Current Concepts Review - Fractures in the Region of the Elbow

Současný pohled na zlomeniny v oblasti lokte

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SUMMARY

Elbow injuries continue to rise with increased athletic activity and life expectancy.

Knowledge of anatomy and biomechanics of this sophisticated joint, various injury patterns, and the implication of injury to the static and dynamic stabilizers will result in improvement in specific diagnosis, and therapy. The surgical treatment of trauma to the adult elbow has evolved rapidly in recent years and many useful concepts and techniques have been established.

This paper reviews the published scientific data and current opinion available to guide patient care.

DISTAL HUMERUS

Epidemiology

Although fractures of the distal part of the humerus are rare in adults, there has been a substantial increase in their number and incidence (62).

These injuries occur in a bimodal distribution. Fractures that occur in physiologically young patients are usually the result of high-energy trauma and are often complicated by open wounds, other ipsilateral upper extremity injuries, and general systemic injury. A second peak is seen in the elderly population, especially women, as a result of low-energy falls (62).

These fractures are characterized by poor bone quality and may be associated with poor general health or preexisting arthritic changes.

Classification

An ideal fracture classification scheme has yet to be developed for the distal humerus. The most commonly used classification is the Orthopaedic Trauma Association/Arbeitsgemeinschaft fuer Osteosynthesefragen (OTA/AO) classification system (49).

The three main categories—types A, B, and C designate extra-articular (A), partial articular (B) and intra-articular fractures (C) in which the articular surface is completely dissociated from the shaft of the humerus. These three types are subdivided with use of the numbers 1, 2, and 3 to indicate increasing degrees of comminution or to further define the location of the fracture.

The drawback of this classification in its current form is that it lacks distinction of important elements such as the height of the columnar injury or the presence of a coronal component to the articular fracture, which will influence the operative tactic and possibly the prognosis.

Clinical assessment and radiography

The clinical evaluation of a patient with a distal humeral fracture should comprise careful assessment of the ipsilateral shoulder and wrist, examination of the skin for open wounds, which most commonly occur on the posterior aspect (43), and a detailed neurovascular examination. The prevalence of incomplete ulnar neuropathy at the time of injury has been reported to be as high as 25% (15, 65).

Computed tomography (CT) scanning can be helpful for classification and preoperative planning in the setting of articular comminution.

Assessment of the fracture pattern and preoperative planning seem to be improved when the CT scan is obtained with three-dimensional reconstruction (8).

Nonoperative treatment

The majority of patients with fractures of the distal humerus should be encouraged to undergo operative treatment.

Nonoperative management is reserved for completely undisplaced fractures, patients who are unable to tolerate anesthesia, and those with advanced dementia.

Operative treatment

Early management is preferable and outcomes are reported to be better with fewer complications for patients who are managed within 24 hours (34)

Surgical approach

Most surgical procedures on the elbow can be done through a longitudinal dorsal incision that will safely permit the elevation of broad skin flaps and provide extensile exposure of both medial and lateral sides of the elbow. We recommend avoiding the tip of the olecranon because of the potential for skin-wound healing problems in that region.

The ulnar nerve should be isolated and protected. It is advisable to mobilize it over a sufficient distance of at least 6 cm proximal and distal to the cubital tunnel to permit the nerve to rest in the subcutaneous tissues anteromedially to the cubital tunnel. Osteotomy of the olecranon (Fig 1) provides excellent exposure of the articular surface and columns of the distal humerus (7, 57).

Problems with the creation and repair of an olecranon osteotomy have led many surgeons to favor alternative exposures of the distal humerus that elevate the insertion of the triceps and then reattach it (43, 54) .

It is our impression that many of these complications are related to technique and we have used the approach reliably and with limited complications for the exposure of fractures and nonunions of the distal humerus (57).

