Lo SCALPELLO (2020) 34:3-8
doi number: 10.36149/0390-5276-001

Nonunion and malunion in proximal humerus fractures

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Summary

Proximal humerus fractures are common injuries and the development of nonunion or malunion is infrequent. However, these complications can occur with both operative and non-operative treatment of the fracture. A complete evaluation of these patients must include an investigation of the original fracture, bone and soft tissue quality as well as an extensive radiological study with X-Ray, CT and MRI. Asymptomatic and low demanding patients can benefit from conservative treatment, otherwise surgery is necessary. Multiple treatment options exist with no consensus upon the gold standard. The management of these complications is case-specific and needs extensive pre-operative planning. Arthroscopic procedures, osteotomies and bone grafting are viable joint preservation techniques. Bone loss or articular pathology are indications for joint replacement. The surgical treatment of nonunion and malunion is challenging even for experienced surgeons.

Key words: shoulder, shoulder fractures, shoulder prosthesis, arthroplasty, replacement, shoulder, fractures, malunited, fractures, ununited, pseudarthrosis, rotator cuff injuries

Received: January 31, 2020
Accepted: February 12, 2020

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Conflict of interest
The Authors declare no conflict of interest

How to cite this article: Vigni GE, Sabbioni G, Tomasi A, et al. Nonunion and malunion in proximal humerus fractures. Lo Scalpello 2020;34:3-8. https://doi.org/10.36149/0390-5276-001

Introduction

The management of proximal humerus fractures evolved greatly during the past few years. Most of these fractures are either non-displaced or minimally displaced and conservative treatment is often successful [1-3]. However surgical treatment is preferable in displaced fractures, where anatomical reduction of the tuberosities and restoration of the medial hinge are mandatory [3]. Nevertheless, osteosynthesis of proximal humerus fractures especially in the elderly does not have a good reputation due to common unsatisfactory results [4,5]. Despite the increased stability provided by new implants, recent biomechanic studies and 3D scans examinations, nonunion and malunion still remain important issues in proximal humerus fractures and have been reported after both operative and non-operative treatment [6-11]. 3D CT scan examination, in addition to standard X-ray study, is absolutely recommended to understand the fracture and plan the treatment in order to minimize complications. Proximal humerus nonunions and malunions can lead to persistent pain, limited range of motion and can affect quality of life [7-11].
Nonunion is defined as a fracture that is more than 9 months old and has not shown radiographic signs of progression toward healing for three consecutive months. In order to avoid delayed treatment, many support early medical therapy at 3 months in suspicion of a nonunion at clinical and radiological evaluation. Nonunions are classified as hypertrophic or atrophic depending on the vascularity of the bone. Atrophic nonunions lack adequate blood supply and may exceed in construct stability whereas hypertrophic nonunions have adequate vascularization but insufficient mechanical stability. The biological causes of failures, which would lead

to humeral head necrosis and/or nonunion are, in our opinion, related to multiple factors: inadequate anatomical reduction of fragments, insufficient neutralization of the forces generated by the rotator cuff, insufficient support of the medial bone arch (calcar), and failure to fill the spaces made empty by the impact in low energy fractures. Furthermore, nonunions can occur for patient factors such as poor bone quality, smoking, medical comorbidities or lack of compliance with treatment [6,9,10,12].

Malunion corresponds to the healing of the fractured bone in a non-anatomical position and have been reported after both operative and non-operative treatment. Proximal humerus malunions are defined as greater than 45° of angulation or 1 cm of displacement according to Neer classification [13]. Nowadays in order to restore the rotator cuff function and avoid impingement, a maximum displacement of 3-5 mm is mandatory in reduction of tuberosities [14]. In the elderly population a functional loss of overhead activity and strength is usually well tolerated as long as pain is resolved. This is reflected in the preference towards a conservative solution in this population. In younger and active patients, functional loss can be disabling and is not acceptable.

The treatment of a not tolerated nonunion or malunion is surgical. Depending on bone quality, degree of deformity and patient related issues different techniques are possible [9,10]. In order to restore native articulation biomechanics or bone loss, treatment may vary among osteotomies and a new osteosynthesis with associated grafting. Especially in the elderly with poor bone stock and limited healing abilities, joint replacement might have better outcomes.

In nonunions, a new osteosynthesis associated with grafting must consider the initial biomechanics of the fracture. In fact, the authors believe that low and high energy fractures should have different bone grafts. The empty space given in metaphyseal cancellous bone may often lead to complications in low energy fractures. On the other hand, in high energy fractures the main issue is the medial hinge insufficiency which can bring the head to a collapse or in a varus displacement. In our opinion, a femoral head allograft and a fibula bone graft (or similar) are indicated respectively. Furthermore, we believe that grafting should also be used as a primary solution in displaced fractures. Osteosynthesis with plate is the most common method of fixation of the construct even if intramedullary nails can be used with similar results.

