ORIGINAL ARTICLE

Fractures of the distal humerus operated on using the Lambda® plate: Report of 75 cases at 9.5 years follow-up

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Summary
Introduction: The study sought to assess the functional results and complications of osteosynthesis using the Lambda® plate (Zimmer, Étupes, France) in treating fracture of the distal extremity of the humerus.

Materials and methods: The initial series comprised 115 patients (116 fractures), treated between 1992 and 2008. Forty-one (mainly foreigners) were lost to follow-up. The final series thus comprised 74 patients (75 fractures): 44 female and 30 male, with a mean age of 46 ± 23 years (range, 16–95 years), 22 (29%) being aged 65 years or over. According to AO classification, 22 of the fractures of the distal extremity of the humerus (29%) were diaphyseal-metaphyseal, corresponding to a particular grade of type A2, 12 (16%) were type A2 or A3, six (8%) type B, and 35 (47%) type C. Eight were open fractures: seven grade 1 and one grade Ila on Gustilo’s classification. The Lambda® plate is an inverted Y shape, with a stem of up to ten holes and sectile arms that can be remodeled to adapt perfectly to the type of fracture and the shape of the distal end of the humerus. A posterior approach was used in all cases: in 26 cases, an extra-articular transolecranal approach and otherwise a transtricipital approach, either vertical for diaphyseal-metaphyseal fracture or inverted V for type-C fracture.

Results: Mean follow-up was 115 ± 64 months (range, 24–227 months). There were no cases of infection, non-union of olecranal osteotomy or disassembly of the internal fixation; there was, on the other hand, one case of non-union of the lateral condyle and one of the distal extremity of the humerus, two cases of dysesthesia in the ulnar nerve territory and one in the radial nerve territory (following preoperative paralysis), and four cases of stiffness requiring surgical arthrolysis between 6 and 12 months postoperatively. At follow-up, mean active elbow flexion was 133° ± 13° (range, 90°–150°) and active extension −12° ± 14° (range, −45°–0°). Mean elbow flexion range of motion exceeded 100° in 58 patients (77%), was between 50° and 100° in 16 (21%) and was less than 50° in one. Mean Mayo Elbow Performance Score (MEPS)...
Introduction

Fracture of the distal extremity of the humerus is rare [1–3]. Treatment is varied, due to the anatomic complexity, and remains very difficult. A conservative attitude may be suitable for non-displaced fracture or, exceptionally, for comminutive fracture, but management is nowadays most often surgical. Surgery should seek as stable an osteosynthesis as possible, to avoid possible disassembly and allow early mobilization, which is the only way to ensure against elbow stiffness (the most frequent complication). Isolated or associated K-wire or screw osteosynthesis has progressively been given up as insufficiently sure; since the 1979 roundtable of the French Society of Orthopedic Surgery (SOFCOT) [4], screwed plate osteosynthesis has been recognized as the technique of choice. The type and optimal location of the plate, however, remains controversial [5–8]. Our team has long been in favor of a posterior plate [9]. In 1992, we developed an “arms-down” Y design, which we called the Lambda® plate (Zimmer, Etupes, France). Its biomechanical qualities were demonstrated by Fornasiéri et al. in 1997 [10]. We have been using it systematically since 1992 in fracture of the distal extremity of the humerus, whether articular, extra-articular or diaphyseal-metaphyseal.

The present study assesses results of 75 Lambda® plate osteosynthesis in 74 patients between 1992 and 2008, at a mean 9.5 years’ follow-up.

Material and methods

Series

Originally, 115 patients (116 fractures) were operated on between 1992 and 2008. Forty-one (mainly foreigners) were lost to follow-up. The final series thus comprised 74 patients (75 fractures): 44 women and 30 men, with a mean age of 46 ± 23 years (range, 16–95 years) at the time of the accident; 22 (29%) were aged 65 years or over. According to AO classification, 22 of the fractures of the distal extremity of the humerus (29%) were diaphyseal-metaphyseal, corresponding to a particular grade of type A2, 12 were type A2 or A3 (16%), six type B (8%) and 35 type C (47%). Eight were open fractures: seven grade 1 and one grade IIa on Gustilo’s classification.

