fragments around the screws to achieve additional compression at the level of the alveolus. The AO/ASIF principles have been used as the model for the application of compression osteosynthesis. Although most of the currently available rigid fixation systems share similarities with the AO/ASIF rigid fixation systems, differences in technique do exist.

Reconstruction plates

The DCP and the EDCP are the most commonly used plates for reduction and fixation of mandibular fractures. For severely oblique fractures, comminuted fractures, and fracture with bone loss, however compression plates are contraindicated. In these situations, compression across the fracture site may lead to overlapping or collapse of the bony segments. In the oblique fracture, a compression plate may not be long enough to avoid screw engagement of the overlapping fracture segments, thereby preventing compression. Therefore, a reconstructive plate may be the best method of fracture fixation. Additionally, patients with questionable postoperative compliance or a non-atrophic edentulous mandible fracture may be candidates for fixation with a reconstruction plate. The reconstruction plate has larger overall dimensions than compression plates, resulting in increased strength [8]. This larger size is designed to stabilize the fragments against functional displacement in the absence of compression. In a series of 54 patients who sustained mandibular angle fractures were treated with a reconstruction plate, Ellis observed a postoperative infection rate of only 7.5%. This incidence of infection is lower than that reported for angle fractures reduced with two miniplates, solitary lag screw, or closed reduction with MMF. He also suggested another indication for reconstruction plates: the patient in whom trans-oral plating is difficult and MMF is undesirable. Initially, it was felt that stripping periosteum from comminuted osseous segments was to be avoided because it would compromise the blood supply to these segments [9]. Thus, many comminuted fractures were traditionally treated with MMF or an external fixation device. Recently, the reconstruction plate has been employed as a successful alternative. In order to place multiple screws proximal and distal to the fractures as well as in the comminuted segments, the placement of a reconstruction plate requires extensive periosteal stripping. However, it is felt that the increased stability offered by the reconstruction plate may outweigh the disadvantages of increased periosteal reflection. If the blood supply to the comminuted fragments is compromised, the proximal and distal ends of the fracture may be fixed to the reconstruction plate while performing a supra periosteal dissection in the area of the comminuted fracture. Thus, the interposed comminuted bone is free from the reconstruction plate but attached to periosteum. This technique preserves periosteal and osseous blood supply, yet also provides stability. The reconstruction plate can be contoured in three dimensions, allowing adaptation to almost any site. The application of a reconstruction plate to the mandible is similar to that of the compression plate [10]. First pilot holes are drilled, then the holes are tapped with the appropriately sized tap, and screws are inserted. If necessary, emergency screws are available. It is suggested, however, that at least three screws be placed in each of the fractured segments, and if an osseous gap is being bridged, it is suggested that at least four screws be placed in each segment. In general, neutral positioning of the screws is recommended.

Titanium hollow screw Osseo integrated reconstruction plate (THORP)

The standard reconstruction plate has been used with varying success for many years. A problem observed with this type of fracture fixation is screw loosening, leading to mobility of the plate and instability of the bone segments. Lippuner and associates hypothesized that the genesis of this problem is that to achieve stable fixation, the reconstruction plate must be applied to the bone with pressure from the screw heads. This pressure leads to a local reduction in blood flow at the plate-bone interface [11]. This ischemia causes remodeling and bone loss under the plate and around the screws, causing them to loosen prior to osseous union. Mobile plates and screws often get infected, necessitating their removal. Other complications of a loose plate include nonunion or malunion of the bony segments. If long-term fixation is required (e.g. a post- traumatic bone graft), early loosening of the screws and mobility of the plate could lead to wound dehiscence, infection, loss of the entire graft, or a combination of these complications. In order to improve on the reconstruction plate, a modification called the titanium hollow screw Osseointegrated reconstruction plate was developed by Raveh. The design of this system provides stability without applying pressure to the underlying bone. This system was designed with screws that will not become loose over long periods and a plate that can provide adequate long- term functional stability.

Lag screw osteosynthesis

Lag screw osteosynthesis, via either true lag screw or a conventional screw and the lag screw technique, has been used to treat maxillofacial fractures effectively.

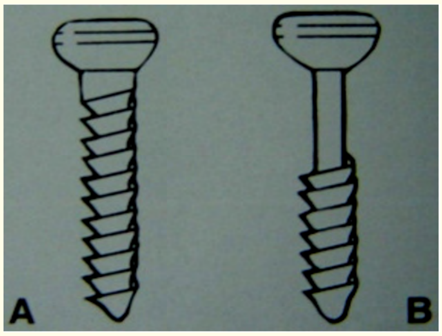

Figure 3: Diagrams representing conventional (passive) screw (A) and a true lag screw (B).

