

Olecranon Fractures

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Olecranon fractures are common injuries of the upper extremity; majority are treated surgically. A variety of fixation techniques are available to surgeons in modern practice, but there is little comparative clinical research to guide one's decision. Nonetheless, good results over all are to be expected after surgical management. This article presents a review of the current understanding and available evidence in the treatment of olecranon fractures, their relevant anatomy, fracture patterns, fixation options, and outcomes. (*J Hand Surg* 2013;38A:593–604. Copyright © 2013 by the American Society for Surgery of the Hand. All rights reserved.)

Key words Fracture, olecranon, proximal ulna, review.

OLECRANON FRACTURES ARE common injuries for all age groups. It is thought that most olecranon fractures occur through a direct force driving the proximal ulna into the distal humerus or an indirect injury through tension from the triceps attachment on the proximal olecranon.¹ Given the anatomic particularities involved, the majority of olecranon fractures are treated surgically. A variety of fixation techniques are available to surgeons in modern practice, yet there is little comparative research to guide the clinician. Symptomatic hardware requiring removal is a recurring and frequent problem.² Although some loss of range of motion is common, good results over all are to be expected after surgical management.

CLASSIFICATION

The Mayo classification (Fig. 1) is the most commonly used in clinical practice. The classification consists of 3 types, with a modifier to indicate comminution. Type I fractures are nondisplaced, type II fractures are displaced, and type III fractures have accompanying injuries and instability. The letters A and B are used to indicate noncomminuted and comminuted fractures, respectively. The AO classification (Fig. 2) is used as

well, but it is more suited to research and academic settings. In the treatment of these fractures, the primary distinctions are displacement and comminution. Accompanying injuries are myriad and will need to be addressed on an individual basis.

EPIDEMIOLOGY

In adults, olecranon fractures account for around 10% of all upper extremity fractures.^{3,4} Simple displaced transverse fractures are the most common, with up to 85% of all olecranon fractures falling into the Mayo type II category.^{5–7}

In a fracture database of 6872 trauma patients from Scotland, 78 patients sustained olecranon fractures. Mean age of the patients was in the 50s, with men sustaining the injuries at younger ages than women, and no sex predominance. Of these patients, 67% sustained the injuries from ground-level falls. Associated injuries⁶ involved ipsilateral proximal radius fractures in 17% and open injuries in 6.4%. Noting the age at which most olecranon fractures are seen, surgeons should be mindful of the possibility of osteoporotic bone.

INDICATIONS

Few fracture patterns of the olecranon in adults are amenable to nonsurgical treatment. Although simple, nondisplaced fractures of the metaphyseal/diaphyseal junction can be treated nonsurgically, vigilance is required because these fractures tend to drift into displacement with time, even with proper immobilization and compliant activity modification. Patients may reasonably opt for surgical management to avoid prolonged immobilization.

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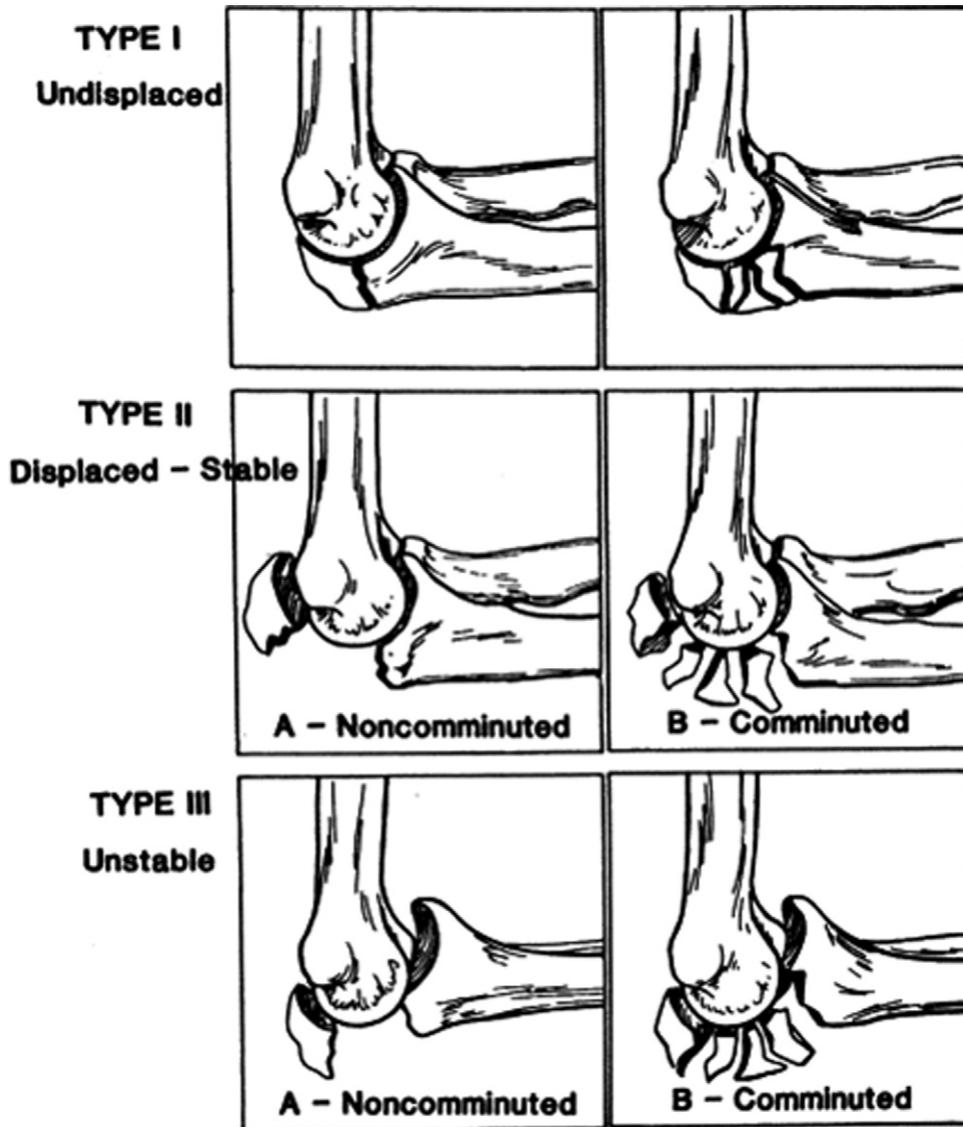


