# How to improve the outcomes of surgically treated proximal humeral osteoporotic fractures? A narrative review

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## Abstract

Proximal humeral fractures (PHF) are the third most common non-vertebral fragility fractures after hip and distal radius. It still controversial which treatment might be more appropriate, and surgically treated outcomes depends also on an appropriate technique. In order to clarify surgical indications, tips and pitfall a narrative review was conducted. Pinning, external fixation, plating and internal fixators has each one its advantages and disadvantages. During the procedure an appropriate use of the fixation device and handling of the soft tissue might be associated with better outcomes. Calcar comminution, varus angulation, medial dislocation of the shaft, fracture-dislocation are factors that could lead to choose a replacement. Hemiarthroplasty and reverse total shoulder arthroplasty are the most common prosthesis used in PHF. The restoration of humeral length and tuberosities might lead to an improvement in clinical outcomes and prosthesis survivorship.

## Introduction

Proximal humeral fractures (PHF) are the third most common non-vertebral fragility fractures after hip and distal radius.[1,2] In fact, these fractures occur mostly in females between 60 and 90 years of age.[3] Recently, Piscitelli *et al* estimated that 57400 humeral fragility fractures occurred in Italy in 2008, with an expected increase of +13.2% in the following six-years.[4]

The occurrence of a PHF is associated with a high morbidity and it was observed that postoperative stiffness, fixation failure, non-union, osteonecrosis, post-traumatic osteoarthritis were the most common sequelae that influence the outcomes and the return to the pre-fracture activity level.[5] Moreover, fracture-dislocations, although rare, represent a surgical emergency and requires immediate surgery. [6]

The constantly increasing in incidence and health costs (both direct and indirect) of PHF, justifies the great interests around this topic. It is still controversial which treatment might be more appropriate, however a recent systematic review showed that conservative treatment is associated to lower complications while assuring good functional outcomes compared with surgery. [7]

However, the observation that most of the single center cohort studies reported good outcomes[8–11] suggested that surgeon experience act in determining the results. Moreover, Boesmueller *et al* observed that the results of surgically treated PHF were related not only to patient's factors (age and smoking habits) but also to the quality of reduction.[12] Therefore, it could be assumed that a correct indication and an accurate surgical technique are relevant factors for PHF outcomes. The aim of our review was to clarify the correct indications, surgical tips and possible pitfalls of fragility PHF, in order to guide the orthopaedic surgeon through the treatment decision making with the final purpose of improving patients' outcomes.

## Research Strategy

During a preliminary meeting the research group identified four questions considered relevant to guide the treatment decision making of PHF: (1) which type of fracture should be surgically treated, (2) which type of fracture has to be repaired and to be replaced, (3) what kind of fixation should be used, and (4) what kind of shoulder replacement should be used.

A PubMed research was then conducted by three independent researchers using *proximal humeral fractures*, *osteoporosis* and *surgical treatment* as keywords. Relevant articles were identified by consensus between at least 2 of 3 researchers. Data extraction was performed, and relevant findings of the included studies were discussed in the research group and accepted when a consensus was obtained between at least 50% of the researchers.

## Which type of fracture should be surgically treated?

### Fracture pattern

Minimally displaced were observed in approximately 50% to 65% of PHF,[13] and the conservative treatment, based on sling and early isometric and passive range of motion exercises,[13] assured extremely satisfactory outcomes.[14]

It is hard to provide a clear guide for the management of proximal humeral fractures in the elderly, considering that it is still unclear what kind of treatment guarantees better long-term outcomes.[15]

Obviously, some fracture patterns, such as head split, fracture-dislocation or high demanding patients usually require surgical treatment, considering that conservative treatment could not provide a satisfactory functional outcome.[16]

### Biological factors

Proximal humeral bone quality and head vascularization are both considered relevant factors that address the treatment choice and affect the final outcomes. Particularly, bone density seems to be a pre-

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dictor of surgical reduction quality and failure of fixation.[17] Two techniques allow to measure local bone density by measuring cortical thickness: the Deltoid Tuberosity Index and the Tingart measurement.[18,19] In practice, this latter consists in the evaluation of the cortical thickness. A proximal humerus cortical thickness value of 6 mm measured at two levels was identified as a predictor of osteoporosis.[19] The Deltoid Tuberosity Index, instead, is measured just above the upper end of the deltoid tuberosity by taking the ratio between the outer cortical and inner endosteal diameter. The cut-off value for osteoporosis was found to be 1.44.[18]

Osteoporosis is a relevant factor that can worsen the incidence and the prognosis of PHFs. Recent studies showed the importance of the treatment of this pathology in order to reduce the hazard ratio of PHF. [20,21]

