PLATE FIXATION IN FOREFOOT SURGERY

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INTRODUCTION

Plates are not commonly used for internal fixation in forefoot surgery. However, they are capable of providing significant rigid internal fixation and in certain situations are an appropriate and excellent choice of fixation. Rigid internal fixation is required for primary bone healing to occur. Primary bone healing is desireable because it provides predictable bone healing, avoids secondary callous formation, and enables the patient to mobilize the adjacent joints quickly.

Plates have been utilized in the fixation of metatarsal or hallux fractures, metatarsal nonunions, metatarsal osteotomies, first metatarsophalangeal joint arthrodesis, Lisfranc arthrodesis, and various repairs of iatrogenic deformities.

BASIC PRINCIPLES OF PLATE FIXATION

A plate can perform three very different functions; neutralization, interfragmental compression, and buttressing. These functions are determined by the operative requirement of the plate and by the manner in which the plate is applied to the bone.

NEUTRALIZATION

A plate implemented for neutralization negates bending and shearing forces around the screw. This principle is used primarily when fixating short oblique fractures or osteotomies of long bones. Compression of the fragments is usually obtained with a single lag screw across the fracture site. Following compression of the fragments, a plate is applied to protect the screw fixation from any external forces. All screws are inserted neutrally (through the middle of the plate hole). This prevents the plate from shifting when the head of the screw sets into the hole of the plate.

AXIAL COMPRESSION

An axial compression plate is used in fixation of transverse or short oblique fractures or osteotomies. In this situation, it is impossible to place a screw perpendicular across the site. A plate can create compression by inserting the screws nearest to the fracture site eccentrically (on the side of the hole furthest from the fracture site). (Fig. 1A) The plate is stressed when the head of the eccentrically placed screw begins to lock into the plate-hole. The stress applied to the plate is transformed through the fragment to compression at

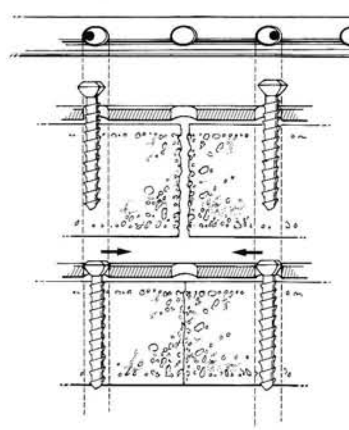

Fig. 1A. Eccentrically placed screws on either side of the fracture site creating axial compression.

the fracture contact surface. Because the force of compression that is created by the plate is on one side of the bone, the opposite cortex will actually gap as axial compression is applied. (Fig. 1B) This side effect is counteracted by "overbending" the plate. (Fig. 1C) The AO group recommends that a 1 mm bend be applied to the plate. The opposite cortices will contact initially and then the compressive force will be spread across the entire fragment to fragment interface as the plate is straightened out. (Fig 1D)

BUTTRESS PLATE

Buttressing supports multiple fracture fragments. A plate is used as a buttress where there is severe comminution or bone loss, such as in a gunshot wound or crush injury to the forefoot. The plate is secured to the main proximal and distal fragments and then secured loosely to the comminuted fragments. This technique will maintain anatomic length and avoid disrupting the vascularity of the smaller fragments. Screws are inserted into the plate holes neutrally so that the plate does not shift. The plate should not be placed under stress. The screws are simply placed into both fragments to maintain length and viability of the bone.

ANATOMICAL AND BIOMECHANICAL CONSIDERATIONS

There are certain anatomic and biomechanical characteristics which dictate how a plate is applied. Placement of the plate must be adapted to conform to the local anatomy with care to avoid disruption of function. A plate applied for fixation of a Jones fracture should be applied so as not to disrupt the insertion of the Peroneal brevis tendon.

The width of the plate and the size of the screws must be appropriate for the size of the metatarsal. If a plate is too large, it will be difficult to cover with soft tissue and may significantly retard vascularization of underlying bone fragments.

A plate is best applied to a relatively flat surface. Some of the most common surfaces for application of a plate in the forefoot are dorsal surface of second, third or fourth metatarsals, dorsal lateral surface of the fifth metatarsal and medial surface of the first metatarsal.

