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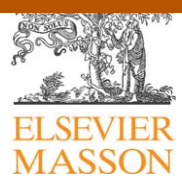

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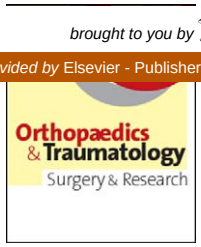

ORIGINAL ARTICLE

Proximal ulna comminuted fractures: Fixation using a double-plating technique

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Summary
Introduction: Comminuted fractures of the proximal ulna are severe injuries often associated with bone and ligament injuries of the elbow joint (Monteggia lesion, radial head fractures, dislocation of the elbow). The treatment of these fractures is very demanding and the functional results often fairly mediocre due to associated injuries. Based on a single-center retrospective study, we report the results of the treatment of these fractures fixed using a double-plate technique. The aim was to evaluate the feasibility and reliability of this fixation mode and to compare it with other fractures series using a single plate fixation (in terms of bone union, elbow joint function, and complications stemming from the plates).
Patients and methods: Eighteen patients sustained a comminuted proximal ulna fracture between 2002 and 2006. The fractures were associated in five cases with a Monteggia type lesion, in two cases with elbow dislocation, and in four cases with a Mason 3 radial head fracture. Four patients had an open fracture. These comminuted ulna fractures included nine Mayo Clinic IIIB fractures. Bone fixation was performed with two third-cylinder tubular plates, one plate on each side of the proximal ulna. This allows more versatile solutions for screw insertion. Functional assessment (according to Broberg and Morrey) and radiological evaluation (bone healing) were provided at 6 months and at the longest follow-up by an independent surgeon.
Results: Sixteen of 18 patients achieved bone union. No septic complications occurred and no hardware removal was required on patient request. In 67% of the cases, the Morrey score indicated excellent or good results with a mean score of 82.
Discussion: There are no reports in the literature on the technical point of fixation concerning complex fractures of the ulna. Two plates mean the possibility of twice the number of

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screw insertions for epiphyseal reconstruction . This fixation remains easy to perform and provides stable anatomic reconstruction of the ulna.
Level of evidence: Level IV. Retrospective study.

Introduction

Fractures of the proximal ulna group olecranon fractures, coronoid process fractures, and metaphyseal fractures. The most complex fractures, often associating these three fractures, are a formidable challenge for the surgeon. They are often comminuted and associated with ligament lesions, a fracture, and/or dislocation of the radial head, the latter of which are vital in the stability of the elbow.

The objective of surgery is first to obtain bone union, but also to restore a stable joint, articular congruence, strength, and a satisfactory and painless arc of mobility.

Classical surgical treatment of these complex fractures should include open plate osteosynthesis, which provides better results than pinning and tension band plating [1—4]. Posterior or lateral screw and plate fixation can pose placement or stability problems. Many authors [5,6] advise against use of a single lateral or medial plate in comminuted fractures so as to prevent nonunion. A slight curve in the coronal plane can require positioning the distal part of a long posterior plate on the ulnar crest in a less stable position [6].

Two cadaver biomechanics studies have been conducted. King et al. [5] found no difference between the posterior and lateral positioning of the plate. Gordon et al. [7] found greater stiffness with a posterior plate than with placement of two plates only if an intramedullary screw was associated with a posterior plate. However, they recognize that in cases of substantial comminution, use of this intramedullary screw limits the placement of posterior screws and the osteosynthesis of certain fragments. Depending on its length, this screw can be difficult to align in the medullary canal because the proximal extremity of the ulna has a slight valgus aspect [8].

The problem with these fractures being fixation of the proximal olecranon and coronoid process, it seemed logical to osteosynthesize these complex fractures with two plates positioned on the medial and lateral sides of the ulna so as to increase the number of screws [7] and to have bicortical fixation [5] of the proximal fragment.

The posterior plate removal reported in 20% of cases [9], required because of postoperative discomfort and pain [5] caused by the posterior plate, seemed to be resolved by using two plates.

The objective of this study was to compare our results with published series using a single plate.

Patients and methods

Twenty-four patients were operated between December 2002 and December 2006 for a proximal ulnar fracture placing two plates. These fractures were sometimes associated with a fracture of the radial head and/or elbow dislocation.

Only 18 patients were seen again (six were lost to follow-up) by a single surgeon with an AP and lateral X-ray of the operated elbow and an AP image of the forearm. Nine females and nine males were thus included in this study.

Table 1 reports the pre- and postoperative data on these 18 patients.

