Olecranon Fractures

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"Olecranon Fractures: A Critical Analysis Review"

Introduction

Fracture of the olecranon process is the most common injury to the proximal ulna and accounts for approximately 18% of proximal forearm fractures[1]. The severity of injury varies from a simple olecranon fracture to a complex Monteggia/Monteggia-like injury[2]. **Fractures of the olecranon process may be considered intra-articular with extension into the greater sigmoid notch or extra-articular avulsion injuries of the triceps tendon insertion.** The management of displaced fractures has consisted of surgical fixation based on fracture characteristics and ulnohumeral stability[3-7]. Recent evidence has highlighted good outcomes with non-operative management even with displaced fractures in the older population, avoiding the risks associated with surgery[8-11]. The aim of this review is to critically **analyze** the current evidence in the management of isolated traumatic olecranon fractures.

Anatomy

The olecranon process plays a key role in elbow stability. The ulnohumeral articulation is **the primary osseous stabilizer of the elbow and resembles** a complex spiral hinge between the humeral trochlea and ulna greater sigmoid notch. **The sigmoid notch can be divided into three zones, anterior-articular surface, posterior-articular surface, with 2 facets in each, and intervening zone which is the non-loadbearing bare area. The posterior zone consists of the olecranon process with the posterolateral and posteromedial facets, the anterior zone the anteromedial and anterolateral facet of the coronoid providing a four-facet support for the forearm on the end of the humerus. An analogy can be made with the hull of a boat (being the humerus) out of the water balanced on a 4-legged cradle (the four facets) (Figure 1). Care must be taken to ensure that the anterior and posterior**

articular surfaces are well apposed against the trochlea. It is not necessary to elevate impaction fractures of the bare area in most cases as this is a non-loadbearing area. The olecranon process prevents anterior translation of the ulna with respect to the distal humerus, and the coronoid process prevents posterior translation. The two work in concert to control varus and valgus displacement. The bare area, lacking hyaline cartilage, between the coronoid and olecranon processes is frequently the site of fracture and care should be taken not to over-compress this area **during open reduction and internal fixation as this can lead to narrowing** of the sigmoid notch and joint incongruency.

It is a common error to assume the ulna is a straight bone. Several anatomical and radiological studies **improved our knowledge of the anatomy of the proximal ulna**[12-15]. Two angles have shown clinical importance when the olecranon is managed surgically. The dorsal bowing of the proximal ulna known as the Proximal Ulna Dorsal Angulation (PUDA) is important to reconstruct and a mal-reduced PUDA of ≥5° can lead to substantial loss in the flexion/extension arc range of movement (ROM)[13, 15]. It is also important to reconstruct the anteromedial angulation which is commonly known as the Varus Angle (VA). A mal-reduced VA can lead to loss in elbow extension/flexion and pronation/supination ROM[16]. This is more important with an intramedullary screw or straight plate osteosynthesis which can lead to mal-reduction and opening at the fracture site. **A medial entry point during screw fixation can cause a mal-reduction of the VA leading to an articular step-off**[14].

The proximal third of the olecranon **acts** as an insertion point for the triceps muscle which is the main deforming force in the displaced fracture. The triceps footprint consists of a deep muscular and a superficial tendinous part[17]. The compression of the plate on the tendinous part can explain the irritational symptoms some patients experience following a direct posterior plate fixation, therefore, some surgeons advocate making a small split in the tendon insertion to accommodate for the plate, which can then be repaired at end of the procedure.

Mechanism of injury:

Olecranon fractures **occur** due to direct trauma, indirect trauma, or repetitive overuse injury. The olecranon process is at risk of fracture during a direct trauma due to its subcutaneous location. A cadaveric study has shown that olecranon fractures usually occur when the elbow is flexed to 90° and the olecranon is impacted into the distal humerus causing a multi-fragmentary fracture configuration[18]. Indirect traumatic fractures are caused by the forceful eccentric contraction of the triceps muscle during a fall onto an outstretched hand causing a transverse or short oblique fracture. It is essential to differentiate those injures from elbow fracture-dislocations during clinical and radiographic assessment as they can have a similar mechanism of injury. Stress fractures are less common and usually **occur** in professional throwing athletes, especially baseball players, due to repetitive microtrauma to the olecranon caused by the throwing motion[19]. This review will focus on the management of traumatic olecranon fractures.

