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Complications of open reduction and internal fixation of distal humerus fractures

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- Treatment of distal humerus fractures is demanding. Surgery is the optimal treatment and preoperative planning is based on fracture type and degree of comminution.
- Fixation with two precontoured anatomical locking plates at 90º:90º orthogonal or 180º parallel is the optimal treatment.
- The main goal of surgical treatment is to obtain stable fixation to allow immediate postoperative elbow mobilization and prevent joint stiffness.
- Despite evolution of plates and surgical techniques, complications such as mechanical failure, ulnar neuropathy, stiffness, heterotopic ossification, nonunion, malunion, infection, and complications from olecranon osteotomy are quite common.
- Distal humerus fractures still present a significant technical challenge and need meticulous technique and experience to achieve optimal results.

Keywords: complications; elbow; fractures; heterotopic ossification; humerus; infection; malunion; nonunion; ORIF; osteosynthesis; osteotomy; stiffness; ulnar neuropathy

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Introduction

The management of distal humerus fractures is considered challenging and technically demanding, because of the complexity of the regional anatomy and the multifragmentary pattern of injury. Distal humerus fractures in adults have an estimated annual incidence of 5.7 per 100,000[1] and occur in a bimodal distribution. The first peak refers to males aged 12–19 years and usually occurs after high-energy trauma, whereas the second peak occurs in elderly women, with osteoporotic bone, as a result of low-energy trauma and falls. Palvanen et al reported a significant increase in the incidence of these fractures in an ageing population and they found a five-fold increase in the annual number of distal humeral fractures in women older than 60 years.[2]

Open reduction and internal fixation (ORIF) is the treatment of choice for these fractures.[3,4] Achieving rigid internal fixation and anatomical reconstruction by restoring the two columns and the articular surface is essential for allowing early motion, adequate bone healing and avoiding future cartilage degeneration.[5] In young patients, open reduction and internal fixation with plate fixation of both columns is the gold standard. Since the introduction of bi-columnar plating by the AO, a number of implants and fixation methods are available. The decision regarding the choice of implants and fixation techniques is dictated by the fracture pattern and degree of comminution. Precontoured anatomical locking plates, orthogonal plates (90°:90°), or parallel plates (medial and lateral supracondylar ridges) are currently the most popular choices of treatment for distal humerus fractures.[6] However, despite evolution of ORIF techniques for distal humerus fractures, an overall complication rate up to 35% has been reported.[3,7–9]

In elderly patients, the presence of osteoporosis, metaphyseal comminution and poor soft-tissue conditions have resulted in less predictable outcomes.[3,10] This group of patients presents unique challenges and may require different strategies from the traditional treatment regime. Obert et al showed a complication rate of up to 44% in patients over 65 years old after internal fixation, including

neuropathies, mechanical failure and wound dehiscence.[11] Other authors have suggested that in patients older than 65 years, who have sustained a highly comminuted type C fracture, with low bone quality due to osteoporosis, total elbow arthroplasty (TEA) is often considered to be a better choice compared to ORIF;[12] however, the evidence for patient selection, complications, and functional outcomes is contradictory.[13,14] In a recent study by Medvedev et al regarding risk factors associated with postoperative complications, no pre-surgery variables were found to be significantly associated with procedure type between TEA and ORIF. The only predictor with a significant independent association with the composite outcome, regardless of procedure type, was patients with severe systemic disease and American Society of Anesthesiologists (ASA) physical status classification system class 3/4.[15]

In order to choose the best surgical treatment for distal humerus fractures, the risks and complications of internal fixation need to be evaluated. To our knowledge very few studies have focused on complications following treatment of distal humerus fractures with ORIF and there is variability in the literature regarding complications in elderly patients.[16,17] The aim of this study is to provide surgeons with a detailed review of the current literature regarding the short-term and long-term complications after open reduction and internal fixation of distal humerus fractures and their appropriate management.