Plate

In all cases, the Lambda® plate (Zimmer, Etupes, France) was used. This is a compression plate, with oval holes, not using locking screws (Figs. 1–3). It has the form of a flat, remoldable inverted Y, cast in a single piece; the diaphyseal branch is 3.6 mm thick. The epiphyseal arms are 2.5 mm thick, at a 50° angle, and are sectile and notched to enable them to be adapted to the lower end of the humerus peroperatively. The plate uses 3.5 mm cortical screws. It comes in five sizes, with diaphyseal branch length ranging from 25 to 145 mm (two to ten holes) in order to treat diaphyseal-metaphyseal-epiphyseal fractures.

Surgical technique

The surgical approach was systematically posterior, with the patient positioned either in ventral decubitus or in lateral decubitus with a support under the arm to hold the elbow at 90° flexion. A pneumatic tourniquet was used whenever possible, except, of course, in diaphyseal-metaphyseal-epiphyseal fracture. The skin incision was systematically posterior, skirting round the olecranon medially. Penetration of the extensor system was variable, depending on the type of fracture. In extra-articular (diaphyseal-metaphyseal-epiphyseal or supracondylar) fracture, a vertical transticipital approach was used, sparing the extensor system. In articular (type B or C) fracture, the approach was either extra-articular transolecranal (26 cases), mainly in young non-osteoporotic patients, or Merle
The Lambda® plate for fractures of the distal end of the humerus

d’Aubigné’s inverted V transtricipital approach [11], mainly in elderly osteoporotic females. Extra-articular transolecranal (EATO) osteotomy has to be carefully prepared to avoid breakage of the bone block. Firstly, using a 2 mm bit, two parallel bone tunnels are drilled toward the anterior cortex of the ulna, tangential to the great sigmoid cavity of the olecranon. Then the hole is measured and threaded with the appropriate tap, and the osteotomy is performed, taking care to locate the proximal beak of the olecranon, avoiding taking too small a bone block, liable to fracture or detach during rehabilitation.

The ulnar nerve was systematically approached, isolated and transposed forward at end of surgery to avoid impingement with the material behind.

In very distal fractures, the plate arms were curved so as to ‘‘envelope’’ the epicondyles and be able to apply as many screws as possible (two, or preferably three) in the distal fragments (Figs. 4–6). Further epiphyseal assemblies were added as necessary: transverse screwing for intercondylar fracture, small sunken K-wires in comminutive fracture. In olecranon osteotomy, osteosynthesis used two parallel 4-mm cancellous screws anchoring in the anterior cortex of the

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Figure 2  Frontal view of Lambda® plate molded onto the lower part of the humerus (material ablation).

Figure 3  Lateral view of Lambda® plate molded onto the lower part of the humerus (material ablation). Note restored anteversion of the lower part of the humerus.

Figure 4  Type-C fracture extending to humeral diaphysis with temporary transolecranal traction.

Figure 5  Osteosynthesis of fracture shown in Fig. 4 using a long Lambda® plate (AP radiograph): excellent results at 6 months postoperatively.
ulna in an assembly described by our team in 1986 [9]. In some cases, notably in women and small patients, the plate arms were a little too long and were cut peroperatively.

**Postoperative course**

Rehabilitation was initiated early in 40 patients (53%) and as of skin healing in ten. Complementary surgeon-dependent brachio-palmar-cast immobilization for 15 to 42 days was considered necessary for 25 patients.