Classification

Several classification systems are described in the literature to classify fractures of the olecranon based on a combination of fracture displacement, configuration, fragmentation, and/or elbow instability. The main limitation of the current classifications is the low reproducibility with fair to moderate inter/intra-observer reliability[20]. The Colton classification was the first described and classified olecranon fractures into undisplaced type-1 and displaced type-2 fractures, type-2 is further subdivided into four categories: avulsion, transverse/oblique, comminuted, and fracture-dislocation[21]. Another classification was introduced by the AO-group and classifies the proximal ulna and radius fractures into three categories (A)extra-articular, (B)intra-articular fracture of the ulna or the radius, and (C)intra-articular fractures of both. The AO classification is mainly used as a research tool rather than in clinical practice[6]. The Schatzker and Mayo classification systems[22, 23] are used more widely in the literature and clinical practice as they have the advantage of guiding treatment and useful in predicting outcomes with Schatzker Types C and D and Mayo Type 3 associated with worse outcomes[24-26]. The Mayo classification system is based on fracture displacement, fragmentation , and elbow stability[25]. This classification is simple and is particularly useful in guiding management and has shown to have better inter/intra-observer reproducibility than Colton and Schatzker classifications. For these reasons it is the classification of choice in our practice and will be used during this review[20].

Etiology

The incidence of olecranon fractures is 12 per 100,000 population[1]. The largest epidemiological studies were published from Italy, Scotland, and Sweden with the study from the Swedish Fracture Registry having the largest cohort of 2462 olecranon fracutres[1, 27, 28]. All studies show that a displaced mid-olecranon (Mayo 2) injuries are the most common and accounts for 71-90% of olecranon fractures with the simple configuration (Mayo 2A) being most common. The mean/median age of patients in those studies ranged from 57 to 66, however, there was a significant difference in age between male and female sex. Men are more likely to have an olecranon fracture in the 5th and 6th decade of age and women in the 7th decade. Those three studies show that low energy injury is the most common mechanism of injury and accounts for approximately 70% of all olecranon fractures. High energy injuries are less common and are more likely to occur in younger male patients.

Diagnosis:

Patients typically present following a traumatic event with pain, ecchymosis, and swelling. Clinical examination can demonstrate a palpable gap and/or inability to actively extend the elbow against gravity in displaced fractures indicating a discontinuity of the triceps mechanism. It is essential to examine the entire limb for other injuries, examine for signs of open injury, and complete a neurovascular examination of the extremity.

The diagnosis of isolated olecranon fractures is made by adequate anteroposterior and lateral radiographs. The lateral radiograph has a key role in assessing the displacement, fracture fragmentation, and the presence of joint subluxation. It is important to ensure a true lateral radiograph of the elbow is obtained and that the **center** of the radial neck is aligned with the **center** of the radial head. Identification of the anterior "V" sign is important as this suggests incongruity between the coronoid and trochlea and/or radial head and capitellum and therefore anterior translation of the forearm (Figure 2), indicating a Mayo Type 3 injury. If there is a suspicion of a more complex injury such as fracture-dislocation of the elbow, then we advocate the use of Computed Tomography (CT) to assess the integrity of the coronoid, radial head, and distal humerus[29]. Radiographs and CT are static modalities and if there is any suspicion of ulnohumeral joint instability (Mayo 3 vs Mayo 2) **then this should be examined intra-operatively by applying anterior and posterior force on the forearm to assess for ulnohumeral stability.** If the decision is to manage the patient non-operatively then a close follow-up with serial radiographs is essential as anterior radio-ulna "escape" can occur.

