Principles and fundamental concepts in the fixation of proximal humerus fractures through a locking plate

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Abstract

**Background:** Proximal humerus fractures account for 5% of all fractures, with an incidence rate of 63 cases per thousand adult individuals per year. They are often considerably displaced and comminuted in the elderly. About 75% of these fractures occur in patient above the age of 60 years. The female to male ratio is about 3:1 and the incidence of this fracture increases with age. It is in these older patients, that the mechanism of injury is usually a low energy trauma. As majority of these fractures occur in the osteoporotic bone, the operative treatment with Philos plate has of now become the gold standard.

**Methods:** A literature review of peer-reviewed publications related to the evaluation and management of proximal humerus fractures was performed. There was a focus on randomized controlled trials and an exploratory search in the Medline, PubMed, Embase database using the keywords “Proximal Humeral Fractures, locking plate, Philos, Delto-Pectoral approach was conducted.

**Keywords:** Philos, locking plate, proximal humerus fracture, calcar screw

**Introduction**

Proximal humerus fractures account for 5% of all fractures, with an incidence rate of 63 cases per thousand adult individuals per year. These fractures have rising incidence late in life and this is directly related to osteoporosis. About 75% of these fractures occur in patient above the age of 60 years and the female to male ratio is 3:1. Treatment decisions are based on the mechanism of injury, the patients’ health, level of activity and the fracture pattern. The outcome of these fractures depends on various factors such as patient compliance, medical comorbidities, problems of neglect and surgical expertise. In contrast, patients with fractures fulfilling the criteria of instability, referred to as displaced or unstable fractures, benefit from surgical intervention which mostly renders reliable results, both clinically and radiographically [2, 3]. The introduction of locking plate systems represents a milestone in fracture treatment with the advantage of improved osseous anchorage and higher resistance to failure by combining axial and angular stability [11, 12]. Additionally, locking plates do not depend on friction or compression between plate and bone to stabilize the fracture and therefore do not compromise periosteal blood supply [13, 14].

In proximal humeral fractures, the particular proximity of tendinous and neurovascular structures of the joint and the characteristic bone strength distribution of the humeral head require a fixation system with predetermined screw placement. The Philos plate system (Synthes, Oberdorf, Switzerland) was developed to meet these requirements by using a three-dimensionally-fashioned locking system for the proximal screws. The insertion of multiple polyaxial locking screws through the specific targeting device into humeral head fragment provides a fixed angle support in multiple planes, which maintains the achieved reduction, while allowing for early mobilization [11].

**Understanding the applied anatomy**

The primary deforming forces are the pectoralis and rotator cuff. The pectoralis major is inserted below the lesser tuberosity and pull the shaft anterior and medial. Greater tuberosity is attached by supraspinatus, infraspinatus and teres minor and when this is fractured, the fragments are displaced superiorly and posteriorly.
The lesser tuberosity is attached by subscapularis and this displaces the fragment medially. In case of surgical neck fractures, the proximal fragment is externally rotated and the distal fragment is displaced upward by the deltoid and medially by the pectoralis major. The glenohumeral joint is stabilized by the articular cartilage, labrum, ligaments, rotator cuff, and deltoid. Most humeral heads have a diameter between 4 and 5 cm, and the head is slightly offset medially and posteriorly in relation to the humeral shaft [9]. The pectoralis major tendon inserts 5 to 6 cm from the top of the humeral head, which is a reliable tool for estimating implant stem length in severe fractures without landmarks. Humeral shortening greater than 1 cm can impair deltoid function, whereas humeral lengthening and retroversion can impair tuberosity healing [10]. The proximal humeral blood supply is from the anterior and posterior humeral circumflex branches of the axillary artery, which are closely associated with the surgical neck and medial calcar (Figure 2). The arcuate artery is the terminal, ascending branch of the anterior humeral circumflex artery and enters the humeral head near the anatomic neck [6, 11]. Fractures with short calcar fragments (<8 mm), a disrupted medial hinge, and anatomic neck involvement are most prone to ischemia [12]. Gross axillary artery injury is exceedingly rare; however, in cases of significant shoulder trauma with a loss of Doppler signals and an enlarging axillary mass, vascular surgery should be consulted. The most commonly injured nerves in descending order are the axillary, suprascapular, radial, musculocutaneous, median, and ulnar nerves. These are most commonly traction injuries that fully recover [13]. During surgery, the axillary nerve can be difficult to identify, particularly in scarred shoulders. It is about 4.5 to 7 cm from the proximal humerus and 0.5 to 4 cm from the surgical neck traveling through the quadrilateral space with the posterior humeral circumflex artery [15]. Care should be taken with incisions greater than 5 cm in length distal to the acromion. With anterolateral plating, the axillary nerve is most frequently in danger when placing screws near the surgical neck through the middle segment of the plate. This is essential to understand in treating the patients by means of ORIF (Open reduction and internal fixation) as well as CRIF (Closed reduction and internal fixation) [16].