Mechanical failure

Mechanical failure may occur in up to 7–27% of patients.[10,18,19] Risk factors include poor bone quality, such as osteoporotic or osteopenic bone, complexity of the fracture and bone defects, mechanical properties of plates and screws and postoperative rehabilitation.[11] Poor surgical technique not strictly adhering to principles of stability and fixation is another risk factor. Surgical technique is dependent on the fracture pattern and O'Driscoll described key surgical principles upon which to base operative fixation.[8]

A linear correlation has been reported between bone mineral density and the holding power of screws.[20] Locking compression plates have been used for osteoporotic fractures, as they provide angular stability and theoretically a more rigid construct due to the head-locking mechanism.[21] However, biomechanical studies have shown no significant difference in stiffness between locking and traditional compression plates.[22] Therefore, although fixed angle plates have gone some way to improving fixation in the presence of poor bone stock, loss of fixation in the osteoporotic patient remains a problem.[3] Thus, when ORIF is planned in patients over 65 years old, an elbow prosthesis should also be available in the operating room.[11,20]

Ulnar neuropathy

Ulnar neuropathy as a complication of distal humerus fractures, preoperatively and/or postoperatively, has been reported with a magnitude ranging from 0% to 51% with an average of 13%.[3,21–27] This can occur either at the time of the injury, intraoperatively, secondarily to postoperative immobilization, due to swelling, to scar tissue development and thickening in the fibro-osseous tunnel, or due to hardware irritation. However, the true incidence of ulnar nerve dysfunction after elbow injury is unknown, since studies have not effectively distinguished acute injury-related, acute surgery-related, and delayed ulnar neuropathies and, moreover, in most of these retrospective studies careful evaluation of ulnar nerve function with strict definitions and objective measures has not been included.[28] Vazquez et al examined 69 patients without preoperative ulnar nerve injury or neuropathy and reported that 10% of the patients had immediate postoperative ulnar nerve dysfunction. The incidence of nerve dysfunction at one-year final follow-up was 16%; however, 64% of these patients did not have immediate postoperative symptoms.[26]

The optimal intraoperative handling of the ulnar nerve, in situ release or anterior transposition, during ORIF of distal humeral fractures in patients with normal preoperative findings on neurological examination, remains an unsettled issue. It seems that anterior transposition of the nerve does not decrease the development of ulnar neuropathy after ORIF.[23,26,29,30] Shin et al found a 22% rate of postoperative ulnar nerve palsies despite performing adequate release and nerve transposition in most patients. When the nerve impinged upon the medial plate during elbow motion, irritation and transient sensory changes were noted. However, despite the high rate of transient ulnar nerve palsies observed in their study, no patient suffered permanent nerve dysfunction.[31]

In a recent retrospective study, 82 patients with a mean age of 62 years were treated with ORIF for distal humeral fractures without ulnar nerve transposition or mobilization. The proportion of ulnar nerve dysfunction was equally common regardless of the use of bilateral plates or a single ulnar plate on the medial column or a lateral plate, and there was no significant difference in ulnar nerve dysfunction between those operated on with or without an olecranon osteotomy. Ulnar nerve affliction, in most cases regarded as mild, was experienced by 22 patients (27%) and was significantly associated with multiple surgeries.[30]

Some authors not only state that anterior transposition of the ulna nerve does not reduce the incidence of ulnar neuropathy, but on the contrary they found that it actually increases it. In a recent meta-analysis, Shearin et al used an electronic database to identify retrospective

studies involving surgical fixation of distal humerus fractures. Only five trials met the authors' inclusion criteria, totalling 362 patients. An overall incidence of 19.3% for ulnar neuropathy was reported. In patients who underwent in situ release, the incidence of ulnar neuropathy was 15.3%, whereas in patients where anterior transposition was utilized, there was a 23.5% incidence.[32] However, in a level II study, Ruan et al examined 29 patients suffering from distal humeral fractures with preoperative ulnar nerve symptoms and compared anterior transposition to in situ decompression. They found a statistically improved rate of complete ulnar nerve recovery (80%) in the anterior transposition group, compared to in situ decompression alone (57%).[25] Perhaps the preoperative or postoperative status of the ulnar nerve plays a role in decision-making regarding the handling of the ulnar nerve during ORIF of distal humerus fractures.

