Malunion of distal humeral fractures: Current concepts

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ABSTRACT

The incidence of complex articular fractures of the distal humeral in adults has increased and will be growing in the future due to the greater incidence of high-energy trauma and to the higher percentage of the elderly population. Successful treatment is challenging for the needed balance between the stability of often comminuted fractures and early motion.

Malunion is a common complication after distal humerus fractures that is influenced by a variety of factors, such as biology, particularly the blood supply of the metaphysis, the nonanatomical reduction of the fracture, the methods of fixation, and mechanical failure. These can involve the intra-articular or extra-articular areas. The clinical presentation may be mainly with pain and instability as for the cubitus varus, or with dysfunction and stiffness as for an intra-articular malunion. However, the symptoms will depend on the degree of articular surfaces damage and the degree of deformities in specific planes. The surgical treatment can be challenging, varying from supracondylar osteotomies and re-contouring arthroplasty for extra-articular deformities to interposition arthroplasty, and elbow replacement for intra-articular deformities.

Current concepts

- Cubitus varus is the most frequent extra-articular distal humeral malunion and is the result of a supracondylar fracture in childhood.
- Numerous osteotomy techniques for treating supracondylar humerus malunions have been described.
- Different surgical options (ulnohumeral arthroplasty, interposition arthroplasty, or elbow prosthesis) are available for patients with intra-articular deformities, depending on the nature and extent of the articular changes, and on patient age.

Future perspectives

- In cases of severe joint destruction that cannot be recovered with conservative procedures, elbow replacement can be considered exposing patients to the potential complications related to the implant, such as mechanical failure or soft tissue issues.
- Recently, hemiarthroplasty has been introduced with anatomical designs that reproduce the trochlea surface with promising results, even though little information is still available from the literature on medium- and long-term follow-up.
INTRODUCTION

Fractures of the distal humerus occur in approximately 1% of all fractures and typically with a bimodal distribution, that is in children and in adults over the age of 60 [1]. The incidence of complex articular fractures of the distal humeral in adults have increased and will be growing in the future due to the greater incidence of high energy trauma and the higher percentage of elderly population [2]. Successful treatment is challenging for the needed balance between a stability of often comminuted fractures and early motion. In addition, the elbow joint has a complex anatomy with three small joints with highly congruent surfaces, which are subjected to strong mechanical forces with long moment arms crossing the articular surface from the forearm to the shoulder, counteracted by the short working length of stabilizing structures [3,4]. This leads to an increased risk of complications after intra- and extra-articular fractures of the distal humerus. Even though their relatively rarity, malunion represents a severe complication influencing remarkably the daily living activities. The risk of malunion is influenced by a variety of factors: biology, particularly the blood supply of the metaphysis, the non-anatomical reduction of the fracture, the methods of fixation, and mechanical failure.

Distal humerus malunion

Malunions of distal humerus fractures occur often following closed-treated fractures and occasionally after open reduction and internal fixation. These can involve the intra-articular or extra-articular areas. Among the extra-articular malunions, the most common deformities are varus malunion and extension malunion. Both are related to elbow deformity at the clinical assessment with or without loss of range of motion. Frequently, different planes can be involved (transversal, coronal, and sagittal planes) with subsequent joint stiffness.

The malunions of intra-articular fractures are related to changes of shape, orientation, and dimension of the trochlea and capitulum humeri. The most frequent deformities are represented by a reduction of the trochlea shape and to the malposition of the capitellum. The intra-articular malunions are typically associated with loss of range of motion in flexion-extension, which severity depends on the extent and nature of the articular surface deformity. Being the elbow characterized by high congruency, these lesions lead to mal tracking of the olecranon and radial head onto the articular surface of the humerus.

EXTRA-ARTICULAR MALUNION

Varus malunion

The malunion of the cubitus varus is the most common cause of deformity following fractures of the extra-articular area in the distal humerus in childhood. Even though the varus represents the most evident deformity, the deformities are observed in the other planes as well, in 80% of these patients [5]. Only 20% of cases had isolated varus deformities, whereas 44% had varus, extension, and rotation deformities [5].