The impairment of humeral head vascularization is another factor that affects PHF outcomes. Humeral head vascularization depends on the contributions of several arteries, like the anterior circumflex, posterior circumflex, circumflex scapular and suprascapular arteries. However, it has been demonstrated that the highest percentage of vascular supply is provided by the anterior circumflex artery that is in strict contact with the medial hinge.[22] A damage occurring to one of these vessels can lead to avascular necrosis of the humeral head, fixation failure, screw pull-out and loss of reduction.[22]

Risk factors for avascular necrosis of humeral head are considered to be some conditions associated with medial hinge disruption like: varus displacement and malreduction of the humeral head, metaphysis extension of the fracture line, medial dislocation of humeral shaft and comminution of the calcar segment (Figure 1).[23] It is important to underline that anatomic reduction and respect of biology are fundamental factors in determining outcomes of surgically treated PHF.

## Which type of fracture has to be repaired and to be replaced?

There is no consensus on the type of fractures to be fixed and to be treated with a shoulder replacement.[1] Common indications for shoulder replacement after a proximal humeral fracture are patients in whom a synthesis is not viable because of sever bone comminution, high risk of avascular necrosis of humeral head and older age.[1] Therefore, four-part displaced fractures, fractures with dislocation, impacted fractures with varus displacement and head-split fractures are more commonly treated with shoulder replacement in the elderly.

## What kind of fixation should be used?

Several techniques had been proposed to fix PHF, such as percutaneous pinning, external fixation, plating and nailing. Each of them presents both advantages and drawbacks, and their knowledge is recommendable to tailorize the treatment to the patient.

### Pin

Percutaneous pinning can be attempted in two- and three-part fractures in case of good bone stock, intact medial calcar hinge, noncomminuted tuberosity fragments and a reliable cooperative patient. Attention must be paid to control under fluoroscopy that a stable reduction and fixation has been achieved after pinning. When these advices are respected, good results had been reported in elderly patients with a mean Constant scores of 89.8% (range 77.3-97.2%).[24]

### External Fixator

Fractures of the surgical neck are the most common indication for external fixation (EF) of PHF. EF avoid dissection and stripping of the soft tissues and might be indicated for the treatment of both two- and three-part PHF in the elderly, especially in cases where a satisfactory closed reduction can be achieved.

Although early studies reported that EF was not associated with acceptable fracture reduction and fixation stability in osteoporotic patients,[25,26] recently its use was encouraged by several authors.[27,28] In the study conducted by Parlato *et al*, the authors reported after a mean follow-up of one-year, a Constant-Murley score of 84 points (67-95 points) for surgical neck fractures treated with external fixator in patients of a mean age of 61 years.[27] According to the authors this technique is associated with a reduction in blood loss and surgical time if compared with other surgeries proposed for PHF.[27] D'Ambrosi *et al* used EF in thirty-two patients with both three- and four-part fractures presenting the two-thirds of the metaphysis intact. Fracture healing occurred in all patients, but a case of malunion was also reported. Functionally, the mean Constant-Murley score increased was 88.9 points at 24 months of follow-up.[28] Figure 2 shows an example of an EF used to treat a 2-part fracture.

### Locking Plates

The advent of locking plates (LP) represented a relevant evolution in the treatment of osteoporotic fractures.[29] Their use in PHF is potentially indicated for all reconstructable fractures, except in cases with significant comminution, head split or impaction that did do not allow a stable synthesis. It has been observed that patients with valgus impaction have better outcomes than those with varus impaction fractures. These two patterns differ in particular for a different kind of calcar involvement.[30,31] The importance of calcar reduction on post-operative fixation stability was recently underlined by Zhangh *et al*, that described a reduction in the fixation failure rate in those patients treated with a medial support screw (3.4% vs 23.1%).[32,33]

The use of bone graft has been demonstrated to improve fracture stability in several fractures,[34–36] and recently Gardner *et al*, demonstrated that the use of an endosteal fibular graft improved fracture stability achieved with LP in patients with an osteoporotic PHF.[37] Another augmentation technique was described by Russo *et al* and it was used with both locking plates and K-wire pinning.[8] The technique proposed consisted of a fixation augmented by a triangular bone block or a metal block putted into the medullary canal in order to fill the bone defect (Figure 3). According to the authors, these techniques allows a stable distribution of rotator cuff and deltoid compressive forces due to an adequate fracture support in patients with poor bone stock and calcar comminution.[8] Based on this principles the authors subsequently proposed the "control volume theory" in order to describe PHF pattern and guide the surgical procedures.[38]

