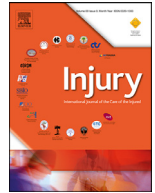




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MIPO helical pre-contoured plates in diaphyseal humeral fractures with proximal extension. Surgical technique and results

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ABSTRACT

Introduction: : The aim of this study was to determine the feasibility of applying the MIPO technique with a helical-shaped plate in the treatment of humeral shaft fractures with proximal extension.

Patients and methods: : We present an observational prospective study of patients with a humeral shaft fracture involving the proximal humerus fixed with a long proximal humerus polyaxial locking plate with an anterior curvature and helical shape (ALPS® Zimmerbiomet, Warsaw, Indianapolis, USA), using a MIPO technique. Between January 2017 and July 2020, 15 patients were treated at our institution. Proximally a 4–5 cm anterolateral transdeltoid approach was made. And distally, a 5–7 cm incision was made 4 cm proximal to the elbow crease. At each follow-up, radiographs were taken to evaluate fracture healing. Functional scales were applied to evaluate clinical results.

Results: : Ten women and five men were included, with a mean age of 62 yo (range 26–86). All but one fracture healed uneventfully. The mean time to union was 28 weeks (range 12–48 weeks). Two out of 15 patients presented complications (an atrophic nonunion and a peri-implant distal fracture). None of the patients had a nerve palsy prior neither after the surgery. No other complications, including infection, were registered during follow-up. Shoulder range of motion showed the following means: abduction of 147° (range 50°–180°), anterior flexion of 144° (range 80°–180°), external rotation of 77,5 ° (range 70°–80°) and internal rotation of 54.5° (range 45°–60°). All patients recovered their pre-fracture elbow range of motion. All patients presented less than 10° of angular deviation in varus/valgus or ante/recurvatum after the surgical procedure. At the end of the follow-up, all final functional scores were “good” or “excellent”: mean Constant-Murley score was 72 ± 13 (range 38–91), ASES score was 73 ± 12 (range 41–88), UCLA shoulder scale was 30 ± 3,5 (range 10–35), and Q-DASH score was 16.5 ± 0,11 (range 4–57).

Conclusion: : When applied correctly, the treatment of diaphyseal humeral fractures involving the proximal humerus using a polyaxial locking helical plate with a MIPO technique is a reliable treatment method. It has high union rates with low complications.

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Introduction

Humeral shaft fractures comprise 3% of all bone fractures [1]; and 13% of all humeral fractures [2]. Within this group, there is a very rare subgroup: multifragmentary diaphyseal fractures involving the proximal humerus.

Most humeral shaft fractures can be successfully treated by non-operative methods. However, there are disadvantages to con-

servative treatment, such as restricted movement in the shoulder and elbow joints, delayed union or non-union, and plaster cast-related complications [3]. In addition, there is a relatively higher incidence of non-union in the proximal end of the humeral shaft when treated conservatively, compared with other regions of the humerus [1]. The indications for operative treatment of humeral shaft fractures include unacceptable alignment after closed reduction, multiple injuries, radial nerve palsy after manipulation, bilateral humeral fractures and open fractures [4].

Compression plating has been regarded as the gold standard for the surgical treatment of humeral shaft fractures [5]. This treatment gives a high union rate and allows early active motion of the near joints. Combined diaphyseal and proximal humeral fractures

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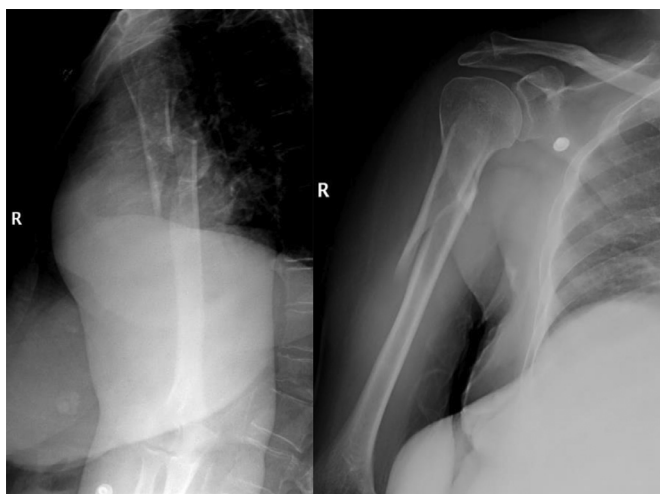


Fig. 1. AP and lateral X-ray of a right humerus arm. Diaphyseal humeral fracture with extension to proximal humerus.

should be treated with stable fixation [6]. The use of open reduction and internal fixation in this scenario would require an extensive surgical approach which could increase the risk of complications. Although some of these complications related to the open approach could be solved using intramedullary nails. But the use of nails in these shaft fractures involving the proximal humerus, might displace previously undisplaced fractures, especially those involving the greater tuberosity. On the other hand, there is an important risk of rotator cuff penetration and fracture nonunion [7].