In patients with postoperative ulnar neuropathy after ORIF of the distal humerus, ulnar nerve neurolysis seems to be an effective treatment. McKee et al evaluated the outcome of 21 patients who developed ulnar neuropathy after treatment of distal humeral fracture, requiring subsequent neurolysis. They found that 17 of 21 patients had good or excellent results with return of intrinsic power and high patient satisfaction.[24] However, the results are not always optimal and ulnar nerve affliction is significantly associated with multiple surgeries.[30]

Taken as a whole, current research has not proved the need for routine anterior transposition when treating distal humeral fractures. Further research and randomized prospective controlled studies with strict definitions and objective measures are necessary to more accurately address this issue.

Heterotopic ossification

The incidence of heterotopic ossification (HO) after ORIF for distal humerus fractures varies widely and has been reported to range from 0% to 49%.[17,33] However, pooled analysis of data from a number of studies show an overall prevalence of 8.6%.[34–36]

Several risk factors have been reported in the literature, including concomitant head and central nervous system injury,[37] delayed internal fixation,[33] use of bone graft or substitute, extended postoperative immobilization, method of fracture fixation and number and position of the plates.[38] Some studies have found that a delay in treatment of greater than 48 hours increases the rate of HO from 0% to 33%.[39,40] Similarly Kundel et al reported an increase in the rate of HO from 29% to 80% when surgical treatment was delayed by more than 24 hours, which was also associated with significantly worse range of motion (ROM) and function.[33]

In their retrospective study, Abrams et al noticed that HO was radiologically visible two weeks after surgery in 86% of patients who finally developed HO. The authors suggested that a more favourable outcome was observed in cases with no early radiographic findings.[41] In most patients, HO does not cause functional deficits[17,31,33] and resection is not always necessary.[42] However, in some cases HO can cause important limitations in elbow motion and function.[36]

The routine use of indomethacin for prophylaxis after ORIF of distal humerus fractures remains controversial with some authors recommending prophylaxis in patients with the aforementioned risk factors.[36] Gofton et al retrospectively reviewed the prevalence of HO in two groups of patients with distal humeral fractures who were treated with ORIF. In the first group (n = 12) prophylaxis had not been used, whereas in the second group patients received indomethacin for six weeks (n = 23 patients). Five out of 12 patients in the first group developed HO, whereas only two of the 11 who received prophylaxis did. While there was no statistically significant difference between the two groups due to the small number of patients evaluated, the study was likely underpowered to detect a clinically relevant difference in the development of HO.[43] Regarding the routine use of anti-inflammatory drugs for prevention of HO, Shin et al used an initial dose of radiation therapy on postoperative day one, followed by two weeks of indomethacin. The authors reported a rate of symptomatic HO of 3% with a nonunion rate of 6%.[31] However, Liu et al used six weeks of celecoxib and reported a 3% rate of clinically symptomatic HO with no nonunions.[44] Consequently, potential benefits of prophylaxis with nonsteroidal anti-inflammatory drugs (NSAIDs) against HO must be weighed against the potential risk for increased nonunion rates.[45]

Regarding the management of clinically significant HO (severe limitation of motion with flexion to extension ≤ 100º) excision should be considered within six to nine months after injury, thus limiting future degeneration of articular cartilage of the elbow. Maturation is usually achieved within four months of injury and can be assessed with serial radiographs which are useful indicators of the appropriate time to intervene. Serum alkaline phosphatase levels and activity on technetium bone scans are no longer believed to be helpful. Ring et al recommended a posterior incision to completely remove HO, beginning at the margin of the olecranon process and distal humerus, while preserving the ulnar nerve and the collateral ligaments.[46] Following surgery, prophylaxis against recurrence should include continuous passive motion and indomethacin or low-dose radiation.[47]

In conclusion, the literature regarding the risk factors and functional implications of HO is sparse, and the underlying mechanisms of ectopic bone formation are

poorly understood as well as the indications and methods of prophylaxis. There is currently insufficient evidence to recommend routine prophylaxis against HO after ORIF of distal humeral fractures.