The mean age was 56.3 years (range, 35—78 years) and ten patients had fractured their dominant upper limb.

Twelve had isolated elbow injury. Four were considered to have multiple injuries and six presented another associated fracture. Three fractures were open Cauchoix 1 and one Cauchoix 2. Two patients had paralysis of the radial nerve.

We used the Mayo Clinic classification, which is based on three variables: displacement, stability, and comminution (Table 2). This group presented two IIA, six IIB, one IIIA, and nine IIIB injuries. Eight fractures were metaphyseal and ten were metaphyseal-epiphyseal. Half the patients had a radial head fracture (five partial and four total), three of which were dislocated posteriorly. In the nine other patients with no fracture of the radial head, we found one posterior dislocation of the radial head, one anterior dislocation of the radial head, two transolecranon dislocations, and one posterior dislocation of both forearm bones. Eleven patients had a coronoid fracture according to the Regan and Morrey classification [10] (Table 3): one stage I, three stage II, and seven stage III.

All the patients had emergency surgical treatment the day of the injury (15 cases) or the next day (three cases), under general anesthesia (15 cases) or locoregional anesthesia (three cases), installed in the supine position with a pneumatic tourniquet. Using a posterior approach, completed in one patient by an anterior approach for osteosynthesis of the coronoid process, the ulnar fracture osteosynthesis consisted of two plates (a lateral plate and a medial plate) (Fig. 1). These were two one-third tubular plates in 15 cases and two 3.5-mm reconstruction plates in the three other cases.

As for the associated radial head fractures, the five partial fractures required non-surgical orthopaedic treatment (two cases), fragment removal (two cases), or screw osteosynthesis (one case). The four total fractures required osteosynthesis (three cases) or resection of the radial head (one case).

Eight patients wore a simple scarf for a few days with no immobilization and with rehabilitation initiated rapidly. The ten other patients had circular cast immobilization (nine cases) or posterior orthosis (one case) for a mean 28 days (range, 2—6 weeks) before beginning rehabilitation.

The results were evaluated using the Broberg and Morrey functional score [11], an elbow function score established based on the following criteria: mobility, strength, elbow stability, and pain. The results were deemed excellent (95—100 points), good (80—94 points), fair (60—79 points), or poor (less than 60 points).

Table 1 Severity of lesions and postoperative data on the 18 patients.

	Age	Mayo stage	Regan and Morrey coronoid fracture stage	Postoperative radial head subluxation	Perfect joint reduction	Complications	Revision
1	71	IIIB	1	No	Yes	No	
2	53	IIIB	2	No	Yes	No	
3	73	IIB	3	No	No	No	
4	58	IIIB	No	No	Yes	No	
5	47	IIB	3	Yes	Yes	No	
6	46	IIB	2	No	No	Elbow dislocation	Coronoid osteosynthesis
7	47	IIIB	No	No	No	No	
8	56	IIB	3	Yes	No	Nonunion	Posterior plate and coronoid osteosynthesis, anterior approach
9	78	IIIA	No	No	No	No	
10	70	IIA	No	No	Yes	No	
11	78	IIB	3	No	No	No	
12	47	IIB	3	No	Yes	No	
13	35	IIIB	3	No	Yes	No	
14	58	IIIB	3	No	Yes	Nonunion	Iliac graft with two plates and radial head implant (RHI)
15	40	IIIB	No	No	Yes	No	
16	47	IIA	No	No	Yes	No	
17	55	IIIB	2	Yes	Yes	No	Arthrolysis and RHI
18	45	IIIB	No	No	No	No	Arthrolysis

RHI: radial head implant.

Table 2 Mayo Clinic classification of proximal ulna fractures.

	A	B
I	Nondisplaced fracture, no comminution	Nondisplaced fracture with comminution
II	Stable displaced fracture, no comminution	Stable displaced fracture with comminution
III	Unstable displaced fracture, no comminution	Unstable displaced fracture with comminution

The postoperative X-rays were reviewed to assess the joint reduction and the absence of subluxation. The radiographs taken at the time of revision made it possible to evaluate bone union, osteoarthritis, absence of synostosis and heterotopic ossifications.

Given the low number of patients included in the study, the statistical test used was the Mann-Whitney nonparametric test, testing the identity that makes no hypothesis on the analytical distributions F1(x) and F2(x) of two populations, 1 and 2. It therefore tests the H0 hypothesis: F1 = F2.

