Minimally Invasive Plate Osteosynthesis: A Review

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Abstract

Present-day concepts of osteosynthesis emphasize upon biological healing of fractures. This has led to advent of minimally invasive plate osteosynthesis. This technique if used when indicated leads to numerous advantages such as higher rates of union with decreased surgical time, blood loss, post-operative pain, infection rates and certain other postoperative complications. This technique is being applied commonly in fractures such as shaft of humerus, proximal and distal femur, proximal and distal tibia with several benefits over its conventional counterparts. In this review, the authors highlight upon historical aspect of development of this technique, its implementation in different fractures, various factors determining its stable application and its pearls and pitfalls.

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Introduction

History of plating dates back to 1886 when the first reported use of a plate for internal fixation of fracture was accomplished by Hansman[1]. The science of plating flourished for several years till the early twenties following an era of disfavor. Plating returned to vogue following the introduction of revolutionary concepts by Muller. He and his colleagues, under the banner of Arbeitsgemeinschaft für Osteosythese (AO) foundation laid down the concepts of operative fixation of fractures. Complete restoration of the bony anatomy under direct vision during fracture fixation was the rule. This resulted in direct fracture healing with absolute stability[2]. But, this came at a price. The price was the risk of bone or soft tissue necrosis and delayed healing as there was widespread soft tissue dissection and interruption of periosteal blood flow[3].

This led to advent to more biology friendly techniques. These biological techniques lay stress upon maximal preservation of blood supply around the fractured bone by minimal direct handling of the fracture environment[4-5]. They offer advantages which include preservation of the fracture hematoma, less surgical trauma to the surrounding soft tissues[6], reduced operative time therefore decreased risk of infection and ultimately leading to indirect bone healing with abundant callus.

Minimally invasive plate osteosynthesis (MIPO) is a novel technique for application of principles of biological fracture healing with a philosophy of dealing with soft tissues with utmost respect. Brunner and Weber are credited for popularizing this method in the early eighties.[7] Further later, following advancements in implant technology and development of techniques of indirect fracture reduction this technique gained more popularity.

The evolution of MIPO began with the use of bridge plating[8]. In initial days a conventional plate was applied for comminuted femoral fractures using long incisions but with preservation of the vastus lateralis muscle resulting in healing with abundant callus[9]. Subsequently, the size of incisions got decreased, rather two small incisions were given at proximal and distal ends and plates were bridged sub muscularly over the fracture fragments[10-12].

This technique causes minimal distress to soft tissues and bone, provides access to the bone through soft tissue windows, with minimal or no contact with the fracture by indirect reduction tools and leaving behind minimal foot prints.

The study focuses over various aspects of application of MIPO technique used in commonly indicated fractures, along with factors influencing its mechanical stability, recent advances and its downside.

What are the indications of MIPO?

Although minimally invasive approach for plating bears numerous advantages, due to its limitations it is not universally applicable. A careful preoperative planning is required prior to its implementation with bearing in mind the anatomical aspect of the fracture, condition of soft tissue, etiology of the fracture, type of construct required and date since injury. Indications for MIPO have been summarized by Babst and Khong[13]:

- epi-/metaphyseal fractures;
- poor soft tissue condition obviating an open procedure;
- conditions where intramedullary nailing is not feasible: unsuitable fracture pattern (intra-articular extension), narrow, deformed or obstructed intra-medullary canal;

- cases in which intramedullary reaming is contraindicated or can be detrimental (polytrauma patients with respiratory compromise);
- fractured bones with other implants or prosthesis in situ;
- Settings where of an image intensifier is not available.

Regional Considerations

Shaft Humerus: A wide variety of treatment modalities are available for treatment of shaft humerus: functional cast bracing[14], open compression plating[15], intra-medullary nailing.[16] All these methods have shown good results when used judiciously with their respective indications.

Non operative treatment is economical and technically less demanding. But it leads to prolonged immobilisation and increased malunion rates. Open compression plating promises better reduction of fracture fragments[17] but causes extensive soft-tissue handling, loss of fracture hematoma and thus loss of biological environment for fracture to heal[18]. It is also associated with complications such as sepsis, iatrogenic radial nerve injury[19] and nonunion. It is also a technically demanding procedure requiring long learning curve[20].

