controversial topics in surgery

Fixation of fractures of the proximal humerus

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The management of proximal humeral fractures remains a controversial area. This is, in part, related to the poor inter- and intra-observer reliability in the application of the common classification systems. This, in turn, makes comparison of outcomes between studies and even treatment arms of the same study difficult. Closely related to this is the importance of identifying the fracture patterns in which natural history is likely to be modified by surgical intervention at an acceptable risk.

The authors acknowledge the variety of techniques available including intramedullary nailing, suture or staple fixation and the Humerusblock. It is fair to say that, although so many

techniques are available, none are completely satisfactory. Whilst reading these two excellent papers one should bear in mind that, while the authors are expert in the techniques they describe, the operations may not be as easy as they appear!

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Fixed angle locking plates for proximal humeral fracture fixation

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Proximal humerus fractures are common injuries in the elderly.¹ While most of these injuries are treated non-operatively with satisfactory results, surgical intervention is used for the more unstable fractures.

Open reduction and internal fixation (ORIF) with plates is one available surgical option. Traditional plate osteosynthesis faced the problems of screw pull out from osteopenic metaphyseal bone. Various alternative techniques such as tension band wiring, suture fixation, intramedullary nailing and hemi-arthroplasty were designed to overcome problems of plate osteosynthesis with varying success.

Fixed angled locking plates (FALPs) introduced in the late 1990s combine the advantages of locking plates with

those of older, fixed-angle devices. These plates have reduced risks of screw pull they are ideal for osteopenic fractures.² These plates are anatomically contoured to provide a template against which fractures can be reduced. They are expected to meet the challenges posed by the fracture pattern, the weak osteopenic bone, and the deforming forces around the shoulder. They also have eyelet holes to allow suture fixation of any displaced tuberosities.

Indications

The absolute indications for surgery of these fractures is still unclear. The senior author (CPK) uses plate fixation for

fractures with significant displacement and/or instability. These include displaced two or more part fractures in the elderly, two part anatomical neck fracture in the young, valgus impacted fractures, fractures in more than 30° of varus.⁵ Longer locking plates can be used for fractures with diaphyseal extension and pathological fractures. Plate fixation may also be indicated in non-union surgery.

Contra-indications include infection, medically unstable patients who are unfit for anaesthesia, minimally displaced fractures and displaced head splitting fractures.

Pre-operative preparation

In the elderly patient, underlying medical problems should be optimised, the cause of the fall explored and osteoporosis investigated and treated appropriately.

Figure 1 (A) Peroperative image of comminuted fracture post fixation with good screw placement. (B) X-ray 12 weeks postoperative showing fracture collapse and screw penetration. This situation needs urgent removal of screws to prevent joint damage.

Careful imaging of the fracture includes true anteroposterior (AP) and lateral radiographs of the joint. Axillary lateral views are usually impossible because of pain and the authors recommend the Nottingham modified axillary lateral view. Pre-operative computed tomography (CT) scans give better details of the fracture alignment and help plan surgery. Ultrasound or magnetic resonance imaging (MRI) scans may be used to assess the integrity of the rotator cuff.

Surgical approach and technique

Regional blocks combined with general anaesthesia are safe and effective and provides good postoperative analgesia.

The beach chair position is commonly used. Pre-operative positioning of the image intensifier is important to secure good orthogonal images during surgery.

Deltoid splitting or deltopectoral approaches can be used. If a deltoid split is used, great care must be taken to avoid injury to the axillary nerve. Careful dissection is the key to identification of the fracture anatomy and preservation of blood supply to the fragments. The biceps tendon is a key landmark to fracture identification; the authors recommend biceps tenodesis in all cases to avoid later problems of biceps scarring or adhesions.

In some cases, the humeral head collapses into varus and should be elevated back gently using X-ray control. This will usually leave behind a space in the metaphysis requiring a bone graft or substitute. The medial calcar must be reduced into an anatomical position without overreduction into varus. If there is poor bone stock or comminution in this area the surgeon must watch closely in the post-operative period for collapse and possible screw penetration (Fig. 1). Once reduced, the fragments may be held with K-wires. The tuberosities and the rotator cuff edges are secured with non-absorbable sutures and reduced onto the head. The proximal humerus is then reduced onto the diaphysis and may be secured with a temporary K-wire.