A straight posterior incision is used and medial and lateral skin flaps are elevated, with care taken to protect

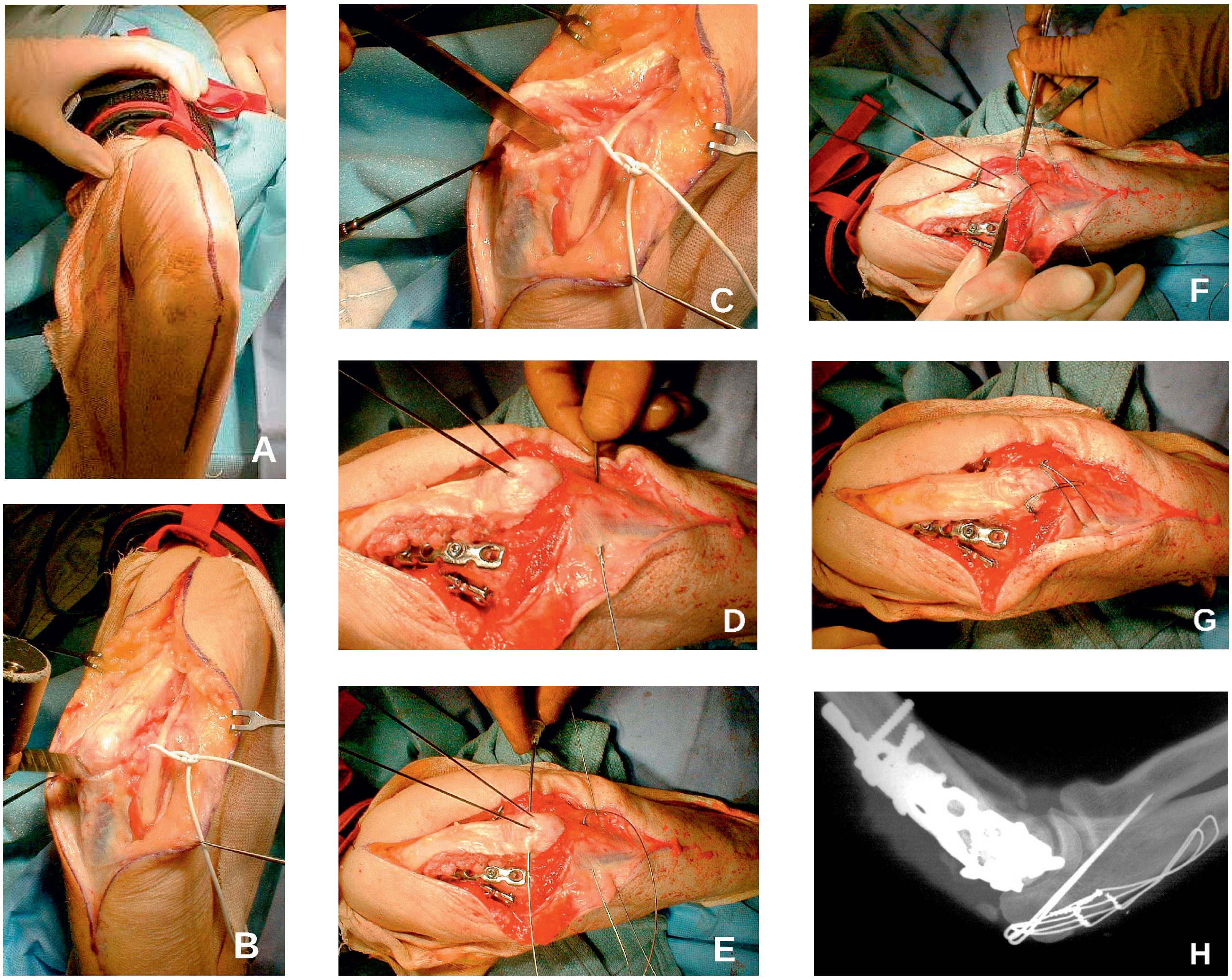

Fig. 1. Technique for olecranon osteotomy and repair.
A – *A straight posterior incision is used.* **B** – *A chevron-shaped osteotomy is planned and initiated with an oscillating saw.* **C** – *The osteotomy is completed using an osteotome. Levering open the subchondral bone and articular surface creates an irregular surface that can facilitate repositioning by interdigitating.* **D** – *Two 0.045-inch Kirschner wires are drilled obliquely across the osteotomy site so that they exit the anterior ulnar cortex distal to the coronoid process. Two drill holes are made through the dorsal apex of the diaphyseal ulna distal to the osteotomy site, and 22-gauge stainless steel wires are passed through using a needle.* **E** – *Using a needle, each wire is then passed through the triceps insertion proximal to the Kirschner wires.* **F** – *The wires are tensioned on both ends. It is neither necessary nor possible to tension the 22-gauge wires tightly. It is sufficient to take the slack out and twist the wires until they contact the olecranon. The Kirschner wires are bent 180° and trimmed. The bent tips of the Kirschner wires can then be turned and impacted into the olecranon.* **G** – *The wires are very low profile with the Kirschner wire tips impacted into the olecranon beneath the triceps insertion.* **H** – *The final radiograph shows the Kirschner wires exiting the anterior ulnar cortex and impacted into the olecranon proximally.*