At an average of two to three decades after the injury, these patients start complaining about lateral pain and symptoms of delayed-onset (tardy) posterolateral rotatory instability of the elbow (Fig. 1) [6]. In addition, the spectrum of symptoms may also include snapping of the medial head of the triceps and the ulnar neuropathy. These symptoms are the result of the medial displacement of the mechanical axis of the upper limb with a medialization of the olecranon and triceps insertion [6]. The repetitive and increased stresses on the lateral side of the elbow, especially when coupled with an axial force, as in the attempt to raise from a chair, lead to a significant and progressive attenuation of the lateral collateral ligament [6].

Even though snapping of the medial triceps and ulnar neuropathies must be addressed if present, the most common surgical treatments are represented by the osteotomy with internal fixation and/or ligament reconstruction or retensioning in cases of lateral ligament deficiency. In the landmark paper of 2001, O’Driscoll drew the way for the surgical
management in adult patients with a tardy posterolateral instability [6]. When dealing with low-demand and older patients, ligament reconstruction alone may provide an excellent result with a small (<15°) varus angulation. However, the reconstructed ligament wound will be subjected to a greater stress with this strategy [6]. Conversely, osteotomy alone may be indicated if the posterolateral instability observed is subtle in low-demand patients. Thus, a corrective osteotomy should be performed at the same time when the patient has a varus deformity of >15° [6]. This would protect the reconstructed ligament, restoring a normal valgus alignment, affording a more lasting stability, especially with young and active individuals. Then, the total elbow arthroplasty can be also considered a potential treatment when the varus deformity has determined a significant joint arthritis, even though it’s rare given the symptoms observed in an earlier stage.

When supracondylar osteotomy is planned for the treatment, the patient’s age may play a crucial role in the surgical plan. The adult individuals cannot rely on the great remodeling capacity typical of children. For this reason, the fixation in the adult patients must usually performed with one or even two plates and an eventual bone graft to improve bone union, whereas a less firm stability with pinning can be adequate in growing children [7]. In addition, the reduced remodeling activity may expose more adults to the lateral protrusion of the distal bony fragment-causing a lazy S-shaped deformity, which is evaluated with the lateral prominence index [7].

**Extension malunion**

The extension malunion is the loss of humerus antversion of the distal humerus on the sagittal plane, also known as “gunshot deformity,” and is clinically defined with hyperextension and loss of flexion (Fig. 2).

Two major groups of surgical procedures can be performed in adults: osteotomy and recontouring arthroplasty. To correct the posterior angulation, osteotomies can be considered in cases of high-degree retroversion of the distal humerus with clinical deformity, as previously described. Recontouring arthroplasty can be performed with either open or arthroscopic techniques. The aim of open and arthroscopic procedures is to increase the range of motion and to alter the retroversion of the distal humerus with no change in the clinical aspect. The remodeling procedure must be performed on both sides of the ulnohumeral articulation, following the anterior capsulotomy and the remodeling of the coronoid and radial head fossa, and also on the ulna side to reduce the coronoid apex. Following these surgical steps, an increase in the range of motion can be obtained. Posterior capsulotomy with incision of the posterior band of the medial collateral ligament associated with ulnar nerve neurolysis is an advanced technique to improve range of motion in terms of flexion and to reduce the risk of secondary neuropathy. A radical debridement of the posterior and anterior compartments can be achieved by an open Outerbridge-Kashiwagi operation as a “house-keeping procedure” which includes olecranon tip resection, transhumeral fenestration, and coronoid tip resection [8].

**INTRA-ARTICULAR MALUNION**

Intra-articular malunions involve the articular surface (shape, orientation, dimension, and axis of rotation) of the trochlea and capitellum humeri. The most common intra-articular deformity is secondary to the loss of orientation and dimension of the trochlea shape with or without change in angulation of the rotational axis. Clinically, patients lose flexion-extension range of motion due to the incongruency between the olecranon and the trochlea. If the intra-articular malunion is associated with an extra-articular deformity, the elbow becomes stiff due to the malunion of the three axes within the elbow (diaphyseal, intercondylar, and rotational axes). Imaging studies are useful to assess the status of the articular surface and its deformity. Computer tomography with three-dimensional reconstruction reproduces the elbow joint and allows the investigator to understand the nature of the articular deformity and the alignment between the olecranon and, trochlea, the radial head, and the capitulum humeri. Different surgical options (ulnohumeral arthroplasty, interposition arthroplasty, or elbow prosthesis) are available for this group of patients with distal humerus deformities, depending on the nature and extent of the articular changes and on patient age.