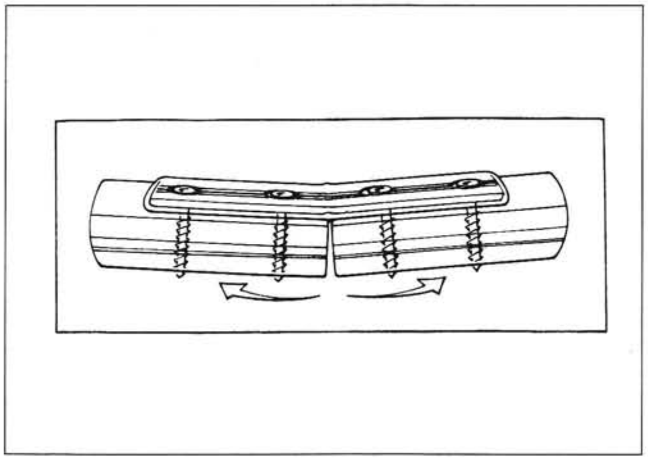

Fig. 1B. Eccentric loading creates compression between the fragments on the plate side and tension (gapping) on the opposite side.

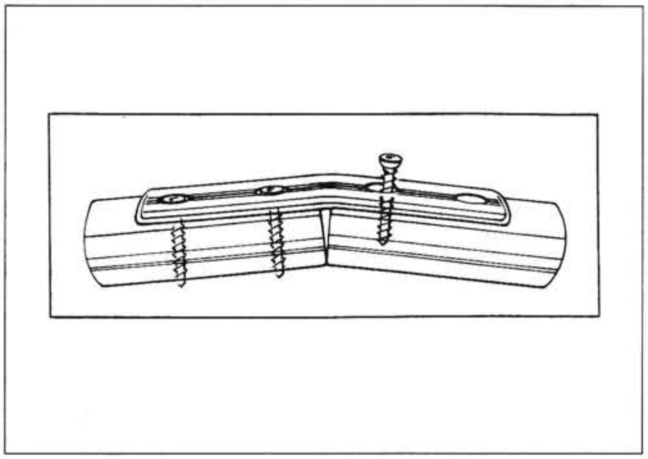

Fig. 1C. Overbending of the plate is performed to counteract the eccentric loading.

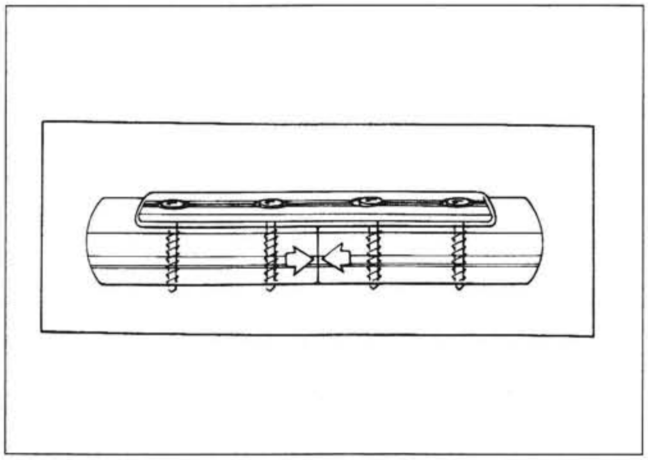

Fig. 1D. Uniform compression following the overbending technique.

The AO group recommends application of a plate on the tension side of the bone to prevent gapping with functional loading. In the metatarsal region, the functional load of weightbearing creates compression at the dorsal surface and tension on the plantar surface. Theoretically, the plate should be applied to the plantar surface. Anatomically, however this is difficult to perform. Dissection of the plantar aspect of the metatarsals makes a plantar approach quite unrealistic.

PLATES

Choosing the appropriate plate is important for the success of the fixation. It also avoids complications. The AO group has set the standard for internal fixation and provide a variety of plates which can be utilized in forefoot surgery.

Trough shaped 1/3 tubular straight plates can be used with either 3.5 and 4.0 mm screws. The trough shape of the screw prevents the screw head from having direct contact with the cortex of the bone. It is made of stainless steel (AISI 316). It is 10 mm wide and 1 mm thick. The plate is commonly used in first metatarso-cuneiform arthrodesis and as a primary part of a Lisfranc joint arthrodesis. (Fig. 2) Small T and oblique T plates identical in thickness can be substituted in this arthrodesis.

2.7 mm straight or 1/4 tubular plates are designed for insertion with 2.7 mm screws. They are slightly troughed shaped and have raised rims. This design strengthens the plate. The plate is used in the lesser metatarsal region. (Fig. 2)

Mini plates are utilized with 1.5 and 2.0 mm screws. The plates are extra long and are cut to the desired length with a cutting forceps. The plates are utilized for lesser metatarsal and digital fixation.

A relatively new plate system which was developed for maxilo-facial surgery has a role in podiatric surgery. (Fig. 3) The plates are constructed of vitallium which enable the plate to be relatively thin. Screw sizes are 2.7, 2.0, and 1.5 mm and are self tapping. Two vertical cutting flutes cut the threads so that the screw hole does not need to be tapped.

