TRAUMA

Minimally invasive plate osteosynthesis — an update∗

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Summary
The advent of locking plates for the management of metaphyseal fractures, and subsequent experience of biological fracture fixation, has led to the development of minimally invasive percutaneous osteosynthesis (MIPO), which is now proven to have multiple advantages. Soft tissue stripping is minimized, with preservation of vascular pedicles, and the fracture haematoma around the site of injury remains undisturbed promoting fracture healing. While early published results are encouraging, MIPO technique is not applicable to every fracture. To avoid complications, defining the correct indications is of paramount importance.

Introduction
The quest for effective fracture treatment has a long history. Indeed, there is archeological evidence of attempts at correction of bone deformities in Neolithic man. Egyptians, ancient Greeks and the Romans all made contributions to the development of fracture treatment and many of the instruments used in medieval times are surprisingly similar to modern fracture osteosynthesis hardware.1

The term ”osteosynthesis” was first used by Lambotte to describe stable bone fixation2 and Gurlt, Lister, Hansmann, Lane, König, and others described methods of internal fixation.3 However Robert Danis was the first to develop a plate designed to provide rigid fracture fixation4 and ”primary” fracture healing, and is generally regarded as the father of modern osteosynthesis.5

The ”Arbeitsgemeinschaft fur Osteosynthesesfragen” (AO) in 1963 described the self-compressing metal plate form based on Danis’ work and the principles of anatomical reduction, stable fixation and early active mobilization.6 Later, in 1969, the dynamic compression plate (DCP) allowed axial compression of the fracture zone. In a perfect situation this led to primary bone-fracture consolidation without visible callus formation.7

After initial enthusiasm, numerous problems arose as the technique was used more widely. Anatomic reduction of
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all fracture fragments usually requires wide exposure of the fracture zone, leading to delayed healing, nonunion, and an increased risk of infection. Greater understanding of the complexity of fracture healing has helped in the development of osteosynthetic techniques that favour biology over rigid fixation and stability. The wave plate, the bridge plate and the Limited Contact-Dynamic Compression Plate (LC-DCP) were introduced to apply the principles of “biological plate fixation”, the aim being to take advantage of biological support from bone and soft tissues that is still present after injury.

However, the LC-DCP, even with a reduced contact surface, still relied on compressive forces, undermining the fracture healing process. Newer implant designs, known as “internal fixators”, addressed this problem; for example the Zespol system, the point contact fixator (PC-fix). The latest AO developments, the less invasive stabilization system (LISS) and the locking compression plate (LCP) were designed to achieve an angular-stable connection between the screw head and the force carrier without frictional forces between the implant and the bone.

Following on from these developments, “Minimally Invasive Percutaneous Osteosynthesis” (MIPO), has been introduced to utilise all of the recent developments in biological osteosynthesis and “internal fixators”. MIPO involves inserting a plate percutaneously, bridging the fracture site which is secured proximal and distal to the fracture zone.

Biological and biomechanical advantages

The MIPO technique has been shown to have multiple biological advantages, as operative exposure and soft tissue stripping are minimized. Vascular pedicles are preserved throughout realignment, as fixation is at a distance to the fracture site, leaving the fracture haematoma around the injury undisturbed. This is important, as over the past three decades many authors have proposed mechanisms by which the soft tissues aid in fracture union. In 1978, McKibbin stated that the primary roles of the soft tissue were in the formation of external bridging callus and stabilization of the fracture fragments. Subsequent researchers have shown that the surrounding soft tissues and haematoma have an extremely important biological role, producing growth factors and other stimulators of osteoprogenitor cells that induce fracture healing and callus formation.

The MIPO technique embodies all the biomechanical advantages of bridge plate fixation, the absolute rigidity that initially was the aim of plate osteosynthesis is now replaced by more elastic fixation allowing micromotion at the fracture level, resulting in indirect bone healing with abundant callus formation. This type of fixation is stronger than the direct healing process that follows rigid fixation with minimal callus formation. The “internal fixators” used for MIPO have been designed to allow less plate to bone contact without compromising stability. The screw holes are designed to allow the screw to “lock” into the plate, converting the plate/screw construct into a fixed-angle device with multiple points of fixation. This makes for minimal vascular damage to the periosteum, whereas a conventional plate fixation relied on bone/plate friction, resulting in early bone porosity underneath the plate. This “stress shielding phenomenon” was initially mistakenly attributed to the mechanical relief of the bone by the plate.