Construct stiffness is another issue of concern especially in the osteoporotic bone. Indeed, rigid implants (*i.e.* stainless-steel plates) applied to fix the «soft» head may lead to bone loss with head excavation or destruction. A reduction in the fixation stiffness and an improve in the elasticity, instead, may allow fragment impaction and promote fracture healing.[39,40] Recently, Schliemann *et al*, performed a study on a LP made of Polyetheretherketone (PEEK).[41] Fixation with a PEEK LP shows lower fixation strength and increases motion at the bone–implant interface compared with a titanium LP. This result suggested that the use of PEEK plates may lead to an increased interfragmentary motion and, subsequently, lower loading failure.[41]

### Intramedullary Nail

The indications for intramedullary nailing (IN) are generally two to four-part fractures with metaphyseal comminution or diaphyseal involvement, but with minor displacement of the tuberosities.[42] The use of

angular-stable locking IN might be a better biomechanical option in the synthesis of osteoporotic bone, considering that it shows higher construct stability in the early phase of fracture fixation, with less motion of fragments and higher bending stiffness. However, in a biomechanical study conducted by Horn et al the failure rate did not differ between the angular stable IM and the classical interlocking IN[43] The classic entry point of the proximal humeral IN may violate supraspinatus tendon at its footprint. In the study conducted by Dilisio *et al*, a more medial starting point was proposed to preserve the footprint of the supraspinatus.[44] This technique requires the split of supraspinatus muscle, that present a higher healing ability. However, this approach sacrifices of a piece of the superior-lateral humeral head articular surface[44]

In the systematic review performed by Wong *et al*, the use of intramedullary nail was associated with a fracture healing rate was 99.3%.[45] Functionally, a mean Constant score of 72.8 points and a mean American Shoulder and Elbow Surgeons (ASES) score of 84.3. The authors observed that the outcomes and the complications were related to the fracture pattern. In fact, the Constant score relieved in two- and three-part fractures was significantly higher than that obtained in four-part fractures, and the reoperation rate of four-part fractures was significantly higher compared with two- and three-part fractures (63.2% versus 13.6% and 17.4%, respectively).[45] According to Konrad *et al* IN has showed similar outcomes compared to plate fixation in three-part fractures.[46] In the prospective randomized trial conducted by Zhu *et al* intramedullary nails showed lower complication rate when compared to locking plate for fixation of two-part proximal humeral surgical neck fractures.[47] However, average ASES and VAS score and average strength of the supraspinatus were significantly better in the locking plate group. At three years postoperatively, no difference was found between the intramedullary nail and the locking plate groups.[47]

## What kind of shoulder replacement should be used?

### Hemiarthroplasty

Shoulder hemiarthroplasty (HA) was historically used to treat complex fractures with no signs of eccentric glenohumeral arthritis. In PHF, HA was associated with lower pain, but did not to better function, compared with non-operative treatment at two-year follow-up.[48,49] These results are not unexpected, considering that the shoulder HA in PHF is a challenging technique and a functional rotator cuff and an anatomic healing of the fractured tuberosities are essential factors to achieve good clinical outcomes with HA. Therefore, considering that one possible complication of four part-fractures is the avascular necrosis of tuberosities, an appropriate handling of tuberosities is mandatory. A trick to reduce its incidence is the handling of tuberosities with non- or semi-absorbable sutures passed into the tendinous part of the rotator cuff.[48,49] It is mandatory to fix tuberosities with both horizontal and vertical sutures, also passing through specific holes designed into the prosthesis. The horizontal sutures are needed in order to connect the tuberosities each other, while vertical ones to give both vertical stability and compression.[50]

Dietz *et al* showed that the use of metallic cerclage as a fixation device for tuberosities could provide better functional and radiological outcomes.[51]Another factor that affects HA outcomes in PHF is the correct restoration of humeral length and retroversion. This goal is extremely hard to achieve, and the correct humeral length


**Figure 1. A 4-part PHF occurred in a 65 years old female. (a) Note the varus head displacement and subluxation. (b) A locking plate was used to fix the fracture. Note the head malreduction. (c) Avascular necrosis of the humeral head occurred 9 months after the surgery.**

**Figure 2. A 2-part PHF occurred in a 67 years old female treated with EF after a closed reduction.**

should be evaluated investigating the contralateral humerus X-ray.[50] Intraoperatively, the correct humeral length might be evaluated using the distance between the greater tuberosity and the upper part of the head of the prosthesis. To evaluate this distance it is necessary to properly reduce the tuberosities on the humeral shaft. Another landmark of a proper humeral length is the restoration of a normal soft-tissue tension, considering that a residual intraoperative laxity is suggested.[50] Boileau *et al* demonstrated that the use of an extramedullary jig anchored on the elbow could improve implant positioning.[52] Krishnan *et al*, instead recommended to restore the *gothic arch*, formed by the medial edge of the humerus and the lateral edge of the scapula, under fluoroscopy.[53]