Management

Treatment of an isolated olecranon fractures is based on the fracture and patient characteristics. The treatment is broadly categorized into non-operative and surgical management. Recommendations for care are listed in table 1 and figure 3 shows the management algorithm followed by the senior author.

Non-operative management

Non-operative management is indicated for most patients with undisplaced fractures (defined as a fracture gap ≤ 2mm)[5, 7]. Recent evidence evaluating non-operative methods shows good outcomes in managing displaced fractures in the elderly with lower functional demands. Most published studies are retrospective observational studies. There is one prospective and one randomized control trial (RCT)[9-11, 30-33]. All these studies included stable fractures only (Mayo 1/2) as it is not desirable to leave a patient with an unstable elbow (Mayo 3) that is likely to lead to substantial disability. A trial by Duckworth et al. was designed to compare the outcomes of displaced olecranon fractures between operative and non-operative management in patients aged ≥75. The study recruited 19 patients and stopped during the recruitment phase due to high complication rates in the surgical arm. Nine-patients (82%) developed a complication in the surgical arm with loss of reduction being the most common in 6 patients (55%). The analysis of those 19 patients showed no difference (although the study lacked power due to the small numbers) in the functional outcomes between the operative and non-operative patients at 6, 12, 26, and 52 weeks with final Mayo Elbow Performance Score (MEPS) of 95 in both groups and Disabilities of Arm, Shoulder and Hand (DASH) score of 23 in the non-operative arm compared to 22 in the operative arm[10]. One meta-analysis published in 2021 compared operative to non-operative management of displaced olecranon fractures in the elderly included the one RCT and 5 observational studies[8]. This study showed an expected finding that fracture union rate was only 14% with non-operative management compared to 95% of the operative group. This, however, did not appear to impact the functional outcomes with both groups showing good to excellent outcomes with average MEPS of 95 and DASH of 12 in the non-operative group compared to MEPS of 92-95 and DASH of 18-27 in the operative group[8]. The main finding from the meta-analysis was the high re-operation rates associated with surgery which ranged from 33-40% and other complications including wound problems, and infection[8]. Another retrospective cohort-study showed good functional outcomes (MEPS 93 and DASH 26) associated with non-operative management with no difference compared to surgery and reported one complication in the non-operative group of ulnar nerve palsy without requiring further surgery[30]. Bruinsma et al. evaluated 10 patients with non-union of olecranon fractures and reported that patients had reasonable outcomes with only two patients, aged 21 and 45 years, going on to have surgery for non-union[34]. There are two on-going multicentered RCTs comparing operative and non-operative treatment of olecranon fractures, SOFIE and SCORE, from Australia and Scandinavian countries in the recruitment phase[35, 36]. Those trials are likely to strengthen the quality of evidence in the management of elderly patients with displaced olecranon fractures.

There is no evidence to guide what is the best non-operative regime. The method and the period of immobilization differed between studies. We would recommend early range of motion as pain allows, with early check radiographs to ensure there is no evidence of an occult unstable injury pattern.

Operative management:

Surgical fixation of the olecranon reports back to 1883 by Lister[37]. Several surgical methods for osteosynthesis are available including Tension Band Wiring (TBW), Plate Osteosynthesis (PO), Suture Repair (SR), Intramedullary (IM) fixation, and fragment excision with triceps advancement**. In the senior author's practice, SR is used for simple fractures with a**

stable ulnohumeral joint and for multifragmentary fractures we use PO fixation with or without SR augmentation.