To avoid radial nerve damage with long straight plates and nail related complications, long helical-shaped plates can be used with a minimally invasive plating osteosynthesis (MIPO) technique. Helical-shaped plates are precontoured utilizing in-situ multi-planar bending of the shaft of approximately 90°. Thanks to the helical-shaped design, the plate lies proximally on the lateral aspect of the greater tuberosity and distally on the anterior aspect of the humeral shaft. In this scenario, the risk of radial nerve injury is minimized.

This technique for isolated diaphyseal humeral fractures has a statistically significant advantage with a better DASH score, lower non-union rate, and lower residual deformity rate [1, 8].

The objective of this study was to determine the feasibility of applying the MIPO technique with a helical-shaped plate in the treatment of humeral shaft fractures involving the proximal humerus using the anterolateral approach proximally and an anterior approach of the arm distally.

Patients and methods

Between January 2017 and July 2020 we took an observational prospective study of all patients treated at our institution presenting with a humeral shaft fracture involving the proximal humerus. Inclusion criteria were: (1) Age >18 years, (2) Clinically fit for anaesthesia and surgery, (3) Closed diaphyseal humeral fracture with proximal extension treated with a long helical-shaped proximal humerus polyaxial locking plate with an anterior curvature (ALPS® Zimmerbiomet, Warsaw, Indianapolis, USA), and (4) Follow-up of at least 6 months. Two surgeons performed all the operations. Fracture classification was based on plain radiographs according to the AO/OTA classification system. Fractures were classified by two experienced surgeons (LGF & CSP). Medical records and X-ray were taken during admission, surgery and follow-up (Figs. 1–3). CT scan was performed in some cases in order to confirm proximal extension.



Fig. 2. Post-op AP and lateral view. Osteosynthesis with precontoured helical plate (ALPS).

The plate is the long version of the proximal humerus ALPS plate, (Zimmerbiomet, Warsaw, Indianapolis, USA). These plates are precontoured with a helical shape (in-situ multi-planar bending of the shaft of approximately 90°) and present an anterior curvature at the level of the deltoid insertion. The anterior curvature reduces the need to release the deltoid distal insertion by navigating the deltopectoral interval.

Surgical technique

All patients received intravenous antibiotic prophylaxis with 2 g of cephazoline iv.

Patients were placed in supine position under general anaesthesia with the upper limb on a table extension in abduction to facilitate reduction of the shaft component of the fracture and good intraoperative x-ray views: either AP, axillary and lateral views. If the proximal humeral component of the fracture is displaced, to help in its reduction, the patient can be placed in slight beach chair position. This way the proximal approach is more comfortable.

A long helical-shaped version of a proximal humerus polyaxial locking plate was used to fix the fracture: A.L.P.S.® proximal humerus long plate (Zimmerbiomet, Warsaw, Indianapolis, USA). The plate curves anteriorly around the deltoid insertion: proximally the plate sits on the greater tuberosity, and distally on the anterior face of the humeral shaft (Figs. 4 and 5).

A minimally invasive anterolateral transdeltoid approach (3 to 5 cm long) was first used to address the proximal humeral fracture. Then the proximal fracture is reduced according to the reduction technique described elsewhere [9]. Once the proximal humeral fracture is reduced, a minimally invasive anterior approach of the arm was done distal to the fracture. A midline distal skin incision (5–7 cm long) was placed around 4 cm proximal to the elbow crease. The biceps muscle fascia was opened and the biceps retracted medially. Then, the musculocutaneous nerve is identified laying on the brachialis anterior muscle. The anterior aspect of the diaphysis was reached through the middle line of the brachialis. There is no need to identify the radial nerve, but care should be taken when retracting the brachialis muscle laterally. The plane underneath the brachialis muscle was developed sliding a long periostotome over the anterior shaft surface of the humerus from distal to proximal up to the deltopectoral plane. From the proximal approach, room is made for the plate to avoid damaging the axillary nerve. The anterior border of the deltoid insertion is identified with a periostotome, so the plate can easily navigate ante-



Fig. 3. Follow-up AP, lateral and transthoracic X-ray. Consolidation of the fracture after 20 weeks.