The plate is placed just posterior to the bicipital groove and at least a centimetre distal to the top of the head. Most designs allow for a central reference guide wire in the humeral head around which the plate is orientated. Aiming devices available in a number of systems improve the accuracy of screw placement. When drilling, care must be taken to enter subchondral bone without penetrating the articular cartilage. This can be done by 'feel' and use of image intensification. All the head screws are now placed under image guidance. Most designs use locking, self-tapping screws; others use a combination of screws and smooth pegs which have smooth ends and reduce risks of articular penetration. Screw lengths must be carefully measured and it is better to under measure off the far cortex. The plate is now fixed to the diaphysis. A cortical screw is then advanced up a gliding hole in the shaft to appose the plate to the bone. This also allows the construct to be moved distally or proximally if required. The remaining diaphyseal screws are

Table 1 Some published series on FALPs of the proximal humerus

REFERENCE	Brunner <i>et al.</i> (2009)⁷	Study type	Prospective, multicentre
Sample size	157 patients, 158 fractures		
Implant/follow-up	PHILOS. One year follow-up – 84%		
Outcomes	Implant related problems (9%); overall problems (35%); constant score (72%); DASH score – 16		
Observations	Primary screw perforation (14%) secondary screw perforation (8%) avascular necrosis (8%). Good functional outcome can be expected. Joint penetration by screws can be reduced by accurate length measurement and shorter screw selection, obtaining anatomical reduction of the tubercles and restoration of the medial support		
REFERENCE	Pajarinen (2006)⁸	Study type	Retrospective single centre
Sample size	72 patients		
Implant/follow-up	PHILOS. One year follow-up		
Outcomes	Not scored		
Observations	Good results achieved advantages in elderly osteopenic bones, No difference in younger patients but had less impingement than with older T plates		
REFERENCE	Helwig <i>et al.</i> (2009)⁹	Study type	Single centre prospective
Sample size	87 patients		
Implant/follow-up	PHILOS (65), T – LCP (22). 27 months		
Outcomes	Constant, DASH, UCLA scores		
Observations	Good outcomes were noted 60–82%. High complication rate with secondary screw penetration into joint in 11 patients, 14 cases of loss of position and 15 cases of avascular necrosis. Metalwork had to be removed in 38 patients. Good reduction and suture techniques were the key to success. Outcomes were related to reduction achieved rather than fracture scores		
REFERENCE	Badman <i>et al.</i> (2009)¹⁰	Study type	Single centre prospective
Sample size	18 non-union		
Implant/follow-up	PHILOS, S ³ . 26.5 months		
Outcomes	ASES 40 pre-operatively, 81 postoperatively. VAS Pain 6.7 pre-operatively, 1.5 postoperatively		
Observations	Radiographic union was achieved in 17 of 18 patients (94%) in 5.4 months (range, 2.5–8.8 months). One failure of fixation. Fibular or iliac crest strut grafts used to fill up metaphysis void to help prevent further displacement. Careful surgical technique, reconstruction of medial buttress and tuberosities important for success		
REFERENCE	Sudkamp <i>et al.</i> (2009)¹¹	Study type	Prospective, multicentre
Sample size	187 patients		
Implant/follow-up	155 patients had 1-year follow-up		
Outcomes	Implant-related problems (40%), overall complications (34%), constant score 70.6 ± 13.7%; DASH score 15.2 ± 16.8		
Observations	Intra-operative screw perforation of the humeral head was the most common complication (21 patients). Twenty-nine patients (19%) needed further surgery in 1 year. Surgical technique stressed on		
REFERENCE	Churl-Woo & Sang-Jin (2009)¹²	Study type	Prospective
Sample size	44 patients, 45 fractures		
Implant/follow-up	PHILOS. 1-year follow-up		
Outcomes	UCLA score 30.9, excellent in 40%, poor in 4%. Cuff/ tuberosity injury patients scored 29		
Observations	Multivariate linear regression analysis of impact of age, fracture pattern, osteoporosis, calcium sulphate graft, rotator cuff suture loop, head-neck shaft angle, and co-morbidity on outcomes. Lack of medial buttress support and delays to rehabilitation due to co-morbidities were the primary prognostic factors that led to poor outcomes. Five failures		
REFERENCE	Thanasas <i>et al.</i> (2009)¹³	Study type	Systematic review of the literature
Sample size	12 of 791 studies met criteria for inclusion		
Implant/follow-up	PHILOS. 1-year follow-up		
Outcomes	re-operation rate was 13.7% and screw cut-out occurred in 11.6% of cases		
Observations	The authors emphasised the importance of reduction and good medial calcar support especially in osteoporotic bone		

