

MINIMALLY INVASIVE PLATE OSTEOSYNTHESIS (MIPO) IN HUMERAL SHAFT FRACTURES – BIOMECHANICS – DESIGN – CLINICAL RESULTS

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ABSTRACT: 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. 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 vascularization, to improve consolidation, to decrease infection rate, to avoid iterative fractures or bone grafting. **MATERIALS AND METHODS:** Between June 2013 and May 2015, patients aged >18 years underwent MIPO using a LCP for types 12-A, 12-B, and 12-C closed diaphyseal humeral fractures.⁸The patients were prospectively evaluated. **RESULTS:** 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 84ml. 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 4° in the coronal plane and 7° in the sagittal plane. **DISCUSSION:** 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. **CONCLUSIONS:** With a good knowledge of the operative technique and careful preoperative planning, these plates represent excellent and safe procedures for difficult articular fractures.

KEYWORDS: Minimally invasive plate osteosynthesis, Humeral shaft fractures and biomechanics, Clinical results.

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 non-unions 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.^{1,2}

The main disadvantages of the anatomic reduction and rigid fixation by plates led to the development of the "biological plate osteosynthesis" concept.³ 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 vascularization, to improve consolidation, to decrease infection rate, to avoid iterative fractures or

ORIGINAL ARTICLE

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 extra articular fractures of the proximal and distal femur.⁴ MIPO techniques avoid direct exposure of the fracture site and transforms the implants in an internal extra medullary 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 osteosynthesis.^{5,6}

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 lateralis.⁷
- b) Minimally Invasive Percutaneous Plate Osteosynthesis (MIPPO) procedure was developed for extra-articular 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 (TARPO) procedure was developed by Krettek (Krettek et al, 1997b), for the osteosynthesis of the distal femoral intraarticular fractures.⁹
- d) Procedures that uses 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.¹⁰
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.¹¹
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.¹²
4. Fixation with long plates only distally and proximally from the fracture site maintains a certain instability degree that is useful for an accurate and fast healing (Relative instability).¹³
5. Minimally invasive plate osteosynthesis is a demanding technique, requiring a cautious intraoperative clinical and fluoroscopic control in order to re-establish limb axis, rotation and length.^{14,15}

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;

ORIGINAL ARTICLE

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.^{16,17,18}

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.^{19,20}

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 supracondylar ridge of the humerus, with retraction of brachioradialis and long carpal extensor muscle, as well as the radial nerve (Even though unseen).²¹

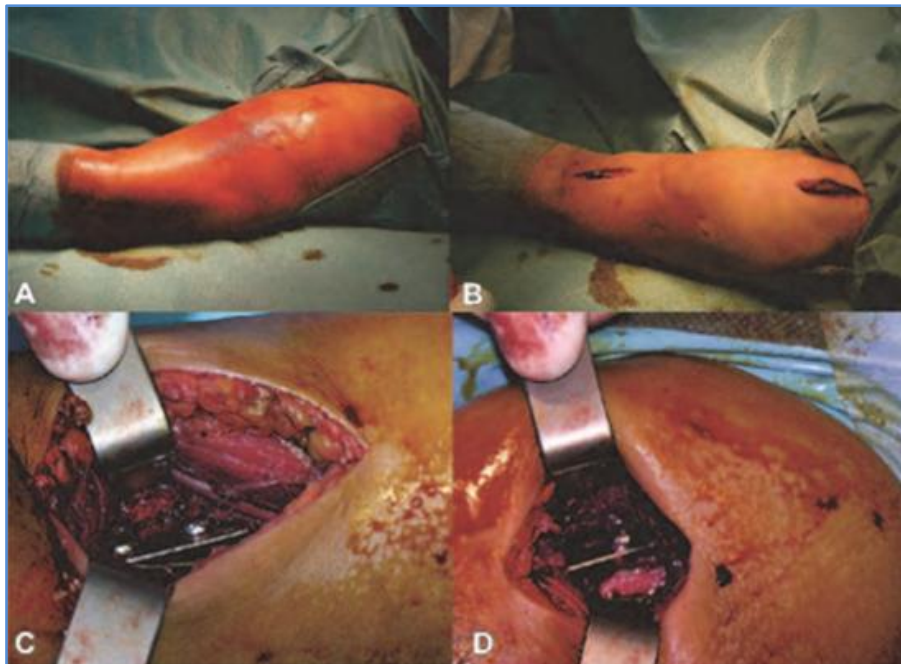


Fig. 1: (A-D): MIPO by anterior approach in a mid-shaft humeral fracture (A) Arm positioning; (B) Proximal and distal approach; (C, D) Plate fixation

