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ORIGINAL PAPER

Minimally invasive plate osteosynthesis in proximal humeral fractures: one-year results of a prospective multicenter study

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Abstract
Purpose The aim of this multicentric study was to evaluate results of minimally invasive plate osteosynthesis (MIPO) for proximal humeral fractures in terms of postoperative shoulder function, radiological outcome and number of complications.
Methods A consecutive series of 76 patients with proximal humeral fractures were treated with locking plate using a minimally invasive antero-lateral approach in two orthopaedic departments. Functional results with Constant score and radiographic evaluation were available for 74 patients at one-year follow up.
Results The patients achieved a mean Constant score of 71 (range 28–100). Each functional result was evaluated also for both centres without significant differences. Significant statistical differences were only found for younger patients with better results ($p < 0.05$). Twenty patients (27 %) developed complications. Subacromial impingement occurred in 16.2 % of cases for varus malreduction (6.7 %) and for too proximal plate positioning (9.5 %). Primary screws perforation (2.7 %), secondary perforation due to cut-out (1.4 %), avascular necrosis (AVN) of humeral head (1.4 %), partial resorption of greater tuberosity (2.7 %), secondary dislocation of the greater tuberosity (2.7 %) and stiffness (2.7 %) were the other complications observed.
Conclusions The MIPO technique for proximal humeral fractures was safe and reproducible for most common patterns of fracture. Major complication rate was apparently low due to a soft tissue sparing, deltoid muscle and circumflex vessels, with easy access of the bar area to correct positioning of the plate.

Keywords Proximal humeral fracture · MIPO (minimally invasive plate osteosynthesis) · Philos · Axillary nerve

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Introduction

Proximal humeral fractures are very common injuries, with greatest incidence in elderly osteoporotic patients [1, 2]. Modern treatment options range from conservative treatment for lesser displaced and stable fractures to open reduction and internal fixation through different techniques or prosthesis replacement for complex and unstable fracture [3–9]. The development of locking plate resulted in an increased spread of surgical treatment due to improvements in fracture stability [10].

The deltopectoral approach is traditionally used in proximal humerus fractures to perform ORIF with plate [11]. However, this extensile approach requires a significant surgical dissection to obtain an indirect exposure of the plating zone that may cause an additional soft-tissue damage due to the stripping of deltoid muscle [12].

Furthermore, the ascending branch of the anterior circumflex humeral artery is at risk with the deltopectoral approach, and artery damage is often associated with complications such as avascular necrosis and early collapse [13, 14].

In recent years a minimally invasive antero-lateral approach through a deltoid split has been extensively used [15–18].

The aim of this multicentric study was to evaluate results of minimally invasive plate osteosynthesis (MIPO) for proximal humeral fractures in terms of postoperative shoulder function, radiological outcome and number of complications. Moreover we compared results of two different centres to check if this surgical technique is safe, effective and simple to repeat for most of the surgeons.

Material and methods

From September 2010 to June 2013, a consecutive series of 76 patients (26 male and 50 female) with proximal humeral fractures were treated. Surgical operation was performed by five surgeons in two different hospitals (Table 1).

The average age of the population was 68.5 years (range 32–87). The most common mechanism of injury was a low energy trauma for a simple fall in 83.4 % (only in five cases, 6.6 %, motor vehicle accident or pedestrian investment). The dominant arm was injured in 53.9 % of cases. All fractures were categorized according to the AO/OTA classification system always using AP plus axillary X-rays and CT scan with the same protocol for both hospitals; fractures were classified as type A, B or C in 3.9 %, 46.2 %, and 49.9 %, respectively.

The average delay between trauma and surgery was 1.5 days (range 0.5–5).

Exclusion criteria for this study were: patients age less than 18 years, polytrauma, presence of additional fractures associated with pathologic fractures, fracture-dislocation type C-3 according to AO classification, and relevant neurologic disorders of injured arm.

Operative technique All procedures were performed in loco-regional anaesthesia (brachial plexus interscalene block) with the patient in beach chair position. A fluoroscopic device was positioned on the contralateral side.

Approach and reduction techniques We used an antero-lateral acromial approach (as described by Gardner [15]) with fibres split of the raphe between anterior and middle deltoid heads, extending for 3–5 cm depending on fracture type and shoulder morphology. Two sutures (one absorbable and one nonabsorbable) were always placed in each rotator cuff tendon (anterior, superior and posterior). Absorbable sutures were used to aid reduction and to perform temporary fixation of tuberosity, while nonabsorbable sutures were knotted onto the plate, to avoid risk of secondary displacement of the tuberosity. In a valgus displaced fracture the articular head surface was elevated with a small Hohmann retractor or with the thumb. Alternatively, varus deformity was reduced using K-wires as a joystick [19] (Fig. 1). A secondary approach was performed to lock distally the plate, respecting the minimal distance of 2.5 cm, the safe zone of the axillary nerve.