Lag screws may be used alone if the fracture is sufficiently oblique to allow the placement of at least two screws. Techniques have been described for the fixation of midline and paramidline fractures of the mandible as well as for fractures of the mandibular angle; however, caution must be observed when only one screw is used. In these instances, supplemental stabilization with miniplates is recommended [12]. A screw can act as a lag screw when it gains purchase in the cortex of the most distant osseous fragment while fitting passively in the cortex of the fragment adjacent to the screw head. This can be accomplished by using a true lag screw, which has threads in the distal end and a smooth shank at the proximal end (i.e. adjacent to the screw head).

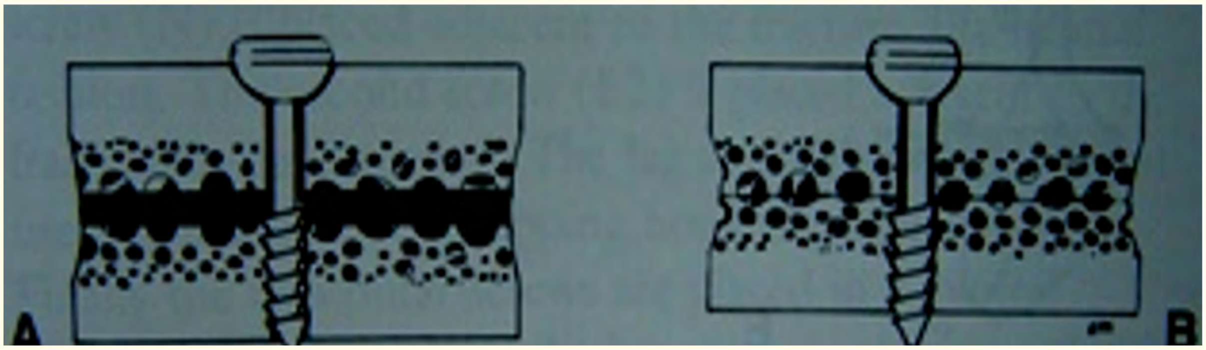

Figure 4: Diagram demonstrating use of a true lag screw. A, Pre-compression. B, Post compression.

The same result can be obtained with a regular cortical screw using the lag screw technique. In order to achieve this, an oversized hole (gliding hole) is drilled through the proximal cortex. The diameter of this hole must be at least as large as the thread diameter of the screw. The remainder of the hole (in the distal segment) must be smaller than the thread diameter. This is often referred to as the traction hole. When the screw is tightened, the distal fragment is pulled into compression against the proximal fragment by the screw head [13]. This compression creates friction, thus reducing the amount of inter-fragmentary movement. It is important to note that cancellous screws should not be used as lag screw in the maxillofacial region because of their tendency to fracture. Cancellous screws have a much thinner core diameter and coarser pitch when compared with cortical screws, making them more fragile.

When properly used, lag screw fixation offers the most rigidity of all rigid fixation techniques. It is possible to achieve between 2000 and 4000 N of compressive force when using lag screw, compared with the 600 N achieved with prebent compression plates. The lag screw fixation technique developed by the AO/ASIF group necessitates careful orientation of the screws to the fracture line. The correct placement of the screws helps distribute the compressive forces evenly across the fracture interfaces without distracting the fragments [14]. To avoid shearing of the fragments, the lag screw should be placed so that their axes bisect the angle between the perpendicular to the fracture line and the perpendicular to the bone surface. At least two lag screws, with diverging axes, should be placed in each fracture.

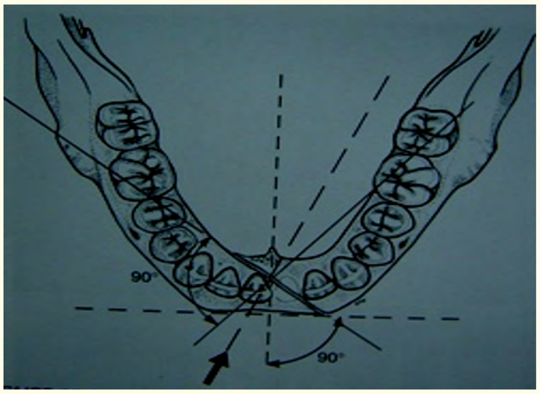

Figure 5: Diagram demonstrating correct position and angle of the lag screw placement.

Proper preparation of the receptor site is crucial in obtaining a successful result. First, the gliding hole is drilled in the near cortex with a diameter equal to the thread diameter of the screw. The traction hole is then prepared with the aid of a centering guide, assuring that the two holes are prepared coaxially. This is performed with a pilot drill (e.g. 2 mm for a 2.7-mm cortical screw). The depth gauge is then inserted prior to tapping the traction hole. This prevents disruption of the threads prepared within the cortical segment. The traction hole is then tapped to the final size (2.7 mm for a 2.7-mm cortical screw). Countersinking of the near cortex should be performed to distribute compressive forces over a broader area and thus prevent microfractures of the bone adjacent to the screw head. Once the receptor site is prepared, the screw can be inserted to achieve compression of the two segments.