Results

The mean follow-up at review was 30 months (range, 8—56 months). Sixteen patients out of 18 (89%) showed union after the first intervention within a mean 3.5 months. The two patients who presented pseudoarthrosis showed union after surgical revision.

Table 4 reports the results of the series found at revision. Tables 5 and 6 compare these results with the results of other series in the literature for mobility (Table 5) and the function score (Table 6).

Figure 1 A 53-year-old female patient with a Monteggia Mayo IIIB fracture associated with anterior dislocation of the radial head. The last X-rays were taken at revision after principled plate removal of the material.

Table 3 Classification of coronoid process fractures according to Regan and Morrey.

Stage 1	Fracture of coronoid tip
Stage 2	Fracture of one-third of coronoid
Stage 3	Fracture of the base with elbow instability

The mean flexion was 129° (range, 90—140°), extension lag was 17.5° (range, 0—35°) for a 111.5° arc of mobility (range, 70°—140°). Pronation was 84° (range, 65—90°) and supination was 70° (range, 10—90°) for a 154° arc of mobility (range, 90—180°).

The patients with immobilization had less mobility in the flexion—extension arc: 108—119° ($p < 0.05$) (pronosupination arc; range, 152.5—156°).

The mean Broberg and Morrey score was 82 (range, 53—99). According to the Broberg and Morrey classification, these results were considered excellent in two cases, good in ten, fair in four, and poor in two cases.

On the postoperative X-rays, seven joint reductions were deemed incomplete and three radial heads dislocated. A single patient had both incomplete reduction and associated radial head subluxation.

Table 4 Data at revision of the 18 patients.

	Follow-up (months)	Flexion/extension lag	Pronation/supination	Broberg and Morrey score	Pain	Osteoarthritis
1	36	140°/−15°	90°/90°	98	None	No
2	39	140°/−10°	90°/90°	85	Slight	No
3	48	140°/−20°	90°/90°	83	Slight	Grade 1
4	27	120°/−30°	90°/60°	83	None	No
5	14	130°/−35°	80°/10°	53	Moderate	No
6	18	110°/−20°	90°/40°	66	Slight	No
7	18	100°/−30°	90°/70°	73	Slight	No
8	48	110°/−15°	90°/90°	57	Severe	Grade 1
9	13	140°/−25°	70°/60°	89	None	Grade 1
10	48	140°/0°	90°/90°	93	Slight	No
11	46	120°/−25°	90°/75°	78	Slight	Grade 1
12	8	140°/−5°	90°/10°	94	None	No
13	8	120°/−20°	70°/60°	78	Slight	No
14	49	140°/−10°	90°/90°	85	Slight	Grade 1
15	10	140°/−15°	85°/90°	91	Slight	No
16	12	140°/−10°	80°/90°	99	None	No
17	36	140°/−10°	65°/75°	85	Slight	Grade 1
18	56	115°/−20°	70°/80°	83	Slight	No

Table 5 Mobility found in our series and in different series reported in the literature.

	Flexion (°)	Extension lag (°)	F/E arc (°)	Pronation (°)	Supination (°)	P/S arc (°)
Doornberg et al. [12]	125	25	100	65	65	130
Teasdall et al. [13]	114	22	92	58.4	61	119.5
Bailey et al. [14]	128.5	8.5	120	76.7	67.2	143.9
Mortazavi et al. [15]	122	22	100	75	83	158
Platz et al. [16]	120	20	100	70	70	140
Kloen and Buijze [17]	132	18	114	75	75	150
Present series	129	17.5	111.5	84	70	154

Table 6 Functional scores found in our series and in different series reported in the literature.

	Broberg and Morrey score	Excellent results	Good results	Fair results	Poor results
Doornberg et al. [12]	83	9	12	1	4
Teasdall et al. [13]	80	4	13	4	3
Bailey et al. [14]	89 (score MEPI)	13	10	1	1
Mortazavi et al. [15]	88	2	5	1	0
Platz et al. [16]		10		4	4
Present series	82	2	10	4	2

The Broberg and Morrey score was significantly higher ($p < 0.05$) in patients who had immediate postoperative joint reduction judged to be perfect and no radial head subluxation (89.6 versus 74.1). This same score was significantly better ($p < 0.05$) in patients with a type 0 or I coronoid fracture than in patients with type II or III (88.6 versus 76.4). The severity of the lesions did not influence this score because in nine patients the Mayo III score was 85, whereas it was 78.5 in the nine Mayo II patients. There was no difference in mobility found according to the Mayo grade.