Elbow stiffness

Stiffness is the most common sequela after ORIF of distal humeral fractures and is often observed even after optimal stable fixation and proper rehabilitation. Sanchez-Sotelo et al treated 34 complex distal humeral fractures with the parallel plate technique and reported only 41% of elbows obtained at least 30° of extension and 130° of flexion.[34] While some authors reported that about one-third of patients failed to regain functional arc of motion after ORIF of intercondylar fractures, most patients can expect to have good to excellent results.[48,49]

Loss of elbow motion can arise from intrinsic or extrinsic causes such as malunion, nonunion, incongruity or articular surface, capsular fibrosis, anterior and/or posterior capsule adhesions, adhesions to the triceps or brachialis muscles, intra- or extra-articular osteophytes, callus formation, HO, prolonged postoperative immobilization and prominent hardware.[50] Several retrospective series have highlighted the importance of early mobilization within 14 days for satisfactory functional outcome.[3,4,34,51]

Surgical treatment of elbow stiffness is highly specialized and can be treated by arthrolysis and contracture release, arthroscopic or limited open release. Open release of elbow stiffness is more effective when HO obstructing motion is removed compared to when there is capsular contracture alone.[52] More complex cases of stiffness after ORIF for distal humerus fractures can be treated using open arthrolysis and hardware removal, when the screws and plates restrict motion. However, re-fracture after release may occur during the postoperative rehabilitation programme.[53]

Nonunion

Nonunion after ORIF of distal humerus fractures has been reported to be between 2% and 10%[54] with many cases involving the supracondylar region. Modern studies of dual plate fixation have demonstrated union rates ranging from 89% to 100%.[4,35] However, failing to adhere to the principles of rigid fixation with a plate on each column can dramatically increase nonunion rates by up to 75% (Fig. 1).[54,55] In other cases, high-energy trauma, high comminution and poor bone stock in geriatric patients were cited as reasons for nonunion. Particularly in elderly patients, fracture union rather than motion is the first priority, because motion can be restored by later contracture release if the fracture heals.[20] Although nonunion may not be a common complication, when present it can severely compromise the patient's quality of life.[47]

Nonunion usually requires technically challenging procedures such as revision of internal fixation, autogenous bone-grafting and aggressive contracture release (Fig. 2). In difficult cases external fixation of the elbow, fibular strut grafts or TEA may be considered as viable alternatives.[55] Computed tomography (CT) scan or a CT arthrography preoperative must be performed to identify intra-articular injuries that could be excised arthroscopically or in an open procedure. Helfet et al analysed the results of 52 surgically treated nonunions and they noticed that 75% of these were the result of unsuccessful internal fixation. Fifty-one of the 52 patients (98% union rate) accomplished union after revision ORIF, with an average time to union of six months. Furthermore, they suggested that elbow stiffness which frequently accompanies nonunions must be addressed during the revision surgery.[54] Failure to release the elbow contracture results in increased forces across the nonunion site and eventual failure of the construct. Ring et al reported the results of treatment of 15 patients with a nonunion of the distal humerus. Revision surgery, joint contracture release and bone grafting led to a successful outcome with an average arc of ulnohumeral motion of 95 degrees, while most of the patients reported only mild pain.[55] Jupiter reported that in cases with nonunion after surgically treated distal humerus fractures, ulnar nerve dysfunction can be significant due to scar formation encasing the ulnar nerve. Therefore, ulnar nerve exploration and transposition was recommended.[56]

Although revision ORIF and elbow contracture release is ideal for young active patients, some patients may benefit from a TEA. Ramsey et al reported on 16 patients treated with a semi-constrained TEA for an unstable distal humeral nonunion. They recommended this treatment should be considered for patients older than 60 years as well as for younger patients with significant bone loss.[49] However, in a recent study, Cha et al reported the clinical and radiologic outcomes of open reduction and internal fixation for nonunion of extra-articular distal humeral fractures in 28 patients aged 70 years or older, in whom conservative treatment had failed. The authors stated that ORIF could be recommended as the primary option even in elderly patients aged 70 years or older.[57]

Regarding which method of plating, orthogonal or parallel, is more predisposed to nonunion, Shin et al compared these two different double-plating methods for intra-articular distal humerus fractures. Seventeen patients were treated with perpendicular plating (group I) and 18 with parallel plating (group II) methods. Although the incidence of nonunion was statistically insignificant between groups, two patients in the perpendicular plating group developed a nonunion, while all fractures in the