**Surgical techniques for preserved joint congruency with limited articular damage (less than 50%)**

Ulnohumeral arthroplasty can be performed following open or arthroscopic techniques. This surgical procedure is indicated if the articular deformity is not further compromised by severe joint destruction, avascular necrosis, or secondary degenerative changes. (Fig. 3)

The open technique can be performed using a posterior midline skin incision; the ulnar nerve is isolated, and triceps splitting is performed. The posterior compartment is exposed, and the articular bone surfaces of the distal humerus and olecranon are reshaped. The anterior compartment can be exposed using medial and lateral column procedures, and the anterior bone remodeling is then adjusted. Once the bony debridement and remodeling are completed, the anterior and posterior capsules are excised. The arthroscopic procedure follows the same open surgical steps. The standard setups and portals are made. We usually isolate the ulnar nerve through a medial skin incision just above the ulnar nerve groove. Posterior debridement is performed with standard approaches, the capsule is lifted from the bone to create a space and bone remodeling is performed with a 5 mm round burr on both sides of the joint to reduce impingement and maltracking of the ulnohumeral joint. Anterior remodeling is routinely performed using blunt retractors to help with visualization and to protect the nearby neurovascular structures. The
medial capsule can be excised through a medial skin incision performed to isolate the ulnar nerve. The aim of both surgical techniques is to improve the range of motion without altering the articular surface.

Surgical techniques for lost joint congruency with extensive articular damage (more than 50%)

Interpositional arthroplasty is indicated for severe joint destruction or avascular necrosis of the articular surface that involves more than half of the joint surface, or with significant incongruity between the trochlea and olecranon, or between the radial head and the capitulum humeri. (Fig. 4)

The trochlea is usually altered in conformity and size due to the reduction with high compression screws. In these cases, the trochlea needs to be treated with a broad remodeling technique to recover an adequate size and congruency with the olecranon. Following this broad remodeling, the use of interposition tissue can be useful to interpose within the articular joint. Tissues commonly used are the Achilles’ tendon (for allografts) or the fascia (for autografts or allografts). The medial and lateral collateral ligaments can be reconstructed using a

Fig. 3. Preserved joint congruency with limited articular damage (less than 50%). As observed in the x-ray (a) and intra-operatively (b), the articular deformity is not further compromised by severe joint destruction, avascular necrosis, or secondary degenerative changes.

Fig. 4. Lost joint congruency with extensive articular damage (more than 50%). Severe joint destruction of the articular surface that involves more than half of the joint surface, and with significant incongruity between the trochlea and olecranon can be detected in the preoperative x-rays (a, b) and intra-operatively (c).
portion of the tissue grafts. External or internal joint distraction may be applied in conjunction to protect the reconstruction for 5–6 weeks and to allow early mobility [9].

In cases of severe joint destruction that cannot be recovered with conservative procedures, elbow replacement can be considered. Elbow replacement (total or hemi) may be the primary indication for older patients or patients with lower mobility requirements. In selected cases, this strategy offers reliable improvements in pain relief and mobility, even if it exposes patients to the potential complications related to the implant, such as mechanical failure or soft tissue issues.

Recently, the hemiarthroplasty has been introduced with anatomical designs that reproduce the trochlea surface. From our experience, this is correctly indicated in cases of preserved olecranon articular surface and ligaments, but little information is still available from the literature, on medium- and long-term follow-up.

OUTCOMES OF MALUNION

There is limited information about the outcomes of surgical correction of the distal humerus malunions, but most of these procedures have been performed in the young or adult populations with high degrees of varus and retroversion deformity.

A large series of adult patients were surgically treated with different strategies for a tardy posterolateral instability of the cubitus varus has been described by O’Driscoll [6]. On 21 patients at an average three-year follow-up, three elbows had persistent instability, and the results were poor only in two patients who suffered from an associated arthritis [6]. In 2001, the authors observed how the indications for preventive corrective osteotomy remained to be determined [6].

