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Review Article

Fixation systems of maxilla and mandible: An overview with review of literature

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ABSTRACT:
The surgical treatment of craniomaxillofacial trauma involves the restoration of both form and function via a complex interplay between the facial bony skeleton and its soft tissue envelope. Advances in the science of internal fixation, improvements in available plating materials and equipment, refinements in exposures to the facial skeleton, and an increase in the volume of facial trauma all fueled the rapid expansion of use of rigid internal fixation for facial fractures. This review of literature gives the detailed explanation about fixation systems in maxillary and mandibular bone.

Keywords: Maxilla, Mandible, Fixation systems, Review

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INTRODUCTION

The surgical treatment of craniomaxillofacial trauma involves the restoration of both form and function via a complex interplay between the facial bony skeleton and its soft tissue envelope. However, it was not until the introduction of open reduction and internal rigid fixation techniques for the facial skeleton that the basic orthopedic principles of accurate fracture reduction, bone fixation, and healing could be applied. [1].Advances in the science of internal fixation, improvements in available plating materials and equipment, refinements in exposures to the facial skeleton, and an increase in the volume of facial trauma all fueled the rapid expansion of use of rigid internal fixation for facial fractures in the 1980s[1]. With growing experience, surgeons came to appreciate the utility of metallic internal rigid fixation systems, along with the potential pitfalls and complications[2]. Whereas many metals were tested and abandoned, three materials—stainless steel, titanium, and vitallium gained popularity during the evolving era of internal rigid fixation for the facial skeleton[3]. 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 skeletal fixation to the facial skeleton requires the surgeon to pay strict attention to details, 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. The future of this constantly developing field will almost certainly center around technologic innovations that will make the application of fixation devices easier and provide devices that are more biocompatible, and bioresorbable [4].The utility of titanium rigid internal fixation devices, however, will not be replaced entirely by the resorbables, as metallic fixation continues to maintain its superiority. Instead, the two modalities will likely reach a new equilibrium in which they will be used in concert to maximize and balance the benefits of stability and bioresorption for each individual patient[2].

OSTEOSYNTHESIS EQUIPMENTSEMIRIGID FIXATION

1. Non Compression Miniplate

The Miniplate osteosynthesis system was developed and modified by Champy and his coworkers. The system based on miniplates and miniscrews (2.0 mm diameter, 5–9 mm length) was the point of origin for all today's miniplate systems. This system is made to satisfy the philosophy and aims of Champy and his colleagues, which means that the materials and instruments are manufactured to the highest standards.The Champy Miniplate System was followed by several other osteosynthesis sets, mainly differing from each other in their screw diameter, depending on the bone pattern of application and the correspondingly necessary load-bearing abilities. Alongside the 1.0 mm and 1.5 mm micro and 2.0 mm mini systems, the 2.3 mm and 2.7 mm systems have been developed. While the micro osteosynthesis systems are mainly used in pediatric craniofacial surgery, neurosurgery, midfacial fracture management, orthognathic surgery as well as preprosthetic surgery, the 2.0 mm and 2.3 mm osteosynthesis systems mainly find application in all types of mandibular fracture treatment, such as primary mandibular reconstruction cases. The 2.7 mm system is suitable for primary and secondary re-construction of the mandible.

SCREWS

Screw Head DesignsVarious types of screw head are available for different systems . The first screw heads were based on simple cruciform or single-slot designs. To facilitate the osteosynthesis technique, self-retaining screw types like the centre drive and the cross drive have been developed by KLS Martin. The screw head is square in shape, whereas the screwdriver is slightly conical. This combination assures a secure connection between screw and screwdriver, with improved intraoperative visibility, especially when using angled screwdrivers in difficult-to-access intraoral regions. Additional self-retaining screw heads, like the star-shaped design, are also available. Screw Thread Designs In general, smaller screws are monocortical and self-tapping, for which careful and accurate drilling is essential. They are available in various lengths and their thread pitch may vary, depending on the outer thread diameter. All these screw types require the drilling of a pilot hole, which generally corresponds to the core diameter of the screw's thread. In a further development, selfdrilling screws with a different screw-tip design have been introduced that do not require pilot holes to be drilled.

