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Olecranon Fractures

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Approximately 10% of fractures about the adult elbow consist of fractures of the olecranon process of the ulna and range from simple nondisplaced fractures to complex fracture–dislocations of the elbow (Table 1). Several treatment options for internal fixation have been described, including tension-band wiring, plate fixation, intramedullary screw fixation, and triceps advancement after fragment excision. The method of internal fixation is chosen based primarily on fracture type. Because olecranon fractures are all intra-articular injuries, they require anatomic or essentially normal surface reduction and trochlear notch contour for predictable outcomes. In addition, fixation must be stable enough to permit early mobilization to avoid significant elbow stiffness. Given the variability in fracture patterns, the complex anatomy, and associated injuries, treating surgeons must be familiar with multiple treatment methods and follow a systematic surgical strategy to avoid complications and achieve reliable outcomes.

Anatomy

The elbow is a complex hinge joint that relies on a combination of bony articulations and soft tissue constraints to optimize stability and mobility [1]. Soft tissue constraints about the elbow are responsible for as much as 40% of the resistance to valgus stress and 50% of that to varus stress in the extended position. The anterior band of the ulnar collateral ligament acts as the major stabilizer to valgus stress. The major stabilizer to varus or rotatory stress is the lateral collateral ligament complex, including the lateral ulnar collateral ligament [2,3].

The ulnohumeral articulation is the essential factor for osseous stability and mobility in the flexion–extension plane. The olecranon and coronoid processes comprise the semilunar or greater sigmoid notch of the ulna, which articulates with the trochlea. The olecranon blocks the anterior translation of the ulna with respect to the distal humerus, whereas an intact coronoid process resists posterior subluxation of the proximal ulna in extension beyond 30° or greater [4].

A transverse bare area devoid of cartilage is found at the midpoint between the coronoid and the tip of the olecranon [5]. This region must not be overcompressed during fracture reduction in an attempt to obtain articular cartilage reduction because this will result in a narrowed trochlear fossa and incongruent radius of curvature. The ossification center of the olecranon generally appears by 9 to 10 years of age, and fuses to the proximal ulna by 14 years of age. Persistence of the physis into adulthood may occur and can be confused with a fracture; clues to this condition include its familial tendency and common presence bilaterally. The triceps tendon inserts into the posterior third of the olecranon and is intimately associated with the periosteum. In addition, the triceps is continuous with the aponeurosis of the anconeus muscle and common extensor origin. Patella cubiti, an accessory ossicle embedded in the distal triceps, may be present and can be mistaken for a fracture [6].

The ulnar nerve passes around the posterior aspect of the medial epicondyle and between the two heads of the flexor carpi ulnaris, which spans in an arcade-like manner from the medial epicondyle to the olecranon process to form the

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Table 1
Summary of olecranon fracture treatment based on displacement, comminution and joint stability

Classification	Description	Treatment
Mayo type IA and IB	Undisplaced (<2 mm) fractures with no comminution (IA) or with comminution (IIB)	Sling immobilization, early active range of motion, close follow-up
Mayo type IIA	Stable fractures with >3 mm displacement, no comminution	Tension band wiring usually adequate; consider plate and screw constructs if fracture lines are distal to coronoid; consider excision in low-demand patients or when small fragments are present
Mayo type IIB	Stable fractures with >3 mm displacement; comminution is present	Plate and screw constructs preferred, especially in patients <60 years old Consider excision in low-demand patients or those >60 years, who have fractures with extensive comminution, or when small fragments are present
Mayo type IIIA	Unstable, displaced fracture–dislocations; no comminution is present	Plate-and-screw constructs preferred
Mayo type IIIB	Unstable, displaced fracture–dislocations; comminution is present	Plate and screw constructs preferred
Avulsion fractures		Tension band wiring or excision may be used

roof of the cubital tunnel. The nerve lies posterior to the ulnar collateral ligament, which forms the floor of the cubital tunnel and attaches in a fan-like fashion to the medial border of the olecranon. The brachialis tendon inserts broadly onto the proximal ulnar metaphysic distal to the tip of the midportion of the anterior coronoid.

