ORIGINAL ARTICLE

Proximal humerus fractures treated by percutaneous locking plate internal fixation

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KEYWORDS
Proximal humerus fracture; Mini-invasive surgery; Locking plates

Summary
Introduction. — There is no consensualy accepted recommendation for optimum surgical treatment of unstable fractures of the proximal humerus.
Hypothesis. — Locked and minimally-invasive plating is a promising treatment option.
Materials and methods. — The aim of this prospective, multicentric study is to describe a recently introduced surgical technique for proximal humeral fractures and to evaluate the radiographic and clinical outcomes of this operation. Closed and minimally-invasive reduction is first performed. A proximal humerus specific locking plate featuring multiple-angle screws is secondly implanted. Proper identification and protection of the axillary nerve with the index finger during plate insertion on the lateral humeral side is highly advisable. If it can’t be palpated, a classic delto-pectoral approach should be preferred. Thirty-four patients were included in this study with a 1-year minimal postoperative follow-up. Twenty-two patients presented a two-part surgical neck fracture according to the Neer classification and 12 patients had a three-part valgus-impacted fracture. DASH (Disabilities of the Arm, Shoulder and Hand) and Constant scoring systems were used for functional evaluation.
Results. — Specifically, no axillary nerve injury and no loss of reduction were observed. The median Constant score and the mean DASH score were 82 and 26 respectively at 1-year follow-up. The age-adjusted functional scores values were satisfactory. Two of the patients (6%) required surgical revision for intra-articular screw penetration.
Discussion. — Our study suggests that percutaneous plating with angular screw fixation of proximal humeral fractures is a safe and effective method, which produces good functional and radiologic outcomes. These minimally-invasive techniques allowing a better preservation

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Introduction

Fractures of the proximal humerus account for approximately 4 to 5% of all fractures Kannus et al. [1]. An increasing incidence of these fractures has been observed in our society due to the ever-growing number of elderly people within the population [1–3]. Management of proximal humeral fractures with plate osteosynthesis in elderly patients with osteoporosis of the humeral head remains quite a challenging problem, principally as regards the stability of the fixation [1,4]. In order to avoid the complications associated with more conventional plate fixations, alternative treatment options were suggested, including wire or screw osteosynthesis [5–7]. The recent introduction of locking-plate fixations with multiple-angle screws has led to renewed interest in this type of fixation devices. Various studies have been conducted to evaluate the biomechanical properties [5,8–10] and clinical results [11,12] of this specific fixation construct. The delto-pectoral approach has been most commonly used for reduction and fixation of the proximal humerus. However, this technique often requires an extensive soft-tissue disruption, which might impair the neurovascular structures, especially the ascending branch of the anterior circumflex humeral artery [13]. Therefore, a higher risk of avascular necrosis of the humeral head might be observed [11,12]. Furthermore, locking-plate fixation on the lateral proximal humerus reveals challenges even if performed through a delto-pectoral approach.

There is no consensus reported in the literature on the treatment of unstable proximal humeral fractures [6,10,14–25]. The ideal surgical approach should provide anatomical reduction, easy plate fixation and preservation of adjacent neurovascular structures of the humeral head. The aim of that prospective multicentric study was to describe a new surgical technique for proximal humeral fractures and to evaluate the radiographic and clinical outcomes. Closed and minimally-invasive reduction was performed. A proximal humerus specific locking plate was implemented with multiple-angle screw fixation.

Methods

Between February 2002 and December 2003, 34 consecutive patients (22 females, 12 males, mean age 64 years [range 38–88]) were included in this study. Most injuries were due to accidental falls. Two patients had an associated fracture (olecranon and acetabulum). Surgeries were performed by five trauma surgeons in university trauma centres. Inclusion criteria were displaced two-part surgical neck fractures (more than 1 cm of displacement or 45° of angulation) or three-part valgus impacted fractures (more than 160° of angulation), consenting adult patients scheduled to undergo surgery with general anaesthesia and informed about the study protocol. All patients with pre-existing shoulder pain were excluded from the study. The study protocol was approved by each University Institutional Ethics Committee.