For patients aged less than 60–65 years, material ablation was systematically proposed at 12–18 months, without associated arthrolysis; this is our standard practice in young adults, whatever the location of the material, and was in these cases straightforward, especially as the ulnar nerve had been transposed. No systematic treatment against periarthicular calcification (indomethacin) was applied, to avoid risk of delayed union or non-union.

**Assessment methods**

All patients were assessed clinically and radiologically by an examiner independent of the surgery team.

A visual analog scale (VAS) was used for self-assessed pain. Functional recovery was assessed in terms of elbow range of motion. Objective functional assessment was made using the Mayo Elbow Performance Score (MEPS) [12] and Quick DASH score converted to a score out of 100; subjective assessment was made by asking the patient if he or she was satisfied with the operation and would be ready to undergo it again if need be.

AP and lateral elbow radiographs were systematically taken at end of follow-up, to assess the consolidation and anatomic reconstruction (physiological anteversion) of the lower end of the humerus in both planes.

Statistically, elbow joint amplitude was analyzed on matched Student test. The significance threshold was set at 0.05.

**Results**

Mean follow-up was $115 \pm 64$ months (range, 24–227 months). There were no cases of infection, olecranon osteotomy non-union or osteosynthesis disassembly. The overall complications rate was 12% (nine cases out of 75 fractures): one case of non-union of the lateral condyle and one of the distal extremity of the humerus, two of dysesthesia in the ulnar nerve territory and one in the radial nerve territory (following preoperative palsy), and four cases of stiffness requiring surgical arthrolysis at 6 to 12 months postoperatively.

Clinically, seven patients (9.5%) had moderate residual pain. Mean active elbow flexion was $133^\circ \pm 13^\circ$ (90° to 150°) and active extension $-12^\circ \pm 14^\circ$ (−45° to 0°). Mean flexion arc exceeded 100° in 58 patients (77%), was between 50° and 100° in 16 (21%) and less than 50° in one. Mean MEPS was $79 \pm 7$ points (range, 40–100) and mean Quick DASH (out of 100) was $10 \pm 18$ (range, 0–54).

There were 67 excellent results (MEPS: 90–100), five good (75–89), two moderate and one poor.

Radiologically, 73 fractures consolidated without complications (97.5%). There were two non-unions (2.5%): one of the lateral condyle, one of the distal extremity of the humerus, both open fractures graded 1 on Gustilo’s classification and C2 on the AO classification. There was heterotopic calcification, without functional impact, in two patients and early posttraumatic osteoarthrosis in three (4%).

There was no significant difference in functional results between the transoscanal and transtricipital approaches, with mean active flexion of $137^\circ \pm 50^\circ$ (range, 120°–145°) ($P=0.46$) and active extension of $-16^\circ \pm 14^\circ$ (range, $-45^\circ$–0°) ($P=1.13$) following olecranonotomy.

The 35 type-C fractures showed no significant differences from the series as a whole ($P=1.24$ for MEPS), with mean active flexion of $135^\circ \pm 7^\circ$ (range, 120°–140°) ($P=0.135$) and active extension of $-17^\circ \pm 13^\circ$ (range, $-45^\circ$–0°).

**Discussion**

Surgery is often far from easy, because of the anatomical complexity of the distal extremity of the humerus, the small size of the fragments and poor bone quality; nevertheless, when osteosynthesis is stable and allows early postoperative mobilization, functional results are satisfactory in 75% to 85% of cases [13–17]. The AO recommends using two locking-screw plates (a dorsal radial plate and a medial ulnar plate) for these fractures [18–21]. For more than 30 years, our team has been using posterior plate assembly, and developed the Lambda® plate (Zimmer, Etupes, France), which is less cumbersome than two small-fragment dynamic compression plates [9]. Long-term clinical and radiological results confirm the quality of the Lambda® plate, as further demonstrated by Luegmaier et al. [22].
Posterior plate osteosynthesis has the advantage that the elbow is approached posteriorly and only the posterior side has to be devascularized; fitting a complementary medial plate involves devascularizing the humerus even more, with risk for consolidation. Precontoured plates obviously cannot adapt to every shape and size of distal humerus extremity. The Lambda® plate is perfectly adaptable to the bone, with no particular difficulty. The well-designed spacing of the screw-holes allows at least two screws to be used in each arm (i.e., 4 distal screws), below the most distal fracture lines, even in certain very distal fractures. Moreover, unidirectional locking screws, as used in precontoured plates, hinder transverse epiphysial screwing and screwing in the plate on the facing column. Finally, long Lambda® plates can cope with certain distal diaphyseal or diaphyseal-metaphyseal-epiphyseal fractures (Figs. 4–6).