cutaneous nerve branches and keep them within the skin flaps. The ulnar nerve is identified along the medial border of the triceps, dissected, and left in an anteriorly transposed position in the subcutaneous tissues.The insertion of the anconeus onto the proximal ulna is partially elevated and an apex, distal, chevron-shaped osteotomy is planned so that it enters the joint at the depths of the trochlear notch. The osteotomy is initiated with a thin oscillating saw and completed with a small, straight osteotome. This maneuver creates an uneven surface that facilitates repositioning and may enhance stability.

The posterior elbow capsule is then incised, and the olecranon fragment and triceps are elevated from the posterior aspect of the humerus.

A tension band wire construct can be used to fix the osteotomy.

Two parallel 0.045inch smooth Kirschner wires are aimed into the anterior cortex of the ulnar shaft distal to the coronoid process to minimize the potential for proximal migration of the Kirschner wires. Two 20-gauge wires are threaded through separate holes on the ulna and tightened on both sides of the osteotomy to ensure symmetric tensioning. The tips of the Kirschner wires are bent under the triceps insertion and impacted into bone.

In posteriorly open fractures, a triceps-splitting approach showed improved results compared with olecranon osteotomy (43). In this situation, olecranon osteotomy further disrupts the integrity of the extensor mechanism. The triceps aponeurosis and medial head are split in the midline. Dissection does not cease at the tip of the olecranon, but continues along the proximal one quarter of the ulna with dissection of the triceps insertion off the proximal ulna medially and laterally. At the conclusion of the procedure, the triceps is repaired back to the proximal ulna with interrupted, nonabsorbable suture through osseous drill holes.

The triceps-reflecting anconeus pedicle (TRAP) approach offers extensile surgical exposure of the distal humerus without the need for olecranon osteotomy (54). The distal humerus and proximal ulna are exposed subperiosteally, and a triceps and anconeus flap is created and mobilized proximally to allow visualization of the distal humerus. Advantages of this approach include preservation of the anconeus as a dynamic stabilizer of the lateral aspect of the elbow and the ability to convert to total elbow arthroplasty should the need arise.

Plate fixation

The main objective of effective operative treatment of distal humerus fractures is to obtain anatomical reduction of the articular surface and a stable fixation to allow for early postoperative functional treatment.

Double-plate osteosynthesis using conventional implants has tested well clinically (53, 59). However, stable fracture fixation can be difficult to achieve in the presence of metaphyseal comminution or diminished bone quality and implant failures and nonunions are still frequent occurrences (21, 32, 53).

Locking compression plates have been developed to address these problems and are reported to provide higher stability and lower failure rate especially in complete intraarticular fractures or metaphyseal comminution (33, 68).

Several studies have reported promising short – or midterm results after the use of these devices (16, 29, 66) but long-term results are not yet available.

Greiner et al. (16) found a mean DASH score of 18.5 points and mean MEPS of 91 points in type B and C fractures after a mean follow-up of 10 months.

Ruebberdt et al. (66) reported a mean DASH score of 51 points and mean MEPS of 81 points. All of the fractures were AO type C and the mean age of the patients was comparatively low (44 years).

Reising et al treated 46 patients (mean age, 60.5 years) with type B and C fractures with the DHP system, finding a mean MEPS value of 84 points after a mean follow-up of 11 months.

Kaiser et al. (29) reported 86% good results, a mean VAS pain score of 1 and an average 16 degree flexion contracture an average of 30.5 months after locking plate fixation of type A, B, and C fractures.

All fractures in this series healed without any incident of screw breakage or secondary fracture dislocation. Ten patients with type C fractures were aged older than 60 years. The authors observed no case of pseudarthrosis, loss of reduction, or deep wound infection in this subgroup.

In our experience, conventional plate fixation fields good results in younger patients with good bone quality.

As proposed by the AO, we use screw fixation of the articular fragments and column stabilization with two rigid parallel or perpendicular plates for the fixation of bicolumnar distal humerus fractures. The use of a third plate can be advisable in the setting of metaphyseal comminution.