FIGURE 1: Mayo classification of olecranon fractures.

Comminuted fractures and all displaced fractures distal to the midpoint of the semilunar notch should be considered unstable and require surgical intervention. The degree of fracture displacement in comminuted injuries is often difficult to assess with common radiographs. Two- and 3-dimensional computed tomography reconstructions may be useful in defining articular fragments before surgery in such cases, but they are unnecessary in simple patterns. Despite this challenge, it is imperative that the alignment of the proximal ulna is anatomic or the effects at the proximal radioulnar joint will be detrimental.⁸

In all approaches, treatment should be aimed at restoring function to the elbow. As in other articular fractures, absolute stability and anatomic articular reduction are the goals of fixation. Reconstructive efforts should be aimed at restoring articular congruity, appro-

priate ulnar length, pain-free use of the joint, functional range of motion, and strength.⁵ Variables that the surgeon can influence surgically that will affect union include fracture gapping, blood supply, and fracture stability.⁹

SURGICAL TECHNIQUE

The patient is positioned either in a lateral decubitus or supine position. If placed laterally, the affected arm is draped over a well-padded stand. If placed supine, the affected arm is draped across the body, with a bump under the ipsilateral shoulder to help maintain the position of the arm across the body. A tourniquet is placed on the upper arm.

A longitudinal, posterior incision is traditionally required for adequate exposure of the olecranon. The incision begins at the most proximal point of

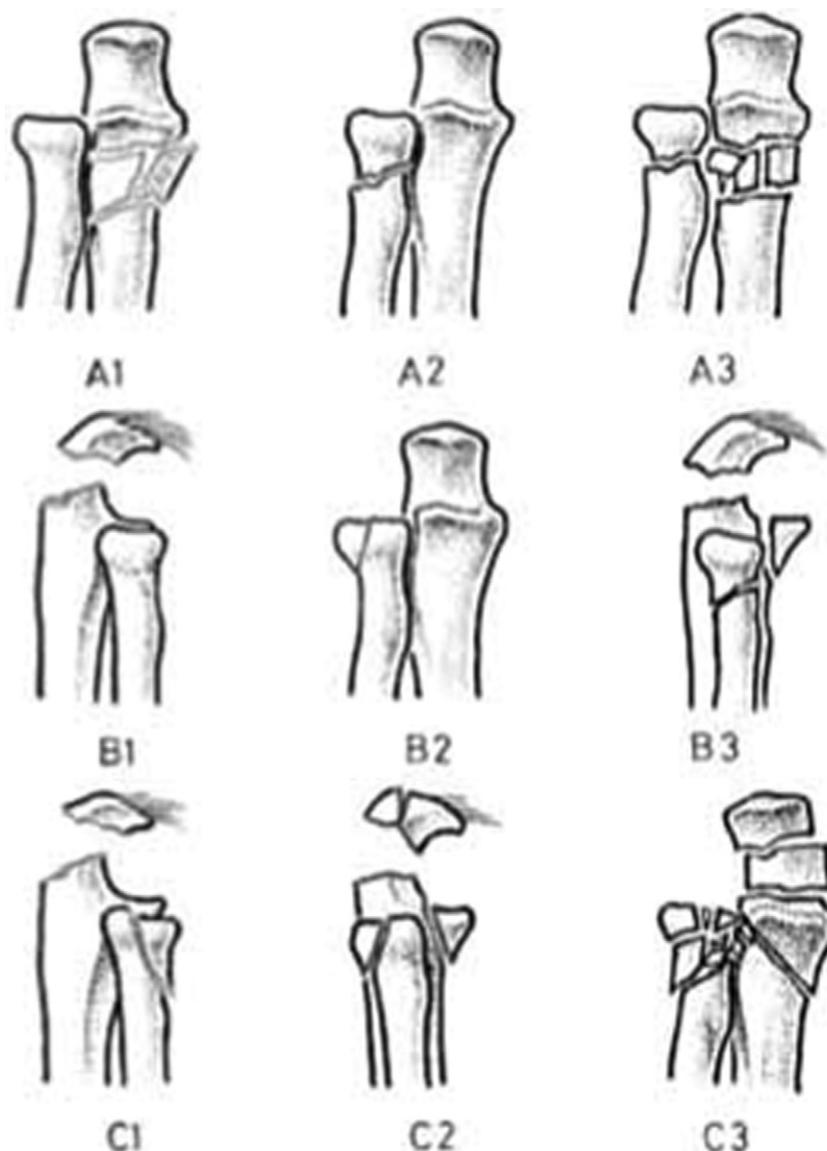


FIGURE 2: AO classification of olecranon fractures.

the olecranon, curves laterally around the olecranon prominence, and continues distally along the subcutaneous border of the ulna sufficiently to expose the fracture and place the hardware. The subcutaneous flaps are retracted with the deep fascia and periosteum in a full-thickness manner. The ulnar nerve is rarely dissected; it is sufficient to identify its position by palpation.