Use of MIPO by the means of anterior bridge plating helps in preservation of biological atmosphere and thus promotes adequate healing at the fracture site. Surgery is minimally invasive so there is less blood loss, neurovascular complications, post-operative pain, chances of sepsis and lesser hospital stay. In the middle third fractures, MIPO is safer from the risks of iatrogenic radial nerve injuries. However, it is not the case with distal third fractures as there is risk of radial nerve entrapment under the plate[21]. Since exposure is minimal chances of infection encountered are less too.

Proximal Femur: The functional outcomes following plating of subtrochanteric fractures are far more inferior to those following the intramedullary devices[22-23]. But nailing in certain complex fracture can be technically demanding. In such situations plating can be beneficial. Additionally plates are less expansive as compared to nails. Other relative indications are cases with small medullary canals or cases of poly trauma involving the pulmonary system in which reaming can be detrimental[24]. In such situations plating can be done with minimal access to have the biological advantages. Implants such as DCS, Condylar buttress plate can be used with satisfactory outcome with MIPO technique[25].

Distal Femur: The conventional lateral approach to distal femur offers the window for excellent visualization and direct reduction of the fracture. But this comes at a price of massive soft tissue exposure, loss of blood, devitalisation of fracture fragments and need for bone grafting in certain circumstances ultimately leading to infections, non-unions[26].

But with the advent of various minimally invasive procedures in different forms has led to decreased incidence of such complications. Various techniques have been devices such as MIPO, MIPPO, TARPO, LISS offering minimal of complications.

MIPO is convenient for cases with extra articular involvement with complex Meta/diaphyseal fragments. MIPPO (minimally invasive percutaneous plate osteosynthesis) technique encompasses use of specialized instruments for application of implants such as DCS. Thus, offering advantage of DCS with minimal soft tissue handling[10].

TARPO (Transarticular Approach and Retrograde Plate Osteosynthesis) offers direct visualization of articular surface with minimal access to the metaphyseal region. Hence, its advantage lies in osteosynthesis of articular fractures. It utilizes the use of an incision given for lateral parapatellar arthrotomy for direct visualization for restoration of the articular congruity and an indirect fixation of the diaphyseal component[27]. Although these techniques are advantageous, but they are technically more demanding.

LISS for distal femur (Less invasive stabilization system) comprises of the use of an anatomically contoured plate which is inserted via minimal access into the sub-muscular plane through an aiming device after indirectréduction of the fracture[28]. Screws are inserted using the aiming device with minimal incisions. Thus the advantages of minimal tissue handling are offered, but the technique is costly and requires availability of high profile instrumentation.

Proximal Tibia: High velocity tibial plateau fractures often encompass a combination of complex articular involvement with substantial communition and associated severe soft tissue injuries. Operating upon such injuries with conventional approaches in presence of the damaged soft tissues leads to incidence of high amount complications such as infections[29], wound dehiscence, hardware prominence. To avoid such situations a two staged approach, use of dual incisions or definitive external fixation is preferred. These methods can increase morbidity and are not cost effective as multiple surgeries are required and increased hospital stay is required.

The usefulness of minimally invasive approaches comes to advantage in such situations. Here, MIPO has shown lower incidence of soft-tissue complications and yields in better end-results than ORIF[30-31].

Distal Tibia: Plating is gold standard in operative treatment of distal tibial fractures. Intramedullary nailing is not preferred treatment for distal tibial fractures as these fractures commonly extend to the tibial pilon[32]. Application of external fixators in distal

tibial fractures is commonly associated with a high complication rate. Complications such as pin tract infection pin loosening and high rate of malunion are common[33].

Optimal treatment of distal tibial fractures is challenging owing to its fragile soft tissue cover and tenuous blood supply. Cadaveric studies have shown that its vascularity is derived from extra osseous anastomosis of branches of anterior and posterior tibial arteries. These arteries arrive into distal tibia from the medial side. Open plating can thus lead to disruption of this blood supply and hamper the vascularity[34].

MIPO has shown to have higher of union rates and lower complication rates as compared with the conventional open method[35-36].

Factors Influencing Stability of Construct[37]

In order to achieve a stable construct the following guidelines are recommended:

Plate Length: Plate length should be two to three times bigger than length of the fracture in comminuted fractures and eight to ten times higher in simple fractures. Use of such longer constructs is requirements for an ideally stable construct. The length increases the pullout force acting on the screw because of long lever arm for each screw. MIPO with its inherent ability of plate insertion with minimal incisions offers such advantage of placement of larger plates without extensive exposure.