No soft tissue complications were found. One patient presented an early osteosynthesis complication (dislocation of the elbow due to insufficient osteosynthesis of the coronoid process) with surgical revision for coronoid process osteosynthesis.

Five patients presented elbow stiffness (three in pronosupination and two in flexion/extension). Two patients required arthrolysis with removal of the two plates in one and placement of a radial head prosthesis in the other. Three patients underwent removal of the material (two on principle and one for discomfort, but this involved removal of a posterior plate and revision for nonunion).

Two patients developed discrete heterotopic ossifications with no functional consequences (Broberg and Morrey score, 98 and 89).

No synostosis was found.

Six patients developed grade 1 osteoarthritis according to the Broberg and Morrey classification. These were four of the seven patients who had joint reduction considered incomplete, one patient who had not undergone bone union initially, and one who had radial head subluxation postoperatively, with these patients undergoing radial head arthroplasty during surgical revision.

Discussion

This study has several shortcomings: the small number of subjects, the retrospective aspect, and the absence of a comparison between this study and another group. It would indeed have been advantageous to compare our series of patients treated with two plates with a series of patients in our department treated by a single plate. Unfortunately, the small number of patients treated with a single plate was insufficient for a reliable comparison, and these single-plate patients often had less complex fractures.

It is also difficult to compare the present series to other series in the literature since these are often specific series (type II Monteggia, fracture dislocation, fracture of the ulna associated with a fracture of the radial head, etc.): the patients were not all treated with a single posterior plate.

Bone union rate

Our results (89% bone union) on a small series seem inferior to others reported in the literature since despite the complexity of these fractures, nonunion was not frequent. McKay and Katarincic [18] only report 1—5% pseudarthrosis in olecranon fractures. Teasdall et al. [13] report 8% nonunion in their series (two cases out of 24). In their series in which emergency iliac grafting made up 20% of the series, Bailey et al. [14] reported 100% bone union.

Overall functional result

The results of our series seem satisfactory in terms of the mobility reported by various authors (Tables 5 and 6).

Doornberg et al. [12], in a series of elbow fracture associated with dislocation, used 22 posterior plates in 26 patients: the mean flexion was 125°, the extension lag was 25°, and supination and pronation were each 65°.

Teasdall et al. [13] found higher mobility in their series in patients with a radial head fracture associated with an ulna fracture (flexion, 123°; extension, −15°; pronation, 66°, and supination, 70°) compared to those with only an ulna fracture (flexion, 110°; extension, −25°; pronation, 55°, and supination, 57°). We found no significant difference between these two groups in our series.

Bailey et al. [14] report better results with a series of fractures treated with a single posterior, sometimes lateral plate, with 128.5° flexion, 8.5° extension lag, 76.7° pronation and 67.2° supination.

In their series of fracture and dislocation of the ulna, Mortazavi et al. [15] provided osteosynthesis using a posterior plate in seven cases out of eight. They found 122° flexion, 22° extension lag, 75° pronation, and 83° supination.

Studying the results of comminuted fractures of the proximal ulna in 18 patients, Platz et al. [16] found 120° flexion, 20° extension lag, and 70° pronation and supination.

The study conducted by Kloen and Buijze [17] reports the results of 26 patients, all of whom had undergone surgery with a dorsal plate for proximal ulna and olecranon fractures.

Morrey et al. [19] show that a stable and painless elbow with a prosupination flexion—extension arc greater than 100° was compatible with normal function.

These same series report Broberg and Morrey scores equivalent to those that we found (Table 6).

Material-related discomfort

In the present series, no material was removed because of discomfort; on the contrary, the only plate removed for discomfort was a revision posterior plate. According to King [9] 20% of posterior plates require material removal because of the pain caused by the prominence of the plate. Mortazavi et al. [15] report three posterior plate ablations in eight patients and Kloen and Buijze [17] report ten ablations in 26 patients. It therefore seems that provided that they are properly placed, double-plate osteosynthesis causes less discomfort than a single posterior plate.

Factors of poor results

This study confirms the importance of good joint reduction with a better functional score and less progression toward osteoarthritis. Doornberg et al. [12] found 10 cases of post-traumatic osteoarthritis in 26 patients operated for elbow fracture and dislocation. According to King [9], this is more frequent if the fracture is associated with dislocation, in cases in which the greater sigmoid cavity is not restored or postoperative alignment of the elbow is poor.