On the other hand, some malunions due to partially or minimally displaced tuberosities can be treated with osteotomies fixed by plates and screws, while others by arthroscopic surgery such as cuff repair either or not associated with tuberoplasty and/or acromionplasty [7,15].

In serious deformities, severe bone loss, advanced arthritis, lack of regenerative capacities or avascular necrosis the only available option is the joint replacement [7-10,16]. Depending on age and comorbidities of the patient as well as cuff tendon/muscle and tuberosities status, the treatment may vary between anatomical or reverse shoulder prosthesis. Even if this solution resolves some issues related to fracture reduction and osteosynthesis, the surgeon must be aware of all the complications related to revision surgery. In particular, bone deformities and soft tissue alterations (especially capsule and cuff) can make arthroplasty very demanding in order to regain good balance of the joint and proper range of motion.

Complications in proximal humerus fractures such as nonunion and malunion are uncommon but represent serious issues for patients and the surgeon. Every case must be evaluated as patient specific and needs to be planned extensively. Different solutions are applicable even to the same problem and arthroplasty, which may seem the easiest choice, and can be extremely challenging.

Discussion

Malunion

The healing of a fractured bone in a non-anatomical position corresponds to a malunion. No treatment is immune to the risk of malunion and the mechanism which leads to the malunion can be related to the initial reduction or to a secondary displacement after non-operative treatment or after surgery. In order to choose the best treatment, every case must be studied with both clinical and radiological evaluations along with detailed history. It is mandatory to understand the structures involved and their position, the amount of misalignment and the functional and biomechanical consequences. X-Ray, CT and MRI are recommended [17]. The classification of proximal humerus malunions proposed by Beredjiklian et al. [18] describes as Type 1 a misalignment of greater or lesser tuberosity of more than 1 cm, as Type 2 an incongruity of the articular surface and as Type 3 a malunion of the tuberosities and the humeral head relative to the shaft. The glenohumeral incongruity is described as an angular deformity of 45° or more in all three planes. The misalignment of the humeral shaft changes the biomechanical characteristics of the humerus whereas alterations and/or remodelling (osteoarthritis, osteonecrosis, collapse) of the humeral head compromise the joint congruity. The displacement of tuberosities alters the rotator cuff muscles and tendons. Usually the greater tuberosity displaces posteriorly and/or superiorly whereas the lesser tuberosity displaces medially. Recent studies describe that a displacement of 3-5 mm represents the limit for good rotator cuff function and grants to avoid impingement [13,14]. However, elderly or low demanding people may tolerate some limitations in range of motion. Another classification was developed by Boileau et al. [19] whereas Griffart et al. [20] has recently proposed a measurement method which relies on CT scans and provides a quantitative assessment of post-fracture disharmony based on four reproducible angles.

Many fixation techniques are available for proximal humerus fractures and there is no consensus on the best solution.

Nevertheless, the precision of the anatomical reduction is a key factor. Non-displaced and one/two parts fractures are usually managed non-surgically with few complications. The conservative approach considers the patient's characteristics/comorbidities and often foresees some loss of shoulder function. Other types of fractures are usually treated surgically. Internal fixation can lead to any kind of malunion just described, while arthroplasty is mainly related to malunion of tuberosities or poor implant positioning. In hemi-arthroplasty poor functional results are associated with non anatomical position of tuberosities. Boileau et al. [21] showed that in 50% of malunion cases associate with hemi-arthroplasty poor outcome and an upper migration of the greater tuberosity. In the active range of motion any displacement of the tuberosities has direct clinical correlations depending on which part of the cuff is involved. While anatomical reduction of tuberosities is fundamental in anatomical shoulder replacement, the same issue is a recent development in reverse shoulder arthroplasty. Nowadays every improvement in active range of motion is pursued and good positioning of tuberosities, even in reverse prosthesis, can lead to it. Osteosynthesis with intramedullary nails is common in humeral neck fractures and in minimally displaced fractures, although it can be used in any kind of fracture depending on the surgeon's preferences. These devices allow the synthesis of the humeral head and tuberosities with centripetal screws. Therefore, this type of osteosynthesis is based on screw fixation of tuberosities since nails are not suitable for sutures. The authors believe that complications with this solution may derive from large parts of cuff attached to small bone fragments which cannot always be suitable for screw fixation. These issues may lead to bone fragment reabsorption or iatrogenic diastasis/dislocation and the subsequent tuberosity malunion.