Mechanism of injury

Fractures of the olecranon occur from either direct or indirect trauma. A fall or blunt trauma on the posterior tip of the elbow may cause fracture directly. Indirect avulsion of the olecranon from forces generated within the triceps muscle may occur with eccentric contraction during a fall on a partially flexed elbow. Amis and Miller [7] investigated the effect of impact mechanisms on olecranon fracture patterns in a cadaveric model. Radial head and coronoid fractures occurred from impact to the forearm with the elbow in 80° of flexion or less; olecranon fractures followed direct blows at 90° of flexion; and distal humerus fractures were caused by impact when the elbow was in greater than 110° of flexion. In cases of severe force to the elbow, a fracture dislocation can occur with posterior displacement of the olecranon fragment and the distal ulnar fragment together with the head of the radius anterior to the humerus.

Classification

The Mayo classification of olecranon fractures is based on three variables: displacement, stability, and comminution [8]. Type I fractures are nondisplaced, type II fractures are displaced but the ulnohumeral joint is stable, and type III fractures are displaced and unstable. Each fracture type is subdivided into noncomminuted (A) and comminuted fractures (B). Colton's [9] classification reflects displacement and the anatomy of the fracture, thus providing guidance as to the most biomechanically appropriate type of fixation. Fractures are described as nondisplaced and stable if they are displaced less than 2 mm and exhibit no change in position with gentle flexion to 90° or with extension against gravity. Displaced fractures can be further divided into avulsions fractures, transverse or oblique fractures, isolated comminuted fractures, or fractures with associated dislocations.

Diagnosis

History

Patients who have an olecranon fractures and associated injuries present with pain and swelling about the distal arm and elbow. Those who have displaced fractures have an obvious deformity, and attempted motion may elicit painful bony crepitus. The mechanism of injury and any associated neurovascular complications associated with the initial injury should be elicited from the patient. Thorough assessment for concurrent illnesses precipitating the injury and a detailed account of comorbid conditions is important.

Clinical examination

Physical examination should begin with assessment of the condition of the soft-tissues around the elbow. Extensive swelling, ecchymosis, and any abrasions or lacerations should be noted and may influence the timing of surgery. An assessment of range of motion or strength of the elbow should not be vigorously pursued. A palpable sulcus may be present at the site of an olecranon fracture, accompanied by a painful and limited range of motion. An important sign associated with isolated olecranon fractures is inability to extend the elbow actively against gravity. Although the pain associated with this maneuver may make patients hesitant to cooperate, this inability indicates discontinuity of the triceps mechanism. A careful neurovascular examination is essential, especially before any planned manipulation of the elbow.

Radiographic and imaging assessment

Plain radiographs in the anteroposterior, true lateral, and oblique projections are usually provide sufficient information for an accurate diagnosis. Severe comminution with displacement and overlap of the fracture fragments can obscure thorough determination of the fracture pattern. Thus, radiographs must be good quality, out of splint, and obtained while maintaining gentle longitudinal traction with inclusion of the elbow joint on the film. Poorly aligned radiographs performed in the splint are not as well suited for accurate diagnosis, classifying the fracture, and formal preoperative planning. Radiographs should be carefully evaluated for the presence of associated injuries, such as a radial head fracture or dislocation, a distal humerus fracture, or a coronoid fracture. Rarely does CT provide additional information that alters decision making, and preoperative planning with an isolated olecranon fracture and should be reserved for more complex fracture combinations.