In cases of poor bone mineral density or extensive metaphyseal comminution, locking compression plates provide superior resistance against implant failure and yield better clinical results (Fig 2).

Complications of distal humeral fractures

Ulnar neuropathy

Ulnar neuropathy is one of the most common complications of operative treatment of fractures of the distal humerus (44).

It is our experience, that the nerve tends to have fibrosis and become adherent in the medial epicondylar region as a result of scar formation and the fracture-healing response. This problem can be minimized by adequate mobilization and anterior subcutaneous transposition at the initial operation (15, 67) .

Ulnar neurolysis and anterior transposition has been proven successful in the management of postoperative ulnar neuropathy . Despite high patient satisfaction and improved objective measures, ulnar nerve symptoms do not seem to completely resolve, and all efforts at mini-

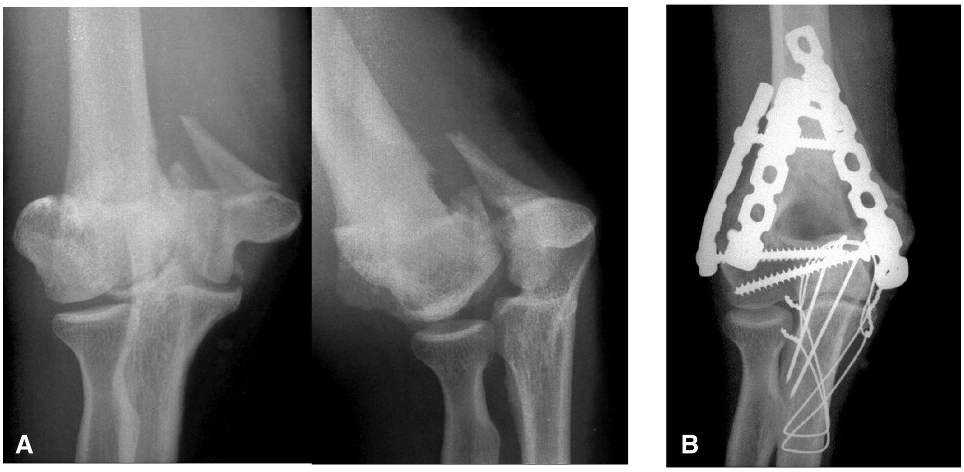

Fig. 2. Extremely comminuted complex intraarticular fracture of the distal humerus in a 28-year-old male patient, sustained after a fall while snowboarding. **A** *– Preoperative radiographs.* **B** *– Three months after triple plate fixation. Active ROM: extension–flexion arc 10–140°, supination 90°, pronation 90°. (Courtesy of Chaitanya S. Mudgal, MD)*

mizing complications of the ulnar nerve should be taken (41, 42).

Nonunion

Nonunion of fractures of the distal humerus has been reported to occur in 2% to 10% of cases (22). More recent studies on dual plate fixation of distal humeral fractures however, have demonstrated excellent union rates up to 100% (29, 72). Nonunion is primarily the consequence of inadequate fixation (31, 67).

Nonunions about the elbow are disabling. Patients present with pain and poor function. Profound ulnar neuropathy in some instances is the most disabling sequel associated with a distal humerus nonunion (28).

Reconstruction of nonunions about the elbow is technically challenging because of the distorted local anatomy, scarring, retained or broken implants, poor bone quality of the articular component, and capsular contracture.

Despite these difficulties, operative reconstruction is the procedure of choice in active individuals. When nonunion of the distal humerus is associated with severe posttraumatic arthritis, severe bone loss or when the patient is 65 years of age or older total elbow arthroplasty is recommended (12).

The senior author's 30 years of experience lead him to believe that although total elbow arthroplasty will continue to present an alternative to surgical fixation, operative reconstruction is the procedure of choice in the vast majority of ununited fractures.

Stiffness and heterotopic ossification

When early motion is not possible or contracture has developed that has not improved with exercises and splinting, operative elbow capsular release is considered (37, 56, 71).

Heterotopic ossification around the elbow is a well-documented complication following fractures of the distal humerus (37, 67).