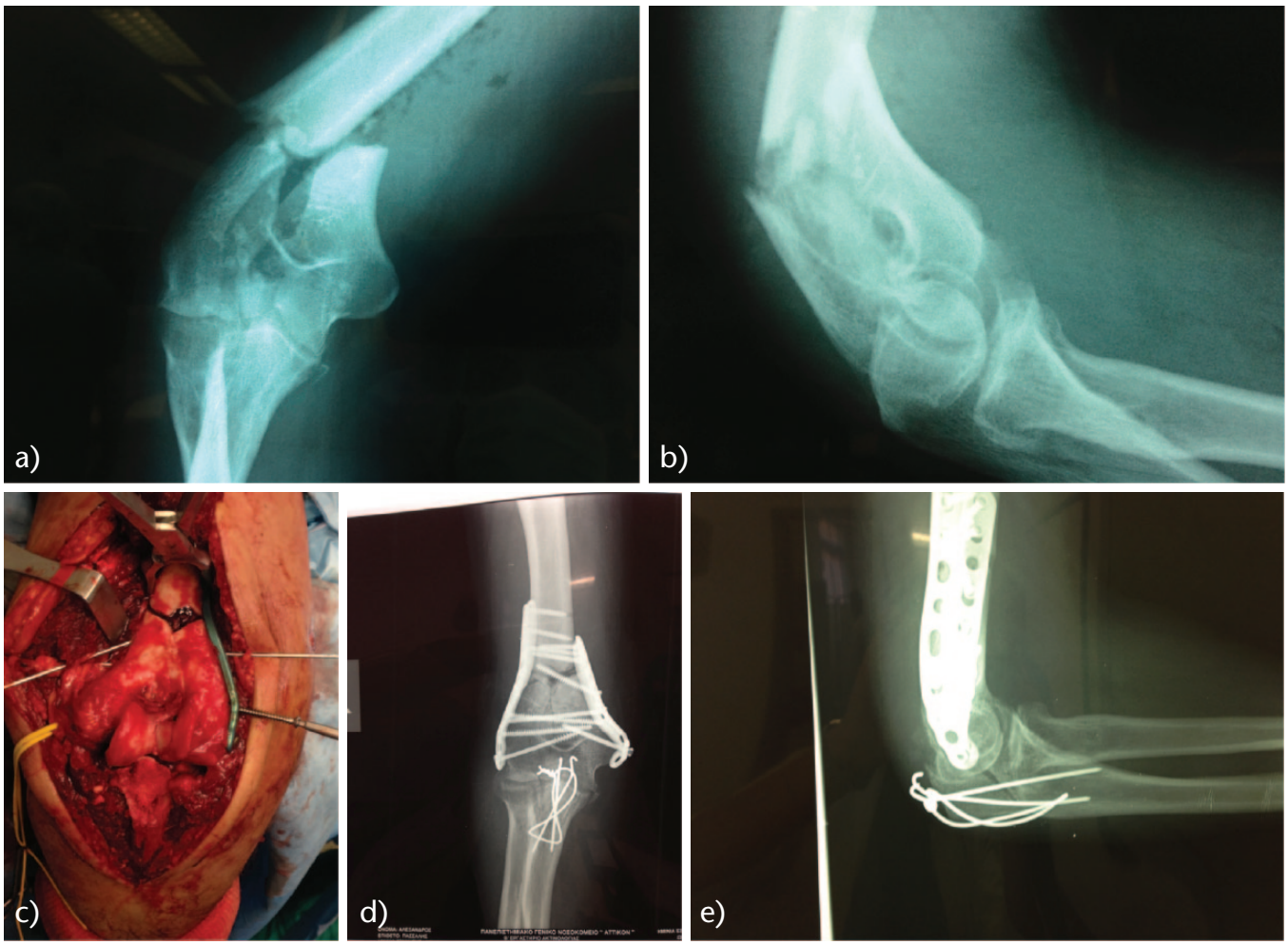

Fig. 1 Fracture of the distal humerus in 52-year-old female treated with ORIF (double plating) with no proper surgical technique. **A**: anteroposterior radiograph of the distal humerus showing supra and inter-condylar fracture with comminution and **B**: lateral radiograph of the distal humerus showing supra and inter-condylar fracture with comminution. **C**: intraoperative image of the distal humerus fracture showing a gap in the metaphyseal area. **D**: anteroposterior radiograph of the elbow and **E**: lateral radiograph of the elbow seven months postoperative showing nonunion in the supracondylar area. The ulnar-medial plate is too short. The olecranon osteotomy is stabilized with tension-band technique; however, it is insufficiently fixed and not compressed.