Treatment

Nondisplaced fractures of the olecranon (Mayo type IA and IB) can be treated nonoperatively. These fractures are defined by displacement less than 2 mm, no change in position with gentle flexion to 90°, or extension of the elbow against gravity. These fractures are immobilization in a long arm cast with the elbow in 90° of flexion for 3 to 4 weeks followed by protected range of motion exercises. Flexion past 90° should be avoided until bone healing is complete radiographically at approximately 6 to 8 weeks. In elderly patients, range of motion may be initiated earlier than 3 weeks if patients can tolerate it, with the goal to prevent stiffness. A follow-up radiograph should be obtained within 5 to 7 days after cast application to ensure that displacement of the fracture has not occurred. Immobilization in full extension is not recommended because stiffness is more likely, and fractures that require full extension for reduction should be treated operatively.

Tension band wire

Displaced olecranon fractures require operative treatment to restore elbow extension, joint congruity, and elbow stability. Transverse fractures without comminution (Mayo type IIA) are amenable to tension band wiring. The tension band wire construct converts the tensile distraction force of the triceps into a dynamic compressive force across the olecranon articular surface (Fig. 1). Traditionally, K-wires have been used in the tension band construct. Intramedullary cancellous screw fixation should be avoided in elderly patients who have underlying osteoporosis, because the proximal fragment may fracture further if a single 6.5-mm cancellous screw is used to secure the longitudinal component of the fracture.

Technique

Two 1.6-mm or 2.0-mm K-wires are inserted into the olecranon tip to obtain proximal control, and engagement distally in the anterior cortex of the ulna increases the stability of fixation [10]. Care should be taken to avoid overpenetration of the wires, because they may cause neurovascular damage, limitation in forearm rotation, or heterotopic ossification. The length of the wire should be noted at the point where it engages the second cortex. Once the wire penetrates the far cortex, it should be partially backed out and bent 180° at the previously noted position and cut. The fibers of the triceps tendon should be split sharply with a scalpel at the site of the K-wires to allow the cut and bent ends to be impacted against the cortex. A figure-of-8 loop of 1.5-mm or 18-gauge wire is positioned through a drill hole