To date, a variety of osteotomy techniques have been described for the treatment of supracondylar humeral malunions, including lateral closing wedge, medial opening wedge, French, dome-shaped, and pentalateral, step-cut osteotomie and three-dimensional osteotomies [7, 10–13]. Even though these have been performed in young or mixed age groups, the clinical results of corrective osteotomies can be different in adults for a reduced remodeling capacity. Thus, the adults are more vulnerable to cosmesis due to lateral protrusion, causing a lazy S-shaped deformity.

Gong et al. reported their experience with twelve consecutive patients treated with lateral oblique closing wedge osteotomy with a larger contact area and stable fixation [10]. The mean age at the time of the surgery was 39 years (range, 31–48 years). The minimum follow-up was 15 months. All patients achieved healing of the osteotomy and regained preoperative arcs of elbow motion at a mean of 7 weeks. The final Mayo Elbow Performance Score (MEPS) and disabilities of arm, shoulder and hand questionnaire (DASH) averaged 95.4 points and 5.5 points, respectively. The conclusion of their report was that humerus osteotomy and fixation with lateral plating is a sound technique for humerus deformities in adults, with early recovery of elbow motion and satisfactory deformity correction [10].

Hahn et al. reported their experience using a corrective dome osteotomy performed on 19 adult patients [12]. The mean age was 31.1 years, and the mean follow-up was 41 months. None of the patients had a recurrence of deformity. An excellent result was achieved in 13 patients and good in 6. They therefore concluded that corrective dome osteotomy with stable fixation is a valid option in cases of distal humerus deformity, especially among adults.

Three-dimensional osteotomies address the varus, internal rotation, flexion/extension, and lateral translation [14]. Chung and Baek recommended this method of 3-dimensional corrective osteotomy for the treatment of cubitus varus in skeletally mature adults; they achieved an humeral-elbow-wrist angle improved from a mean 26 degrees of varus preoperatively to a mean of 3 degrees of valgus postoperatively in 23 adult patients [14]. Lim et al. analyzed the results of 3-dimensional corrective osteotomy in the middle-aged population [13]. Twenty consecutive patients underwent corrective osteotomy at an average age of 47.9 years (range, 41–55 years). The osteotomy was fixed with single plating in 8 patients and with double plating in 12. The average follow-up was 23 months (range, 18–109 months). Osseous union was radio-graphically demonstrated in all patients at an average of 17.5 weeks. Delayed union of fracture was observed in 15 patients (75%). The average time to union in the single-plating group was 21.0 weeks, compared with 15.1 weeks in the double-plating group. Failure of fixation occurred in two patients who had single plating. The average final MEPS was 90.3 points (range, 70–100 points) [13].

Kim et al. have evaluated seventeen consecutive patients treated with translation step-cut osteotomy and fixation with an Y plate [7]. The mean humerus–elbow–wrist angle improved from 14.7 ± 6.4° (range, 6–23°) varus preoperatively to 12.1 ± 6.6° (range, 5–20°) valgus post-operatively (p < 0.001), and the lateral prominence index improved 9.6% from its preoperative value [7]. Other experiences have been reported in the literature with good results in osteotomy healing and useful outcomes in elbow motion and pain relief [15,16].

About intra-articular malunion, McKee et al. reported 13 patients treated with osteotomy and bone graft associated with capsular release [17]. The mean age of patients was 40 years, and the mean follow-up time was 25 months (ranging from 12 to 60 months). According to the MEPS, 2 were excellent, 3 good, 8 fair. All the osteotomies healed with an average range of mobility between 25 and 122° [17].

The outcomes of re-contouring arthroplasty were reported in patients with a lesser amount of extra-articular or intra-articular deformities. Husband and Hastings used this technique on 7 patients with a mean age of 32 years at 38-month follow-up [18]. They were able to recover functional arc of motion in 6 patients with a mean range of 117°. Mansat and Morrey reported 37 patients were treated with the column procedure [19]. At 43 months of mean follow-up, they reported a satisfactory result in 82% of cases, while 89% improved the range of motion with a mean arc of 94°. More recently, Stans et al. reported 37 patients treated with capsular release and bony debridement at 15 months of mean follow-up [20]. They described an improvement in elbow motion in 75% of cases with an average arc of 94°.