parallel plating group healed without nonunion or hardware failure, even in elderly patients. These two patients were successfully treated with conversion to a precontoured parallel plate system and autogenous bone grafting. Therefore, the authors stated that both parallel and orthogonal plate positioning can provide adequate stability and anatomic reconstruction for distal humerus fractures.[31]

Parallel plates are considered to increase stability in the metaphyseal area, as they enable long screws to be inserted transversely from lateral to medial at the epiphyseal level, which increases screw purchase. Moreover, it has been postulated that repetitive varus deforming forces across the elbow in daily activities place the lateral column under tension and distract it away from any fixation point along its posterior surface. Furthermore, in orthogonal plating position, the number of screw fixations in the distal lateral column is often limited to one or two short screws passing through the plate from posterior to anterior. This may reduce the screw-holding strength of lateral distal fragments.[31] According to O'Driscoll, a disadvantage of the orthogonal plating technique is the weak fixation of the distal fragment to the humerus shaft.[8] Similarly, Sanders et al also emphasized that the lateral plate is better applied in the sagittal plane as a primary stabilizer, as the lateral column is larger than the medial column.[58]

Regarding elderly patients with poor bone stock prone to nonunion, systemic anti-osteoporotic treatment has become a significant part of fracture treatment.[59] However, further studies are needed to clarify the correlation