PHILOS – Synthes, Oberdorf, Switzerland. S³ – Hand Innovations (DePuy), Miami, USA.

filled using either cortical screws or locking screws depending on the bone quality. Now the rotator cuff/ Tuberosity sutures are passed through the suture eyelets in the plate and secured. The authors recommend the use of tough braided non-absorbable sutures which resists abrasion/rupture against sharp edges of bone or metal.

It is essential to screen the fixation carefully using the C arm image intensifier to check for quality and adequacy of reduction, position of metalwork and rule out any screw penetration into the joint.

Postoperative management

Regional anaesthesia and cryotherapy are valuable means of analgesia. The security of fixation of tuberosity dictates the postoperative regimen. The authors recommend that comminuted fractures with tuberosity fixation require relative immobilisation for 4–6 weeks. Limited active assisted forward flexion and external rotation to 30–40° may be allowed. Extension and internal rotation are restricted until 6 weeks to minimise tuberosity displacement in comminuted fractures.

Patients need regular review with good quality X-rays to establish progress of healing and in particular to exclude screw penetration due to fracture collapse (Fig. 1). If the latter is identified, early removal of screws may be indicated to prevent joint damage.

Literature review and results

The literature on FALP for the proximal humerus remains controversial. All published papers on FALP are retrospective or prospective case series with no randomised controlled trials (RCTs) between different modes of fixation and none comparing different locking fixed angle systems. A Cochrane review of interventions in proximal humeral fractures includes 12 articles; none, however, include trials involving FALPs.⁵ A systematic review of the literature¹³ illustrates the relative high incidence of re-operation using plates. They postulate that the rigidity of the implant in combination with poor medial support is the cause of collapse and screw penetration.

Fracture modelling and biomechanical studies have shown the improved pull out strength of locking plates, improved torsional stiffness and fatigue resistance compared to blade plates.^{4,5} There is greater torsional and bending stability in comparison to intramedullary nails.⁶

Table 1 summarises the published results of FALPs. Most conclude that:

1. Meticulous surgical technique is the key to good outcomes.
2. Tuberosity reduction and medial buttress reconstruction is vital.
3. Early displacement heralds poor outcomes.
4. Careful screw placement is crucial, both initial and subsequent screw penetration are well reported.
5. Impingement symptoms are reported, patients improve after metalwork removal.

6. Any voids in the metaphysis after reduction should be grafted.
7. Complication rates are high but FALP appears to have advantages in osteopenic bones.

The authors feel that good FALP design should include:

1. Low profile design to reduce impingement.
2. Multiple suture eyelets for tuberosity reconstruction which are accessible after fracture reduction.
3. Multiple screw options including smooth pegs.
4. Options for both locking and non locking screw and a central gliding hole distally for diaphyseal fixation.
5. Multiple holes in the plate to allow temporary wire placement.
6. Both titanium and steel options should be available.
7. Low profile aiming device for humeral head screw placement.

Conclusions

Fixed angle locking plates (FALPs) are increasingly popular in the treatment of complex proximal humerus fractures and are particularly useful in the elderly with poor bone quality. Good surgical technique is the key to a successful outcome. There is a need for well constructed RCTs comparing different plate designs and modes of fixation of these injuries.

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Minimal invasive flexible fixation for fractures of the proximal humerus

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Proximal humerus fracture is common, particularly in the elderly.¹ Management of these fractures remain controversial. The reliability of the different classification systems is poor² and, despite consistency of management of non-displaced or minimally displaced fractures, optimal management of more complicated fractures continues to be a vexed subject. Often, the bone is osteoporotic with reduced bone mass and trabecular connectivity. In those with good bone quality, fractures tend to occur as a result of high-energy injuries and are associated with significant soft tissue injuries.² These account for the mixed outcomes following different surgical techniques since risks of fracture displacement, malunion and avascular necrosis are significant.