PLATES

A wide selection of preshaped plates is available according to their range of application, to suit individual requirements. They differ from each other in thickness, hole-to-hole distance, hole diameter, and design. Mini-plates, for example, are excessively rigid in non load-bearing areas with thin bones, and can be palpable through the skin where there is little interposing soft tissue. This is where micro osteosynthesis systems are applied following the aim of basic principles of general orthopaedics always to reduce the volume and quantity of any implanted material. For bridging large mandibular defects after tumor resection on the other hand, thicker and stronger reconstruction plates are used to withstand the high forces.

RIGID FIXATION

1. Dynamic compression plates

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

2. 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 [30]. 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. 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. 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. 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. 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. [31].

3. 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 over- lapping 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. 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. Thus, many comminuted fractures were tradition- ally 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 re- construction plate may outweigh the disadvantages of increased periosteal reflection. If the blood supply to the comminuted 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 peri- osteal and osseous blood supply, yet also provides stability. The re- construction 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. 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 [32].

4. LAG screws

Lag screw osteosynthesis is a form of osteosynthesis in which absolute interfragmentary stability is generated by screws that transfix the fracture gap. The screw is under tension. The screw holes are prepared in such a way that when a screw is tightened, it engages the bone only in the distal fragment not in the fragment adjacent to the screw head. With a minimum of hardware the lag screw produces interfragmentary stability directly in the center of the fracture line. In contrast, plates apply stability indirectly from the external cortex by tension bending. The function of a lag screw provides mechanical rest and stability. Therefore, lag screws facilitate direct bone healing. In contrast, a true lag screw has threads only at its terminal end. When used, the threads engage the distant cortex and the head sits against the proximal cortex, resulting in compression and mechanical rest. A depression or countersink corresponding to the screw head is created at the opening of the gliding hole. Screws with a spherical head provide an area of extensive surface contact of the screw head with the bone, thus avoiding stress concentration and micro fractures. Conical heads or screws with a washer used without countersinking produce a random, circular bone contact. Circular bone contact by concave screws or spherical screws with bi-concave washers (Krenkel, 1994) can produce stress concentration and local overload. This can result in a fracture of the cortical bone when tightening the lag screw and in complete failure of the osteosynthesis. All lag screws that are conical, conical with washers, spherical, spherical with biconcave countersink washers, or of concave head design can crack the thin cortex of craniofacial bones. Problems of transfer of load between the screw head and the bone are even more severe when the screw is inserted at an angle. To prevent any fragmentation of bone by lag screw application, a technique has been developed that includes a self-adapting spherical washer (Terheyden, 1998). The spherical washer has a spherical hole on top, which corresponds to the spherical shape of the screw head. At the bottom it has an excentric slot, so that the washer automatically aligns its position with the cortical surface at any angle of the screw. In combination the screw and washer act like a spherical articulation. Countersinking of the bone is not necessary, thereby avoiding weakening it. The screws for maxillofacial applications must be remarkably strong and provide stability for early postoperative mobilization. Rotational forces on the fragments can be neutralized by the use of two or more lag screws.However, under compression there is a high interfragmentary friction because of the serrated surfaces of the fragments. In anatomical reduction, this may allow the use of a single lag screw in certain indications. To avoid shearing forces on the fragments in mandibular fractures, the holes for lag screws should be drilled perpendicular to the fracture plane. It must be emphasised that the use of lag screws demands technical precision; however, limited exposure of the operative field often makes it difficult to evaluate their placement. In some it may be necessary to perform a trans-cutaneous stab incision. with the aid of lag screws, and additional stabilization is achieved by a plate.Lag screws are useful for fixation of inlay and onlay bone grafts. Stable fixation is obtained in various orthognathic procedures, such as genioplasties, subapical osteotomies, and sagittal split ramus osteotomies, as well as in alveolar ridge augmentation procedures. For lamellar fractures, bone graft fixation, and small fragment fixation a lag screw can suffice.