In young or non-osteoporotic patients, we prefer the extra-articular transolecranal (EATO) to the intra-articular transolecranal (IATO) approach, for two reasons: firstly it avoids another joint fracture and secondly it enables a mold to be taken for use in case of comminutive fracture of the humeral trochlea, which is not unusual and is always difficult to repair. We reserve the transtriptic inverted V approach for elderly or osteoporotic patients, so as to avoid any complications with the bone block; it conserves the great sigmoid cavity and thus has the same advantages as the EATO approach. In the literature, olecranal osteotomy is associated with a non-union rate of up to 10% [23–26]. In the present series, however, thanks to careful patient selection, the extra-articular design of the osteotomy and the use of compression osteosynthesis, there were no complications.

Moreover, the rate of heterotopic calcification was only 2.6%: i.e., two cases, both involving isolated fracture with no cranial trauma and no preventive indomethacin treat-

ment.

Regarding the ulnar nerve, some authors recommend isolation without transposition [27], others recommend not approaching it at all [28–30], and yet others [26,31,32], including our team, perform systematic transposition. We consider this necessary when posterior plates are being used on both columns, firstly because postoperatively the nerve would be in contact with the plate and at risk of impingement, and secondly because of the high risk of nerve lesion in case of secondary plate ablation, which is always a possibility and indeed desirable in younger patients. Ulnar complication rates vary in the literature, from 0 to 12.5% [2,26–32]; the 2.5% rate of transitory paresthesia in the present series argues in favor of our attitude.

The present functional and radiological results were altogether satisfactory, with a mean MEP score of 97 ± 7 (range, 40–100) and a Quick DASH score (out of 100) of 10 ± 18 (range, 0–54) and only two cases of non-union (one partial, one total) and three of osteoarthritis at a mean 9.5 years’ follow-up. There were 67 (89.5%) excellent (90–100 points), five (6.5%) good (75–89), two moderate (60–74) and one poor result (<60 points). These results correlated with good recovery of elbow motion, with mean active flexion of 133° ± 13° (range, 90°–150°) and active extension of –12° ± 14° (–45°–0°); mean flexion arc exceeded 100° in 58 patients (77%), was between 50° and 100° in 16 (21%), and was less than 50° in one.

Comparing series from the literature is always difficult as populations often differ, as do techniques and postoperative course. Even so, compared with the 84–100% rate of satisfaction found in the literature [2,18,33–35], the present results are upscale, testifying to the quality of our choices. In type-C fracture, results were unexpectedly similar to those of the series as a whole, which was an especially satisfying finding.

In the present series, age and osteoporosis did not seem to impair results, with 22 patients (29%) aged over 65 years; some authors recommend primary elbow arthroplasty in such cases [36–40], an attitude which the present results do not bear out.

Conclusion

Osteosynthesis using the Lambda® plate in fractures of the distal extremity of the humerus gave excellent medium-term results in terms both of fixation stability of the fracture and functional recovery of the elbow, even in elderly osteoporotic patients. It can be used in any type of fracture, from distal diaphyseal to AO type C. It adapts perfectly to the distal extremity of the humerus, thanks to its secilie “arms” that can be molded onto the bone peroperatively. The lack of locking screws has never been a problem in our experience.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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