Sensory and motor function of the axillary nerve was documented and radiographs were performed (face and profile axillary view) on admission to the emergency department. Function of the axillary nerve was considered normal when sensitivity was identical in the sensory region of the axillary nerve and on evaluation of the deltoid contractility.

All patients were re-examined on the first day after surgery, at 6 weeks, 3 months, 1 and 2 years. Clinical assessment was performed by an independent examiner. Examination included measurement of incision length, evaluation of sensory and motor function of the axillary nerve, assessment of gleno-humeral ROM and supervision of evaluation questionnaires. Constant-Murley [26] and DASH shoulder-specific scoring systems [27] were used for functional assessment. Constant strength was measured by use of a Jamar dynamometer (Sammons & PrestonTM). The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire included 30 validated measurement items to assess disability and clinical symptoms. Radiographic evaluation was performed by a single independent observer according to the Neer classification system [28]. Fracture union was considered anatomical when residual displacement was below 20°.

Data were analyzed by use of SPSS v.13 software. The Student t-test and Chi-square test were conducted for univariate and multivariate analysis respectively. An analysis of variance (ANOVA) using a regression model was performed to determine clinical factors and functional performances correlation. The chosen level of significativity was p < 0.05.

### Table 1 Demographic data.

<table>
<thead>
<tr>
<th>Number</th>
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<tr>
<td>Gender</td>
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<td>Female</td>
<td>22</td>
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<td>Male</td>
<td>12</td>
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<td>Fracture pattern</td>
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<td>Neer 2</td>
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<td>Neer 3</td>
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<td>Age (years)</td>
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<td>Mean</td>
<td>64 (38–88)</td>
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<tr>
<td>&lt;60 years old</td>
<td>14</td>
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<td>&gt;60 years old</td>
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**Operative technique**

Surgery was performed under general anaesthesia and antibiotic prophylaxis (first generation cephalosporin) was administered preoperatively and during the first 24 h after the operation. The patient was placed in a supine position on a flat radiolucent table, with the injured arm freely movable and sterile. The C-arm fluoroscope was positioned on the contralateral side of the injury. The tip of the acromion was palpated and used as a landmark. A first longitudinal incision was made from the antero-lateral acromial border, stretching approximately 3–4 cm. Following skin, subcutaneous and fascia dissection, the deltoid muscle bundles were separated using blunt dissection for exposure of the tuberosities and the humeral head. This proximal transdeltoid approach enabled the deltoid muscle to be freed from the proximal humerus by progressive digitoclasy. The axillary nerve was palpated by hand and identified [29]. Palpation could be easily performed on the undersurface of the deltoid as the axillary nerve runs to the anterior part of the shoulder. Proper identification and protection of the axillary nerve during the course of the surgery was highly advisable to ensure a safer surgical procedure and avoid any potential injury. The axillary nerve was easily identified in all cases. It lay posteriorly to the incision just outside the quadrangular space.