Devices A three-hole or five-hole proximal humeral locked plate (Philos, Synthes) was used to stabilize fractures; the specific guide for the MIPO technique was not used for internal fixation. We used a classic guide of the Philos plate, self-modified by one of the authors (P. M.) to adapt it to the minimally invasive antero-lateral acromial approach (Fig. 2). The plate was inserted through a proximal approach and slid distally in the submuscular plane with finger dissection and finger protection of the axillary nerve. Definitive plate fixation was performed using a compression screw just distally to the fracture site, on metaphyseal bone; finally, a variable number of locking screws, four proximally in the humeral head and one or two distally in the humeral shaft, were used.

Postoperative care We used a sling immobilisation, night and day, for three weeks; however, patients started passive and limited active exercise beginning from the second postoperative day. In osteoporotic patients with complex fractures (three- and four-part) only passive assisted abduction exercise up to 90° was allowed and active motion was allowed from the fourth week after surgery.

We performed post-operative X-ray control in perpendicular antero-posterior and axillary view. The other X-rays were performed after two weeks, six weeks, three months, six months and 12 months to evaluate fracture healing, quality of reduction, head-shaft angle [20] (Fig. 3) and number of complications (bone or plate related).

All patients were functionally evaluated with Constant score one year after surgery [21].

Statistical analysis Statistical analysis of data was measured using Wilcoxon rank test to compare results into two groups (centres A and B) and non-parametric analysis of variance by Kruskall Wallis test for functional outcome in multiple groups (age sub-groups) with post-hoc analysis for pairwise comparison of subgroups according to Conover. MedCalc statistical software version 14.12.0 (MedCalc Software bvba, Ostend, Belgium) was used for the statistical analysis.

Results

The final follow-up was at one year for both centres. Two patients were excluded from the study. One patient had a pedestrian investment two months after surgery with a humeral fracture just distally to the plate; the second patient was lost to follow-up three months after surgery.

On X-rays control of all fractures healed within three months after surgery.

Table 1 Demographic data

Variable		Centre A		Centre B		Total data	
Number of patients		37		39		76	
Age	Mean	69.1		67.9		68.5	
	≤60 years	21.6 % (8)		23.1 % (9)		22.4 % (17)	
	>60 and < 80 years	51.4 % (19)		48.7 % (19)		50 % (38)	
	≥80 years	27 % (10)		28.2 % (11)		27.6 % (21)	
Sex		M: 13	F: 24	M: 13	F: 26	M: 26	F: 50
Dominant arm		45.9 % (17)		61.5 % (24)		53.9 % (41)	
AO Fx Type	A3	5.4 % (2)		2.6 % (1)		3.9 % (3)	
	B1	16.2 % (6)		12.8 % (5)		14.5 % (11)	
	B2	27 % (10)		25.6 % (10)		26.4 % (20)	
	B3	5.4 % (2)		5.2 % (2)		5.3 % (4)	
	C1	24.3 % (9)		20.5 % (8)		22.3 % (17)	
	C2	21.6 % (8)		33.3 % (13)		27.6 % (21)	

Complications Overall, 20 patients (27 %) in the study developed complications (Table 2). The most frequent complication was subacromial impingement, which occurred in 16.2 % of cases (12 patients) due to varus malreduction in five cases (6.7 %), and in seven cases (9.5 %) the plate was positioned too proximal (less than 5 mm from the apex of the greater tuberosity).

Primary screw perforation of the humeral head was recognized in 2.7 % (two patients) while secondary perforation due to cut-out occurred in only one patient (1.4 %).

At final follow-up only one (1.4 %) elderly patient (86 years old) with a C-2 fracture type developed an avascular necrosis (AVN) of humeral head; it was reoperated four months after surgery and treated with shoulder hemiarthroplasty. A partial resorption of greater tuberosity was observed in two cases (2.7 %); both patients had a type C-2 valgus impacted fracture; however, radiographic resorption had, in our experience, no functional implications at last follow-up one year after surgery.