More substantial heterotopic bone can limit motion or cause complete ankylosis and operative removal is recommended (37). Patients with central nervous system injury and elbow dislocation are at increased risk for heterotopic ossification (24), and prophylaxis with radiation should be considered. We have used prophylactic radiation only in select cases, although we encourage most patients to use nonsteroidal anti-inflammatory medication as part of their pain control regimen.

Hamid et al. (19) experienced a high nonunion rate (38%) following prophylactic radiation therapy after open reduction and internal fixation of intraarticular distal humerus fractures or elbow dislocations with proximal radius or ulna fractures.

We therefore believe that NSAIDs should be the mainstay of treatment in the acute setting surrounding elbow fractures and that perioperative radiation is best reserved for delayed HO excision

A waiting period of 12 to 18 months before surgical removal of heterotopic bone was common in the past. However, more recent studies demonstrated good results when the intervention was performed 3 to 6 months after injury (45).

FRACTURES OF THE OLECRANON

Epidemiology

Fractures of the olecranon comprise 10% of all upper extremity fractures (63).

Classification

The Mayo classification system for olecranon fractures evaluates displacement, stability, and comminution and accounts for most of the important issues and helps guide treatment (47).

Type I is a stable, minimally displaced fracture (less than 2 mm of gap between the fracture fragments), type II is a displaced fracture, and type III fractures are associated with instability of the ulnohumeral articulation. The fractures are further subdivided into subgroups A and B, according to the absence or presence of comminution, respectively.

Nonoperative treatment

Nondisplaced and minimally displaced fractures are treated nonoperatively.

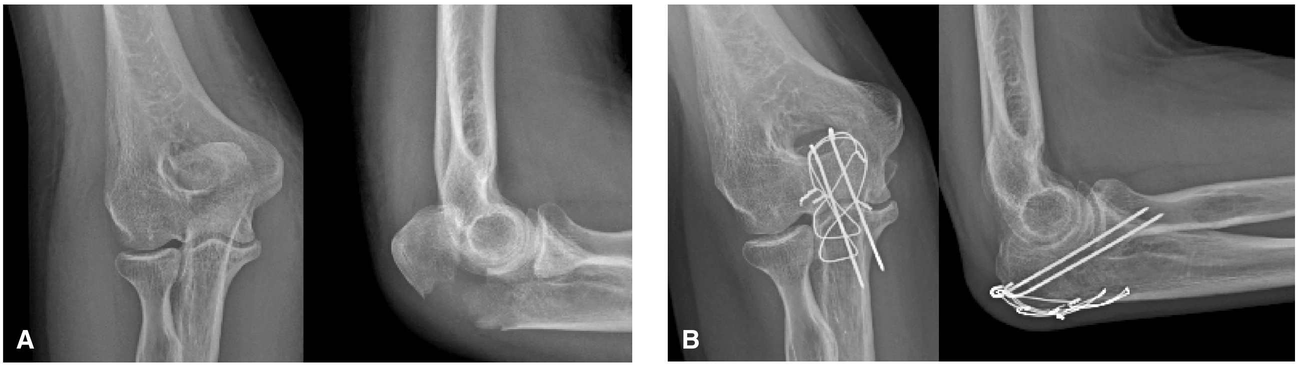

Fig. 3. Displaced olecranon fracture in a 50-year-old female, sustained after tripping and falling on an outstretched right hand. **A** *– Preoperative radiographs.* **B** *– Two months after Tension-band-wiring. The patient reported no pain or discomfort. Active ROM: extension–flexion arc 0–130°, supination 90°, pronation 90°.*

The elbow is immobilized at 90 degrees of flexion and neutral forearm rotation. The cast is discontinued after 3 or 4 weeks, and active-assisted elbow ranges of motion exercises are initiated. Resistive exercises are delayed until healing is established on radiographs

Operative treatment

All displaced fractures of the olecranon merit operative fixation.

Surgical approach

A midline posterior skin incision is used for all complex fractures of the proximal ulna.

Excision and triceps advancement

Fragment excision and triceps advancement are mostly of historical interest, although they may still be useful for patients with limited functional demands.

Tension band wiring

Use of the tension-band principle requires an intact (or nearly intact) cortex opposite the implant and is therefore reserved for relatively simple fractures without associated ligament injuries or fracture of the coronoid or radial head.

We use 0.045-inch Kirschner wires directed to engage the anterior ulnar cortex distal to the coronoid and bent 180 degrees and impacted into the olecranon proximally. We use two 22-gauge stainless steel tension wires each passed through its own hole to limit the prominence of the implants (Fig 3).

