(ii) Plate fixation of proximal humeral fractures

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Abstract

Proximal humeral fractures account for about 5% of all fractures with a peak incidence in females aged over 80 and the incidence of these fragility fractures expected to increase. Whilst the majority can be conservatively managed, those with displaced fractures may benefit from surgery.

Fractures requiring fixation are a heterogeneous group ranging from simple displaced two part fractures to complex four part fractures and those with disruption of the medial calcar and humeral head blood supply. They require a variety of fixation techniques to achieve anatomical restoration and stability. Locking screw technology permits more stable low profile fixation for these challenging fractures and are now the mainstay of treatment.

Whilst these developments aid the surgeon in maintaining stable fixation, successful outcomes continue to rely on the basic principles of initial anatomical reduction and stable fixation with specific attention to the tuberosities to which the powerful rotator cuff muscles attach.

Keywords fracture; plate; proximal humerus; shoulder

Introduction

Proximal humeral fractures account for about 5% of all fractures with a peak incidence in females aged over 80 and the incidence such fragility fractures expected to increase.[1,2] Thus such fractures are often associated with poor bone quality and significant patient co-morbidity.[1,3,4] A number of classification systems exist but none are entirely satisfactory in guiding treatment. As approximately 80% of proximal humeral fractures can be managed conservatively, surgery is only advocated for displaced fractures as these otherwise have poor long-term outcomes both with regard to pain and function[5] and for complex fracture-dislocations, intra-articular head split fractures, pathological fractures, open fractures and those with neurovascular injury. Relative indications for surgery include young active patients and unstable fractures.

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Recently locking plate technology which gives angle stable fixation has become the procedure of choice in some centres. However high complication rates have been reported and the conventional indications for surgery have been challenged with non-operative treatment of displaced fractures shown to give equivalent outcomes in some studies.[4,6]

The decision to operate therefore needs careful consideration on an individual patient basis as neither the indications for surgery nor the appropriate implant are yet clearly proven. In this review we discuss the available plating options, surgical techniques and results.

Plating options

In 1949 Bosworth introduced a 120° blade plate to provide angular stability when plating the proximal humerus to mitigate both fracture comminution and poor bone quality.[7] Since then there have been a number of clinical and biomechanical reports of various techniques including wave plates, 'T' plates and bent tubular plates to confer angular support against varus, valgus and rotational failure of fixation.[8–10] The AO group published good results in 2001 using a blade plate for treatment of proximal humeral non-union.[11] At about the same time the Pan–Tan plate was introduced. This conferred a degree of angular stability using locking cancellous screws into the lateral plate, but the failure rate in osteoporotic bone was high.[12] The advent of locking screw technology meant that low profile angular stable locking plates quickly became a mainstay of operative treatment. They rely on the screw–bone interface for stability; the plate and screws function as a single fixed angle unit without the need for bone to plate friction. Biomechanical cadaveric studies have shown the proximal humeral locking plate has greater torsional fatigue resistance and stiffness than previous plate designs including the blade plate and T plate.[13,14] One of the most commonly used of such devices is the PHILOS (Proximal Humeral Interlocking System) (DepuySynthes) which utilizes multiple divergent proximal locking screws.[15] This has been developed with plates that have poly-axial locking options.

Operative approaches

Most authors recommend the beach chair position which permits near all round access to the shoulder and the ability to extend the arm. This position requires careful positioning of the patient's head and there is some risk of cerebral hypo-perfusion for those under general anaesthesia.[16] It can also be difficult to obtain adequate lateral X-ray visualization without rotation of the arm which would put at risk the fracture reduction. Fully radiolucent operating tables allow more proximal humeral fractures to be treated supine, reducing the anaesthetic and imaging difficulties inherent in the beach chair position but can restrict operative access to the posterior structures including the greater tuberosity fragment. The last alternative is a lateral position which permits good imaging access and minimizes anaesthetic risk but makes the delto-pectoral approach more difficult.[17]

The two standard approaches to access the proximal humerus are the delto-pectoral and the lateral or deltoid splitting approach. The delto-pectoral approach goes between the deltoid muscle thus protecting the axillary nerve and pectoralis major protecting the medial and lateral pectoral nerves.[18] It affords access to the proximal shaft and the joint can be visualized through the rotator interval to confirm reduction of intra-articular segments as required. Access to posterior structures such as displaced greater tuberosity fragments requires retraction of the deltoid, which can be aided by abduction of the arm to release tension. The deltoid splitting approach gives excellent visualization of the tuberosities but necessitates identification and protection of the axillary nerve to access the proximal shaft.

A retrospective analysis of 63 patients found no difference in clinical, radiological or electrophysiological outcome between the two approaches for locked proximal humeral plating. However Hepp in a prospective analysis of 83 patients, found better Constant scores at 1 year in those patients who had had a delto-pectoral approach but also a higher rate of avascular necrosis.[19,20] If allowance is made for the possibility of revision surgery to total joint arthroplasty, the delto-pectoral approach may be preferred.