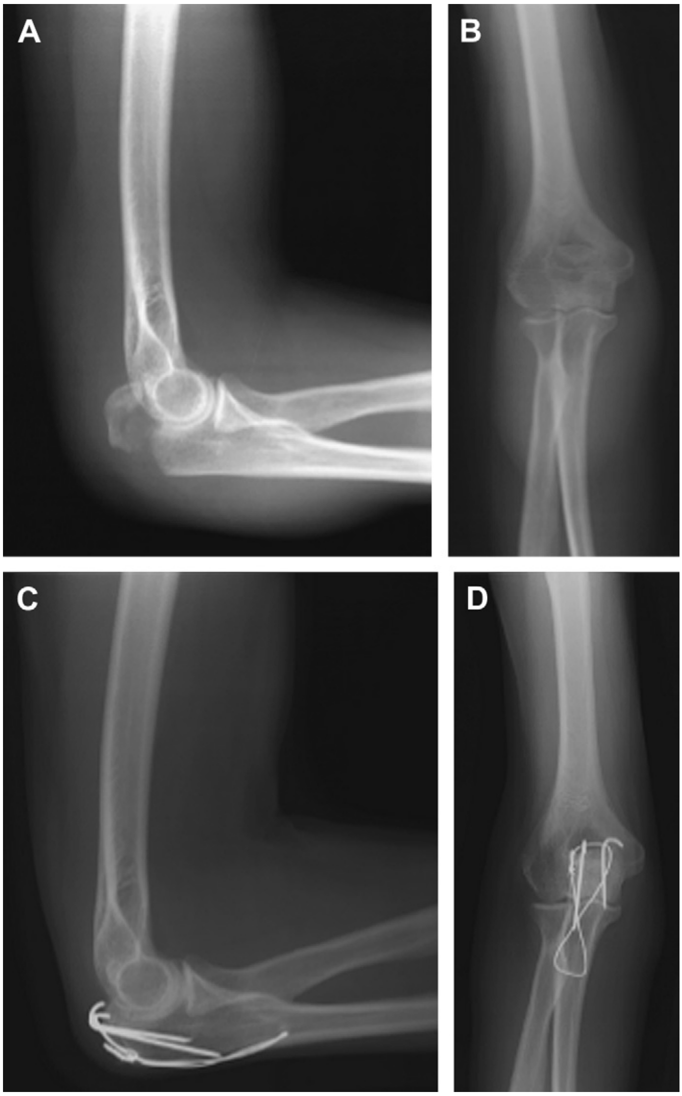

Fig. 1. This 60-year-old nurse practitioner fell while running and sustained a type IIA olecranon fracture (*A*, *B*). She underwent open reduction and internal fixation with tension band wiring (*C*, *D*). At latest follow-up she had range of motion from 10° to 100° in the flexion/extension arc. She complained of prominent hardware and underwent hardware removal at 20 months after her fracture fixation. (*From* Adams JE, Steinmann SP. Fractures of the Olecranon. In: Berry DJ, Steinmann SP. Adult reconstruction. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2007. p. 440; with permission.)

located distally approximately and equal distance from the fracture as the tip of the olecranon. The wire is then passed deep to the fibers of the triceps, adjacent to bone, beneath the K-wires. The wire is tightened by twisting in two places on opposite arms of the crossed portion of the figure-of-8 for additional stability. The K-wires are seated firmly in the bone using an impactor, beneath the fibers of the triceps to prevent wire migration.

In transverse fractures with comminution (Mayo type IIB), the tension band technique will collapse the fragments together, leading to a narrowed olecranon articulation that does not track properly. The most optimal fixation for these fractures is offered with contoured, limited-contract dynamic compression (LCDC) plate fixation, with or without bone graft depending on the size of the comminuted region [11]. Similarly, plate with lag screw fixation is preferred over the tension band construct for oblique fractures or unstable displaced olecranon fracture–dislocations with and without comminution (Mayo type IIIA and IIIB). Treatment with the tension band technique in this fracture pattern often results in displacement, because compression along the tension band causes shortening along the inclined plane of the obliquity or does not allow adequate fixation to restore stability and permit early mobilization.

Limited-contract dynamic compression plate fixation

Using the LCDC plate for fixation has several advantages [12,13]. The plate allows improved contouring and can be appropriately placed on the dorsal tension surface of the proximal ulna around the tip of the olecranon to help hold the proximal fragment when poor bone quality limits screw purchase (Fig. 2). The redesigned screw holes allow greater angulation of screw placement

Fig. 2. This 66-year-old right-hand–dominant retired laboratory technician slipped on the ice and fell, sustaining a direct blow to her left elbow and this Mayo type IIA fracture of the olecranon (*A*, *B*). She underwent plate-and-screw osteosynthesis (*C*, *D*). At 18 months postoperatively, she was pain-free and her range of motion was 0° to 140°, with supination to 70° and pronation to 80°. (*From* Adams JE, Steinmann SP. Fractures of the Olecranon. In: Berry DJ, Steinmann SP. Adult reconstruction. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2007. p. 440; with permission.)

and the option of compression from either side of the screw hole. In addition, its lower profile allows its use in subcutaneous situations when soft tissue coverage may be in question. The proximal fixation of the plate is often the greatest challenge because the bone may be thin, and thus cancellous screws rather than cortical screws should be used in elderly patients. The advent of newer precontoured plates allows for an increased number of fixation points in the proximal fragment and cradles the olecranon along its dorsal surface. In complex fractures of the proximal ulna, a large coronoid fragment is often present. This fragment is very important to the final stability of the elbow and must be fixed with lag screws placed either through or adjacent to the implanted plate to prevent early posterior subluxation of the elbow [14]. Mobilizing the proximal olecranon fragment in the same way as an olecranon osteotomy allows the coronoid to be visualized and reduced through the olecranon fracture.