Reported outcomes are generally favorable with good or excellent results in more than 90% of cases (30, 63). The major problem has been symptoms related to prominent hardware (6, 38). Careful surgical technique can reduce this problem (7, 73).

Plate fixation

Contoured plating of the olecranon, in which the proximal end of the plate is wrapped around the tip of the olecranon, is the current gold standard for the treatment of comminuted fractures (Fig 4) (1, 2, 18). In recent years, an increasing number of published studies have reported successful results with locking-plate osteosynthesis in comminuted olecranon fractures (4, 69).

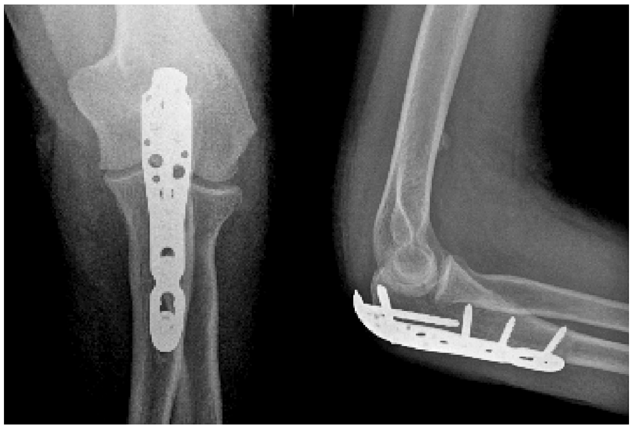

Fig. 4. 6 months after contoured locking plate fixation for a displaced fracture of the distal third of the olecranon, extending into the coronoid in a 54-year-old female patient with known osteopenia, sustained when she slipped and fell directly onto her elbow. The patient reported some discomfort over the plate but refused implant removal. Active ROM: extension–flexion arc 10–130°, supination 90°, pronation 90°.

Buijze and Kloen (4, 69) reported good and excellent results with locking compression plates in combination with axial intramedullary screws in 94% of patients. Siebenlist et al. found good and excellent results in 14 of 15 patients treated with anatomically pre-shaped locking compression plates.

Intramedullary nailing

Recently, intramedullary techniques for stabilization of displaced olecranon fractures have been introduced (11). The purported benefits are reported to be limited soft tissue dissection, low profile implants with less risk of soft tissue irritation, divergent subchondral screw placement, and locked fixed-angle fixation, affording sufficient stability to allow early elbow motion (52).

Intramedullary nail fixation has only recently been described, and results of treatment are not yet available.

Complications

Early failure of fixation

Early failure of fixation usually reflects inadequate size or placement of a plate and screws for treatment of a complex fracture. Tension band wire constructs can fail when used for complex fractures or fracture-dislocations, but they rarely fail when used for simple fractures.

Nonunion

Nonunion after simple olecranon fractures is very rare and reported to occur in 0 to 3% of cases (4, 6, 30). Union can usually be achieved with contoured dorsal plate fixation and autogenous bone grafting (60).

Stiffness/heterotopic ossification

Limitation in joint movement is common after elbow surgery; however, it is mostly limited to a 10° to 15° loss of extension with olecranon fractures. Dynamic or static progressive splints are useful in this situation. If nonoperative treatment is unsuccessful, operative capsular excision will restore motion in most patients.

If heterotopic ossification is restricting motion, this can be resected as soon as radiographically mature (within 3 to 4 months) as long as the soft tissue envelope is stable and mobile (58).

Arthrosis

Despite being intra-articular, posttraumatic arthritis is uncommon. Severe, symptomatic arthrosis is salvaged with interpositional arthroplasty in healthy active patients(51) or total elbow arthroplasty in older, infirm patients (46).

FRACTURES OF THE RADIAL HEAD

Epidemiology

Fractures of the radial head are common, constituting approximately one-third of all elbow fractures (55).

Classification

Several classification systems have been developed to characterize radial head fractures; however, they lack reliability among observers. Mason (40) classified fractures of the radial head into three types: type I, fissure or marginal sector fractures without displacement; type II, marginal sector fractures with displacement; and type III, comminuted fractures involving the whole head.

There are several additional injury factors that will affect management and prognosis of fractures of the radial head but are not consistently accounted for in classification systems, including the Essex-Lopresti lesion and the so-called terrible triad of the elbow.