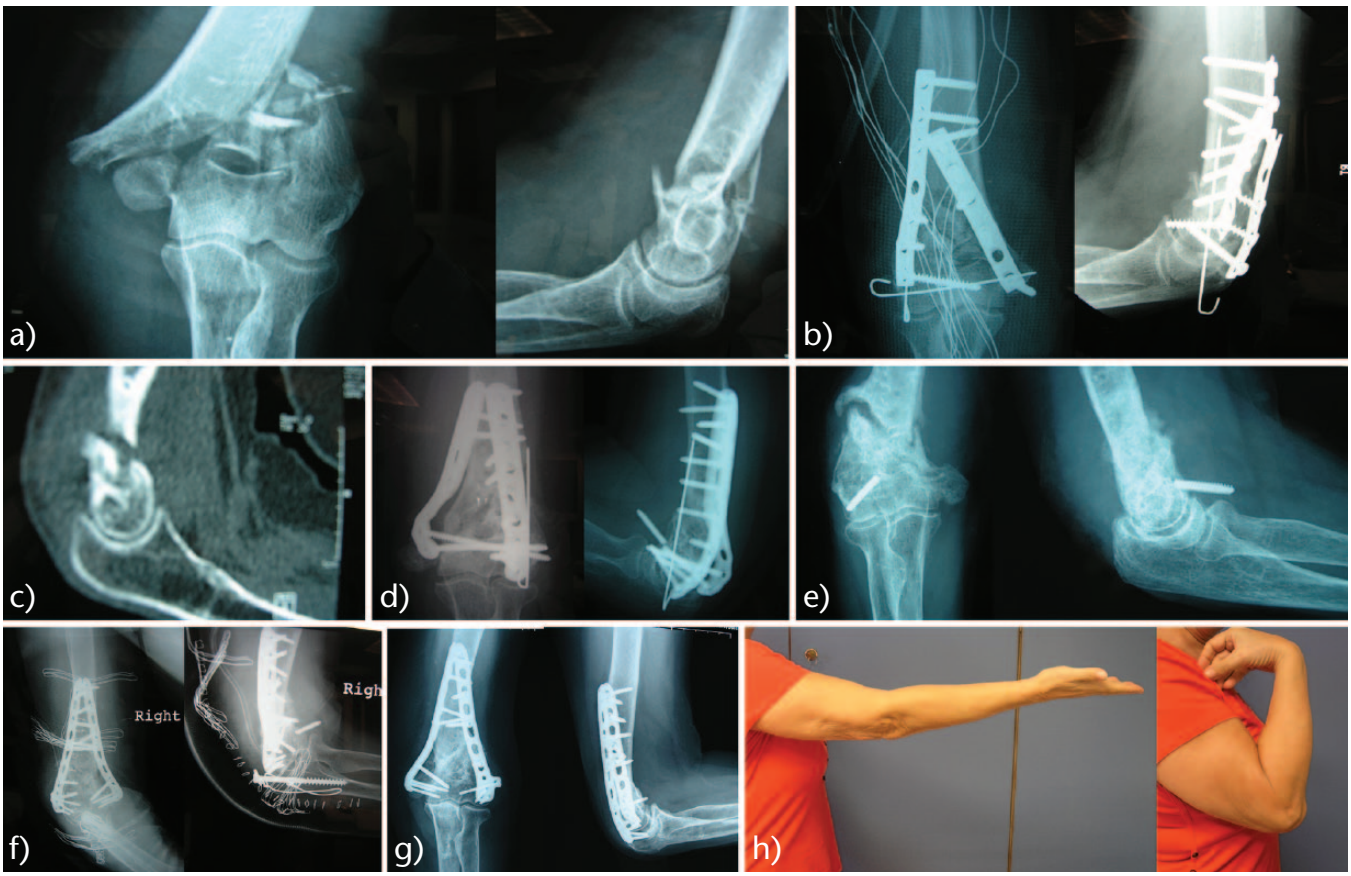

Fig. 2 Fracture of the distal humerus with severe comminution in 48-year-old female after a car accident. **A**: anteroposterior and lateral radiographs of the right elbow. **B**: anteroposterior and lateral radiographs of the elbow showing unstable osteosynthesis of the fracture (poor surgical technique) with two one-third tubular plates and a K-wire without olecranon osteotomy. **C**: CT-scan of the elbow eight months postoperative showing nonunion in the supracondylar area. **D**: second operation using two anatomic locking plates, without olecranon osteotomy. **E**: anteroposterior and lateral radiographs of the elbow showing nonunion in the supracondylar area. **F**: anteroposterior and lateral radiographs of the elbow after a third operation with two anatomic precountour locking plates, bone graft and olecranon osteotomy. **G**: anteroposterior and lateral radiographs eight months postoperative showing union at the supracondylar area. **H**: range of motion of the right elbow, with lack of extension (10º) and full flexion.

between bone healing pathways and systemic anti-osteoporotic treatment regimes.

Malunion

Malunion is one of the most frequent complications (30%) of distal humerus fractures that have been treated conservatively, whereas it is encountered less frequently following ORIF of these fractures.[60,61] Malunion of the distal humerus can be either extra-articular or intra-articular. The extra-articular type is treated with humeral osteotomy and fixation, whereas the intra-articular, due to lack of anatomical restoration of the joint surface, is more challenging to treat. An intra-articular distal humerus malunion is a disabling condition which presents with stiffness, pain, posterolateral rotatory instability, ulnar nerve palsy, weakness, deformity, post-traumatic osteoarthritis and an increased risk of lateral condylar fractures due to the malunion.[62] Knowledge of treating intra-articular malunited fractures of the distal humerus is sparse as there are not enough reports in the literature.[61,63] Intra-articular corrective osteotomy should mostly be considered for young patients who present with moderate to severe functional disability and/or pain and secondary post-traumatic arthritis at an early stage.[61] The goal of treatment is to restore the articular anatomy in order to improve range of motion, relieve pain and enhance stability in active young patients. Alternatively, in low-demand elderly patients, TEA for malunion of the distal humerus may be a treatment option.[64]

Infection and wound complications

The incidence of wound complications after fixation of distal humerus fractures is substantial, with significant

morbidity. The elbow is at risk for serious wound complications after surgery because of significant soft tissue damage, its relatively thin soft tissue envelope, postoperative swelling, and shear forces occurring when early motion is commenced.[65] Infection should be suspected in any patient with persistent drainage and delayed union or nonunion of the fracture.