ORIGINAL ARTICLE

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.²²

MATERIALS AND METHODS: Between June 2013 and May 2015, patients aged >18 years underwent MIPO using a LCP for types 12-A, 12-B, and 12-C closed diaphyseal humeral fractures.⁸ The 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. Eight of the patients were aged \geq 50 years. The bone quality was assessed using radiographs; DEXA scan to assess osteoporosis was not used. 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 anteriorly placed LCP thus reducing the risk of radial nerve injury.⁹The first incision was made at the deltopectoral groove. The cephalic vein lies in this interval. The vein was identified and protected while dissecting through the interval. Dissection was carried down to the humerus, where the anterior border of the humerus distal to the crest of greater tubercle was identified. The anatomic importance of the anterior humeral border is that it extends in almost a straight line up to the coronoid fossa, so that a straight plate can be placed on it without pre-contouring. In patients with big muscle bulk, the anterior part of the deltoid insertion was released. A blunt Cobb periosteal elevator was passed to make an extra periosteal sub-muscular tunnel under the brachialis. A narrow (n=26) or broad (n=16) 4.5-mm LCP was used depending on the width of the bone. The length of plate was sufficient to accommodate at least 2 screws in each fragment.

In 4 patients aged 27 to 39 (mean, 33) years, only 2 screws in either of the fragments were inserted. In the remaining patients, \geq 3 screws in either of the fragments were inserted. The plate was passed from the proximal incision to the distal fragment through the sub-muscular tunnel. The plate bypassed the fracture and was observed over the distal fragment under image intensifier. Fracture reduction was performed under image intensifier guidance by the indirect method, using gentle traction (Fig. 2). When needed, Steinman pins were placed in each of the fragments as joysticks to aid reduction. An assistant held the elbow semi-flexed with the forearm supinated. A second incision was made over the distal part of the plate, over the lateral border of biceps muscle, which was retracted medially to expose the brachialis muscle. Fibres of brachialis were split longitudinally, providing extra periosteal access to the anterolateral distal humeral shaft.

The radial nerve lies laterally, protected by the lateral portion of brachialis. A 4.2-mm drill bit was used to make a screw hole in the proximal fragment but the drill bit was not removed. Fine

ORIGINAL ARTICLE

tuning of the fracture reduction was carried out under image intensifier guidance and another 4.2-mm drill bit was used to make a screw hole in the distal fragment. The drill bit was left in situ and reduction checked again under image intensifier. With the fracture satisfactorily reduced both the drill bits were replaced by appropriately sized locking head screws. After provisional fixation, at least 2 screws were placed in each fragment. Postoperatively, an arm pouch sling was used for support. Assisted elbow and shoulder mobilisation was allowed on day 1. Sutures were removed on week 2. 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.



Fig. 2: DASH Score at 3months, 6months and 12 months

RESULTS: 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 4° in the coronal plane and 7° in the sagittal plane. No patient had angulation of >10° 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 re-fixation 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.

ORIGINAL ARTICLE

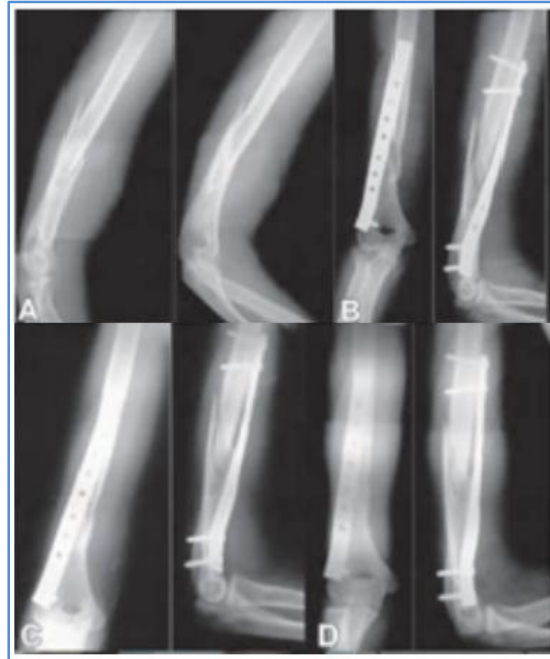


Fig. 3: Clinical case. Distal Shaft Fractures; MIPO by anterior approach; (A) Preoperative X-ray; (B) Postoperative X-ray; (C) At 3 weeks; (D) Callus formation at 8 weeks

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 and interlocking nail techniques. MIPO seems to be the best option for distal third humeral fractures and a viable solution for distal fractures with radial nerve palsy and also for the fractures of midhumeral shaft.

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 insure a proper close reduction before insertion of the locked screws. In the future, the real

ORIGINAL ARTICLE

time photogrammetry and triangulation techniques by topper formance software will allow the trauma surgeon to obtain accurate images in order to re-establish the length, axis and rotation during minimally invasive techniques (Ip, 2006) Close cooperation between orthopaedic 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.

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ORIGINAL ARTICLE

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