Stable fracture patterns

Transverse, displaced fractures proximal to the midpoint of the semilunar notch are considered stable and may be treated with several options. Traditionally, tension banding techniques have been favored. This construct was thought to convert the posterior tensile forces across the fracture into compressive forces at the artic-

ular surface. However, this has not been proven either clinically or in the laboratory.¹⁰ Despite this, the technique has been popular for many years.

Recently, there has been a trend away from tension banding toward more rigid plate-and-screw constructs.^{10,11} Although it has been accepted that tension banding may have a lower profile than plating, hardware removal rates of 65% to 80% are no lower than the rates observed with plates.^{12–16} Modern intramedullary nailing has been advocated as a method that combines the strength of plating with the low-profile nature of nailing.¹⁵ One clinical series reported no nail removals in a cohort of 18 patients with a minimum follow-up of one year.¹⁵

During the surgical approach, it is important to expose the fracture medially and laterally to fully assess

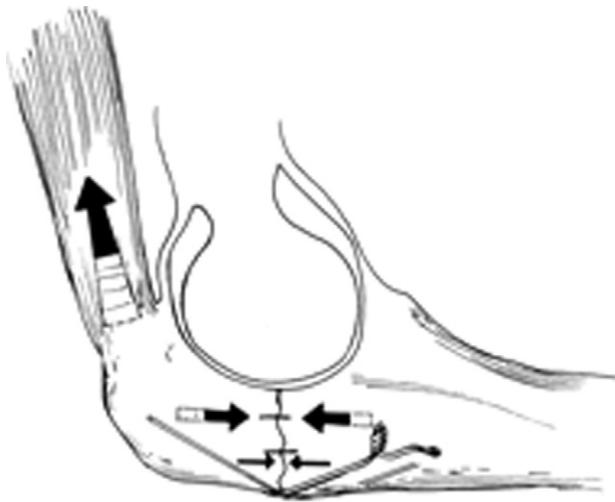


FIGURE 3: Tension band theory: the bending moment created by the contraction of the triceps results in a compressive force across the fracture site. This theory has not been validated clinically or in the laboratory.

the reduction and address any interposed tissue. Extending the elbow and reducing the tension from the triceps tendon may facilitate reduction until provisional fixation is placed. Fractures are typically reduced with a tenaculum under direct visualization.

If using a tension band technique, either 2 parallel 1.6-mm (0.062-in) K-wires or a 7.3-mm partially threaded cancellous screw may be placed antegrade across the fracture site. The K-wires may be placed either intramedullarily or bicortically across the anterior cortex of the ulna. If placed intramedullarily, there is an increased risk of proximal migration of the pins.^{9,17,18} To protect the anterior neurovascular structures, bicortical wires should be placed with no more than 10 mm of tip protrusion at least 15 mm distal to the tip of the coronoid.¹⁷ Case reports have described perforation of the ulnar artery and synostosis of the proximal radioulnar joint after penetration by a K-wire.¹⁹ A small incision in the triceps tendon is made to allow the wires to sit flush on bone. If placing the K-wires bicortically, care must be taken when burying the pins, as they may advance up to 10 mm distally during this process.^{1,19} Some evidence suggests that a single 7.3-mm intramedullary screw, with or without tension band wiring, may be biomechanically superior to K-wire tension banding in terms of compression at the articular surface and resistance to gapping, although no clinical data support this.^{2,10} In addition, the classic teaching that tension banding converts posterior tension forces to articular compression has failed to be validated in multiple biomechanical studies (Fig. 3).^{3,4,10,20} Traditionally, 18-gauge stainless steel wire is used to tension the con-

struct in a figure-of-eight fashion. Braided suture, such as FiberWire (Arthrex, Naples, FL), may be used instead to attempt to avoid the soft-tissue irritability of the metal wire. Although one biomechanical study has shown equivalent stability between the two in a cadaver model, no clinical data aside from case reports have been published.^{5,21,22}

Plating has grown in popularity for fixation of stable fracture patterns as the biomechanical deficiencies of tension banding have become better understood. In a cadaver model of transverse fractures, precontoured plate fixation was found to be superior to tension band wiring, both statically and during active extension of the elbow.^{6,7,20} Clinically, there has been one prospective randomized study directly comparing plate fixation with tension banding for Mayo type IIA fractures. Plate fixation had a lower complication rate and higher outcome scores, although objective motion at the elbow was equivalent between the 2 methods.^{6,12} This study did not demonstrate higher rates of hardware removal following plate fixation.

Given the biomechanical advantage of plate fixation over tension band wiring, the lack of evidence supporting the tension band theory of compression, and similar rates of hardware removal, we favor plating over tension banding for stable fracture patterns. The specific plate seems to be less important. One biomechanical study demonstrated that the current selection of precontoured plating options in osteoporotic bone shows little difference in their load to failure.^{8,23}

Recently, intramedullary nails have been developed to address the problems of soft-tissue irritation and the subsequent need for hardware removal. In a simple fracture model in cadaver specimens simulating early active motion, the intramedullary nail demonstrated notably less gapping and loosening at the fracture site than the tension band construct.^{5,24} With apparently lower removal rates and superior rigidity, intramedullary fixation may be a better solution than tension banding. Given its minimally invasive technique, some surgeons have broadened the indication for olecranon fixation to nondisplaced fractures. Although nondisplaced olecranon fractures have traditionally been treatment nonsurgically, intramedullary nails through percutaneous techniques allow immediate postoperative motion (Fig. 4).