The surgical treatment of proximal humerus malunion must have a precise and realistic goal and any other source of shoulder pain must be excluded. In particular, subacromial impingement, cuff tears, labrum tears and post traumatic stiffness should be considered possible and need a specific evaluation and treatment. Based on localization of the malunion, the treatment can widely vary (Fig. 1) [7,15-19]. However, as with any kind of revision surgery, the treatment of malunion has a higher complication rate and lower functional outcome than treatment of the acute fracture. Preserving or not the humeral head is the main discriminant and when possible the most conservative option is always preferable. Glenohumeral incongruity with osteoarthritis, osteonecrosis or long lasting severe malunion are indications for an arthroplasty. These issues associated associated with a non-functional cuff direct to a reverse shoulder arthroplasty. Alternatively, an anatomical arthroplasty can be associated with the repositioning of the tuberosities when the cuff is healthy [16]. Whenever tuberosities need repositioning, this might look easier than their reduction in trauma surgery. Neyton et al. [22] showed better and faster functional outcomes with a reverse implant than with hemi-arthroplasty. Revision cases are always demanding especially because of soft tissue complications and wide and accurate releases are mandatory especially in arthroplasty. Nevertheless, postoperative instability, though infrequent, is the most common complication due to soft tissue incompetency. A preserved articular surface and a humeral head with intact blood supply are the requirements for surgery which preserves the humeral head. Removal of impingement, soft tissue releases and osteotomies are the head-sparing techniques.

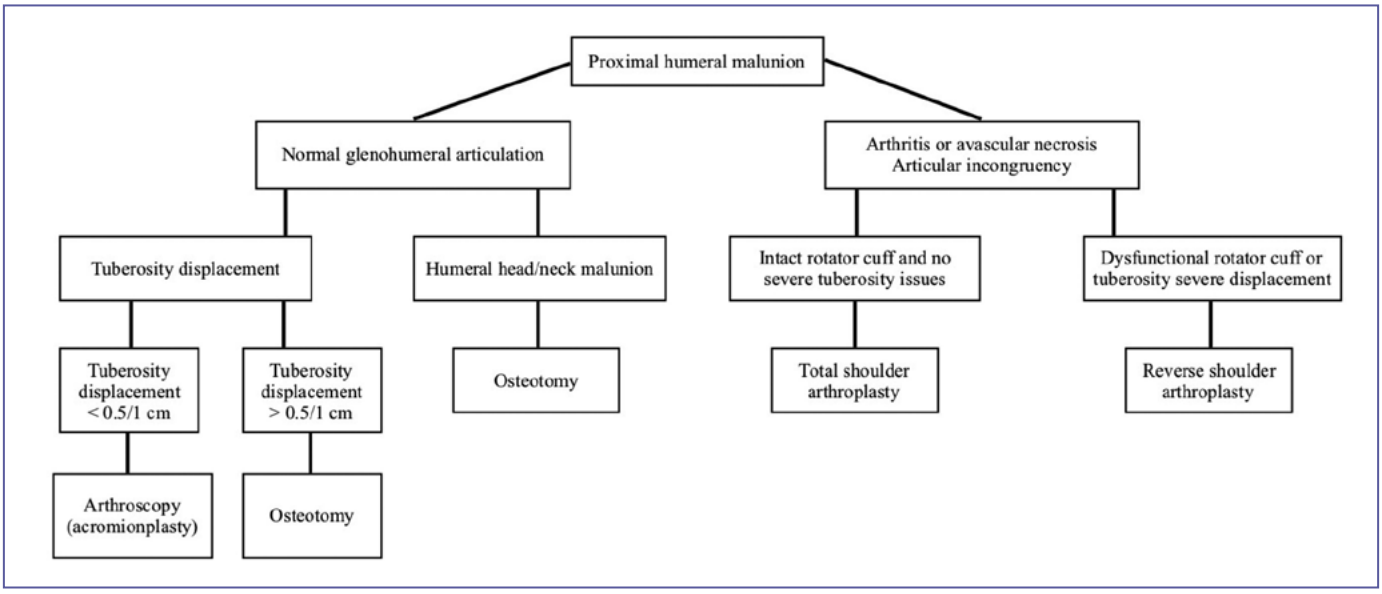

Figure 1. Flow-chart for treatment of malunion.