A secondary dislocation of the greater tuberosity was detected at two months follow-up in one patient with type C-2 valgus impacted fracture. In this case we performed an arthroscopic trochitoplasty with functional repair of rotator cuff through two anchors three months after surgery.

Two patients with fracture-dislocation type B3 developed a stiffness of the shoulder; in one of these the stiffness was associated with heterotopic periarticular ossification, probably due to soft tissue trauma secondary to dislocation.

At final follow-up we did not find any infection despite a high percentage of patients with infection risk factor (38.2 % diabetes, 22.4 % insulin-dependent, 9.2 % alcoholism, 31.6 % obesity). No hardware failure nor axillary nerve palsy were reported.

There were no statistically significant differences between the two centres in terms of distribution of complications.

Head-shaft angulation The cervico-diaphyseal angle was calculated according to the method of Hertel et al. [20], with the angle measured on the perpendicular anteroposterior radiographic projection and formed by the intersection of the axis of the proximal humerus and the line perpendicular to the anatomic neck (Fig. 3). An angle between 130° and 140° was considered as a goal of the treatment. After two weeks the mean head-shaft angulation was 132° ± 7°. We observed a small progression of varus displacement at

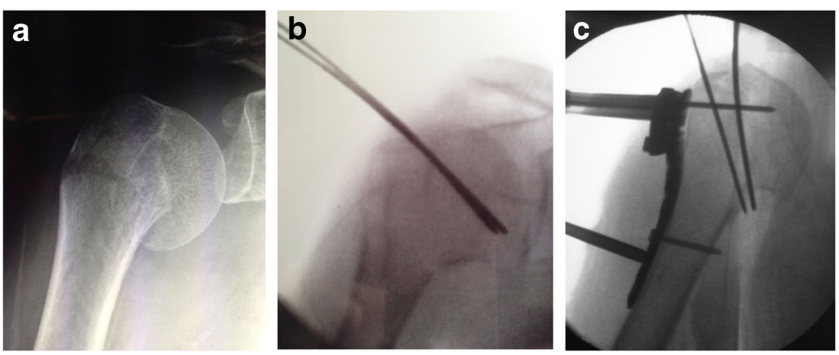

Fig. 1 **a** Varus-impacted fracture type. **b** Fluoroscopy image of reduction with joystick-technique. c Temporary stabilization with K-wire during plate osteosynthesis in AP view

Fig. 2 Comparison of a classic guide (*arrow*) of Philos plate and modified guide (*star*) by one of the authors (P.M.) to adapt it for minimally invasive antero-lateral approach

three months after surgery with a mean head-shaft angulation on X-rays of 130° ± 6°.

Shoulder function The mean Constant score one year after surgery was of 71 (range to 28–100). The average score of type A fractures was 96.6 (range 94–100), of type B 69.7 (range 28–100) and of type C 70.2 (range 36–100).

Average score in patients younger than 60 years old was 82 (range 54–100), in older than 60 years old but younger than 80 years it was 69.6 (range 28–100), and in older than 80 years it was 64.3 (range 36–94).

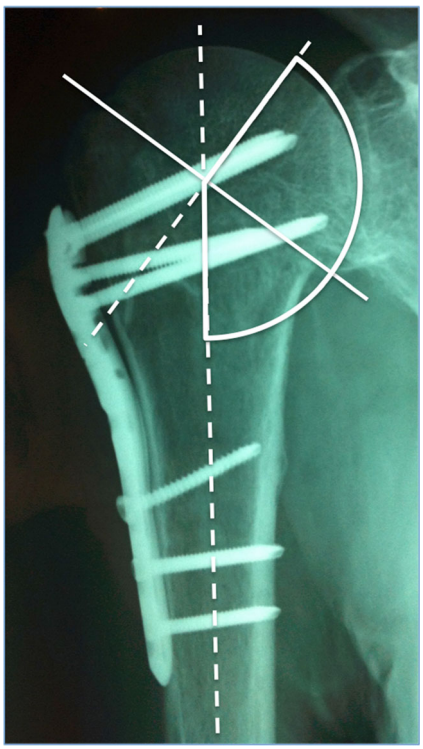

Fig. 3 The method to evaluate the head-shaft angulation

Significant statistical differences were only found for younger patients with better results ($p < 0.05$).

Each functional result was evaluated also for both centres (Table 3) without significant differences.

Discussion

Proximal humeral fractures represent an increasing problem in orthopaedics trauma centres. The majority of patients with these fractures are more than 60 years old, and stabilization of the fracture is often impaired gravely by osteoporosis [1, 2].