Unstable fracture patterns

Comminuted fractures and fractures extending distal from the semilunar notch are considered unstable. Tension banding has long been considered inappropriate in these cases, and plating has been the standard method for years.^{1,5,9} Although these implants are strong and



FIGURE 4: Intramedullary nail inserted percutaneously for a nondisplaced fracture. **A** Because no open reduction was necessary, an intramedullary nail was placed under fluoroscopic guidance. Typically, these fractures are treated nonsurgically with immobilization, but in this particular case, **B** the patient elected to have a minimally invasive procedure to allow for immediate motion because the fracture is fixed rigidly.



FIGURE 5: Wound dehiscence exposing a posterior plate.

reliable, they have high rates of soft-tissue irritation (Fig. 5) and often require hardware removal.^{3,10,13,14}

Traditional AO technique for plating comminuted olecranon fractures uses a 1/3-tubular nonlocking plate contoured for the proximal ulna.^{10,11,25} The use of precontoured plates with locking screw options has increased as surgeons gain experience with this tech-

nology in other regions of the body. However, in a cadaver model, no differences in stiffness or load to failure have been noted between nonlocking plating and locked compression plating.^{12–16,26} Second, many of the precontoured plates should not be used without consideration of the ulna's osteology, as considerable variation in ulnar morphology has been documented. Few plates accommodate the proximal ulnar dorsal angulation, which bends an average of 5.7° (range 0° to 14°). If a straight plate is applied to an ulna with proximal dorsal angulation, the plate may force the fracture into a malunion²⁷ (Fig. 6). Inconsiderate use of such a plate may alter crucial elbow relationships, such as the radiocapitellar joint and proximal radioulnar joint.^{15,27}

Most intramedullary devices designed for the proximal ulna are indicated for simple, transverse fractures. However, one multiplanar, locked intramedullary nail (OlecraNail, Mylad Orthopedic Solutions, Doylestown, PA) is indicated for unstable, comminuted fractures (Fig. 7). Similar to a locking plate, this particular nail has a fixed-angle design and rigidly stabilizes bone

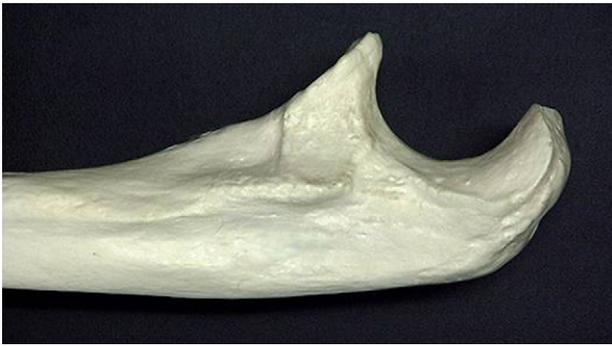


FIGURE 6: Ulna morphology demonstrating the proximal ulnar dorsal angulation.



FIGURE 8: Malreduced olecranon.



FIGURE 7: Multiplanar locked intramedullary nail.

fragments in all planes. In a study comparing nailing to locked plating for unstable olecranon fractures in a cadaveric model, both implants controlled fragments equally well and survived an equal number of cycles.^{9,15,17,18} The nail, however, held fragments stable under greater maximal loads, suggesting that nailing may be of benefit to patients who must weight bear with their upper extremities in the immediate postoperative period, such as elderly or polytrauma patients.

Regardless of the fixation method chosen, the majority of complications arising from treatment of unstable fractures are due to improper reduction. The sigmoid notch must be scrutinized. Anything short of a perfectly anatomic reduction will result in loss of motion in the short term and posttraumatic degeneration in the long term. It is common to reduce the posterior cortex first, thereby indirectly reducing the articular surface. Although this technique may work well for simple fracture patterns, the articular fragments are often detached from the posterior cortex in comminuted fractures. This may result in a malreduced articular surface despite an anatomic reduction of the posterior cortex (Fig. 8). A more accurate technique is to reduce the bone in layers, beginning with the articular surface and working dorsally. With this technique, the posterior cortex is the last layer, not the first, to be reduced. Some fragments may be trapped between 2 other fragments, and others may need provisional fixation such as a

1.14-mm (0.045-in) K-wire. After all layers have been reduced and provisionally fixed, definitive fixation is placed, usually one or more plates and screws or a fixed-angle intramedullary device (Fig. 9). Overly aggressive compression of olecranon fragments may alter the radius of the semilunar notch (Fig. 10). For this reason, compression of intra-articular portions of the proximal ulna should be monitored closely intraoperatively and probably avoided in most unstable fracture patterns. Locking technology lends itself well to these situations.