Fig. 4. Surgical position: supine with extended arm.

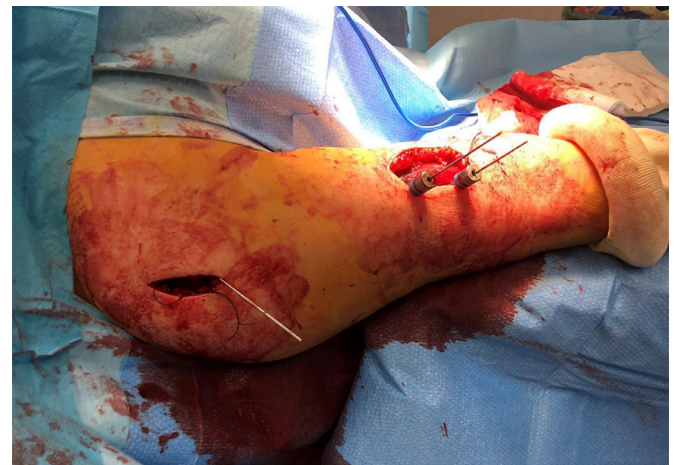


Fig. 5. Surgical MIPO approach: proximal anterolateral and anterior the distal one.

rior to the deltoid insertion without detaching it. The plate was slid from proximal to distal, always touching the lateral aspect of the humerus proximally and anteriorly once the distal deltoid insertion is overtaken. Two pins were placed proximally for temporary fixation of the plate. Under the image intensifier the diaphyseal component of the fracture was reduced with traction, and one k-wire fixed the very end of the plate. We started fixing the distal end of the plate: first a non-locking screw for the final fracture reduction and perfectly sit of the plate, and then three to four locking screws). Secondly, we fixed the proximal humeral fracture with at least 4 locking screws. We made sure the plate sat nicely on the proximal humerus and it was not apart from the lateral cortex, which could protrude into the deltoid muscle.

All patients followed a rehabilitation program: free range of movement of the elbow (active and passive motion) and pendulum exercises for the shoulder were allowed as soon as the patient felt comfortable [10]. Patients were allowed and encouraged to perform, from the very beginning, their activities of daily living for self-care, such as feeding, dressing, and washing themselves, except for lifting weights heavier than one kilogram until callus formation was seen on plain x-rays during follow-up checks.

At each follow-up, radiographs were obtained to evaluate fracture union. Time to union was established when callus was identified in three of the four cortices on AP and lateral radiographs. In the follow-up evaluations, Constant–Murley score, Quick Disabilities of the Arm, Shoulder, and Hand (Q-DASH) score, UCLA shoulder rating scale, ASES score and SF-36 were used.

Data were analysed using SPSS 26.0 (SPSS, Chicago, IL).

Results

Between January 2017 and June 2020, 17 patients presenting a humeral shaft fracture with proximal extension were admitted at our institution and screened for this study. All of them received surgical treatment with MIPO with the long version of the proximal humerus ALPS plate, (Zimmerbiomet, Warsaw, Indianapolis, USA). One patient was lost to follow-up due to mental illness, and another patient died due to complication of previous medical pathologies unrelated to the surgical intervention, so finally a total of 15 patients fulfilled the inclusion criteria.

Ten women and five men were included, with a mean age of 62 years old (range 26–86). Left side was involved in nine patients and the right side in six patients. The mean time between trauma and surgical treatment was 6 days (range 1–22). Two patients had associated head injuries without neurological deficit. According to

the AO/OTA classification, all fractures were classified as 12C3. The mean surgical time was 138 min (range 90–259 min).

All patients had a minimum follow up of 6 months (range 6–30). All fractures but one healed uneventfully. The mean time to union was 28 weeks (range 12–48). Two out of the 15 patients presented complications. The one fracture that didn't heal presented with an atrophic nonunion of the shaft fracture. The nonunion was diagnosed at 16 months follow-up, when the plate failed and broke. This patient presented a history of chronic alcoholism, bilateral hip avascular necrosis as well as bilateral idiopathic humeral head avascular necrosis prior to the humeral fracture. At the time of plate breakage, the patient had shoulder and elbow complete range of motion without pain and no sign of screw loosening on the X-rays. The patient underwent surgery for fixation revision: open anterior approach, removal of the broken plate, refreshing of fracture ends, heterologous bone grafting and fixation with the same type of helical plate. After the second surgery, the fracture healed in 24 weeks. The second patient, an elderly female with dementia, presented a peri-implant distal fracture right through the distal screws due to an accidental fall 8 months postop, with the fracture already healed. The second fracture was fixed through a posterior approach with an LCP extraarticular humerus plate (Synthes, Switzerland), without removing the helical plate.