Dynamic Compression Plates (DCP) and the Limited Contact Dynamic Compression Plate (LC-DCP) have a limited role in forefoot surgery. They are specially constructed plates which self compress the osseous fragments. The special geometry of the screw hole produce gliding of the eccentrically drilled screw. The DCP is a flat and relatively thick plate which has proven to have its shortcomings. Probably one of the most significant of these is the extensive contact of the plate to the bone which interferes with periosteal blood supply and has led to local osteonecrosis. The LC-DCP is the newer version of the Dynamic Compression plates which are constructed with deep oblique cuts between the screw holes to limit contact.

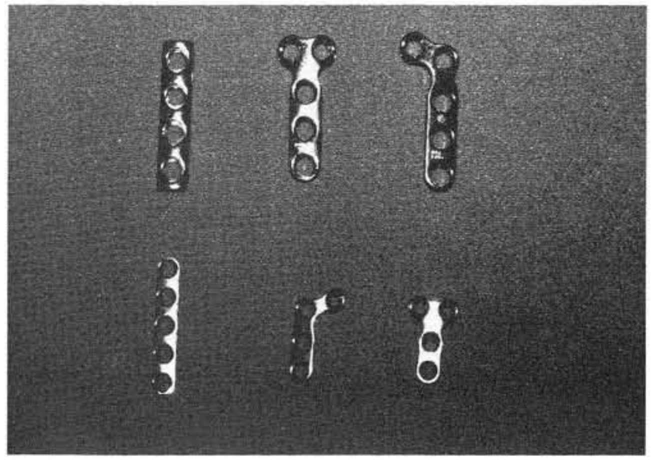

Fig. 2. 1/4 tubular and mini-plates used in lesser metatarsal and digital procedures.

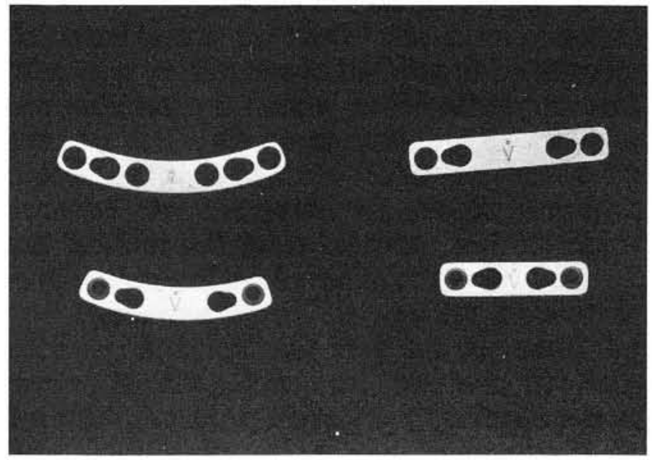

Fig. 3. Maxilo-facial vitalium plates for 2.7 and 2.0 mm self-tapping screws.

TECHNIQUE OF PLATE INSERTION

Adequate exposure for the insertion of the plates is essential. An idea of the type of plate and approximate size should be known preoperatively, however, the specific choice of a plate is obviously made intraoperatively. Periosteum should be elevated during the initial dissection and used to cover the plate upon closure.

The plate must be contoured to the surface of the bone. A malleable aluminum template can be applied to the surface of the bone to help determine the amount of bending that needs to be performed on the plate. Plate benders are then used to bend the plate into the appropriate shape.

The number of cortices held by each screw is important in the strength of the internal fixation. The AO group have determined that the lever arm and functional loads onto the plate increases in the direction of the trunk. To accommodate these functional loads there are specific recommendations to the number of cortices crossed on each side of the fracture site. Specifically these are three in the phalanges and four in the metatarsals. The specific technique of plate insertion differs upon the specific function of the plate.

Fig. 4A. Radiographs revealing short oblique fractures of the neck of the second, third, and fourth metatarsals.

AXIAL COMPRESSION

This technique is applied to a transverse or short oblique fracture or osteotomy. The fragments are visualized and a plate of the appropriate size is chosen. The plate is contoured to the surface of the metatarsal. A slight bend of the plate is made. The bend of the plate is at the section of the plate which will directly overlay the fracture or osteotomy site. The screws are first inserted into the distal fragment using the standard AO techniques. The holes are predrilled, measured, tapped, and followed with insertion of the screw. The distal screws are inserted centrally. The plate is then used as a handle to reduce the fracture or osteotomy to its anatomical position. A plate clamp temporarily fixates the plate to the proximal fragment. The screw hole nearest to the fracture site is drilled eccentrically away from or proximal to the osteotomy or fracture. As this screw is inserted, the fragment to fragment interface is compressed. The remaining proximal screws are then inserted neutrally. (Fig. 4A, 4B)

Fig. 4B. Postoperative radiographs revealing axial compression technique with L-shaped mini-plate and 2.0 mm screws.