In some Mayo type IIB fractures with irreducible intercalary comminution, excision of the intercalary fragments and advancement of the proximal ulnar fragment has been successfully used, with the proximal fragment carefully contoured to re-establish the proper radius of curvature for the articular portion of the ulna.^{17,28}

One technical hurdle is the plating of small proximal fragments.^{19,29} The most proximal screws from a posterior plate provide the only fixation in the proximal fragment and can split the fragment along the sagittal plane (Fig. 11). Reinforcing the plate construct with suture augmentation through the triceps tendon has been successfully reported in case reports.²⁹ In biomechanical testing of a cadaver model, suture augmentation increased the ultimate load to failure of the plate construct compared to plate fixation alone.²⁹

Proximal fragment excision and triceps advancement is not a preferred first-line therapy. It is typically reserved as a salvage procedure after failed internal fixation or as first-line therapy in patients for whom the risks or expected outcomes of internal fixation would be unacceptable. Biomechanical studies have suggested that it is safe to remove up to 50% of the olecranon's articular surface without undue instability in the elbow joint.³⁰ It is critical to assess the residual stability of the elbow when performing this technique. Overall, low

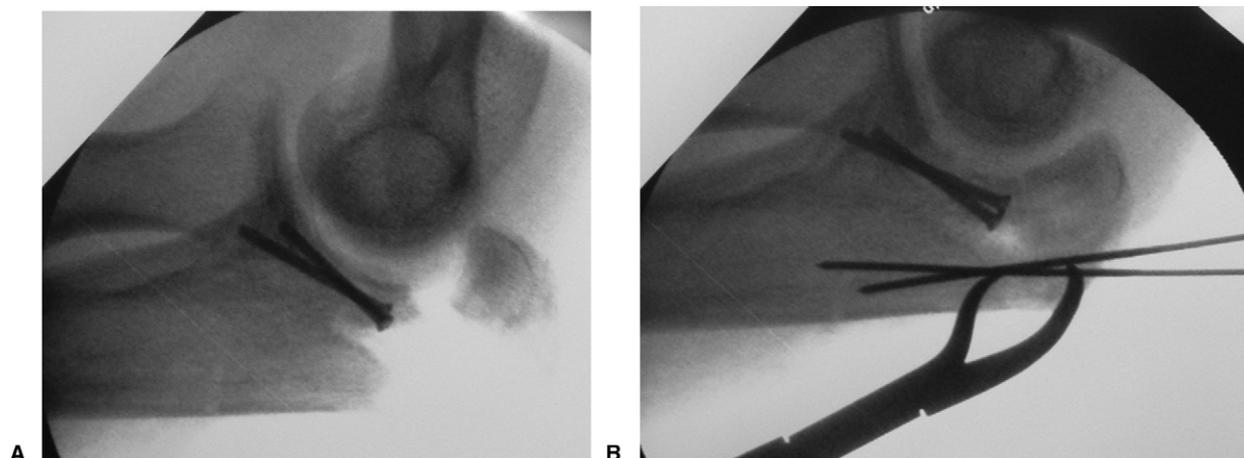


FIGURE 9: Preferred reduction technique: distal to proximal, anterior to posterior. **A** Note that the articular fragments anteriorly are reduced and provisionally fixed first. **B** The last fragment to reduce is the olecranon posteriorly.

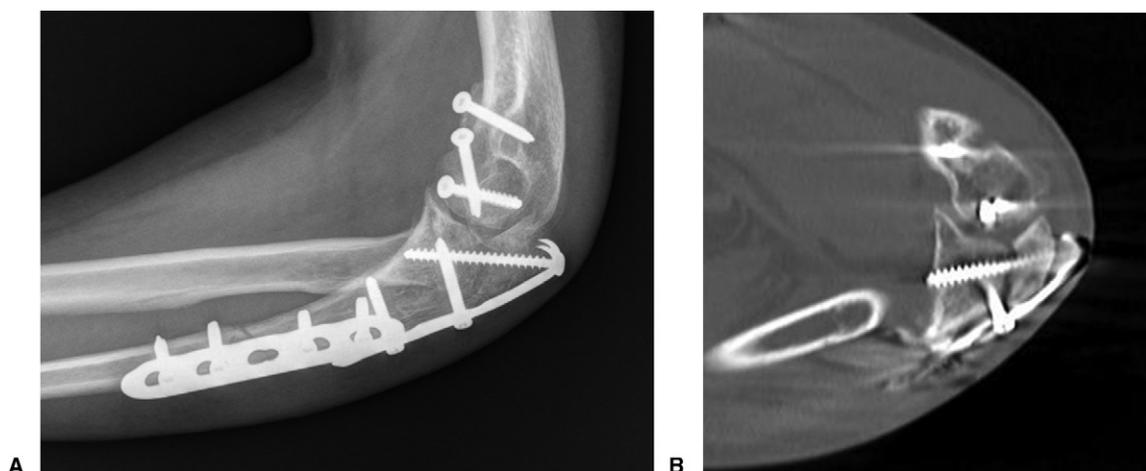


FIGURE 10: Over-compression of the articular surface resulting in malunion of the semilunar notch. **A** Plain radiograph; **B** computed tomography image.

complication rates have been reported with this procedure, although this may be due to the absence of hardware rather than the procedure itself.^{31,32} When performing this technique, it is important to attach the triceps to the posterior portion of the ulna to maximize its mechanical advantage. We tend to use bone tunnels, although some have reported success with suture anchors.^{33,34}

REHABILITATION

In the immediate postoperative period, the elbow is splinted in full extension to decrease tension across the fracture site. Many surgeons will keep the elbow immobilized for the first week for soft-tissue rest and healing.⁴ We feel that if the fixation is secure enough, passive and active assisted range of motion can begin on the first postoperative day. If a tension band con-

struct is used, we recommend splinting for 2 weeks, followed by range of motion exercises. Strengthening is usually reserved until 12 weeks following surgery. With triceps advancement, we typically immobilize the elbow in 45° of extension for 4 weeks and progressively allow 10° of additional flexion each week.