None of the patients developed a nerve palsy neither prior nor following the surgical interventions. No infection or other complications were registered during follow-up.

Shoulder range of motion showed the following means: abduction of 147° (range 50°–180°), anterior flexion of 144° (range 80°–180°), external rotation of 77,5 ° (range 70°–80°) and internal rotation of 54.5° (range 45°–60°). All patients recovered their pre-fracture elbow range of motion. All patients presented less than 10° of angular deviation in varus/valgus or ante/recurvatum after the surgical procedure. At the end of the follow-up, all final functional scores were “good” or “excellent”: mean Constant-Murley score was 72 ± 13 (range 38–91), ASES score was 73 ± 12 (range 41–88), UCLA shoulder scale was 30 ± 3,5 (range 10–35), and Q-DASH score was 16.5 ± 0,11 (range 4–57). Results are shown in Table 1.

Discussion

Diaphyseal humeral fractures with extension to the proximal humerus are difficult to solve with the additional problem of the lack of relevant studies dealing with this topic. Open reduction and compression plate fixation allow early active motion of the joints. On the other hand, it is technically demanding and requires extensive surgical dissection with risk of nerve injury [10]. This problem can be avoided with a MIPO procedure [10,11] with the benefits of less soft tissue disruption and preservation of the fracture haematoma and blood supply.

Kulkarni et al. [12] and the meta-analysis carried out by Hu et al. [13], compared the use of intramedullary nailing vs open reduction and plate osteosynthesis vs MIPO in the treatment of humeral diaphyseal fractures. They concluded that a MIPO technique had less rate of radial nerve palsy. Our series supports their results, as we did not find any case of radial or axillary nerve palsy. Rancan et al. [14] found MIPO approach using a PHILOS plate to be a safe procedure for the treatment of metaphyso-diaphyseal fractures of the proximal humerus with low morbidity and full restoration of quality of life in elderly patients. With a straight plate, it is necessary to release the anterior insertion of the deltoid in the humerus, for a correct fit of the plate on the lateral aspect of the humerus. The curved helical plate sits right anterior to the deltoid insertion in the humerus, thus no release is needed. Their complications were subacromial impingement, screw breakage and displacement of the distal fragment. In their series, there were no

Table 1
Epidemiologic data from the patients, their fractures, complications and clinical results.

Case No.	Sex	Age (years)	AO classification	Accompanied lesions	Complications	Shoulder range of motion (Abduction/ Flexion/ ER/ IR)	Constant	ASES	UCLA	q-DASH
1	F	32	12 C3	-	-	105/100/70/50	67	88,3	32	4,54
2	F	69	12 C3	-	-	170/170/80/60	91	78,3	33	15,9
3	M	51	12 C3	-	Plate breakage	180/180/80/60	91	58,3	34	11,36
4	M	69	12C3	-	-	155/160/80/60	61	65	25	20,3
5	F	63	12 C3	-	-	160/170/80/50	79	81,6	35	13,6
6	M	43	12 C3	-	-	155/175/80/60	85,2	71,6	29	9
7	F	54	12 C3	-	-	155/160/80/60	60	66,6	29	25
8	F	86	12C3	-	-	140/160/80/55	49,3	62,1	26	25,9
9	F	86	12 C3	-	-	160/160/80/60	78,5	83,3	29	11,3
10	F	26	12 C3	CET	-	100/120/80/60	82	86,6	33	4,5
11	M	62	12 C3	CET	-	150/150/70/50	62,5	70	27	22,7
12	F	85	12 C3	-	Peri-implant fracture	105/100/75/50	57	70	33	36,3
13	F	52	12 C3	-	-	150/150/75/45	51,5	51,6	22	38,6
14	F	68	12C3	-	-	160/140/80/50	74	83	31	6
15	M	81	12C3	-	-	160/165/75/50	71	85	32	5,8

No number, F female, M male, CET Cranio-encephalic trauma, ER external rotation, IR internal rotation.

associated nerve injuries. On the other hand, a straight long lateral plate needs to identify the radial nerve on the lateral aspect of the humerus as the plate sits where the radial nerve turns from posterior to lateral. Moreover, to get the radial nerve apart during the surgical procedure, the arm is placed in supination as Apivatthakakul et al. [15] described in a cadaveric study. In our series we did not observe any radial palsy placing the arm in supination during surgery. Besides, traction in supination helps reducing the diaphyseal segment of the fracture.