When combined with a miniplate osteosynthesis system, the lag screw should have spherical screw heads that coincide with spherical holes in the miniplate. Finally, we need a 2-mm drill for the gliding hole preparation, an inlet countersinker and a self-centring sleeve drill guide. Lag screws can be applied in an increased range of situations by utilizing a self-adapting washer with spherical hole and eccentric slot. In a median mandibular fracture the screw load is greater. In such a situation a larger, 2.7-mm screw, with a core diameter of 2 mm, is necessary. This screw should be combined with the self-adapting spherical washer to prevent bone overload.

5. Drill Free Screws

Normally, self-tapping screws have asymmetric threads with sharp edges to the screwshaft. The surface of the threads is nearly perpendicular to the direction ofpull-out force, to provide maximum load transmission. The thread spirals around a cylindrical core with a pitch (the distance between the threads) of 0.75 mm or 1 mm. A cutting flute is engraved at the leading end of the threaded portion of the screw.After drilling a pilot hole with a comparable diameter to that of the screws core, the sharp flute cuts the bone in preparation for the threads further along the screw's shaft, as the screw is turned. Inserting drill-free screws without the need to drill pilot holes beforehand was made possible by changing the tip of the screw. The pointed screw tip with its thread is comparable in design and function to a corkscrew. Here, in contrast to self-tapping bone screws, the threads are spiraled along a cone-shaped axis of rotation up to the tip of the screw. Again, the thread pitch is 0.75 mm or 1 mm. An additional cutting flute cuts part of the bone like a chisel and acts as a channel for the removal of bone chips produced at the cutting site. The threads cut into the bone must not be broken or compressed. After drill-free screws are inserted, bone dust accumulates around the screw head.Drill-free screws are available in both micro (1.5 mm) and mini (2 mm) diameters. In a comprehensive experimental trial compared different parameters (such as insertional, maximum torque, and, especially, the pull-out force) of common, titanium self-tapping microscrews and miniscrews with drill-free screws of the same size. Test materials included mandibular cortical bone of pigs and, to enable a statistical comparison between the parameters of the screws used, hard-wood and PVC as a homogenous substance with constant material qualities.Depending on the thickness of the test material, the measured pull-out force of drill-free screws was found to lie between 70 % and 104 % of that of self-tapping screws. The maximum torque in bone and wood was comparable with that of common self-tapping screws . The results of the experimental evaluations suggested that drill-free screws should be used in bones with a thin cortical layer, up to 2–3 mm thick. In a first clinical pilot study, the use of 1.5-mm drill-free screws, especially for osteosynthesis of segmented parts of the midface (Le Fort I, II, and III osteotomies), in orthognathic surgery and also in traumatology, gave excellent results. The use of drill-free screws is therefore recommended for the fixation of bone fragments in the entire midface and, with some reservations, in the cranial and periorbital regions.Although the use of drill-free screws in bone segments in orthognathic surgery is almost without problems, in traumatology their use in fixation of small pieces of bone is sometimes difficult. Here it is advisable to put a small hook behind the bone to resist the pressure of the screw and screwdriver on the bone. Once the bony surface is perforated by the tip of the screw, the thread cuts itself into the bone and continuous insertional torque pulls it into the bone, in a corkscrewlike manner.The use of drill-free screws in the mandible is limited to children up to 13 years of age and, in adults, to application in the paramedian regions only. For treatment of mandibular angle fractures, the dense bone structure and the thickness of the cortical layer in the osteosynthesis area along the oblique line will occasionally require the use of a drill as a guide pin.[35]