Minimally or undisplaced proximal humerus fractures are treated successfully non-operatively. In fractures where the humeral head is highly comminuted, the proximal humerus may not be reconstructable and arthroplasty, particularly in elderly, may be the best option. With other fractures and in younger patients, attempts are made to reconstruct the proximal

humerus since hemi-arthroplasties for fractures can be associated with poor function as a result of tuberosity malunion, non-union or resorption, instability and limitation of motion.²

When reconstructing proximal humerus fracture, the objectives are to achieve a stable, accurate restoration of the proximal humerus anatomy to maintain or restore cuff integrity and avoid extensive soft tissue dissection. The least invasive techniques may minimise scarring, optimise postoperative mobility and decrease the risk of devascularisation of the humeral head with consequent avascular necrosis or non-union. Furthermore, the risks of plate fixation must be appreciated, *e.g.* secondary impingement, screw breakage, migration, penetration or cut out, and plate failure, pullout or fracture. All may compromise the outcome and necessitate further surgery. Rigid fixation device, such as a locking plate (see below), may contribute to cutting out of the screws through osteoporotic bone in which the humeral head may subside while the screw remains locked.¹

Figure 1 (A) 4-part fracture dislocation. (B) Immediately after minimally invasive reduction, the tuberosities re-approximated and held with sutures, through the rotator cuff insertions, against the reduced head (closing the book) and 'Palm-tree' fixation, with bone graft substitute filling the void.

Figure 2 Final outcome after removal of the 'Palm-tree' wires.

Angular stable plates with locking systems are popular for proximal humerus fracture management. A number of studies have reported noticeable complication rates with their usage.¹ Brunner *et al.*¹ reported a prospective multicentre analysis involving eight trauma units, 158 proximal humerus fractures in 157 patients, with an overall complication rate of 44%. These included primary screw perforation (14%), secondary screw perforation (8%), avascular necrosis (8%), impingement (3%), secondary loss of reduction (3%), secondary dislocation of the greater tuberosity (3%), frozen shoulder (3%) and plate/screw pullout (3%). Re-operation was required in 25% of the patients. The fracture configuration requires evaluation in order to be in a position to achieve accurate reduction, to neutralise the displacing forces, to elevate and to hold the humeral head, and to reduce and maintain the tuberosities at their anatomical position.² A rigid fixation, however, may also keep the anatomical structures apart and thus prevent secondary impaction, therefore compromising the healing process.² Non-rigid fixation also permits some motion which may reduce the forces acting on the bone/metal interface during strain and, therefore, allow the interface to remain intact. Thus, we believe that minimally invasive techniques, which allow these goals to be achieved, provide a better solution than fixed angle or locking plates.

Available minimally invasive techniques include transosseous suture fixation, closed reduction/open reduction and

percutaneous wire fixation and flexible plate osteosyntheses.⁵ Closed reduction involves longitudinal traction, abduction and external rotation. It is important to emphasise that, with all minimally invasive techniques, if an accurate closed anatomical reduction cannot be achieved, one has to proceed to open reduction. Successful open reduction is dependent on an understanding of the fracture anatomy. There is some consistency with fracture pattern. A classic four-part fracture, pectoralis major pull results in medial and anterior displacement of the humeral shaft, medial displacement of the lesser tuberosity, posterior/superior displacement of the greater tuberosity and lateral rotation and displacement of the articular segment. In the valgus impacted four part fracture, however, the articular segment, rather than becoming completely separated from the shaft is impacted into valgus. The medial periosteum and, therefore, the blood supply to the articular segment may remain intact, resulting in better prognosis. Open reduction of such fractures requires an intact medial hinge, which if not, needs reconstruction.² The humeral head needs to be reduced and 'lifted up'. The tuberosities are reduced anatomically, re-approximated with sutures, through the rotator cuff insertions, against the reduced head (closing the book). A void between the head and the tuberosities, may require bone graft or bone graft substitute. It has been argued that the anatomical reduction of the tuberosities provide the 'stable platform' on which the humeral head sits.² The humeral head is further stabilised by the joint reaction forces provided by the resting tone of the rotator cuff muscles.