Technique

Patients are placed in a lateral position on the operating room table with the injured arm on a bolster across the chest. A sterile tourniquet is placed on the upper arm after skin preparation and draping. A posterior midline incision centered on the olecranon is extended proximally 5 cm from the tip of the olecranon. The ulna is approached along its subcutaneous border and the anconeus can be elevated to approach the radial head if required. Impacted articular fragments are elevated and the coronoid is then reduced and provisionally fixed to the ulna with one or two K-wires. The use of a heavy suture passed around the coronoid fragment can assist with temporary reduction. A narrow 3.5-mm LCDC plate is then contoured to fit the proximal ulna with the maximum bend, near 90°, between the second and third screw holes of the plate. The plate length must be able to accommodate three or four screws distal to the fracture. Once fracture reduction is achieved, the contoured plate is applied to the dorsal aspect of the olecranon and the triceps fascia is incised to allow the implant to sit on the bone. The plate is secured proximally with one screw from the fourth or fifth hole obliquely upward into the coronoid process. Fixation of the coronoid can also be performed or supplemented with lag screws adjacent to the plate. A long cancellous screw is placed from the first or second hole across the fracture toward the proximal shaft at the base of the coronoid. Additional screws are placed proximally in the olecranon and the plate is secured distally to the shaft with three or four bicortical screws.

In the osteoporotic olecranon, direct trauma to the posterior aspect of the elbow can cause an isolated severely comminuted fracture. Excision of the fracture fragments and reattachment of the triceps tendon may be indicated in elderly patients whose olecranon fracture fragments are too small or too comminuted for successful internal fixation (Fig. 3). However, the coronoid and anterior soft tissues, collateral ligaments, and interosseus membrane must be intact, otherwise instability will result. The triceps tendon is reattached adjacent to the articular surface with nonabsorbable sutures that are passed through drill holes in the remaining proximal ulna. Reattaching the triceps this way creates a sling for the trochlea and a smooth congruent transition from the triceps tendon to the articular surface but decreases the moment arm, and may result in a weaker extensor mechanism but enhanced elbow stability [15]. The amount of olecranon that can be excised safely has been debated. Based on in vitro [4] and clinical studies [16,17] between 50% and 70% of the olecranon articular surface can be excised without compromising elbow stability provided the coronoid and distal trochlea are preserved.

Complications

Painful hardware irritation requiring removal is one of the most common complications after internal fixation of olecranon fractures. Complaints related to prominent hardware have been reported in up to 80% of cases. A higher incidence of prominent painful hardware has been reported after tension band wiring than compression plating [18,19]. Although Simpson and colleagues [12] reported no cases of symptomatic hardware irritation after LCDC plating, Bailey and colleagues [20] reported that 20% of patients required plate removal because of prominence of the plate fixation.

Loss of motion is rarely a significant problem in patients with isolated olecranon fractures. The typical lose of motion is 10° to 15° of extension in patients who have isolated injuries. However, patients who have associated fractures of the radial head or coronoid are more likely to develop limitations in their range of motion.

Nonunion of olecranon fractures have been reported in up to 1% of patients, with typical