In three- and four-part fractures there are additional problems due to the poor blood supply of the fragments [22]. Recent advances in locking-plate technology and less invasive approaches seem to allow more rapid healing and fewer complications, without loss of reduction [10, 15–18, 23].

In our patient's series, significant functional improvement was noted at one-year of follow-up. The average Constant score was 71. Better results were observed in patients of age less than 60 years old. This data was probably due to major attendance to the physiotherapy of younger patients.

No significant difference was noted in functional results between the two trauma centres using the same surgical technique.

We observed 20 complications in 74 patients during the entire period of follow-up. The most common complication, observed in 12 patients (16.2 %) was sub-acromial impingement, a minor complication that can cause a partial reduction of ROM, often painful, and easily solved with plate removal. This complication was related to incorrect surgical technique, and may be caused by too far cranial positioning of the plate (9.5 % in our series) or malreduction of fracture with residual varus deformity (6.7 %). In our series the patients with subacromial impingement due to too far proximal plate

Table 2 Complications at one-year: final follow-up (74 patients)

Variable		Center A	Center B	Total data	Solution
Number of patients		36	38	74	
Minor complications: 16.2 % (12)					
Subacromial impingement	Varus malreduction	(3) 8.3 %	(2) 5.2 %	(5) 6.7 %	One case: shoulder arthroscopy (acromionplasty + tenotomy of LHB)
	High plate position	(4) 11 %	(3) 7.9 %	(7) 9.5 %	Three cases: plate removal
Major complications: 10.8 % (8)					
Primary perforation		(1) 2.7 %	(1) 2.6 %	(2) 2.7 %	Two cases: removal and substitution of perforated screws after two weeks
Perforation secondary to loss of reduction		–	(1) 2.6 %	(1) 1.4 %	Removal of perforated screws after six weeks
AVN of head		(1) 2.7 %	–	(1) 1.4 %	Shoulder hemiarthroplasty after four months
Resorption of greater tuberosity		(1) 2.7 %	(1) 2.6 %	(2) 2.7 %	–
Secondary dislocation of greater tuberosity		–	(1) 2.6 %	(1) 1.4 %	Shoulder arthroscopy (trochitoplasty and functional repair of rotator cuff) after three months
Periarticular heterotopic ossification		(1) 2.7 %	–	(1) 1.4 %	–
Infection		–	–	–	–
Auxiliary nerve palsy		–	–	–	–

AVN avascular necrosis, *LHB* long head of biceps

positioning were recognized in obese patients, where the big subcutaneous fat layer make it difficult to achieve correct positioning of the plate. Roderer et al. [16] reported similar results in terms of subacromial plate impingement (7.4 %) that required an implant removal to improve ROM.

The other major complication was primary screw perforation of the humeral head, a rare occurrence in our series (2.7 %) unlike other studies where this complication was more frequent [24]. In our experience, to be sure to check a correct intraoperative length of screws was very important to make accurate antero-posterior and axillary fluoroscopy views; moreover, a final check in continuous fluoroscopy is also essential to assess stability of osteosynthesis, and its very important to plan early post-operative rehabilitation.

Table 3 Shoulder function (Constant score at one year)

Variable		Center A	Center B	Total data
Number of patients		36	38	74
Mean Constant score		70.4 (28–100)	71.6 (38–100)	71 (28–100)
Mean single Constant score	Pain (15)	12.1	12.3	12.2
	Straight (25)	17.2	16.7	16.9
	Living activity (20)	14.6	15.5	15.1
	ROM (40)	24.2	23.9	24.1
Constant score related to age	≤60 years	79.4 (54–100)	84.3 (65–100)	82 (54–100)
	>60 and < 80 years	66.4 (28–100)	73 (61–100)	69.6 (28–100)
	≥80 years	70.7 (58–94)	59 (36–72)	64.3 (36–94)
Constant score related to fractures type	A3	98 (96–100)	94	96.6 (94–100)
	B1	69.3 (60–74)	77.8 (69–100)	73.2 (60–100)
	B2	70.3 (54–100)	73.7 (62–100)	72 (54–100)
	B3	35 (28–42)	61.5 (38–85)	48.2 (28–85)
	C1	70.1 (62–78)	69.2 (54–100)	69.7 (54–100)
	C2	73.9 (54–100)	68.7 (36–92)	70.6 (36–100)