Nonoperative treatment

Nondisplaced and minimally displaced radial head fractures can be treated with a sling or splint for a few days followed by early motion exercises of the elbow to prevent stiffness (64).

Operative treatment

An appreciation of the role, played by the radial head in the overall stability of the elbow and forearm (3, 48) has motivated many investigators to recommend preservation of the radial head, either by operative fixation or by prosthetic replacement. Improvements in the techniques and implants for operative fixation (27) and prosthetic replacement (35) of the radial head have increased the appeal of these treatments.

Surgical approach

For isolated fractures, operative exposure of the radial head is performed through the Kocher interval between the anconeus and extensor carpi ulnaris muscles. Care should be taken not to incise the capsule posterior to the anterior margin of the anconeus because this can damage the lateral collateral ligament complex and lead to chronic posterolateral rotatory instability.

The posterior interosseous nerve (PIN) is at risk during approaches to the radial head due to its vulnerable location in the supinator muscle and its proximity to the radial neck. Restricting dissection to within 4 cm from the radiocapitellar joint will protect the nerve from harm, regardless of forearm position (36). Displacement of diaphyseal fractures of the proximal aspect of the radius results in a minimal effect of forearm rotation on posterior interosseous nerve position. Second, proximal translation of the radius in Essex-Lopresti injuries is accompanied by proximal posterior interosseous nerve migration in all forearm positions (5). Direct visualization and protection of the posterior interosseous nerve might therefore be advisable.

Excision of the radial head

When the elbow is stable, excision of the radial head without prosthetic replacement is still a very useful treatment option in older patients with limited functional demands, and select younger patients. Radial head resection has been associated with delayed complications, including pain, joint instability, decreased strength, proximal radial migration, cubitus valgus, and osteoarthritis (23, 26).

A recent study (25) however reported excellent or good results in 96% of patients with Mason type II-IV fracture an average of 17 years after the operation. Moderate or severe degenerative changes were described in 56% of patients with Mason type III and 83% of patients with type IV fractures; however, no significant differences in functional outcome were detected based on the degree of radiographic osteoarthritic changes. Ulnar shortening osteotomy was required in two cases of symptomatic proximal translation of the radius of >5 mm with persistent wrist pain.

Open reduction and internal fixation

The majority of partial (Mason type 2) fractures of the radial head are amenable to operative fixation. The results of the operative repair of fractures involving the entire radial head (Mason type 3) are much less predic-

Fig. 5. Displaced fracture of the radial head and lateral epicondyle in a 54-year-old healthy male, sustained when he slipped on ice and fell directly onto his elbow. **A** *– Preoperative radiographs. Note the positive fat pad sign.* **B** *– Five months after screw fixation. The patient reported no pain. Active ROM: extension–flexion arc 30 -140°, supination 90°, pronation 90°.*

table and excision with or without prosthetic replacement is often preferable (61).

A dental pick or fine K-wire can be used as a joystick to manipulate fragments into position. Impacted fragments can be repositioned by elevating them with a bone tamp. Bone graft can be harvested from the olecranon or the lateral epicondyle to fill larger defects.

Partial head fractures can be treated with small standard screws (1.5–3.0 mm) or headless screws (Fig 5). Fibrin glue and bioabsorbable implants have also been reported (14). For more complex fracture patterns or those involving the radial neck, plates are useful. A variety of implants are available, including standard and locked T and L plates, mini condylar plates, and precontoured plates specifically designed for the proximal radius.

Plates and screws placed upon the portion of the radial head that articulates with the sigmoid notch of the proximal ulna must be countersunk to limit the potential for impingement. The posterolateral aspect of the radial head that does not articulate with the sigmoid notch of the ulna during forearm rotation has been defined as a safe zone for insertion of hardware in the radial head. With the forearm in neutral rotation, the safe zone is the portion of the radial head that presents laterally in the wound (70).

Ring and colleagues found excellent results with operative treatment of isolated Mason type 2 fractures, but unsatisfactory results in four of 15 patients with Mason type 2 fractures associated with complex injuries. Among Mason type 3 fractures with fewer than three articular fragments, two had nonunions (one of which eventually healed over 2 years after the injury), and all had good forearm rotation. On the other hand, among patients with Mason type 3 fractures and greater than three articular fragments, only one of 14 achieved a satisfactory result (three early failures, six nonunions, four poor forearm rotation) (61).