External manipulations were performed for proper reduction through the proximal approach under fluoroscopic guidance. In three-part valgus impacted fractures, the humeral head was raised, reduced with a blunt elevator and temporarily stabilized by means of Kirschner wires. The greater tuberosity fragment was then reduced below the articular surface. Non-resorbable sutures were used to repair the greater tuberosity (by means of transosseous sutures inserted in the lateral side of the metaphysis) and repair the rotator cuff. The plate had to be carefully positioned down the humeral shaft to ensure the axillary nerve was not entrapped beneath the plate. The axillary nerve was protected with the index finger during plate insertion (Fig. 1). A long proximal humeral locking plate (LCP 3.5 mm Synthes©) was inserted through the proximal incision. Two locking screw guides were introduced in the plate most proximal holes (screw holes A; Fig. 1) to facilitate prehension during insertion. The plate was systematically positioned on the lateral side of the humerus, at least 5 mm below the greater tuberosity. Two 3.5-mm locking screws were initially inserted through the appropriate proximal holes of the first row (screw holes A; Fig. 1). A 2-mm incision was made under fluoroscopic guidance and centered over the distal screw holes. This incision was situated far underneath the course...
of the axillary nerve. Three 3.5-mm bicortical screws were inserted through the humeral diaphysis to secure the plate. Two additional 3.5-mm locking screws were placed through the remaining proximal holes to further stabilize the plate (screw holes B). The humeral head was thus fixed with four locking screws (Figs. 1 and 2) which correct placement and length had to be meticulously controlled (Fig. 2). However, accurate measurement of the screw length was made difficult due to the poor quality of the proximal humeral bone. Accurate placement of any locking screws ≥ 40 mm was confirmed radiographically on several views.

No postoperative immobilization was required. A standard rehabilitation protocol was implemented (pendulum exercises and active-assisted range-of-motion techniques) for 6 weeks or until complete fracture union. Subsequently, passive stretching and strengthening exercises were progressively included in the shoulder rehabilitation protocol.

Results

Minimum follow-up period was 12 months and mean follow-up period was 19 months [12–34]. Seven of the patients could not be followed-up at 12 months (no complication was reported in this group): one patient died (no correlation with trauma), three patients were lost to follow-up and three could only be reached by telephone. Therefore, 27 patients had a complete radiographic and clinical evaluation.

The axillary nerve could be easily palpated on the undersurface of the deltoid (1 to 3 cm relative to the incision) in all 34 patients. The nerve was always protected during plate insertion. The proximal incision was approximately 4 cm long (3–5, 5 cm) and the distal incision was approximately 2 cm long (1.5–2.5 cm). No extension of the surgical approach was necessary. The mean surgery duration was 53 minutes (28–135 minutes). Blood loss during surgery was approximately 113 cc (50–250 cc). No case of axillary nerve palsy was noted. Two patients had to be reoperated on after fracture healing: one for removal of a protruding intra-articular screw and the second one for removal of the locking plate due to its impingement with the acromion during maximum abduction. No avascular necrosis was observed at the last follow-up (Fig. 3).

At follow-up, the average Constant score was 80 and mean DASH score was 26 in the sub-group "more than 1-year follow-up" (n = 27 patients). Mean abduction was 100° (50–120°), and mean antepulsion was 113° (50–135°). In our study, the Constant score mean value for women was 77 with a mean age of 65 years and 92 for men with a mean age of 61 years. Regarding the Constant score subcategories (Table 2), results were significantly better for "pain" (85%) and "strength" (87%) items (p < 0.05) (activities (76%) and range of motion (75%), p > 0.05).

Final healing position was satisfactory in all cases. Eighteen patients achieved anatomical union (Figs. 2C and 3) whereas nine had residual angulation (two valgus [10 and 15°] and seven mid-varus of 12° [5–20°]). In the 27 patients with an average follow-up of 19 months, all fractures united in an acceptable position with no signs of avascular necrosis, axillary nerve injury or implant loosening. In these patients, constant improvement of clinical function was observed up to 1-year follow-up. From that date, all sub-groups reported similar functional results (Table 2).

A statistically significant age-related difference was noted in each gender group (p < 0.05). Women showed a bimodal distribution with a peak in both ‘‘under 60’’ and ‘‘over 60’’ subpopulations. Men had a unimodal distribution of scores demonstrating a single peak under 60 years of age (Fig. 4). Only follow-up time could be correlated with functional results. The average Constant-Murley score
angle screws were recently developed [5, 8, 9]. These new proximal humeral locking plate systems featuring multiple- on which depends the overall prognosis for proximal evaluation of bone quality prior to surgery is a critical fac-

tion of proximal humeral fractures [13, 23, 25, 30, 31]. Proper approach remains the most widely used in the treatment of displaced and unstable proximal humeral fractures and a variety of fixation devices are available [6, 10, 14—25]. The use of conventional plate fixation designs provide better stability than conventional plates [10].