6. Toulouse Mini Lag Screw

The Toulouse mini lag screw is a further development within the Champy Titanium Mini Osteosynthesis System . The same instruments and drills may be used for insertion. To understand the concept of a lag screw it is necessary to understand the basic design of the cortical screw, which is the predominant type of screw used in the maxillofacial region. Each cortical screw consists of a head and a shank; the entire length of the shank has threads and defines the screw length. Screw heads come in a variety of configurations; the popular ones have either a straight, cruciform, hexagonal, or square slot. The shank has an internal diameter, also known as the core diameter, and an external diameter or thread diameter. The cortical screw can act as a lag screw only when the hole in the fragment adjacent to the screw head is over-enlarged. This is called the gliding hole. The diameter of the gliding hole is equal to or greater than the thread diameter of the screw. The diameter of the screw hole in the distal fragment is smaller than the gliding hole and corresponds to the core diameter of the screw. The hole in the distal fragment is called the traction hole.[34]

7. 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. 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 re- construction 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 [33].

INTERNAL FIXATION OF MAXILLOFACIAL OSTEOTOMIES

The use of internal fixation devices for maxillofacial osteotomies paralleled the developments made in the treatment of fractures. Internal wire fixation was used extensively throughout the 1960s and 1970s. However, the implementation of plate and screw fixation came much later in the United States than it did in Europe. In fact, it was not until the early 1980s that an American surgeon reported the use of plate and screw fixation for orthognathic surgery. In 1983, Frost and Koutnik described the use of metacarpal bone plates for a re- positioned maxilla in which direct transosseous wires failed to provide stability.Michelet should probably be credited with popularising the use of plate and screw fixation in orthognathic surgery. In 1971, Michelet and co-workers described the use of miniplates to stabilize the proximal and distal segments following sagittal ramus osteotomy , they described the application of plate and screw fixation to various types of orthognathic surgery, including maxillary and mandibular osteotomies. This latter article sparked the rapid application of plate and screw fixation to orthognathic surgical procedures, especially in Europe.In 1974, Spiessl described his technique of using lag screw fixation for sagittal ramus osteotomies." This technique, which used three 2.7-mm lag screws inserted transbuccally through a trochar, has become one of the most popular methods of securing rigid internal fixation of sagittal osteotomies worldwide. However, many modifications of the original procedure have evolved over the years both in Europe and the United States, involving the size of the screws and instruments, the use of bicortical instead of lag screws, and the intraoral placement of the screws. Miniaturization of rigid internal fixation instruments and screws was first attempted by Jeter and co-workers in 1984.94 Today, most surgeons in the United States seem to favor 2-mm self-threading screws for the sagittal osteotomy of the ramus. Another major modification of the use of bone screw fixation of the sagittal osteotomy came with the intraoral placement of the bone screws, eliminating the need for an extraoral incision. Since the early reports, the shapes of bone plates have been altered to facilitate the use of plate and screw fixation in midfacial osteotomies as well [39].