Capsular release and bone recontouring can be also performed using either an open or arthroscopic procedures. Most of these cases are analyzed as part of a post-traumatic series, and it is difficult to understand whether the stiffness in the elbow is the consequence of distal humerus malunion from the simple contracture with heterotropic ossifications.

In 2000, Cohn et al. reported their experience with the treatment of osteoarthritis (primary and post-traumatic) in the elbow, comparing open and arthroscopic debridement [21]. The outcome of 18 patients treated by the Outerbridge-Kashiwagi (O–K) open procedure and 26 patients treated by arthroscopic debridement and fenestration of the olecranon fossa were compared at mean follow-up of 35 months. At the end of their study, they found that both procedures were effective, with no major complications. Patients treated by arthroscopic debridement and fenestration achieved better relief of pain, whereas those patients undergoing the O–K open procedure achieved significantly greater improvement in range of motion. In the same years, Kim et al. reported their series of sixty-three patients focused on arthroscopy for limited elbow range of motion [22]. The mean range of motion was 79° before surgery. Patients with post-traumatic stiffness had a more marked reduction in extent and total range of motion (73°) compared to those with degenerative stiffness (86°) before surgery. However, no significant differences were found in the postoperative range of motion (post-traumatic stiffness, 123°; and degenerative stiffness, 121°).

Charalambous and Morrey published a systematic review on the treatment options for post-traumatic stiff elbow [23]. They described how arthroscopic treatment for post-traumatic conditions is a challenging procedure. Good results with improvements in range of motion and daily living activities have been reported in the literature, but the fact that it carries with it a steep learning curve to avoid complications, in particular in the post-traumatic conditions, has to be borne in mind.
In cases of severe intra-articular malunion, interposition arthroplasty represents the alternative to total elbow arthroplasty in young, high-demand patients. Cheng and Morrey reported the outcomes of this technique in 13 patients at 63 months of mean follow-up [24]. They found 62% of satisfactory results based on the Mayo Elbow Performance Index. Four cases were subsequently revised as requiring total elbow arthroplasty. Nolla et al. reviewed 13 patients with severe post-traumatic elbow arthrosis treated with interposition arthroplasty and temporary hinged external fixation [25]. For 11 patients at a mean of 4-year follow-up, the mean arc of flexion improved from 48° before surgery to 110° after surgery. However, four patients had severe instability associated with bone loss of the distal humerus or trochlear notch. Larson and Morrey analyzed forty-five elbows at a mean follow-up of 6.0 years [26]. Excluding seven patients undergoing revision surgery, the mean flexion-extension arc improved from 51° preoperatively to 97° postoperatively (p < 0.001) and the mean MEPS improved from 41 points preoperatively to 65 points postoperatively (p < 0.0001); thirteen patients had a good or excellent result, fourteen had a fair result, and eleven had a poor result [26]. The authors concluded by stating that this procedure is not feasible when patients present with preoperative instability on physical examination [26].

Laubscher et al. observed a high complication rate and a need for revision surgery [27]. In 15 cases out of 18 reviewed at least one reoperation was performed. Seven cases were revised, with four of these to a total elbow replacement, an arthrodesis was performed in two cases, and a re-do interposition was carried out in one case [27].

In the young portion of the population with severe deformity of the articular surface because of post-traumatic lesions, total elbow arthroplasty may be considered as a salvage procedure. In a recent Mayo experience, this indication was correlated with a higher risk of complications and implant failure than the degenerative conditions [28]. The experience, this indication was correlated with a higher risk of complications and implant failure than the degenerative conditions [28]. The authors concluded by stating that this procedure is not feasible when patients present with preoperative instability on physical examination [26].

CONCLUSION

The distal humeral malunion represents a challenging issue, and surgical treatment is necessary for symptomatic patients. Even though better management of pediatric supracondylar fractures have been decreasing the rate of malunion, different and technically demanding osteotomies are often required to correct symptomatic deformities. For intra-articular malunion, elbow replacement may be the treatment of choice when the damage to the articular surfaces is severe and less invasive remodeling techniques are not feasible. In these scenarios, and with younger patients, hemiarthroplasty can play a remarkable role to reduce severe complications and increase implant survivorship as well.

References