Arthroscopy is the best option for tuberosity malunions which leads to an impingement as well as for release of soft tissues (bursectomy, capsular release, debridment, acromioplasty). During an arthroscopic procedure it is also possible to carry out additional actions such as heterotopic ossification resection, release of bursa, capsula, labrum, tendon debridemnt, and long head of biceps fixation, to achieve better functional outcomes. In addition, it is also possible to manage simple tuberosity osteotomies in arthroscopy. Laddermann et al. [23] recently described the advantages of using arthroscopy to perform osteotomy and reposition the tuberosity in order to restore cuff tension. However, when the evaluation at the planning stage shows a complex malunion it is necessary to perform an osteotomy in open surgery. When the glenohumeral joint is congruent with no tuberosity malunion, the procedure can and should remain extra articular. Only in these cases a can a single osteotomy at the humeral neck correct rotational defects and some studies have reported good outcomes after an isolated humeral neck osteotomy. Nevertheless, rotational deformity in all planes and osteotomy angle, level, number and size must be extensively and precisely planned before the surgery [18,24,25]. Even if with a small number of patients, Russo et al. [25] reported improvements in pain and function after biplanar and triplanar osteotomies. These procedures require a rigid internal fixation once the realignment is achieved.

Nonunion

The lack of healing of a fractured bone after 9 months of non-operative treatment or a lack of radiograph progression of healing after 3/6 months of surgery corresponds to a malunion. The incidence is not well defined probably because of the many variables in place and the literature reports a frequency between 1.1 and 20% [6,8-10,26,27]. In particular, the rate of nonunion after plating has been described to be as high as 13% [12]. Several factors play a role in the malunion development and are related to both the patient and the fracture type. In fact, severe displacement, poor anatomical reduction, soft tissue interposition and early mobilization along with osteoporosis, female sex, age and smoking are the risk factors described in literature. Specifically, Boesmueller et al. [12] recently reported that the risk for development of nonunion after open reduction and internal fixation was 3.9 higher in heavy smokers. Classification of the nonunion as atrophic or hypertrophic is the main discriminant. It helps identify the factors involved and guide choice of treatment. Lack of biologic response together with excessive stability is accountable for atrophic nonunions. On the contrary, a good healing capacity along with an inadequate stability result in hypertrophic nonunions.

Nonunions are often associated with pain, stiffness, limitations in range of motion and daily living might be compromised. Although some patients can be asymptomatic and a non-surgical treatment can be feasible. Especially in atrophic nonunions an attempt at improving the biologic capacity of healing should be done. Medical therapy, magneto-therapy and growth factors/platet-rich plasma injections can be valuable options. Hypertrophic nonunions require rigid fixation and nearly always these will have a good bone stock. Therefore, the open reduction with a more stable fixation and a fracture freshening is adequate treatment. Joint replacement in hypertrophic nonunions is rare and limited to glenohumeral osteoarthritis.

The literature describes many surgical techniques to treat atrophic nonunion of proximal humerus [8-10,28]. However, there is no consensus upon the optimal technique. Nevertheless, severe cavitation of the humeral head, advanced age and osteoporosis, noticeable avascular necrosis, severe osteoarthritis are direct indications for joint replacement (Fig. 2). Obviously hemi-arthroplasty and anatomical total shoulder arthroplasty are recommended in patients with a preserved cuff, otherwise the choice is reverse shoulder arthroplasty [29]. In cases where there is an acceptable bone stock and no osteoarthritis, an open reduction and internal fixation is the most common indication and leads to variable results. Plates with screws and intramedullary nails can be associated with bone grafts and other growth factors depending on the surgeon preferences. The author's preferred treatment is open reduction and internal fixation with a bone allograft depending on the original biomechanic of the fracture. A femoral head allograft is indicated in low energy fractures and a fibula bone graft (or similar) should be used in high energy fractures. In low energy fractures it is usually the empty space in the metaphyseal cancellous bone that may lead to complications. On the other hand, in high energy fractures medial hinge insufficiency can bring the head to a collapse or in a varus displacement. Furthermore, the authors believe that this solution should be applied in almost all complex and displaced proximal humeral fractures as primary surgery. The use of a femoral head allograft provides both a triangular fragment from its neck to support the medial calcar, as morcellized cancellous bone that can be pressurized to fill any space produced by the meta-epiphyseal collapse. This solution grants support to both the humeral head and tuberosities. Sutures passed in the tendon-bone junction of the cuff, once tightened, close the perimeter of the epiphysis also compacting the restored bone in the center of the humeral head. In high energy fractures a fibula bone graft (or similar) is necessary when the medial hinge (calcar) is damaged. The fibula splint is inserted in both the diaphysis and the center of the epiphysis. Doing so, the lever arm between the screws and a good bone stock point is reduced, limiting the forces in play. The decrease of bending and torsional forces in the system plate-screws-bone lessen the bone reabsorption and loosening of the screws, avoiding progression to a varus displacement. An osteosynthesis with a plate that connects the diaphysis to the epiphysis and counteracts rotational stress is the best option when applicable. In particular, the oblique screw that reaches the medial part of the neck could avoid, when properly