Finally, the pectoralis major is another useful intraoperative landmark. Greiner *et al* showed that the distance between the superior part of the pectorals major tendon and the apex of the humeral head is equivalent to a mean of 5.5cm.[54] In HA implantation, a retroversion of 20 to 30° is commonly recommended for correctly positioning the humeral stem. However, while implanting the stem the surgeon should consider that the measurement of retroversion using the forearm with the elbow flexed as a landmark, might be underestimated of 10° because of elbow's physiological valgus.[50] A retrospective study conducted by Giovale *et al* on the use of HA in PHF showed an implant survival rate of 88.9% after a mean of 10-years follow-up.[55] In their series, tuberosities-related complications (*i.e.* non-union, necrosis) and reduction of the acromion-humeral distance were the factors that negatively affected the clinical outcomes.

### Reverse Total Shoulder Arthroplasty

Reverse total shoulder arthroplasty (RTSA) showed better results compared to hemiarthroplasty in PHF,[56,57] and their use could be a valuable option for both primary and secondary procedures. Although, it was previously observed that the use of RTSA as a primary procedure might be associated to better functional outcome,[58] recently the meta-analysis conducted by Torchia *et al*, did not show a significant difference in both complication rate and outcomes.[59] RTSA in PHF were demonstrated to be associated to good outcomes in both pain and function, although this latter tends to get worse with age.[60–62] Anyway, it is to underline that clinical outcomes were reported to be poorer compared with the use of RTSA in cuff-tear arthropathy[50] (Figure 4 shows a PHF treated with a RTSA).

Although theoretically the RTSA did not need a functionally rotator cuff to move, the healing of greater tuberosity was observed to be a factor that could increase active external rotation.[1] The fixation of the tuberosities follows the same principles of the hemiarthroplasty.[50] Limited data exist on the effects of lesser tuberosity or subscapularis repair on outcomes. Jobin *et al* observed that the repair of subscapularis seems to limit anterior instability, but it could reduce the efficacy of the weakened external rotators.[1] In fact, in the study conducted by Friedman *et al* the group without subscapularis reattachment showed an increased active abduction and passive external rotation.[63]

Werner *et al* underlined the importance of glenoid lateralization as a discriminant factor to choose whether to repair subscapularis or not.[64] In fact, in their retrospective study, patients with subscapularis being repaired and a lateralized glenosphere the American Shoulder and Elbow Surgeons (ASES) improvement was significantly lower compared to those without lateralization and subscapularis repair. The authors concluded that, although individually these parameters did not have an effect on ASES score, they could assure a statistically significant improvement when were in combination.[64] The positioning of RTSA should be between 0 and 30° of retroversion. The length of the implant, glenoid lateralization and polyethylene height should be planned preoperatively in order to increase the lever arm of the deltoid, avoid scapular notching, prosthesis instability or excessive soft-tissue tension, which may lead to peri-prosthetic fractures.[1,65] Finally, it is to underline that very few data analysed long term RTSA survivorship in PHF.

## Conclusions

Chronologic age is not the only factor that can predict the outcomes of surgically treated PHS. Biological age is a concept that surely act in this field and include local bone


**Figure 3. A 4-part PHF occurred in a 69 years old female. (a) Note the medial displacement of the humeral shaft.( b) Note the undamaged calcar. The patient was treated with a plate-and-screws plus k-wires synthesis augmented by a "DaVinci" triangular metal block to fill the bone gap, resulting in complete fracture healing (c).**


**Figure 4. A 4-part PHF occurred in a 71 years old female with a medial humeral shaft displacement and head luxation (a), treated with a reverse total shoulder arthroplasty (b).**

density. Even if conservative treatment was demonstrated to be not inferior compared to surgical treatment, the results of this latter are influenced by an appropriate surgical technique. A second surgery is not a viable option in many elderly patients, because of comorbidities. Therefore, when surgery is chosen it should be considered as a single shot surgery. It is still unclear which procedure could assure the best outcome, therefore the surgeon must consider all possible factors that can influence the outcomes in each case in order to perform a tailorize-to-the-patient surgery. Each fixation device has its own advantages and disadvantages and knowing them could aid in the appropriate choice. The restoration of humeral head bone stock seems to be associated with better outcomes. Some factors could be useful to decide between PHF fixation and replacement such as calcar comminution, varus angulation, medial dislocation of the shaft, fracture-dislocation. In case of shoulder replacement handling and fixing appropriately the tuberosities and restoring the proper length of the humerus are relevant factors in determining final outcomes. Anyway, RTSA is associated to more reliable mid-term outcomes compared to HA.

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