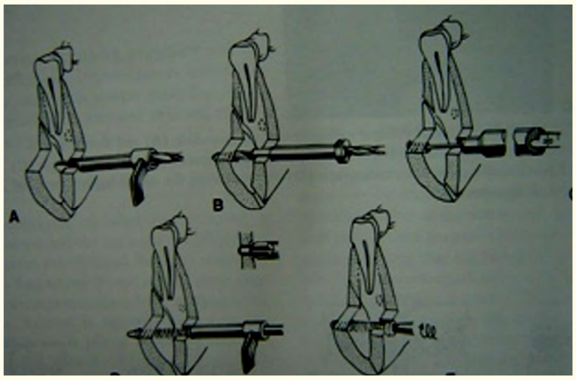

Figure 6: Diagram of steps in lag screw technique. A, the outer cortex & marrow are drilled up to the fracture site. B, the inner cortex is then drilled using special drill guide. C, the depth gauge is then used to determine correct length of the screw needed. D, the inner cortex is then tapped. E, the screw is placed, causing compression across the fracture.

Lag screw may also be used to stabilize bone grafts in the midface. When placing lag screw in the thin membranous bones of the upper maxillofacial skeleton, self-tapping screws have been shown to have greater holding ability than those placed in pretapped holes. Recent evidence also suggest that bone grafts retained with lag screw resorb to a lesser extent than do those fixed by other means. Two-millimeter self- tapping screws are most frequently used in the upper maxillofacial skeleton with the same basic principle as described for the mandible. After preparing the gliding hole with a 2mm drill, the traction hole is prepared with a 1.5mm drill, again using a centering guide. Since self-tapping screws are used, however, there is no need to tap the traction hole. Finally, the lag screw technique can be effectively used in conjunction with a standard noncompression plate or compression plate, depending on the anatomy of the fracture site.

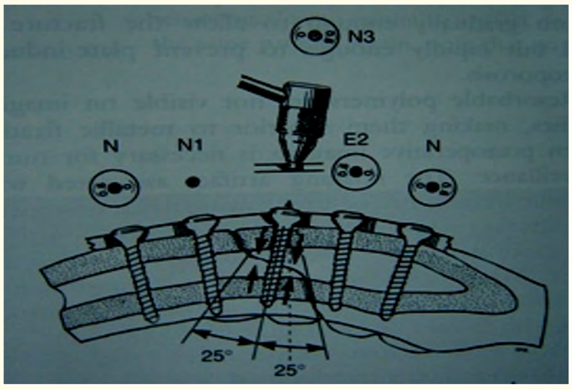

Figure 7: Sequence of screw placement when a compression plate is combined with a lag screw technique.

Discussion

Rigid skeletal fixation of facial fractures has evolved from the principles established in orthopedics. It has taken a long time to develop rigid internal fixation devices that provide stability combined with safety. The application of rigid skeleton fixation to the facial skeleton requires the surgeon to pay strict attention to detail, which may add a small time increment to the procedure. However, the benefits to patients of having early use of the jaws and exact placement of bony segments seem to outweigh the disadvantages. Although biocompatible materials such as titanium are generally used for osteosynthesis, they have certain disadvantages such as the liberation of metal ions, accumulation in some organs, and the continuation of the mechanical stimulus [15]. Therefore, in many instances, miniplates are removed at the earliest opportunity after bone healing has occurred. A miniplate system for promoting osteosynthesis using poly-L-lactide (PLLA), which is a strong bioabsorbable polymer, has been developed and applied to oral and maxillofacial surgery [16, 17]. In recent years, new techniques using rigid internal fixation of mandibular fractures have been introduced. These procedures allow immediate limited function rather than requiring time-honored maxillomandibular fixation (MMF) during the convalescent period. The techniques are all based on precise alignment of the dentition and the bone with plate and/or screw osteosynthesis, with or without axial compression of the bone ends. In uncompromised patients, the benefits of this treatment include increased comfort, improved diet, decreased joint damage secondary to immobilization, and an earlier return to work. In compromised patients with potential airway problems or seizure disorders, there is the additional benefit of not requiring more extraordinary measures of avoiding MMF.

Conclusion

Rigid internal fixation has become a popular method to treat fractures of the facial skeleton. Rigid fixation can produce three-dimensional stability of the fracture site, promoting primary fracture healing. When absolute stability of the fragments is achieved, immediate postoperative jaw function is possible. To minimize the morbidity associated with maxillomandibular immobilization and to avoid difficulties encountered in the management of the partially edentulous and edentulous mandible, many clinicians have selected rigid internal fixation over other methods of treatment.

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