Original Article

Minimally Invasive Plate Osteosynthesis (MIPO) in Humeral shaft Fractures – Biomechanics – Design – Clinical Results

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ABSTRACT Purpose. To assess outcomes of minimally invasive plate osteosynthesis (MIPO) in 42 humeral shaft fractures. Methods. 28 men and 14 women aged 18 to 68 (mean, 34; median, 29) years underwent closed reduction and MIPO using a LCP for type 12-A (n=26) and type 12-B (n=16) humeral shaft fractures. Eight of the patients were aged 50 years. Patients were followed up monthly until radiological union in at least 3 of the 4 cortices. Functional assessment was based on the Disabilities of Arm, Shoulder and Hand (DASH) score. Results. The mean follow-up period was 25 (range, 14–35) months. The mean DASH score was 35.1 at month 3 and improved to 8.9 at month 6 and 5.2 at year 1. The mean angulation was 4° in the coronal plane and 7° in the sagittal plane. All fractures united after a mean of 14 weeks. Two patients with transverse fractures had delayed union and received bone marrow injections at 12 or 13 weeks; they achieved union at week 20. One patient developed a radial nerve palsy immediately after surgery and underwent surgical exploration through the anterolateral approach. The plate was re-applied, and the nerve recovered in 48 hours with full power in all the muscle groups. Conclusion. MIPO is effective technique for fixation of diaphyseal humeral fractures, and results in faster bone union, better cosmesis, and minimal complications.

1. Introduction

Complex periarticular fractures of the long bones are difficult to treat. Classic intramedullary osteosynthesis do not provide a stable fixation, while open reduction and rigid fixation by classic plates (recommended in the 60s-70s) is requiring large incisions with important deperiostation. Potential complications as infections, consolidation delays and construct damage due to nonunions undergo frequently. At that time, standard operative procedures considered that in epiphyseal-metaphyseal fractures, each fragment either from the articular or metaphyseal area should be subject for anatomical reduction and stabilization. There were obtained superior biomechanical results (absolute stability) but poor long-term biological effects.

The main disadvantages of the anatomic reduction and rigid fixation by plates led to the development of the "biological plate osteosynthesis" concept3. By the development of new plates (bridging plates, Limited Contact-Dynamic Compression Plate / LC-DCP, Point-Contact fixator / PC-Fix, plates with angular stability) and new surgical techniques (indirect reduction and Minimally Invasive Plate Osteosynthesis / MIPO), biological plate osteosynthesis is important to preserve bone vascularity, to improve consolidation, to decrease infection rate, to avoid iterative fractures or bone grafting. While indirect reduction techniques (using a distractor) are limiting the medial dissection and avoid bone grafting, MIPO techniques are limiting both the medial and lateral dissection in complex extraarticular fractures of the proximal and distal femur4. MIPO techniques avoid direct exposure of the fracture site and transforms the implants in an internal extramedullary splint. Furthermore, MIPO was successfully extended to complex tibial fractures, being actually indicated in all long bones complex fractures that are not suitable for intramedullary osteosynthesis5–9.

MIPO can be structured in 4 steps or techniques:

a. MIPO technique with proximal and distal incisions. It was described by Wenda (Wenda et al., 1997) that have used a femoral limited lateral approach, proximally and distally from the fracture site, with plate insertion beneath the vastus lateralis7;

b. Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) procedure was developed for extraarticular fractures of the distal and proximal femur; the key for this technique is represented by the usage of a two-part implant, the Dynamic Condylar Screw8 (DCS) [Krettek et al., 1997a];

c. Transarticular Approach and Retrograde Plate Osteosynthesis (TARPPO) procedure was developed by Krettek [Krettek et al., 1997b], for the osteosynthesis of the distal femoral intraarticular fractures9.
d. Procedures that use specific implants for MIPO procedures (Plates with angular stability and tools for percutaneous insertion).