The axillary nerve may be injured if the plate is introduced lateral to it and then compressed against the bone during screw fixation. This complication can be avoided sliding the tip of the plate against the lateral cortex of the humerus, deep to the axillary nerve or approaching the proximal humerus from the anterior aspect [15]. No axillary palsy was observed in our series. This iatrogenic injury is a major concern when using a deltoid-splitting approach and percutaneous screw insertion. In proximal humeral fractures, the deltopectoral approach is commonly used, but this approach requires extensive dissection. A minimal anterolateral approach does not require extensive soft tissue dissection and provides room enough to visualize the proximal screw holes in the plate. [7, 9]

Fixing these fractures with an intramedullary nail has advantages since it preserves the biology of the fracture and the exposure of the radial nerve is not necessary, but the rotator cuff injury and the distraction at the fracture site may cause pain and problems with fracture healing. The small diameter of the humeral canal and the distal extension of the fracture in the shaft can be an important limitation for the use of intramedullary nailing. In addition, the proximal component of the fracture might not be controlled in multifragmentary fractures or might displace a previously non-displaced fracture, specially the greater tuberosity fragment. Simple or multifragmentary humeral shaft fractures extending from the deltoid insertion down to 6 cm proximal to the trochlea fossa, in humerus with a small canal diameter are not suitable for intramedullary nailing [15]. But can be satisfactorily stabilized by plate fixation.

Eventhough, these fractures have many aspects for debate, such as: the incision site, the plate length, plate location, and whether or not the plate should be contoured or pre-contoured [3]. Regarding the choice of plate, straight plate, helical plate, and humerus proximal plates with specific distal contouring can be used. Brunner et al. [16] used the PHILOS plate (Synthes, Switzerland) with an anterior distal curve, which was contoured by the surgeon. We prefer to use specific precontoured helical shaped plates with an anterior bent for several reasons: the adjustment of the plate is more anatomical to the shape of the humerus, there is no need for radial nerve identification, and there is no need to detach the anterior insertion of the deltoid in the humerus. When trying to shape the PHILOS plate, it is easier to get a twist rather than a helical turn, which does not match the anatomy of the humerus. When the PHILOS plate or any other straight plate are applied without any bent, it is mandatory to identify the radial nerve distally and to detach the anterior part of the deltoid insertion in the humerus to fully seat the plate onto the lateral aspect of the humerus. Moon et al. [17] analysed the results of contouring the plate preoperatively, with clear benefits: avoid soft tissue damage, no injuries to the axillary nerve, the radial nerve, nor to the biceps tendon, and preserve the deltoid muscle distal insertion. They obtained good results using a MIPO technique combining a deltopectoral and a brachialis-splitting approaches.

Zamboni et al. [18] analysed the best contouring method for long locking plates in the treatment of humeral diaphyseal fractures with proximal extension concluding that spiral modelling at 70° allows anatomical accommodation at the greater tuberosity proximally and in the diaphyseal region. They also found that ac-

commodation of the implant was better with the spiral model than with the helical model. Yang et al. [19], in a series of 9 patients, obtained two cases of unsatisfactory results by contouring a plate in a helical fashion. In our series, we use a pre-contoured plate, designed specifically to fit the proximal and middle one-thirds of the humerus. We believe that the mechanical properties of the plate are unaffected. Moreover, when using a locking plate, it is possible that the screws do not lock in the locking holes because of the contouring as the original thread in the locking holes might be modified.

Surgical time in our series was 147 min. Other series obtained a shorter surgical time: 99 min [16], 110 min [14, 20] or 131 min [12]. We think our surgical time is longer because we included the time for general anaesthesia induction, patient positioning, procedure time and recovery time from general anaesthesia.

Functional scores obtained in our series are similar to other series evaluating MIPO approach for humeral shaft fractures. In our series, mean UCLA score was 36.6, whereas Oh et al. [20]; and Kulkarni et al. [12] obtained 34.3 and 32.26 respectively.

Conclusion

MIPO with a long helical-shaped version of a proximal humerus polyaxial locking plate for the treatment of humeral shaft fractures involving the proximal humerus is a reliable treatment method. When applied correctly in accordance to the principles, union rates are high with low complication rates. We believe that larger series are needed to fully validate the effectiveness and security of this treatment.

Declaration of Competing Interest

Hector J Aguado is a Consultant for the Zimmerbiomet institute.

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