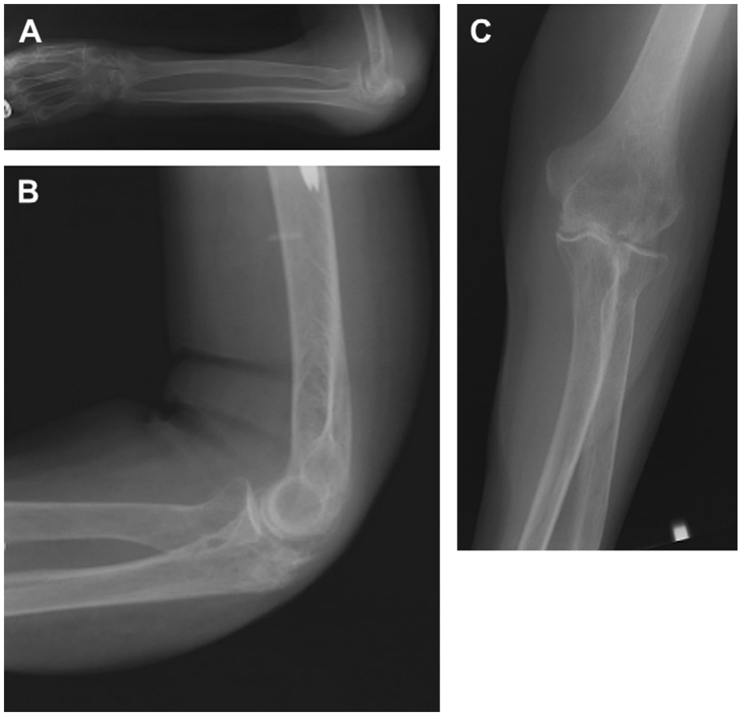

Fig. 3. This 84-year-old right-hand–dominant woman experienced a syncopal episode and fell down the stairs at home. She sustained concomitant fractures of the left proximal humerus, left distal radius, and left ulnar styloid, and a fracture of the left olecranon (*A*) treated with excision of the proximal fragment (*B*, *C*). At 6 months postoperatively, she was pain-free and her range of motion in the flexion extension arc was from 20° to 135°; pronation was to 70° and supination was to 70°. (*From* Adams JE, Steinmann SP. Fractures of the Olecranon. In: Berry DJ, Steinmann SP. Adult reconstruction. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2007. p. 440; with permission.)

symptoms of pain, instability, or loss of motion [21]. Treatment options for olecranon nonunions include excision, osteosynthesis with a LCDC plate, and bone graft or elbow arthroplasty in the presence of severe posttraumatic arthritis. Acceptable management of elderly patients includes excision of the proximal portion of the pseudarthrosis and repair of the triceps tendon, ensuring that the coronoid and anterior soft tissues are intact.

Rehabilitation

In elderly patients, early initiation of physical therapy is one of the most important issues in elbow surgery. An initial posterior plaster slab with the elbow flexed to 90° can be applied in the operating room to help manage immediate postoperative pain. The posterior slab is discontinued after 5 to 7 days and a removable splint is provided. Gentle active-assisted and passive motion is then started, with patients instructed to support the wrist with the opposite hand and gently flex and extend the elbow, gradually increasing the range of motion. Patients are instructed to take the arm out of the splint several times daily for these exercises and to let gravity work on extending the elbow. Active motion against resistance is avoided until callous formation is evident, usually at 8 to 10 weeks. If the stability of the fixation is a concern, then a hinged fracture brace can be used to provide additional support.

Results and outcome

Outcomes after olecranon fracture are generally good to excellent, with most series noting satisfactory outcomes and restoration of normal or near-normal function in more than 95% of patients.

Bailey and colleagues [20] evaluated the functional outcome of plate fixation for displaced olecranon fractures (Mayo type II or III) in 25 patients at an average of 34 months follow-up. Patient satisfaction was high (9.7/10) with a low pain rating (1/10). Based on the Mayo elbow score, 22 patients had excellent or good outcomes, and the mean DASH score showed almost normal upper extremity function.

Karlsson and colleagues [22] evaluated the long-term outcome of closed olecranon fractures in 73 patients at a mean of 19 years after fracture. Primary treatment consisted of open reduction and internal fixation in 84% of the elbows. Of these patients, 61 had no complaints at follow-up, 9 had occasional pain, and 3 had daily pain; 96% had an excellent or good overall outcome.

Summary

Olecranon fractures are commonly seen in orthopedic practice and have good to excellent outcomes with adherence to a treatment algorithm based on displacement, comminution, and joint stability. Although decreased range of motion, radiographic evidence of degenerative changes, and requirement for hardware removal are common, they can be minimized through careful attention to proper technique, anatomic reduction with stable fixation, and early mobilization.