Although plating may seem to provide sufficient stability for early strengthening, biomechanical data suggest that plates will resist gentle motion, but not more active motion, such as rising from a chair.²³ This further emphasizes delayed strengthening, with early focus on range of motion only. Stable fixation is paramount to allow early motion of the elbow, which is linked to better final outcomes.^{7,35} Passive motion generates less distraction at the fracture site and should be emphasized early in the rehabilitation process.¹⁰

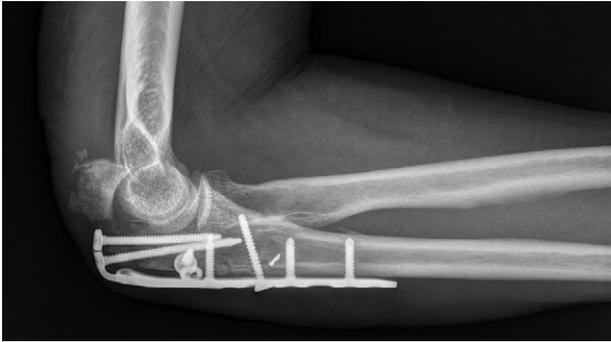


FIGURE 11: Hardware failure through sagittal splitting of the proximal fragment by the proximal screw in osteoporotic bone after plating.

OUTCOMES

Outcomes have historically been good in the treatment of olecranon fractures.⁴ Regardless of the fixation method, bony union is the expected outcome of surgical fixation. Mayo type III fractures are associated with worse long-term outcomes than more stable fracture patterns.³ Average time to union for fixation is typically 3 to 4 months.⁹ Loss of terminal extension is the most frequent complaint after surgery, and late improvement of up to 12° in range of motion may be seen over the course of follow-up.^{4,17} Overall, plate fixation and tension banding have similar outcomes in the literature.

One of the longest follow-ups available in the literature is a cohort of 45 women and 28 men followed up an average of 19 years in Sweden. In this cohort, 84% had open reduction and internal fixation, and 94% reported good or excellent results, with 50% of the injured elbows demonstrating radiographic signs of degeneration compared to 11% of the uninjured, contralateral elbows.³⁶

Results in 78 patients treated with tension band constructs demonstrated a nonunion rate of 1.3%. In the same study, an overall infection rate of 2.56% was observed.⁹ Another study of tension band techniques¹⁸ showed an average arc of motion of 116° ± 22°, with an average extension loss of 15° ± 17°.

With regard to plating, multiple studies have shown similar results to tension banding. Results of 19 patients with comminuted olecranon fractures treated with locking plating showed that all healed at a mean time of 4 months, with a mean arc of motion from 13° to 136°; complications included one infection and one ulnar nerve palsy that did not resolve. Overall results showed a 94% good or excellent outcome,⁵ although 19% of the patients in that study had a loss of extension more than 30°, and 56% had hardware removal within the 2-year study window.

A Canadian study of 25 patients with a mix of Mayo type II and III fractures treated with plate fixation with

an average follow-up of 34 months demonstrated no cases of nonunion, 22 of 25 good or excellent results, high patient satisfaction, and low pain scores. Mean Disabilities of the Arm, Shoulder, and Hand scores showed near-normal upper extremity function, and the Short-Form 36 Health Survey scores showed no difference from those of average Americans. Plate removal rate¹⁴ was 20%. A Chinese study on mid-term results for comminuted and complex olecranon fractures treated with contoured plating demonstrated an average time to union of 15 weeks, with no nonunions, mean range of motion of 14° to 125°, and 78.6% good or excellent outcomes.³⁷ This is a somewhat poorer outcome than those of the other studies, but this cohort sustained more severe injuries, which are known to be associated with worse outcomes.

In a study of outcomes with the use of locked intramedullary nailing, 18 patients with unstable proximal ulnar fractures followed up for a minimum of 1 year after surgery showed a range of motion within 10° of that of the contralateral elbow, no pain, and full return of function to normal activities.³⁸ Another series from Germany using a different intramedullary nail reported 68 of 73 good or excellent results in a mixed pool of simple and comminuted fractures.³⁹

There is a lack of randomized, controlled studies for comparable injury patterns and treatment methods. We are unable at this time to make a recommendation based on level I clinical data between the use of plates and intramedullary fixation. At this time, surgeons must consider the advantages and disadvantages of each device as it applies to each clinical situation.

COMPLICATIONS

Common complications seen after olecranon fractures are nonunion, malunion, infection, ulnar neuritis, elbow stiffness, posttraumatic arthritis, and heterotopic ossification.

Loss of motion

Loss of terminal extension is to be expected frequently following olecranon fractures, and patients should be counseled as such.³ An average loss of 10% to 15% as compared to the contralateral side may be expected, with a frequency^{1,12} of up to 75%.