Number of screws: Two screws on each side of the fractures are prerequisite for a stable construct. But, being on the safer side it is recommend to use three screws on either side so as to take care of chances of failure due to screw breakage. A plate screw density below 0.4 to 0.5 is recommended, this implies that less than half of the plate holes are occupied by screws

Locking versus non locking screws: Use of locking screws is recommended especially in bones with poor quality as locking heads provide strength against not only pullout but also bending.

Bicortical versus unicortical screws: A purchase of certain amounts of threads in the engaging cortex is necessary for firm anchorage of plate to the bone surface. Healthy cortices are dense enough for a good purchase. In such bones even a monocortical screw can resist the torsional forces acting over the fracture site. Whereas, in case of porous bones the cortex is thin. Here, even minimal torsional forces can lead to instability as the screw pullout strength becomes lower due to decreased working length of the screw. Therefore, in such cases use of bicortical screw is recommended.

Self-drilling versus non self-drilling screws: Use of self-drilling screws is recommended only for unicortical screws as they can cause soft issue damage while drilling far cortex for bicortical applications.

Screw direction: Parallel insertion has lesser strength against pull-out, as a pull-out force is applied, entire screws and plate interface pulls out as a whole. The pull-out strength can be increased by use of screw in diverging directions[38].

Pearls for performing MIPO

1. In order to achieve desirable outcome a few steps are critical: performing *MIPO earlier the better* as reduction and achievement of adequate length becomes difficult by indirect measures in older fractures; having *accurate knowledge of surface anatomy* as precise incisions and dissection is required; achievement of indirect closed reduction, *avoiding exposure of the fracture* and using *special tools* if required (described below); making *small incisions* for implant insertion; use of plates preferably *anatomically contoured* with *low bone contact* as pure *splints; elastic bridging* of the fracture to formulate a relatively stable construct[39].
2. Attainment of intra-operative control over bone alignment and rotation of fragments can be cumbersome even to the experienced hands. Repeated use of intra-operative use of fluoroscopy exposes the surgeon to hazards of radiation[13]. The following few signs can minimize the hassle while using fluoroscopy- ***Cortical step sign***: the opposite bone ends have unlike cortical thickness; ***Diameter step sign****:* in presence of malrotation, diameters of proximal and distal ends appear to be of different dimensions; ***lesser trochanter sign***: limb rotation leads to altered appearance of the lesser trochanter[40].
3. In order to minimize these hardships, development of better instruments and techniques is essential. These include better navigation tools, plates with newer types of instrumentation such as aiming devices, indirect reduction tools such as clamps, pointed forceps such as collinear forceps, use of distracters, wire passers, modified t handles and the f-tool.[41-42]
4. Location of a plate hole without Fluoroscopy: Fluoroscopy is not required to locate a plate hole. Place identical plate over the subcutaneous plate and locate holes, then make small stab incisions. Use small hemostat to locate the holes.

Pitfalls

1. As the fracture site in not directly visualized, chances of mal-reduction exist which lead to malunion of fractures[43]. Also, use of this

technique limits its application in articular fractures where direct visualization of the joint surface is required. In such cases this technique is used in conjugation with standard open approaches.

2. As the procedure involves meticulous soft tissue handling and minimal exposure the procedure is considered technically demanding and a longer learning curve is required[44-45].
3. This technique is contraindicated in cases of open fractures with severe soft tissue loss with no coverage of exposed bone, as the fracture site is already exposed, associated neuro-vascular injuries as exploration of injured structure is required, pathological fractures and cases of non-union and delayed unions as these fractures require freshening of fracture margins with or without bone grafting.
4. As compared to conventional plating this procedure requires higher fluoroscopic control and thus exposes the surgeon to higher amount of radiation[13].
5. Implant removal can be tedious, as small incisions are required for plate insertion and often incisions are not in place of position of screws as swelling subsides. Large extensile incisions are then required for implant removal[46].

Conclusion

MIPO is simple, safe and effective method of treatment for diaphyseal & metaphyseal fractures. It does not require direct visualization of the fracture at the cost of extensive soft tissue dissection. We are confident in suggesting this alternative approach of plating.

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