Open distal humerus fractures Gustilo grade III, as well as the use of a plate construct to stabilize the olecranon osteotomy, are considered to be significant risk factors for wound complications. However, fracture healing rates and elbow range of motion do not appear to be affected by wound complications when they are handled with proper soft tissue coverage technique. Lawrence et al studied 89 distal humerus fractures (mean patient's age, 58 years) which were treated with internal fixation. Fourteen patients (15.7%) developed a major wound complication requiring on average 2.5 (range, 1–6) additional surgical procedures. Six patients required plastic surgical soft tissue coverage with flexor carpi ulnaris flap or radial forearm flap. The great majority of wound complications in this study were successfully treated with debridement and primary or delayed wound closure. All 14 fractures complicated by wound problems united.[66]

Athwal et al reported on a series of 32 type C distal humerus fractures fixed with parallel plates, of which two (6%) developed a superficial wound infection and another two required a radial forearm flap.[67] Furthermore, in a review of 34 fractures fixed with parallel plates, Sanchez-Sotelo et al identified three patients (9%) who underwent additional surgical procedures for wound-related complications.[34] In another study, Kundel et al documented minor wound complications in 8 of 99 patients (8%) and more serious infections in 10%.[33]

Few studies have investigated the management of this uncommon but challenging complication. Serial debridements with preservation of internal fixation are an effective treatment of acute non-aggressive infections. However, if multiple debridements and systemic antibiotics fail to treat the infection, implants should be removed and a more thorough debridement should be performed.[68]

Failure of olecranon osteotomy

Olecranon osteotomy is considered the best method for visualization and accurate reduction of complex intra-articular fractures, although some investigations have revealed that patients treated using olecranon osteotomy achieved less favourable clinical results than those treated using an olecranon sparing approach, because of the additional hardware required for secure fixation.[69] Complications of olecranon osteotomy include hardware failure, nonunion, malunion and skin irritation because of the prominent implants. Future need for implant removal and potential limitation of a future arthroplasty are other issues to be considered. The incidence of complications associated with this technique ranges from 0% to 31%.[70–72]

Nonunion and symptomatic implant prominence are the most commonly cited complications in the literature. Olecranon osteotomy often necessitates more time to achieve bone healing than the distal humerus fracture itself, possibly because of the ulna's distinctive blood supply.[73] The rate of nonunion is reported to reach 11.9%.[7] A significant increase in complications regarding the tension band construct was recognized suggesting that a plate construct may be preferable.[7,74] Coles et al investigated the outcome after 70 olecranon osteotomies fixed with either a screw, tension band or plate fixation and found no nonunions; however, 8% of patients required an isolated implant removal for symptomatic irritation.[70]

Minimally invasive exposure, such as the paratricipital 'windows' approach for fractures with limited articular involvement with triceps attachment and indirect reduction, or the Bryan and Morrey triceps reflecting technique, generally showed lower rates of postoperative complications with a statistically significant reduction in procedure times, blood loss and complication rates, and improved Mayo Elbow Performance Score (MEPS) outcomes as well as shorter rehabilitation time while maintaining the benefits of a wide exposure.[8,75]

Conclusion

Open reduction with dual parallel or orthogonal locking anatomical plates is considered the gold standard for the treatment of distal humerus fractures. However, high complication rates, even in young patients, after internal fixation remain a main concern, highlighting the need for meticulous technique and experience, which maximizes fixation and stability in the distal segments, as well as allowing early elbow motion and achieving satisfactory results. Risk factors for mechanical failure include poor bone quality, complexity of the fracture, bone defects and postoperative rehabilitation. Ulnar neuropathy may occur either preoperatively or postoperatively, with no clear evidence to prove the need for routine anterior transposition. Regarding HO, there is currently insufficient evidence in the literature to recommend for routine prophylaxis against it. Elbow stiffness is the most common sequela after ORIF of distal humeral fractures and is often observed even after optimal stable fixation and proper rehabilitation. Surgical treatment of elbow stiffness is highly specialized. Nonunion, malunion, infection, wound problems and problems with olecranon osteotomy are not so rare complications that need to be addressed when treating distal humeral fractures.

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