The neer’s classification
This classification is based on 4 fracture parts:
1. The greater tuberosity,
2. The lesser tuberosity,
3. The humeral head and
4. The humeral shaft.
For practical purposes, fractures are discussed based on the number of parts involved.
A fragment is considered to be displaced if it is separated more than 1 cm
or has displacement angulation more than 45 degrees.

Neer’s classification system – The most widely used.

<table>
<thead>
<tr>
<th>Displaced fractures</th>
<th>2-part</th>
<th>3-part</th>
<th>4-part</th>
<th>Articular surface</th>
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<tr>
<td>Anatomical neck</td>
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<td>Surgical neck</td>
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<td>Greater tuberosity</td>
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<td>Lesser tuberosity</td>
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<td>Head-splitting</td>
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**Radiological evaluation and general considerations**

Important historical elements include the patient’s level of ambulation, functional demands, and any pre-existing rotator cuff conditions. Evaluation should begin with inspection of the soft tissues and skin, as elderly patients are susceptible to poor wound healing. A full neurologic examination can be difficult following trauma, but function of the fingers, wrist, and elbow can often be evaluated. Axillary nerve innervation of the deltoid needs to be tested as reverse shoulder arthroplasty (RTSA) is a viable treatment option that requires an intact and innervated deltoid. True anteroposterior (AP), lateral, and axillary X-rays of the glenohumeral joint should be demanded. Computed tomography is recommended for complex fracture patterns or when fracture lines cannot be clearly visualized on the x-rays. Magnetic resonance imaging (MRI) may be useful for assessing rotator cuff integrity when considering nonoperative treatment. In a prospective study of 30 patients, nearly 40% of proximal humerus fractures were associated with rotator cuff tears.18 Bone density is a predictor of surgical reduction quality and screw cutout. 21, 22 Density can be assessed with cortical bone thickness measurements on AP views of the shoulder. Two techniques are detailed in Figure 4: the Tingart measurement and the deltoid tuberosity index. Bone quality and social independence can serve as indicators of physiologic age, which is more important than chronologic age when weighing treatment options.
Management

Treatment of proximal humerus fractures is controversial. There is significant heterogeneity among studies, so making conclusions is difficult. In general, minimally displaced fractures, poor surgical candidates, and low demand patients are treated conservatively. Displaced, comminuted, or angulated fractures occurring in good surgical candidates are treated with percutaneous techniques, open reduction and internal fixation or arthroplasty depending on the type of fracture pattern. Despite the risk of nonunion, symptomatic malunion or osteonecrosis, non-operative therapy even of complex proximal humerus fractures may be adequate in the very elderly or cognitive impaired population and in patients with a nonfunctional limb, well advanced drug or alcohol abuse or severe medical comorbidities [17]. These settings often require close cooperation with a geriatric physician in order to prevent secondary conditions and further falls.

Minimally displaced fractures

Around 50% to 65% of all proximal humerus fractures are minimally displaced fractures of the greater tuberosity and/or surgical neck that respond well to nonoperative management. 28, 29(p) The shoulder should be placed in a sling followed by early and adequate physiotherapy. Isometric, pendulum, or passive range of motion exercises should be started within a few days of injury. The sling can be worn until healing is evident, which usually occurs by 4 to 6 weeks. Around this time, active strengthening exercises can begin.30,31 Recently, a study by Clement et al included 211 minimally displaced proximal humerus fractures in patients aged 65 to 98. At 1 year, the mean Constant-Murley score was 68.8 (greater than 55 was considered an acceptable outcome) [19]. They can be closed reduced with immobilization in slight external rotation. On the other side, large, displaced fragments or fragments involving the articular surface warrant fixation.

Operative treatment

In osteoporotic bone, reduction might be difficult to obtain and yet—independent of the chosen implant—precise anatomic reduction is the cornerstone of a stable fixation and essentially enhances its longevity [38]. Therefore, correct interpretation of the fracture pattern and its trauma mechanism is essential. Knowledge of the deforming forces of the muscular attachments helps in reducing and retaining displaced fractures. The humeral head or the articular fragment can also be pushed into a varus deformity due to the axial load of the trauma. First and foremost, the integrity of the medial hinge-calcar must be ascertained and in case of disruption reconstructed before further reduction maneuvers are applied. The most efficient method to gain osseous medial support of the humeral bone is perfect reduction of the medial cortices. The medial periosteum plays a key role in the fracture management, because it allows indirect reduction using ligamentotaxis and it maintains the blood supply of the head fragment via branches of the posterior humeral circumflex artery. Krappinger and colleagues postulated that anatomical fracture reduction and the correct alignment of the medial cortices are the two most important prognostic factors in terms of secondary displacement [39, 40]. Because of neighboring neurovascular structures and the insertion of rotator cuff and biceps tendons, extramedullary fixation of proximal humeral fractures mostly has to be approached from the lateral aspect [34, 35]. Therefore, reduction of the medial fracture zone can only be achieved through indirect manipulation or across the fracture line. Direct visual control is not possible. To confirm perfect reduction, fluoroscopy guidance is mandatory. Fractures with medial comminution are technically difficult or not at all manageable. In some cases, the treatment of choice then is the intended impaction of the humeral head.