Ulnar nerve neuritis

Ulnar nerve neuritis is uncommon, occurring in 2% to 12% of cases.^{1,17,40} Observation until resolution is typically sufficient. However, ulnar neurolysis with or without transposition may be required if symptoms fail to improve. Timing of EMG studies is not clear. Im-

provement of ulnar function has been documented from 3 to 20 months after surgery.^{17,40} If there is substantial soft-tissue swelling at the time of the index procedure, it may be wise to perform an *in situ* neurolysis. Ulnar nerve palsy is also associated with poor reduction of the fracture, particularly with medially displaced fragments.⁴⁰

Heterotopic ossification

One study of 786 fractures about the elbow, including olecranon fractures, found delay to surgery of 8 days or more and delay to mobilization of 15 days or more to be associated with increased rates of heterotopic ossification (HO).⁴¹ However, that same study found the rates of HO in isolated olecranon fractures to be less than 1%, with only 1 of 221 fractures developing HO. Based on these rates, there is no role for prophylaxis against HO in isolated olecranon fractures. In more complex injury patterns, there may be a role for chemoprophylaxis with indomethacin; however, there are insufficient data for a more specific recommendation. Radiation treatment has not been found to be successful.⁴²

Arthrosis

Rates of posttraumatic elbow arthrosis of up to 20% have been reported following olecranon fracture. An articular stepoff of 2 mm or greater has been associated with this outcome.¹⁶ In one follow-up study with an average follow-up of 4 to 5 years, 16 of 21 patients demonstrated radiographic signs of arthrosis, with 13 having only minor changes on x-ray and 3 having more severe signs of arthritis. Initial fracture displacement was also associated with development of arthrosis.¹⁸ This reinforces the classic AO principle of anatomic reduction for intra-articular fractures.

Hardware removal

The most common complication after fixation of olecranon fractures is symptomatic hardware issues. Tension banding was thought to be less irritating; however, this has not been supported in the literature. Removal rates of 20% to 100% have been reported for tension banding, equivalent to that of plating.^{3,11,13,14,16,43} Intramedullary nails for the olecranon have been shown to have low hardware removal rates.³⁹ One clinical series demonstrated no soft-tissue irritation and no occurrences of implant removal after use of a locked intramedullary nail at 1 year after surgery.³⁸

Regardless of fixation method, surgeons may not be aware of the full extent to which these implants affect patients. In a survey distributed to 538 surgeons, the vast majority believed their implant removal rate to be

less than 30%. Patients, however, reported a removal rate of 65%. Although surgeons believed that they removed the implant they originally placed in 92% of cases, patients reported that they returned to the original surgeon for removal only 13% of the time.² The authors hypothesized that because patients did not often return to the original surgeons, the surgeon is left to assume that all is well with the implants but, in reality, it is not. This particular study did not include intramedullary nails, which appear to have a lower removal rate.² Unless an intramedullary implant is used, it is our opinion that, given the high probability of hardware removal, it is important to counsel patients so that they have appropriate postoperative expectations.

Nonunion

There is an approximately 1% rate of nonunion after internal fixation, with nonunions being more common in higher-energy injuries.^{44,45} The most common site for ulnar nonunion is at the metadiaphyseal junction. This may be due in part to a relative paucity of vascularity and in part to surgeon error. If the patient has formed a painless, fibrous nonunion with ulnohumeral motion of more than 90°, surgical intervention is unlikely to benefit the patient, and any interventions should have a compelling rationale.⁴⁴

After a nonunion has occurred, it has been our experience that changing the biological milieu to encourage healing can be extremely challenging. Bone quality quickly deteriorates, and fixation will be compromised. Segmental defects and gaps of missing bone are commonplace. Whereas in nonarticular fractures in which such gaps may be closed by shortening the bone, closing such gaps in these cases will shorten the radius of the semilunar notch and result in articular incongruity. Consequently, in addition to rigid fixation, use of autograft and off-label bone morphogenetic protein (BMP) has been routine in our practice. In our series evaluating BMP use for upper extremity nonunions, we observed that fracture defects of less than 4 cm and the presence of vascularized soft tissue are good prognostic indicators for success using BMP techniques.⁴⁶

Looking at the treatment of 12 nonunions of the proximal third of the ulna, Rotini et al recommended rigid fixation and structural bone graft and advised against a reconstruction-style plate (as being insufficiently rigid).⁴⁴ They observed better outcomes among the patients whose nonunions were more than 5 cm distal to the tip of the olecranon.

Should nonunion repairs be unsuccessful, alternative measures must be considered. If the proximal fragment is small, fragment excision and triceps advancement is

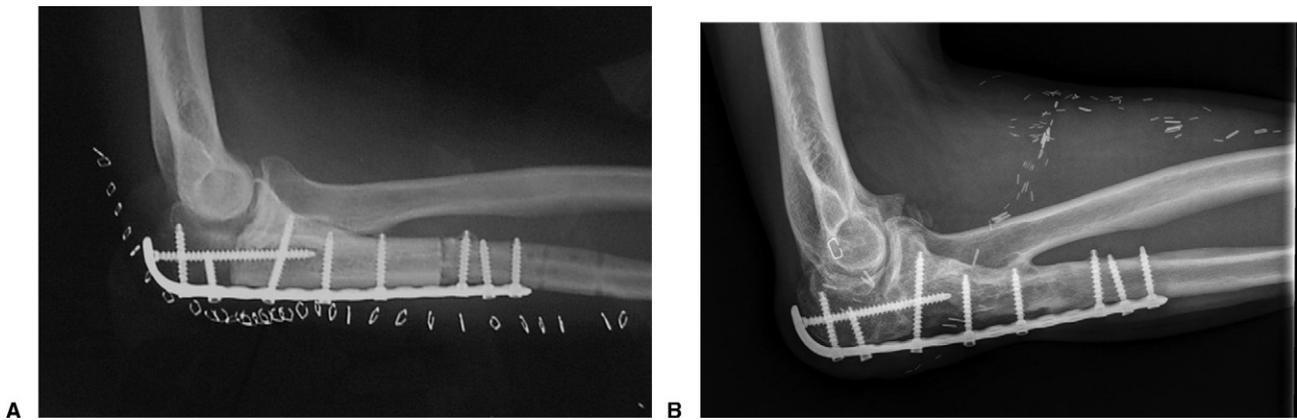


FIGURE 12: Segmental bone loss reconstructed with allograft interposition. **A** Interposed allograft spanning segmental bone loss; **B** 3 years following reconstruction.