Our surgical technique aimed at decreasing the incidence of avascular necrosis of the humeral head [13, 23, 24, 33, 34]. All 27 patients with a 19-month follow-up reported successful outcomes (bony union with no avascular necrosis and no axillary nerve injury). Yian et al. [35] have published a study in which they evaluated the age and gender-related shoulder function using the Constant score values in healthy volunteers. Women, between 61 and 70 years old achieve a 77 to 87 Constant score whereas men from the same age-group reports score values ranging from 84 to 90. Therefore, satisfactory functional recovery of the proxi-humeral joint might be expected within 1 year after surgery. However, taking into account the great variation and disparity of the Constant and the DASH functional results, Table 1 of this study does not provide sufficient data to determine which are the factors that mainly affect the outcome of that surgery.

Potential injury to the axillary nerve remains a major concern during shoulder and proximal humeral surgeries [16, 36, 37]. Even percutaneous wire osteosynthesis may induce neurovascular injuries [38, 39]. According to an anatomical study [40] and percutaneous insertion of a LCP proximal humerus plate (Synthes™) proves a safe technique for axillary nerve preservation. D, E and F screw holes (Fig. 1) were considered as an unsafe portion of the plate. Appropriate external manipulations are advisable to provide an anatomical reduction through a percutaneous approach. McLaughlin et al. [40] have demonstrated that anatomic reduction is not crucial in achieving a good shoulder function [7, 40]. According to Park et al. [21], the greater tuberosity should be reduced up to or underneath the humeral head articular surface. A residual 20° of varus or valgus after reduction of the humeral neck is considered acceptable [21]. Our study has demonstrated that reduction could be easily performed through a minimally-invasive approach and percutaneous fixation was achieved in all cases. We could not establish any correlation between shoulder function and quality of reduction (p > 0.05). Larger patient populations should be studied to evaluate the adverse effects of improper reductions.

Robinson et al. [41] have recently described a direct lateral approach with release of the deltoid through an extended incision in the treatment of severely impacted valgus proximal humeral fractures. No axillary nerve injury or avascular necrosis was observed among the 25 patients of the series. Gardner et al. [33] have recently described a mini-invasive anterolateral approach in the management of proximal humeral fractures with plate fixation. According to their study, location of the axillary nerve is predictable when it passes the anterior deltoid raphe (5 cm distal to the acromion). This approach was performed in 16 patients with no sign of neurovascular structures injury. Another recent study Lill et al. [9], has reported the good short-term results of a locking plate fixation through a minimally-invasive anterolateral approach. Such encouraging results are probably due to the excellent biomechanical quality of the plates used for osteosynthesis of proximal humeral fractures [42]. These fixation designs have revealed better outcomes than Kirschner wires combined with transosseous sutures of the tuberosities or even staples with a centro-medullary pin. Actually, the plate provided a higher resistance to the
lateral displacement of the humeral head and a better support for the tuberosities than the two other constructs. Centromedullary nailing demonstrated higher deformability than the two other devices. Gabrion et al. [43] reported a significant rate of implant loosening (23%) after osteosynthesis with a Telegraph® humeral nailing system and underlined the challenging management of proximal humeral fractures in elderly patients with major osteoporosis.

**Conclusion**

Percutaneous locking plate osteosynthesis with multiple-angle screws for proximal humeral fractures is a safe and effective method, which produces promising functional and radiologic outcomes. The suggested surgical approach reduces the risk of soft-tissue damages and provides early functional recovery. Proper identification and protection of the axillary nerve with the indexfinger is highly advisable during plate insertion on the lateral humeral side. If it can’t be palpated, a conventional delto-pectoral approach should be performed.

**References**