MIPO using locking plates is particularly effective in managing fractures of osteoporotic bones. In such cases, locking head screws have better resistance against bending and torsion forces and the screws are less likely to pull out. Additionally, fixed angle devices are not subject to the toggling (windscreen wiper effect) seen with unlocked screws, which adversely fixation in osteoporotic bone.

The MIPO technique

A suitable plate is chosen pre-operatively and contoured if needed. The patient is placed on a radiolucent table. The fracture is then reduced, preferably by indirect reduction techniques such as manual traction, use of a temporary external fixator or by direct reduction using fracture reduction tools inserted through small stab incisions (Fig. 1). The pre-shaped plate (Fig. 2) is then tunneled percutaneously, bridging the fracture site itself. Then the plate is fixed distally and proximally by screws (Fig. 4a, b). The recently developed “internal fixators” allow for better fixation of osteopenic and highly comminuted fractures as the bone-plate interface is not dependent on screw purchase in bone.

Indications and complications

Defining the correct indications for implant usage is probably the most difficult part of trauma surgery, especially in the MIPO technique. Fracture location and configuration, soft tissue damage and general patient condition must be considered. Other factors involved in the decision making process include the presence of other implants, the availability of the implants and the correct instrumentation and last, but not least, the preferences and experience of the surgeon. It must not be forgotten that MIPO is a demanding technique. The limited access to the fracture site has

Figure 1 Use of an external fixator as temporary stabilisation and reduction tool.
disadvantages; compared with the traditional open reduction techniques the assessment of frontal and sagittal plane axial alignment, length, and rotation can be difficult. Failure to recognize malalignment intraoperatively may necessitate further surgery and every effort should be made to prevent mal-reduction at the time of definitive osteosynthesis. Consequently, intraoperative fluoroscopy is significantly prolonged and, for the less experienced surgeon, operation time can be prolonged as well.

Within these limitations, the MIPO technique can be used to treat simple and multi-fragmentary fractures in the diaphysis and metaphysis of long bones, in opening wedge ostotomies (e.g. proximal tibia), and for secondary fractures after intramedullary nailing and in tumour surgery. Additionally, it can be used in selected fractures with fracture extension into the joint such as Pilon and tibial plateau fractures, in patients with narrow or very large medullary canals and in shaft fractures in children.29 Finally, as it can be difficult to obtain stable fixation with traditional implants around TKA components, MIPO using fixed-angle locking plates allows for multiple screws to be passed around TKA components and offers the capability to provide further stabilization with unicortical locking screws.27 Very good results have been published using MIPO in periprosthetic fractures around total knee and hip replacements,51–53 but a number of minor and major complications have been reported in published series, including delayed union or non-union, loss of reduction, breakage of the implant, infection and in many cases implant-related pain (Table 1).

**Published outcomes**

The first minimally invasive plate osteosynthesis techniques were developed in the late 80’s for subtrochanteric30 and later for distal femoral fractures.31–35 Since then, the MIPO technique has been applied to a variety of fracture sites and types, including the femoral shaft,36 the tibia,37–46 the humerus,47–49 the distal radius50 and complex cases such as periprosthetic fractures51–53 and fractures with bone defects.54

Table 1 summarizes the outcomes in some of the published series of the MIPO technique since 1997. Most concern tibial fractures. The overall success rate judged by fracture healing without the need of secondary intervention ranges between 57% and 100% (mean 91%), but almost 10.2% (range 0–26.9%) of the patients required reoperation for various reasons including non-union, infection, implant failure or malposition. Data from large multicentre studies31,35 suggests that more than 23% of

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**Figure 2** The pre-shaped plate.

**Figure 3** Sliding of the plate through a small incision.

**Figure 4** (a) Fixation of the plate with screws through small stab incisions. (b) Anteroposterior intraoperative x-ray of a plate in situ.
patients required reoperation. It is apparent that MIPO is not a panacea for every kind fracture, and defining the right indications is of paramount importance to avoid complications.

In conclusion, Minimal Invasive Plate Osteosynthesis is in its infancy, and there are opposing opinions, which is to be expected of a new technique. However, the associated implants, techniques, and applications will certainly

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<th>Table 1</th>
<th>Summary of the outcome of some of the published series of patients treated with MIPO technique, since 1997</th>
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