Biomechanical studies could prove that even with correct axial reduction, missing calcar stabilization leads to secondary displacement with varus impaction of the humeral head [41]. The absolute indications for the surgery are:

a) The fracture dislocation of proximal humerus.

b) Head-splitting fractures.

c) Fractures with neurovascular injuries.

Two part surgical neck fractures

In two part surgical neck fractures, the shaft is usually displaced medially and anteriorly by the pectoralis major. The deltoid pull results in overlapping of the fragments and shortening. When the distal fragment is displaced medially and superiorly, there is a high incidence of soft tissue interposition of long head of biceps that prevents reduction which warrants open stabilization. It is important to remember that the results are dependent on Antero Posterior displacement of fracture and not on surgery. Displacement up to 66% in AP view seems to be acceptable as reported by Court-Brown et al. in their recent study. Indications for surgery include displacement, polytrauma, association with other upper extremity fractures, vascular injury and open fracture. The fracture is approached anteriorly through the deltopectoral approach. Philos locking plate is the choice of fixation in osteoporotic as well as young patients [34].

Two-part isolated tuberosity fractures

Closed reduction of two part Greater tuberosity fractures are difficult because the fragment is pulled superiorly and
posteriorly by the attached rotator cuff muscles. This must be treated like full thickness rotator cuff tear. Hence ORIF with Philos locking plate is indicated if there is superior displacement of 5 mm and posterior displacement of 10 mm. Greater tuberosity fractures are often associated with anterior dislocation of the shoulder and this should always be seen in axillary view. A deltopectoral exposure is used if there is a long inferior spike on the greater tuberosity. Exposure of the inferiormost portion of the fragment through a superior approach could damage the axillary nerve. When exposing the greater tuberosity through a deltopectoral incision, posterior exposure is greatly facilitated by abduction of the arm to relax the deltoid muscle.

Three & four part fractures
These fractures are more complex and are major orthopedic challenge – the decision is mainly based on the age, comorbidities, comminution, head split, fracture dislocations and activity level of the patient. The main decision in elderly is fixation or replacement. Four part displaced fractures, four part fracture dislocations, impression fractures of the articular surface involving more than 40% of the head and head-splitting fractures are best treated by primary prosthetic replacement.

Surgical technique: Surgery is performed under brachial block with patient in supine position and the shoulders on radiolucent support at the edge of the table. The shoulder is exposed through the deltopectoral approach and this forms the workhorse approach to the joint. Care must be exercised that the dissection is lateral to coracoid process. Identifying Cephalic vein and preserving it should be always kept in the mind. Its important to stay lateral to bicipital groove so that the arcuate artery is not disturbed. At this stage, the arm must be completely abducted continuously so that the deltoid remains in lax position and retraction is easier. Pectoralis insertion is a good landmark as its proximal edge indicates the level of axillary nerve. The reduction is secured with K-wires and later stabilized with locking plate and screws depending on the fracture pattern and bone quality. It is very important to get the calcar screw in plate as it reduces the varus collapse. Gardner et al suggested obliquely positioned inferomedial screws as an additive support tool. A calcar screw reduces the risk of a varus collapse with subsequent screw perforation by counteracting the varus deforming forces acting on the humeral head. This results in a significantly higher reposition stability after 6 and 12 months. With new minimally invasive techniques, the need for calcar screws often has been questioned. However, the positive clinical impact of calcar screws in terms of complication rate, fracture reduction, and Constant score has been repeatedly shown, especially for more complex fractures. In order not to harm the axillary nerve in minimal invasive plate osteosynthesis, the insertion of calcar screws should only be performed under direct vision.

The insertion of calcar screws does not increase the risk of humeral head necrosis by compromising the medial periosteal blood supply. Insertion of more than one calcar screw does not provide additional torsional or axial stability.

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**Surgical hardware- philos plate system construct**

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<tr>
<th>Screws used with PHILOS</th>
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<tr>
<td>X13.012 – 060</td>
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<tr>
<td>X04.814 – 860</td>
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*Stardrive*  
*Hexagonal*
Conclusion
The treatment of proximal humerus fractures still remains challenging. The majority of proximal humerus fractures are nondoncised by Neer’s criteria. The results of surgical management of displaced fractures are variable and dependent on fracture type, bone quality, quality of the surgical reduction and fixation, surgeon experience, and patient compliance.[34] When the decision for surgical fixation is made, anatomic reduction with restoration of medial support and protection of vascular and periosteal structures are crucial prognostic factors and the most reliable feature in the prevention of secondary varus dislocation.

Philo plate provides stable fixation in proximal humerus fractures. Additionally, meticulous surgical dissection to preserve vascularity of humeral head is necessary to prevent potential complications such as AVN. As majority of these fractures occur in the osteoporotic bone, the operative treatment with Philos plate has of now become the gold standard.

In geriatric patients, nonoperative management can also produce a high percentage of acceptable results, provided that rehabilitation exercises are instituted within 2 weeks of injury. A close cooperation with a geriatric physician is recommended for the purpose of early active rehabilitation and to prevent secondary conditions.

Disclosure
The author reports no conflicts of interest in this work.

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