COMBINATION FIXATION

This term describes the use of a lag screw for compression in combination with a plate functioning as a neutralization plate. This fixation is performed in fixating short or medium oblique fractures. Reduction of the fracture can be performed with a bone clamp. An appropriate plate is chosen and contoured to the surface of the bone. The fracture orientation is evaluated and a determination of whether or not to place the lag screw through the plate is made. If the lag screw is placed outside of the plate, it is inserted and tightened first followed by application of the plate. The screws of the plate are inserted neutrally. If the fracture orientation favors the use of lag screw through the plate the lag screw is inserted through the plate with overdrilling of the near cortex, followed by the insertion of the remaining screws. All other screws through the plate are inserted in the manner previously described. (Fig. 5A, 5B)

DOUBLE COMBINATION FIXATION

Double combination fixation is the term used to describe the use of a lag screw in combination with an axial compression plate. This technique is utilized specifically in fusions of the first metatarsocuneiform and metatarsophalangeal joints. The first metatarsocuneiform joint is temporarily fixated with a K-wire from dorsal to plantar. A plate is chosen to be applied to the medial surface of the first metatarsal and medial cuneiform and contoured to the appropriate shape. A 5-hole straight 1/3 tubular plate with 3.5 mm fully threaded screws is commonly used. The plate is first anchored proximally to the medial cuneiform. The distal aspect of the plate is then temporarily clamped to the first metatarsal. A screw is then placed eccentrically at the hole just distal to the arthrodesis site. This is tightened and creates compression across the site. A lag screw is then placed dorsal to plantar or plantar to dorsal to provide additional tension at the site. The remainder of the screws are then inserted neutrally. (Fig. 6)

SUMMARY

This paper has been an introduction to the principles and techniques of plate fixation and how they specifically apply to the forefoot. Plates if correctly used can be an effective type of fixation for a variety of forefoot surgery.

Fig. 5A. Radiographs revealing long oblique fracture of the neck of the fifth metatarsal.

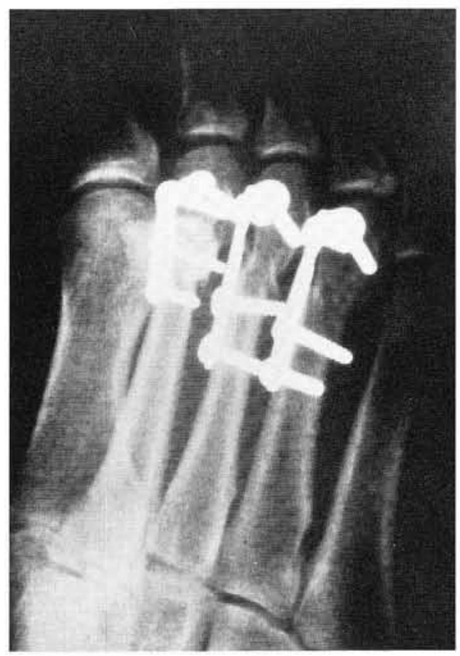

Fig. 5B. Postoperative radiographs revealing combination fixation technique with a lag screw and neutralization plate.

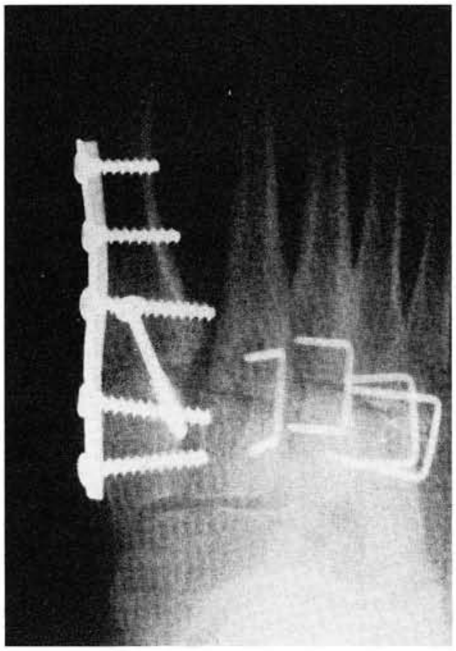

Fig. 6. Postoperative radiographs of Lisfranc arthrodesis revealing double combination fixation technique of the first metatarsal medial cuneiform joint fusion.

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