RECENT ADVANCES

Effective management of facial fractures is crucial to restore compromised form and function, and typically involves open reduction and internal fixation. An essential component of fracture management is achieving adequate fracture segment reduction and stabilization, and miniplate osteosynthesis is the standard approach to achieve this [44]. In recent years, multiple modifications to the standard miniplate have been proposed.Bioresorbable fixation systems: There are many disadvantages to metal fixation hardware including infection, hardware visibility and palpability, hypersensitivity to temperature variation, interference with radiologic evaluation, leaching of metal ions into the soft tissues, and the stress shielding effect. Furthermore, titanium plates need to be removed in roughly 10% of cases, subjecting the patient to an additional operation. These shortcomings inspired the development of bioresorbable implants with hopes of minimizing hardware-associated complications and the need for hardware removal. Studies have proven that the mechanical strength of bioresorbable hardware is, in fact, inferior to that of titanium hardware. Therefore, the use of bioresorbable fixation devices must be limited to select patients. Bioresorbable devices provide adequate stability to maintain reduction in low load bearing regions of the face, such as the zygoma, maxilla, and upper regions of the face. Many studies have demonstrated satisfactory bone healing and stability (compared to metallic fixation) when applied in these regions. Metallic plates are the standard devices for internal fixation of mandibular fractures. Because the mandible is a load bearing bone, bioresorbable systems may not be strong enough to provide adequate stability in some fractures, particularly those that are comminuted or in the setting of multiple fractures of the mandible. Biodegradable systems may be an option in compliant patients with simple fractures. Bioresorbable fixation systems stabilize fracture segments long enough for fracture healing and union to occur then degrade, thereby reducing complications frequently encountered with metallic hardware such as palpability, visibility, cold sensitivity, and need for removal. Of course, these devices are associated with their own complications. A meta- analysis including 1673 patients found that the bioresorbable group experienced significantly more complications when compared to the titanium group (RR 1.20), specifically foreign body reaction (RR 1.97) and mobility (RR 5.64).Relatively higher costs and increased operative time have been a barrier to bioresorbable fixation devices supplanting metallic hardware as first line options in most practices[45].Three-dimensional fixation systems: Three-dimensional fixation systems are essentially two miniplates joined by interconnecting crossbars. They are not actually three-dimensional structures, but their closed quadrilateral-shape yields stability in three dimensions when secured with bone screws. Multiple studies have found them effective treatment alternatives to standard miniplates in the management of mandibular angle fractures (MAF) [31,32]. MAF fixation with 3D plates is associated with fewer complications, and the plates are often less time intensive and simpler to apply compared to standard miniplate systems [85] Though less thoroughly investigated, one study supports the use of 3D plating systems in the fixation of midface fractures [46].Locking plate systems: Locking plates utilize double threaded screws that lock into both the bone and the plate to create an internal “external” fixator of sorts. Thus, the fractures segments can be stabilized without compressing the bone tightly to the plate. As a result, locking plate systems offer many advantages including easier plate adaptation (as the plate does not require intimate contact with underlying bone), less impairment of blood supply to underlying bone, and less screw loosening. In vitro studies have demonstrated that locking plate systems provide more stability and greater resistance to displacement than standard miniplate. Locking plates are often used in reconstructive procedures and are considered valid alternatives to conventional miniplates. Prospective studies have found similar complication rates between the use of locking and nonlocking plates. As such, any differences in complication rates are more likely related to bone quality and surgical technique than the fixation system, and the decision to use locking or nonlocking plates should be based upon cost and ease of placement [38]. Clearly, however, locking plates require less bending to adapt the plate to the bone.3D modeling, computer-assisted design, and virtual surgical planning: The unique three-dimensional contour and nonlinearity of the facial skeleton presents challenging management issues for facial fractures, and recent advances in software technology and 3D modeling have revolutionized management. Three-dimensional modeling can be used as an adjunct to standard preoperative preparation. 3D models may serve as a template upon which fracture fixation plates are precontoured prior to entering the operating room, thus reducing operation time. 3D printers have also been used to create custom-designed titanium implants, that may be preferred over conventional implants due to their precise fit and reduced surgical time. 3D modeling can be used to rehearse complex procedures, giving surgeons the opportunity to become familiar with the approach and troubleshoot problems prior to entering the operating room [47]. One author's institution has been using three-dimensional modeling and virtual surgical planning for all craniomaxillofacial reconstructive and ablative cases for more than 5 years. Virtual surgical planning and model design allows the team to design the optimal approach preoperatively, construct guides for the surgeon to follow intraoperatively, and compare the actual outcome to the virtual design. These technologies have been used to reconstruct a multitude of craniofacial defects of the midface, mandible, and orbit. Orbital wall fractures are ideal candidates given the complex anatomy and challenging exposure of the orbit and difficulty restoring its precise volume. Many of the common complications associated with these injuries have been addressed and successfully managed with computer-assisted surgical planning and 3D modeling. As the costs continue to decline and software tailored to craniofacial reconstruction is developed, the role of 3D modeling and computer-assisted surgical planning will continue to evolve[48,49].