References

[1] Morrey BF, An KN. Articular and ligamentous contributions to the stability of the elbow joint. Am J Sports Med 1983;11(5):315–9.

[2] O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am 1991;73(3):440–6.

[3] Cohen MS, Hastings H II. Rotatory instability of the elbow. The anatomy and role of the lateral stabilizers. J Bone Joint Surg Am 1997;79(2):225–33.

[4] An KN, Morrey BF, Chao EY. The effect of partial removal of proximal ulna on elbow constraint. Clin Orthop Relat Res 1986;209:270–9.

[5] Stormont TJ, An KN, Morrey BF, et al. Elbow joint contact study: comparison of techniques. J Biomech 1985;18(5):329–36.

[6] Winter M, Balaguer T, Tabutin J. Bilateral patella cubiti. A case report. J Bone Joint Surg Am 2006; 88(2):415–7.

[7] Amis AA, Miller JH. The mechanisms of elbow fractures: an investigation using impact tests in vitro. Injury 1995;26(3):163–8.

[8] Morrey BF. Current concepts in the treatment of fractures of the radial head, the olecranon, and the coronoid. Instr Course Lect 1995;44:175–85.

[9] Colton CL. Fractures of the olecranon in adults: classification and management. Injury 1973;5(2): 121–9.

[10] Prayson MJ, Williams JL, Marshall MP, et al. Biomechanical comparison of fixation methods in transverse olecranon fractures: a cadaveric study. J Orthop Trauma 1997;11(8):565–72.

[11] Hak DJ, Golladay GJ. Olecranon fractures: treatment options. J Am Acad Orthop Surg 2000;8(4): 266–75.

[12] Simpson NS, Goodman LA, Jupiter JB. Contoured LCDC plating of the proximal ulna. Injury 1996; 27(6):411–7.

[13] McKee MD, Seiler JG, Jupiter JB. The application of the limited contact dynamic compression plate in the upper extremity: an analysis of 114 consecutive cases. Injury 1995;26(10):661–6.

[14] Doornberg J, Ring D, Jupiter JB. Effective treatment of fracture-dislocations of the olecranon requires a stable trochlear notch. Clin Orthop Relat Res 2004;429:292–300.

[15] Coonrad RW, Morrey BF. Management of olecranon fractures and nonunion. In: Morrey BF, editor. Master techniques in orthopaedic surgery: the elbow. 2nd edition. Philadelphia: Lippincott Williams & Wilkins; 2002. p. 103–26.

[16] Inhofe PD, Howard TC. The treatment of olecranon fractures by excision or fragments and repair of the extensor mechanism: historical review and report of 12 fractures. Orthopedics 1993;16(12): 1313–7.

[17] Gartsman GM, Sculco TP, Otis JC. Operative treatment of olecranon fractures. Excision or open reduction with internal fixation. J Bone Joint Surg Am 1981;63(5):718–21.

[18] Hume MC, Wiss DA. Olecranon fractures. A clinical and radiographic comparison of tension band wiring and plate fixation. Clin Orthop Relat Res 1992;285:229–35.

[19] Wolfgang G, Burke F, Bush D, et al. Surgical treatment of displaced olecranon fractures by tension band wiring technique. Clin Orthop Relat Res 1987;224:192–204.

[20] Bailey CS, MacDermid J, Patterson SD, et al. Outcome of plate fixation of olecranon fractures. J Orthop Trauma 2001;15(8):542–8.

[21] Papagelopoulos PJ, Morrey BF. Treatment of nonunion of olecranon fractures. J Bone Joint Surg Br 1994;76(4):627–35.

[22] Karlsson MK, Hasserius R, Karlsson C, et al. Fractures of the olecranon: a 15- to 25-year followup of 73 patients. Clin Orthop Relat Res 2002;403:205–12.