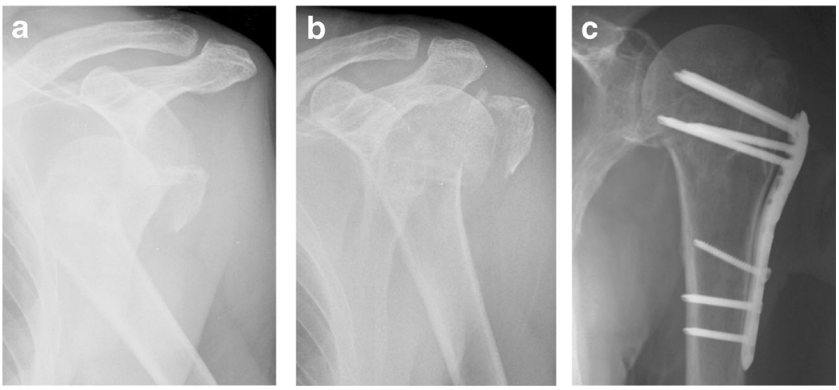

Fig. 4 **a** AO type B3 fracture-dislocation (male 63 years. **b** Immediately after closed reduction. **c** One-year AP X-ray control

Secondary screw perforation of the humeral head is difficult to prevent, and in our series it occurred in one patient with C2 valgus impacted fracture type. Perforation was caused by subsidence of the humeral head at six weeks; we removed the perforated screws (two) without progression of subsidence. This patient with secondary screw perforation was elderly (more than 85 years) with very osteoporotic bone quality. Actually, to avoid this complication, we use the augmentation techniques with beta-tricalcium phosphate block to support head in impacted-valgus fractures or cementation of screw-tips in osteoporotic and unstable fractures.

We did not have any secondary screw perforation of humeral head due to a loss of reduction in varus. The key to achieve a stable reduction and fixation is a correct reduction of calcar with restoration of medial support [25] (Figs. 1 and 4). If an adequate reduction is not obtained and medial support is insufficient, it is very probably a secondary loss of reduction, mainly if associated with a varus malreduction [26].

Acklin et al. [18] sustained that to use a five-hole plate could allow higher elasticity and prevent secondary screws cut-out. This hypothesis is possible but we have also a low rate of secondary perforation using a three-hole plate in more than 80 % of patients.

Only one patient with C2 fracture type developed an AVN of humeral head three months after surgery treated with shoulder hemiarthroplasty.

The low rate of AVN of humeral head (1.4 %), tuberosity resorption (2.7 %) and the absence of nonunion in our study emphasize the advantages of a minimally invasive approach as suggested in many reports [15–18, 27]. Gardner et al. [28] studied vascular implications of MIPO in proximal humeral fractures focusing on the importance of the bare spot area, approximately 3 cm wide, in the lateral proximal humerus, between the humeral-head penetrating vessels from anterior and posterior circumflex systems.

Certainly, the damage of vascularity in proximal humeral fractures was variable and depends on the fractures configuration [22], but to minimize further devitalization of fragments during fracture reduction and fixation it is favourable to use a less invasive antero-lateral acromial approach.

We did not find any neurological problems due to damage of the axillary nerve. This data, according to available studies [15–18, 27], confirm that, with an accurate finger dissection and protection of axillary nerve, the antero-lateral deltoid split is a safe technique for proximal humeral plate osteosynthesis.

Furthermore, there were no infections, superficial or deep, despite a high rate of association with the factor risk for infection. These data, confirmed by other authors [15–18, 27], emphasize the importance of this approach, minimally invasive and more rapid to perform than the deltopectoral approach and associated with low fluoroscopy time exposure [18].

The MIPO technique for proximal humeral fractures was safe and reproducible for most common patterns of fracture. Major complications rate appear to be low due to a soft tissue sparing, deltoid muscle and circumflex vessels, with easy access of bar area to correct positioning of plate [28, 29]. A good fluoroscopy vision on two planes is mandatory to avoid primary perforation of the humeral head by the screws. Major bone related complications such as cut-out and AVN are most frequent in C2 type fracture specially in presence of osteoporotic bone; in these patients it would be good to consider the use of augmentation technique. Augmentation technique is an innovative method that we are use routinely for over than one year and it showed preliminary very good efficacy; we firmly believe that through cement screws augmentation in the future can be resolved many of the issues related to the failure of synthesis, particularly in patients with severe osteoporosis.

Compliance with ethical standards

Ethical standards All procedures were in accordance with the ethical standards of the institutional and/or national research committee.

Conflict of interest The authors declare that they not receive any financial payments or other benefits from any commercial entity related to the subject of this article.

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