CONCLUSION

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 skeletal 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. The future of this constantly developing field will almost certainly center around technologic innovations that will make the application of fixation devices easier. 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 for the aim of early re-establishment of functional stability structural integrity and satisfactory esthetics.

REFERENCES

1. Rahn BA. Theoretical considerations in rigid fixation of facial bones. Clin Plast Surg 1989;16:21–27
2. Gilardino MS, Chen E, Bartlett SP . Choice of Internal Rigid Fixation Materials in the Treatment of Facial Fractures Craniomaxillofac Trauma Reconstr. 2009 Mar; 2(1): 49–60
3. Steinemann S. Metal for craniomaxillofacial internal fixation implants and its physiologic implications. In: Greenberg A, Prein J, eds. Craniomaxillofacial Reconstructive and Correc- tive Bone Surgery. New York, NY: Springer; 2006:107–112
4. Kelley P, Crawford M, Higuera S, Hollier LH. Two hundred ninety-four consecutive facial fractures in an urban trauma center: lessons learned. Plast Reconstr Surg. 2005 Sep;116(3):42e-49e.
5. Ellis E 3rd , Carlson DS The effects of mandibular immobilization on the masticatory system. A reviewClin Plast Surg. 1989 Jan;16(1):133-46.
6. Kuriakose MA, Fardy M, Sirikumara M, Patton DW, Sugar AW. A comparative review of 266mandibular fractures with internal fixation using rigid (AO/ASIF) plates or miniplates. Br J Oral Maxillofac Surg. 1996 Aug;34(4):315-21
7. Edward RC, Keily KD, Eppley BL. Resorbable PLLA-PGA screw fixation of mandibular sagittal split osteotomies.J Craniofac Surg. 1999 May;10(3):230-6.
8. Joos U. An adjustable bone fixation system for sagittal split ramus osteotomy: preliminary report Br J Oral Maxillofac Surg. 1999 Apr;37(2):99-103.
9. Ellis E 3rdUse of a 2.0-mm locking plate/screw system for mandibular fracture surgery.J Oral Maxillofac Surg 60:642-645, 2002
10. Yerit KC[1], Enislidis G, Schopper C, Turhani D, Wanschitz F, Wagner A, Watzinger F, Ewers R.Fixation of mandibular fractures with biodegradable plates and screws Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002 Sep;94(3):294-300
11. Erkmen E[1], Simşek B, Yücel E, Kurt AComparison of different fixation methods following sagittal split ramus osteotomies using three-dimensional finite elements analysis: Part 1: advancement surgery-posterior loading. Int J Oral Maxillofac Surg. 2005 Jul;34(5):551-8.
12. Collins CP[1], Pirinjian-Leonard G, Tolas A, Alcalde R.A prospective randomized clinical trial comparing 2.0-mm locking plates to 2.0-mm standard plates in treatment of mandible fractures. J Oral Maxillofac Surg. 2004 Nov;62(11):1392-5
13. Eppley BLUse of resorbable plates and screws in pediatric facial fractures. J Oral Maxillofac Surg. 2005 Mar;63(3):385-91.
14. Yerit KC, Hainich S, Enislidis G Biodegradable fixation of mandibular fractures in children: Stability and early results. Oral Surg Oral Med Oral Pathol Oral Radiol 2005 Jul ;100(1):17-24
15. Chritah A(1), Lazow SK, Berger JRTransoral 2.0-mm Locking Miniplate Fixation of Mandibular Fractures Plus 1 Week of Maxillomandibular Fixation: A Prospective Study. J Oral Maxillofac Surg. 2005 Dec;63(12):1737-41
16. Brasileiro BF[1], Grotta-Grempel R, Ambrosano GM, Passeri LAAn In Vitro Evaluation of Rigid Internal Fixation Techniques for Sagittal Split Ramus Osteotomies: Advancement Surgery. J Oral Maxillofac Surg. 2012 Apr;70(4):941-51.
17. Kumar I[1], Singh V, Bhagol A, Goel M, Gandhi SSupplemental maxillomandibular fixation with miniplate osteosynthesis—required or not? Oral Maxillofac Surg. 2011 Mar;15(1):27-30
18. Bhatnagar A, Bansal V, Kumar S, Mowar A Comparative analysis of osteosynthesis of mandibular anterior fractures following open reduction using

stainless steel lag screws and mini plates. J Maxillofac Oral Surg. 2013 Jun;12(2):133-9