Nalbantoglu et al. reported good or excellent results in 80% of isolated Mason type III fractures treated with low-profile, 2.0-mm,T-shaped miniplates and screws, headless screws alone or a radial head plate (50).

Arthroplasty of the radial head

Comminuted fractures and those associated with complex elbow or forearm dislocation are better treated by radial head excision with or without prosthetic replacement (Fig 6).

The use of silicone prostheses has lost favor due to reports of mechanical failure of the implant, inflammatory arthritis, and reactive synovitis (74)

A recent study (23 patients, mean follow up 70 months) however, reported no clinical or radiographic features of silicone synovitis, a mean MEPS score of 88.9 and a mean DASH score of 11.8 after silastic radial head arthroplasty and concomitant ligament repair (39).

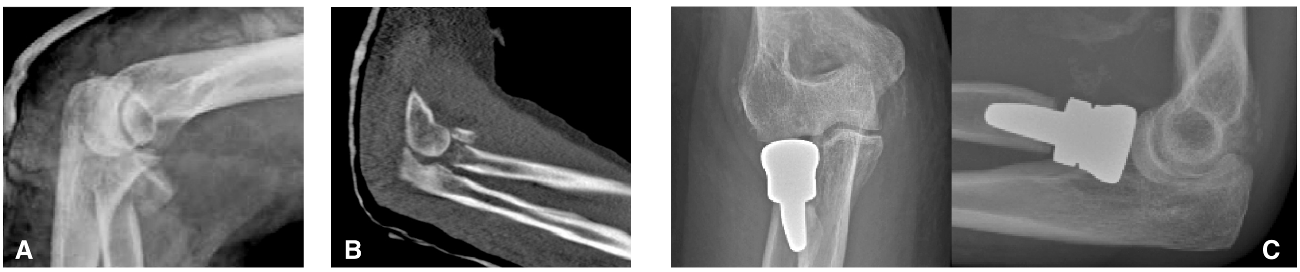

Fig. 6. Comminuted radial head (Mason type III) fracture in a 54-year-old femal, sustained after falling off her bicycle. **A** *– Preoperative lateral radiograph.* **B** *– Select sagittal CT cut. Note the anterior radial head comminution.* **C** *– Two months after a radial head arthroplasty and medial and lateral collateral ligament repair. The patient reported minimal, nonspecific discomfort. Active ROM: extension–flexion arc 10–125°, supination 90°, pronation 90°.*

In many studies, encouraging short-term results have been reported for monobloc as well as bipolar implants for comminuted radial head fractures (10, 20).

Whereas at least 1 study has described the results at a mean of 12 years (range, 6 to 29 years; 20 patients, 16 good or excellent results, no implant-related problems), (20) the long-term effect on the capitellar articular cartilage and problems such as implant loosening and failure require further study.

In the short to medium term, reported problems associated with a metal prosthesis included the insertion of a prosthesis that is too large in longitudinal length (9). This can cause painful erosions of the capitellum and malalignment of the elbow.

A primary technical goal during radial head arthroplasty is the placement of an implant that closely replicates the dimensions of the native radial head.

A reliable method to determine correct radial head implant size is to use the native head as a template. When measuring the thickness of the fractured head, it is best to measure from the articular margin to the fracture surface with the least amount of radial neck. An implant that is selected on the basis of the thickest portion of the fractured radial head will lead to overlengthening of the radius. The arthroplasty should articulate at the height of the proximal radioulnar joint, about 2 mm distal to the coronoid.

The radial head has a complex anatomy that is difficult to replicate with a prosthesis. Most prosthetic designs are therefore either spacers with a loose smooth stem in the radial neck or bipolar implants featuring a mobile articulation between the head and the neck of the prosthesis. Reported outcome results of both types of prosthesis are comparable (9, 10, 17).

Complications

Stiffness is the most common sequel of fractures of the radial and can be caused by capsular contracture, scarring of the annular ligament, retained chondral or osteochondral fragments, malunion, or heterotopic ossification. Capsular contracture usually responds to passive stretching under the supervision of a physical therapist. In patients, struggling to regain motion, static progressive or turnbuckle splinting can be useful (13). Open or arthroscopic capsular release is used if therapy and splinting fails.

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