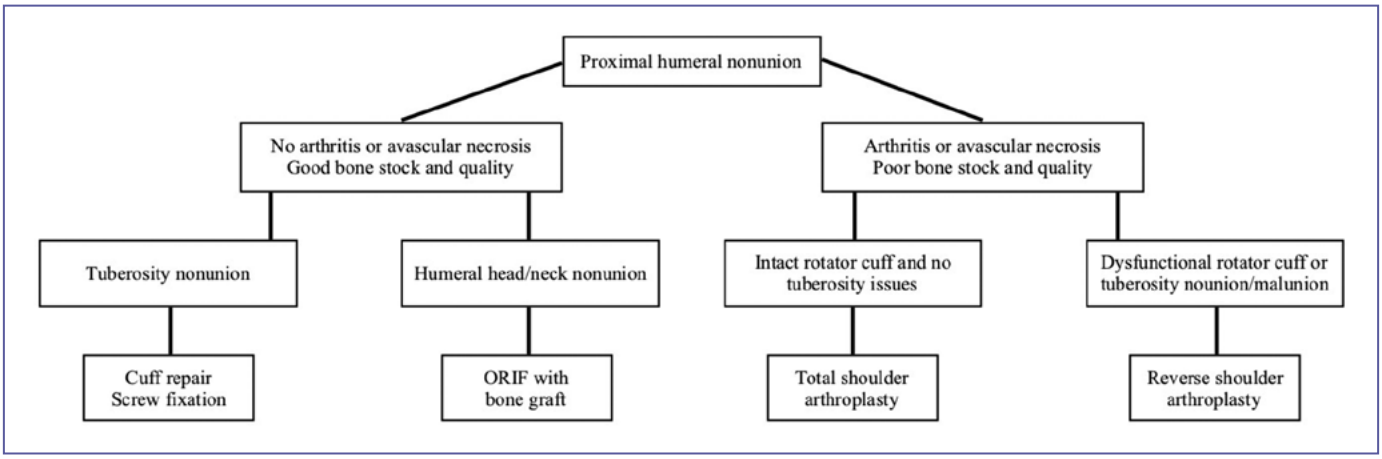

Figure 2. Flow-chart for surgical treatment of atrophic nonunions.

associated with a bone graft, nonunions or malunions related to the collapse or the varus deformity of the humeral head. Following the same biomechanical principles, it is possible to achieve similar results with intramedullary nails. Quadlbauer et al. [28] recently showed, even if in fewer than 10 patients, that open reduction and locking plate fixation without bone grafting in proximal humerus nonunion can also be a reasonable option. Yamane et al. [30] noted a union rate of 100% in a group of 14 patients treated with interlocking intramedullary nail and bone graft. However, recent literature on treatment of nonunion with new generation intramedullary devices is lacking.

The main issue about nonunion in proximal humerus fractures concerns the humeral neck and head, although it is possible that a nonunion occurs at tuberosities. The literature is poor as the majority of the tuberosity nonunions tend to heal and the main issue becomes a tuberosity malunion which is widely more frequent. Pain and significant weakness associated with limitations in shoulder function are the prevalent clinical signs. Treatment, when required, can involve arthroscopic or open surgery. The most anatomical reduction possible along with bone-freshening is mandatory. If the fragment is large enough and has cuff attached it can be fixed with a screw, otherwise arthroscopic cuff repair is indicated.

Conclusions

Nonunion and malunion are relatively uncommon complications. Different techniques are applicable and no gold standard exists. However, bone preservation techniques as well as joint replacement are difficult to manage and should be reserved to experienced surgeons. Extensive evaluation of each specific case must be carried out. Clinical examination along with patient and fracture history need to be associated with complete radiological evaluation (X-Ray, MRI and CT). Pain and shoulder function limitation are the main issues. Some malunions can benefit from conservative treatment, especially in low demanding patients, otherwise surgery is necessary. We recommend open reduction and internal fixation with bone grafting, if suitable, for humeral head/neck nonunions. A non-surgical approach can be an early option in the suspect of a developing atrophic nonunion. Joint replacement is always a viable option even though as a revision surgery it can be extremely challenging and not always associated with acceptable functional outcomes.

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