19. Meslemani D[1], Kellman RMRecent advances in fixation of the craniomaxillofacial skeleton. Curr Opin Otolaryngol Head Neck Surg. 2012 Aug;20(4):304-9
20. Degala SK, Shetty S, Ramya S. Fixation of zygomatic and mandibular fractures with biodegradable plates. Ann Maxillofac Surg. 2013 Jan-Jun; 3(1): 25–30.
21. Saman M, Kadakia S, Ducic YPostoperative Maxillomandibular Fixation After Open Reduction of Mandible Fractures. JAMA Facial Plast Surg. 2014;16(6):410-413
22. Sehgal S[1], Ramanujam L[2], Prasad K[2], Krishnappa RThree-dimensional v/s standard titanium miniplate fixation in the management of mandibular fractures – A randomized clinical study. J Craniomaxillofac Surg. 2014 Oct;42(7):1292-9
23. Bhatt K, Arya S, Bhutia O, Pandey S, Roychoudhury A. Retrospective study of mandibular angle fractures treated with three different fixation systems. Natl J Maxillofac Surg 2015;6:31-6
24. Chouinard, AF., Troulis, M.J. & Lahey, E.T. Curr Trauma Rep (2016) 2: 55. https://doi.org/10.1007/s40719-016-0040-4
25. Van Bakelen, N., Gareb, B., de Visscher, J., Hoppenreijs, T., Bergsma, E., & Bos, R. (2017). Long-term clinical performance of a biodegradable versus a titanium fixation system in maxillofacial surgery: a multicentre randomised clinical trial. International Journal of Oral and Maxillofacial Surgery, 46, 169. doi:10.1016/j.ijom.2017.02.579
26. Ul Haq ME, Khan AS. A retrospective study of causes, management, and complications of pediatric facial fractures. Eur J Dent 2018;12:247-52
27. Rao E, Naveen S, Rao RC, Kollabathula K, Srirambhatla M, Gandham S. Principle of Lag-Screw Fixation in Mandibular Trauma. J Int Soc Prev Community Dent. 2019;9(3):282–289. doi:10.4103/jispcd.JISPCD_64_19
28. Franz Harle, M Champy, Bill C. Terry; Atlas of Craniomaxillofacial Osteosynthesis: Microplates, Miniplates,and Screws .2nd ed Published 2009.
29. Strelzow, V. V., & Friedman, W. H. (1982). Dynamic Compression Plating in the Treatment of Mandibular Fractures: Early Experience. Archives of Otolaryngology - Head and Neck Surgery, 108(9), 583–586. doi:10.1001/archotol.1982.007905700490
30. Evaluation of rigid internal fixation of mandible fractures performed in the teaching laboratoryAssael, Leon A.Journal of Oral and Maxillofacial Surgery, Volume 51, Issue 12, 1315 - 1319
31. Ewers R and Harle F. “Experimental and clinical results of new advances in the treatment of facial trauma”. Plastic and Reconstructive Surgery 75 (1978): 25.
32. Kanno T, Sukegawa S, Nariai Y, Tatsumi H, Ishibashi H, Furuki Y, Sekine J. Surgical treatment of comminuted mandibular fractures using a low-profile locking mandibular reconstruction plate system. Ann Maxillofac Surg 2014;4:144-9
33. Koch, W. M., Yoo, G. H., Goodstein, M. L., Eisele, D. W., Richtsmeier, W. J., & Price, J. C. (1994). Advantages of mandibular reconstruction with the titanium hollow screw osseointegrating reconstruction plate (THORP). The Laryngoscope, 104(5), 545–552.doi:10.1002/lary.5541040507
34. Kallela, I., Ilzuka, T., Laine, P., & Lindqvist, C. (1996). Lag-screw fixation of mandibular parasymphyseal and angle fractures. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology, 82(5), 510–516. doi:10.1016/s1079-2104(96)80195-8