an option. When the size of the proximal olecranon fragment exceeds 50% and joint stability is compromised, linked total elbow arthroplasty (TEA) can be an effective salvage procedure for maintaining motion. Although much has been written about TEA in the setting of comminuted distal humerus fractures, there is no clinical evidence specific to olecranon fracture revisions. Without a biological footprint for ingrowth, it is our observation that attaching the triceps tendon to the metal prosthesis invariably fails within a year. Fractional lengthening of the triceps may be used successfully to gain up to 6 cm of length, decreasing the tension of the repair. If more length is desired, the anconeus may be used as a local tissue graft. In the revision setting, the anconeus is often fibrotic and not a good option for transfer or augmentation. Autograft or allograft gracilis tendon may serve as an alternative in those cases. In our experience, these graft reconstructions are unpredictable and often result in failure.

Traditionally, allograft reconstructions of the olecranon have been disappointing, with high rates of failure. We have used allograft reconstruction successfully in one instance and attributed this success to the fact that the allograft was flanked on either side by vascularized bone (Fig. 12). Regardless, we still advocate that *en bloc* allograft reconstruction is an unpredictable surgery and should be avoided if possible.

Malunion

Malunions at the olecranon can result in loss of motion and degeneration due to joint incongruity. Malunions occur more commonly with comminuted fractures because of the greater risk of inadequate reduction or improper fixation. Should fixation be judged inadequate to allow early motion of the joint, it is better to immobilize the elbow until union and accept a stiff elbow. It

is more predictable to surgically release a stiff elbow than to correct a malunited elbow joint.

Intra-articular malunions often result in rapid joint degeneration, so that by the time a patient presents with pain, malunion correction is futile and a salvage procedure must be considered, such as fascial interpositional arthroplasty or TEA. As in the setting of primary arthritis, TEA is reserved for low-demand patients, and patient expectation should be guided appropriately. In our experience, linked TEA has been more predictable than unlinked TEA, with fewer complications. Fascial interpositional arthroplasty is generally reserved for younger patients who are not good candidates for TEA.

Extra-articular malunions typically occur at the junction of the metaphysis and diaphysis. Patients with these malunions typically present with either reduced motion or radial head subluxation. Often, these patients are misdiagnosed as having residual posterolateral instability or an incompetent annular ligament. Loss of the usually straight dorsal ulnar cortical line should guide the surgeon toward the proper diagnosis.^{47,48} Even experienced surgeons may believe that the proximal ulna has been reduced anatomically, only to be surprised by a radial head dislocation at the first postoperative visit. This requires a corrective osteotomy of the ulna, not a lateral ligament reconstruction. In addition to scrutinizing the ulna, careful attention must be given to appropriate bony apposition, rigid fixation, and consideration of bone grafting and even BMP, as necessary.

Subluxation

The most common causes of subluxation after surgery are malreduced Monteggia fractures, fragment excision, and triceps advancement. We believe that all but the smallest excision in the acute traumatic setting has untoward consequences and should be avoided if pos-

sible.³⁰ Only the most comminuted proximal fragment with the poorest of bone quality in the lowest-demand patient should be considered for excision. The chances of subluxation rise with associated bony or ligamentous injuries.

Infection

The elbow lacks an ample soft-tissue envelope compared to other joints. As a result, the risk of infection and wound problems should be taken seriously. If a postoperative wound becomes erythematous or dehisces, aggressive measures should be taken. It is not acceptable to place the patient on oral antibiotics for outpatient follow-up. Because of the paucity of soft tissue, any superficial infection may soon develop into a deep infection.

If improvement is not observed within 24 hours of initiating antibiotic treatment, the surgeon should have a low threshold for surgical debridement. In the past, we have used external fixation and antibiotic beads in severe cases. After 6 to 12 weeks of antibiotics, we recommend waiting an additional 12 weeks to clinically validate that the infection has been eradicated before considering reconstructive efforts. Although few clinical data exist for the protocol, it has been our experience that the elbow does not tolerate multiple reconstructive efforts, and the chance for a successful outcome should not be jeopardized by impatience.

In conclusion, olecranon fractures are a frequent upper extremity injury, with generally good results after treatment. Unfortunately, there is a paucity of good clinical data comparing treatment options to guide surgical decision making. The tension band technique, although historically associated with acceptable outcomes, does not provide the mechanical stability for which it was initially touted. Most of the available evidence is from biomechanical models, with plate and intramedullary fixation being best supported. Symptomatic hardware issues and loss of motion are frequent complications, and patient expectations should be managed appropriately. In the setting of residual instability, the surgeon should look to the bony reduction as the likely etiology, not ligamentous incompetence. Infections should be treated aggressively. However, the fixation methods available to the surgeon, combined with adhering to the principles of fracture fixation, result in good to excellent outcomes in the majority of cases.

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