Eriksson et al. [20] state that persistence of displacement exceeding 2 mm at the greater sigmoid cavity has a significant incidence on the appearance of secondary osteoarthritis. In our series, we found a lower Broberg and Morrey score in cases in which the greater sigmoid cavity was not restored or postoperative alignment of the elbow was poor. Five of the six patients who developed osteoarthritis had poor joint restoration or poor elbow alignment after surgery. On the other hand, Regan and Morrey [10] found no correlation between radiographic osteoarthritis and the indexed elbow performance score.

Bailey et al. [14] believe that reduction is important rather than the nonseverity of the initial injury. They found no difference between Mayo II and Mayo III fractures, which is confirmed in our series since we found no significant difference in mobility as reflected by the Broberg and Morrey score in relation to the severity of the initial injury. Murphy et al. [1] found that poor joint reduction greater than or equal to 2 mm is associated with a poor result. Restoration of the joint cavity seems to be a better guarantee of a good result, with the persistence of a gap not necessarily negative [14,15].

We also showed that the results of these fractures were related to the fracture of the coronoid process, with better results in type 0 or 1 fractures, showing that good osteosynthesis of the coronoid process is a major component of osteosynthesis of these complex fractures. For Doornberg et al. [12], the poor results are all related to inadequate fixation of the coronoid process. According to Regan and Morrey [21], the results of a coronoid fracture are correlated with the Mayo classification. Dislocation of the elbow and poor results are proportional to the size of the coronoid fragment.

It is certain that proper fixation of the coronoid apophysis guarantees good joint reconstruction. Different techniques for this are described. Mortazavi et al. [15] fix fractures of the coronoid process using screws inserted into the posterior plate. King [9] advised fixation of the coronoid using medial pins or screws before putting the posterior plate so that coronoid process reduction can be better visualized. Marchessault and Dabezie [22] describe a posteromedial approach to treat coronoid process fractures associated with a proximal ulna fracture. This approach could provide better visibility and maintains the reduction, and also places osteosynthesis material using a direct anterior screw or a posterior screw through the plate. Osteosynthesis with the rope-down technique is not as good as direct osteosynthesis, which is why Bégué [23] also advises using a posteromedial approach with or without osteotomy of the medial epicondyle for better control and direct osteosynthesis of the coronoid process.

We found that placing a lateral plate and a medial plate provided good visibility of the reduction of the coronoid process and made it possible to apply fixation to this apophysis using two screws (one in each plate), providing the size of the fragment is sufficient. We used the association with an anterior approach in one case, but like O'Driscoll [24], we believe that this approach can be difficult because of the insertion of the brachial muscle approximately 11 mm from the top of the coronoid process [25].

Which plate should be used, how many should be placed, and where?

We have preferred using two one-third tubular plates. Ring et al. [26] found one-third tubular plates too fragile and recommended a 3.5-mm dynamic compression plate. It is clear that osteosynthesis using a single one-third tubular plate may not be sufficiently rigid, but we believe that the use of two one-third tubular plates is sufficient. These plates are smaller than reconstruction plates are easily twisted.

In a recent cadaver study, Buijze et al. [27] found no biomechanical difference in terms of the osteosynthesis of a comminuted fracture of the olecranon using a one-third tubular plate or a locking screw plate. The majority of authors therefore suggest a single posterior or lateral plate and we found no study using two plates.

In certain highly comminuted fractures, King [9] recommends adding a tension band to the posterior plate, particularly when it is impossible to insert three cancellous screws in the proximal fragment [14], which is often osteopenic in the metaphyseal zone [6].

The lower number of screws in a single plate is compensated by the compression effect contributed by the posterior plate. Nevertheless, certain fractures presenting a medial fragment and a lateral fragment are, in our opinion, better suited to double-plate osteosynthesis.

Although Gordon et al. [7] suggest the possibility of adding another lateral or medial plate to the posterior plate, it is certain that two lateral and medial plates are less prominent than a posterior plate [5,7]. Placing two plates also obviates the need for incision and partial loosening of the triceps, as is recommended in the placement of a posterior plate [23]. This can avoid forearm discomfort when the triceps is contracted.

Conclusion

Complex fractures of the proximal ulna require a combination of different techniques whose objective is joint reconstruction as close to perfect as possible because this seems to be the best guarantee of a good prognosis. The difficulty is osteosynthesis of the coronoid process and restoration of the joint cavity. The simplicity of osteosynthesis using two plates gives the operator time to come to terms with other problems. Plate positioning considerably reduces the discomfort caused by the prominence of the posterior plate, while increasing the number of screws for stable fixation.

Conflict of interest statement

None.

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