MIPO special characteristics are represented by:

1. The treatment purpose in minimally invasive plate osteosynthesis consists in anatomic reconstruction of the articular area, axis, rotation and length reestablishment for the metaphyseal-diaphyseal area, long plates osteosynthesis with screws fixed only distally and proximally from the fracture, bridging the comminution and with early functional rehabilitation.

2. Various studies results demonstrate that MIPO and TARPO have undeniable advantages over classic techniques: fast healing, reduced complication rate, reduced primary or secondary grafting requirements, and shortening of the operative time. Moreover, TARPO procedure provides a good exposure of the knee joint.

3. Good results obtained by minimally invasive plate osteosynthesis are due to a fast healing by vascularization protection and also to an increased resilience to mechanical stress.

4. Fixation with long plates only distally and proximally from the fracture site maintain a certain instability degree that is useful for an accurate and fast healing (relative instability).

5. Minimally invasive plate osteosynthesis is a demanding technique, requiring a cautious intraoperative clinical and fluoroscopic control in order to reestablish limb axis, rotation and length.

MIPO techniques in complex humeral shaft fractures The treatment of complex humeral shaft fractures is a challenge due to the fact that open reduction and internal fixation with plates by anterolateral or posterior approach (the gold standard) is associated with a high morbidity (Livani et al., 2004; Sirbu et al., 2008) while locked intramedullary nails (the best option) do not offer a sufficient control of rotational movements in unstable and distal fractures (Rommens et al., 2000; Changulani et al., 2006; Sirbu et al., 2008). In a recent study on plastic bones (Asaftei et al., 2010) we have evaluated the mechanical behavior of three different types of implants used in the osteosynthesis of comminuted humeral shaft fractures.

We instrumented the fractures with 3 types of implants: an intramedullary nail, two types of locked plates and a "classic" DCP. All of them were submitted to torsion essays in external and internal rotation as to obtain the same amount of torque. The loading-deforming diagrams were compared and statistically analyzed for each type of implant. The shorter locked compression plate seems to be the most rigid implant for each type of loading essay, the mean values of the loading forces being the highest in the entire group. The intramedullary nail proved to be the most elastic implant on all types of loading. In external rotation, the Dynamic Compression Plate - DCP gives surprisingly values of torsion forces relatively close to the longer locked plate. This seems to be related to the different "working length" of the different plates and also to the different total length of the implants. Regarding the advantages of indirect reduction and biological plate osteosynthesis, Livani and Belangero (Livani et al., 2004) developed MIPO technique by anterior approach in humeral shaft fractures.

This MIPO technique avoids the problems related to the neural vascular structures of the arm and especially to the radial nerve. For proximal and middle shaft fractures they have used a proximal limited approach (between biceps - medially and deltoid muscle - laterally) and a distal approach between biceps and brahialis muscle (Fig. 1). A DCP narrow plate with 12 holes and no previous molding was inserted from proximal to distal, placed on the anterior humeral face and fixed onto the shaft with at least 2 proximal and 2 distal screws. For distal fractures, they have used the same proximal approach and a distal limited approach performed by subperiosteal dissection of the lateral supracondylyar ridge of the humerus, with retraction of brachioradialis and long carpal extensor muscle, as well as the radial nerve (even though unseen).

![Fig.1](A-D) MIPO by anterior approach in a mid-shaft humeral fracture (A) Arm positioning; (B) Proximal and distal approach; (C,D) Plate fixation

A narrow DCP plate of 4.5 mm with 12 holes was molded and twisted medially to adapt to the anterior face of the humeral lateral column and diaphysis, thus avoiding occlusion of the coronoid or of the olecranon fossae. The plate was inserted from distal to proximal and fixed onto the shaft with at least 2 proximal and 2 distal screws, after reestablishing the humeral axis, length and rotation. The radial nerve may be endangered in the lateral column approach but even in such circumstances its identification is not required. This technique can be used for fractures of the distal humerus with paralysis of the radial nerve. Following identification and restoration of the radial nerve through a separate approach, the molded plate is inserted from distal to proximal and fixed as previously described.