35. Heidemann, W., Gerlach, K. L., Gröbel, K.-H., & Köllner, H.-G. (1998). Drill Free Screws: a new form of osteosynthesis screw. Journal of Cranio-Maxillofacial Surgery, 26(3), 163–168.doi:10.1016/s1010-5182(98)80007-3
36. Serebrakian, A., Maricevich, R., & Pickrell, B. (2017). Mandible Fractures. Seminars in Plastic Surgery, 31(02), 100–107.doi:10.1055/s-0037-1601374
37. Soodan KS, Priyadarshini P, Debdutta D, Gupta M. Techniques f rigid internal fixation of mandibular fractures. Acta scientific dental sciences 2018:12(2):153-159
38. Singh V, Kumar I, Bhagol A Comparative evaluation of 2.0-mm locking plate system vs 2.0-mm nonlocking plate system for mandibular fracture: a prospective randomized study.Int J Oral MaxillofacSurg 2011;40: 372-377.
39. Roccia F, Tavolaccini A, Dell'Acqua A, Fasolis M. An audit of mandibular fractures treated by intermaxillary fixation using intraoral cortical bone screws. J Craniomaxillofac Surg. 2005;33(4):251–254.
40. Schneider A, Schulze J, Eckelt U, Laniado M. Lag screw osteosynthesis of fractures of the mandibular condyle: potential benefit of preoperative planning using multiplanar CT reconstruction. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;99: 142–14
41. Krenkel C. Biomechanics and osteosynthesis of condylar neck fractures of the mandible. Chicago: Quintessence; 1994: 73–115
42. Meyer C. Biomechanics of the temporomandibular joint. In: Kleinheinz J, Meyer C, eds. Treatment of condylar fractures of the mandible. Berlin: Quintessence; 2009a; in press
43. Meyer C. The TCP® platting technique. In: Kleinheinz J, Meyer C, eds. Treatment of condylar fractures of the mandible. Berlin: Quintessence 2009b; in press.
44. Singh M, Agrawal A, Chaudhary M, Kaur G, Harjani B. Use of Three-dimensional Plates in Mid-face Fracture: A Prospective Study.J Contemp Dent Pract 2015;16: 571-577
45. Suuronen R, Lindqvist C. Bioresorbable materials for bone fixation: review of biological concepts and mechanical aspects. In: Greenberg A, Prein J, eds. Craniomaxillofacial Reconstructive and Corrective Bone Surgery. New York, NY: Springer; 2006
46. Al -Moraissi EÀ, El-Sharkawy TM, El-Ghareeb TI, Chrcanovic BR. Three-dimensional versus standard miniplate fixation in the management of mandibular angle fractures: a systematic review and meta-analysis.Int J Oral MaxillofacSurg 2014; 43: 708-716.
47. Singare S, Yaxiong L, Dichen L, Bingheng L, Sanhu H, et al. Fabrication of customisedmaxillo-facial prosthesis using computer-aided design and rapid prototyping techniques. Rapid Prototyping J 2006;12:206-213.
48. Shaye DA, Tollefson TT, Strong EB Use of intraoperative computed tomography for maxillofacial reconstructive surgery.JAMA Facial PlastSurg 2015; 17: 113-119.
49. Levine JP, Patel A, Saadeh PB, Hirsch DL Computer-aided design and manufacturing in craniomaxillofacial surgery: the new state of the art.J CraniofacSurg 2012 23: 288-293.

50. Barone CM, Eisig S, Wallach S, Mitnick R, Mednick R. Effects of rigid fixation device composition on three-dimensional computed axial tomography imaging: direct measurements on a pig model. J Oral Maxillofac Surg 1994;52:737– 740