Surgical considerations

A proper understanding of the normal anatomy of the proximal humerus, common fracture patterns and their classification is essential when undertaking fracture reduction and reduction. The normal head to shaft angle is between 130 and 150° and humeral head retroversion of between 25 and 30°. At the minimum, orthogonal plain radiographs are essential for management but CT scans often provide valuable additional information, as the exact nature of tuberosity fractures and intra-articular head split fractures can be difficult to ascertain from plain radiographs. The advent of 3-D CT reconstruction is a further aid to pre-operative planning.

The basic fracture configurations are two, three and four part. These refer to the four main fragments comprising the head, the shaft, and the lesser and greater tuberosities. Two part fractures can be treated by reducing the fracture and fixing the head back onto the shaft, because there is no concern about the tuberosities. However three and four part fractures require specific reduction and fixation techniques. The strong bone of the bicipital groove means that the typical split of the tuberosities in a four part fractures tends to occur just posteriorly to this groove. At operation to gain access for fracture reduction, the tuberosity split can be developed as this split will lead into the tendon itself but taking care not to violate the supraspinatus proximally. The long head of the biceps tendon can be released from its anchor to further improve access and later tenotomized if necessary.

Impacted valgus fracture: the most common fracture pattern is an impacted valgus fracture.[2] This is often amenable to elevation of the head into its anatomical position by accessing it through the tuberosities. Anatomical reduction of the tuberosities behind the head (analogous to closing an envelope) then prevents any further valgus collapse. A lateral plate can then be applied as a further buttress. Beneath the plate, sutures can be used between the tuberosities and from the tuberosities to the plate as an augmentation to lateral plate and screw fixation. If the medial calcar remains intact, as is often the case in this fracture pattern, the final construct is stable.

Three and four part fractures: in the management of three and four part proximal humeral fractures successful reduction and fixation of the tuberosities is a key component of outcome.[21] Tuberosity components can vary from large bone fragments to thin sleeves of bone which may have significant rotator cuff attachment. The greater tuberosity is of particular importance, as the strong external rotators pull the fragment both medially and posteriorly which necessitates particular attention to retrieve and reduce it. Fragments can be provisionally fixed with Kirschner wires while the plate position is optimized. Current locking plate designs have holes to allow the tuberosities and rotator cuff to be secured to the plate with strong sutures. These can be placed either through the cuff to bone interface or through the bone itself before reduction and securing the fragment to the plate. This then ensures the pull of the rotator cuff loads the implant directly rather than stressing a potentially weakly fixed fragment. Large tuberosity fragments can sometimes be managed with direct plate fixation without suture augmentation, using a lateral locking plate as a buttress to hold the reduced fragments in place and supplementing with screws through or outside the plate. However Figure 1 shows an intra-operative radiograph of a fracture where the greater tuberosity fragment was fixed under the plate with screws alone without sutures to anchor the rotator cuff. At 3 months post operatively the cuff has pulled the tuberosity posteriorly leading to severe restriction of external rotation.

Medial comminution: it gives rise to an unstable fracture pattern in which the blood supply to the humeral head may be compromised. Hertel described posteromedial metaphyseal fracture extension and loss of the medial hinge as the greatest predictors of ischaemia in proximal humeral fractures.[22] The loss of medial support means that resistance to varus collapse of the humeral head is entirely reliant on the implants used rather than a primary bony anatomical reduction (Figure 2). There are a variety of techniques to achieve this.

The first is to use medial support screws, sometimes referred to as ‘kickstand’ or calcar screws. These fixed angle oblique screws are a feature of most contemporary locking plate designs. They are designed to run distal to proximal just above the calcar into the head to resist to varus collapse by supporting the calcar. A prospective randomized trial of 72 patients demonstrated benefit in both functional outcome and maintenance of reduction at 31 months, for three and four part fractures, with the use of medial support screws.[23] The position of these locking screws is controversial however; they may cross the fracture and effectively splint the fracture apart and thus have the potential to increase the risk of non-union. Additionally if the head collapses due to poor bone quality with a poor bone/screw interface, the screw can enter the joint.

The second technique is to use structural augments such as fibular strut allograft, cancellous or synthetic bone graft. In cadaveric models with a deficient medial calcar, a locking plate construct with the addition of a fibular strut has been shown to increase stiffness 2.4 times[24] and fibular strut grafting in combination with a locking plate has a greater number of cycles to failure and a greater resistance to deformation. The disadvantages include a greater surgical exposure for the insertion and obliteration of the humeral canal which makes subsequent humeral stemmed arthroplasty surgery more challenging. However, most biomechanical studies of fibular strut augmentation test a model where deficiency of the medial calcar is simulated in a two