2. Materials and Methods

Between June 2013 and May 2015, patients aged >18 years underwent MIPO surgery. A total of 40 patients were prospectively evaluated. Patients with multiple or open fractures, associated periarticular or intra-articular fractures of the shoulder or elbow, radial nerve palsy, or entailed polytrauma were excluded. Four patients in whom satisfactory closed reduction was not feasible by indirect methods were also excluded. 28 men and 14 women aged 18 to 68 (mean, 34; median, 29) years underwent MIPO using a LCP for type 12-A (n=26) and type 12-B (n=16) humeral shaft fractures. The patients were positioned supine and operated on by a single senior surgeon under general anaesthesia and image intensifier guidance. Two incisions were made over the anterior aspect of the arm, with the forearm supinated (Fig. 1). In the supinated position, the radial nerve moves away from the
The mean follow-up period was 25 (range, 14–35) months. The mean operating time was 52 (range, 40–82) minutes. The mean blood loss was 84 ml. The mean hospital stay was 2.8 days. The mean DASH score was 35.1 at month 3 and improved to 8.9 at month 6 and 5.2 at year 1. The mean angulation was 40 in the coronal plane and 70 in the sagittal plane. No patient had angulation of >100 in either plane. All fractures had united within a mean of 14 weeks. Two patients with transverse fractures had delayed union and inadequate callus formation, with pain at the fracture site and difficulty in activities of daily living. Both patients received bone marrow injections 12 or 13 weeks later and achieved union at week 20. No bone grafting or refixation was undertaken. One patient in whom a 14-hole broad LCP was used developed a radial nerve palsy immediately after operation. He underwent surgical exploration through the anterolateral approach and plate re-application, and the nerve recovered within 48 hours with full power restored in all the muscle groups. The LCP provided a potential space between the plate and the bone. The comminuted fracture may have resulted in a soft bed against which the nerve was pressed resulting in a neuropraxic injury to the nerve. Two patients had hypertrophic scars but none were functionally dissatisfied. No patient had a wound infection or implant failure warranting re-fixation.

### 4. Discussion

We have just finished a prospective study including 42 humeral shaft fractures (26 type 12-A, 16 type 12-B /AO classification) treated with MIPO technique by anterior approach (using Livani and Belangerotechnique). We have used classic or narrow large fragment DCP plates of 10-14 holes, LCP plates of 10-14 holes according to the fracture type.
After a short immobilization (1-2 weeks) the patients started rehabilitation. All fractures healed within a mean time of 12 weeks following surgery, with good functional results regarding elbow and shoulder mobility. There were no vascular or nerve complications, except 2 postoperative temporary paresthesia for the radial nerve in distal fractures.

The following tips and tricks are crucial in this technique: last distal screw – first inserted – relatively loose; arm abduction 60°; slide traction of the distal fragment, first proximal screw inserted, tightening the distal screw; clinical and radiological assessment; two more screws placed in each fragment; tightening the screws for pulling to the bone to the plate and reduction completion. At the end of this study we can emphasize the advantages of this technique regarding safety and feasibility, without requiring special tools and demanding implants or excessive radiographic control. The plate stability allows a fast rehabilitation with superior functional results comparing with the conservative techniques. MIPO seems to be the best option for distal third humeral fractures and a viable solution for distal fractures with radial nerve palsy.

5. Conclusions

With a good knowledge of the operative technique and careful preoperative planning, these plates represent excellent and safe procedures for difficult articular fractures. Internal fixators can be expected to maintain, but not obtain fracture reduction, so care should be taken to ensure a proper close reduction before in sertion of the locked screws. In the future, the real time photogrammetry and triangulation techniques by topperman software will allow the trauma surgeon to obtain accurate images in order to reestablish the length, axis and rotation during minimally invasive techniques (Ip, 2006) Close cooperation between orthopedic surgeon, biomechanics and robotics specialist, and the departments of cell biology and pathology will contribute to the creation of the ideal internal fixator and will represent the premises for experimental investigations required to elucidate the dynamic and coherent process of callus formation.

References