Percutaneous fixation involves closed or open reduction of the fracture (see above) and stabilisation with Kirschner wires³ inserted percutaneously into the lateral cortex, just distal to the deltoid insertion (within 3–4 cm window of safety between axillary and radial nerves) and advanced into the humeral head without penetrating the articular cartilage. Techniques for closed reduction involve a pointed hook retractor inserted in the subacromial space to manipulate the greater tuberosity into its anatomical position. A periosteal elevator may elevate the articular fragment. Open reduction with percutaneous wire fixation is necessary in cases of failed closed reduction.

Percutaneous wire fixation may be performed with straight (parallel or non-parallel configuration) or contoured wires and in a antegrade or retrograde direction. There is no consensus for the optimal percutaneous technique. Blocks (Humerusblock) and PEEK plates (Buttonfix) may provide anchorage for the wires and reduce risk wire migration, which have also been described.

The Palm-Tree technique involves, following the reduction of the fracture (close or open trough the anterosuperior (Neviaser-Mackenzie approach), insertion of three divergent pre-bent 1.8-mm wires, through a drill hole just distal to the deltoid insertion, into the medullary cavity. The wires are passed retrogradely towards the humeral head controlling rotation with

a T-handle.^{4,5,9} They provide three-point fixation for each wire: the subchondral bone in the humeral head, the medial cortex of the proximal shaft and the cortex at the entry point (3 point fix-

ation times three – for the 3 wires).⁵ Biomechanical studies suggest that contoured pins inserted in different planes provide better stability than parallel straight pins (Figs 1 and 2).

Table 1 Summary of outcomes using percutaneous fixation of proximal humerus fracture

Reference Jaberg *et al.* (1992)⁶

Technique	Percutaneous wire fixation
Patients (n)	48
Average follow-up (months)	36
Outcome measures (mean)	78% had good or excellent results

Reference Mansat *et al.* (2008)⁷

Technique	Palm tree fixation for 4-part valgus impacted fractures
Patients (n)	19
Average follow-up (months)	28
Outcome measures (mean)	Mean constant score = 74

Reference Bogner *et al.* (2008)⁸

Technique	K-wire fixation with Humerusblock for 2/3- and 4-part fractures
Patients (n)	153
Average follow-up (months)	More than one year
Outcome measures (mean)	Constant score for 2-part fracture achieved 81% compared to other side; 3-part fracture achieved 84%, 4-part fracture achieved 69%

Reference Levy *et al.* (2006)⁵

Technique	Palm tree fixation; 22 two-part; 3 three-part; 1 four-part
Patients (n)	26
Average follow-up (months)	28
Outcome measures (mean)	Constant score = 75.3

Reference Keener *et al.* (2007)⁹

Technique	Percutaneous pin fixation
Patients (n)	35
Average follow-up (months)	35
Outcome measures (mean)	Mean pain score on VAS was 1.4; Constant score of 73.9; ASES of 83.4

Reference Fenichel *et al.* (2006)¹⁰

Technique	Percutaneous fixation with 3–5 K-wires for 2- and 3-part fractures
Patients (n)	59
Average follow-up (months)	30
Outcome measures (mean)	Constant score = 81

Reference Blonna *et al.* (2009)¹¹

Technique	Percutaneous fixation with K wires for varus impacted proximal humerus fractures
Patients (n)	32
Average follow-up (months)	30
Outcome measures (mean)	Constant score = 72

Reference Calvo *et al.* (2007)¹²

Technique	Percutaneous fixation with a minimum of 3 K wires
Patients (n)	74
Average follow-up (months)	13.6
Outcome measures (mean)	Constant score = 65.8

Percutaneous fixation of proximal humerus fracture is not without complications, which include wire migration, infection, fragments re-displacement and avascular necrosis. Reports of outcome with this technique are outlined in Table 1.

It is advantageous biomechanically and, when performed correctly, results in less soft tissue damage and better outcome than locking plates.

Furthermore, the percutaneous pins are easily removed after a few weeks thus no metalwork remains in the proximal humerus.

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