Tension Band Wire

TBW technique is advocated for a nonfragmentary fractures with a stable elbow. It works on the principle that the bending moment of the forearm created by the triceps contraction resulting in a dynamic compression across the fracture site. Cadaveric studies disputed if this principle works and one study showed that the tension principle only works during active elbow extension between 20°-120°, this means that TBW construct works as a simple neutralization method for majority of the time (flexion or passive extension)[38]. Several different TBW constructs have been described in the literature, the most common used construct is the AO-technique which includes two 1.6mm bicortical K-wires in combination with 18-gauge stainless steel wire to provide tension in a figure-of-eight configuration (AO-TBW). Transcortical wires which are subchondral and exit through the volar cortex provide a more stable construct and lower risk of k-wire migration than intramedullary K-wire placement but if left long can be responsible for neurological injury, radius impingement, or even synostosis[39-41]. An alternative technique uses an antegrade partially-threaded cancellous screw with the same figure-of-eight stainless steel wire (S-TBW) and biomechanically S-TBW is better than AO-TBW in preventing fracture gapping[42]. Clinical studies show 95-100% union rate using any TBW construct, however, this was associated with complication rates as high as 85% with the highest two complications being implant prominence and removal. Ahmed et al., in a quasi-RCT, compared the two commonly used constructs, with 15 patients in each group, showing no significant difference in the functional outcomes. The results from this study, however, showed higher rate of implant prominence and removal surgery associated with AO-TBW. Other modifications have been described including the use of pins with eyelets (instead of bending the k-wires), two screws, cable-pin TBW, and biodegradable-wire-and-screw TBW. There is one small size RCT published for each construct comparing it with AO-TBW. The results are promising in those studies, but the lack of further studies means the evidence is non-conclusive regarding their effectiveness and safety (Table 2) (Appendix 1)[10, 43-48].

TBW using k-wires was thought to be a simple, reproducible procedure, however, this was challenged by Schneider et al who evaluated the X-rays of 233 patients and rated the fixation by expert elbow trauma surgeons based on 10 key elements and showed a mean of 4.24 errors in each procedure[49]. This study clearly demonstrated that TBW procedure is challenging to reproduce, which might explain the high complications rates.

Plate Osteosynthesis

PO is a common method of fixation in olecranon fractures. It can be used for all subtypes, however, it is also associated with complications and higher operative cost[50]. **The main two indications of using PO are multi-fragmentary fractures or ulnohumeral instability, and it can also be used for simple fracture patterns.** In all olecranon fracture fixation ulnohumeral stability should be assessed with anteroposterior draw and PO is required where instability is detected (Figure 4). In unstable fractures and those with an anterior "V" sign, care must be taken to reduce the forearm dorsally before plate fixation ensuring that all four facets of the greater sigmoid notch are apposed to the trochlea (Figure 5).

Several PO constructs are being used and can be classified by the screw technology used into locking or non-locking plates or based on the number of plates used into single-dorsal or dual-plating (DP). DP uses lower profile plates in an attempt to reduce the irritation caused by the plate. Biomechanical studies show that all PO constructs results in adequate stability to permit early postoperative ROM. Those studies suggested that risk of failure is higher with osteoporotic bone and when the fracture is proximal to the midpoint of sigmoid notch. The use of 2 proximal triceps screws and augmentation with SR or TBW might be beneficial in more proximal fractures (Figure 6)[51-62]. Clinical studies, compromising largely of retrospective case-series (level-IV), examining PO in different types of olecranon fractures suggest good outcomes associated with use of PO in all fracture types including multifragmentary and unstable injuries. PO has a high union rate (93-100%) and high functional outcomes with an average Oxford Elbow Score of 44, MEPS range 89-99, ROM range 116°-139°, quick-DASH range 13-17, DASH range 4.6-17, and Broberg-Morrey range 81-97. The implant removal in these studies ranged from 11-80%[63-71]. In a study of 321 olecranon fractures fixed with pre-contoured PO, 15.6% patients underwent implant removal[72]. This study has shown that re-operations occur more in young patients and in more complex fractures including Mayo Type-3 and Monteggia like fractures[47, 72-74]. Two comparative studies compared different types of PO and showed comparative functional outcomes and re-operations regardless of the type of plate used[30, 75-78].

Tension Band Wire versus Plate Osteosynthesis:

Both TBW and PO remain the most performed procedures worldwide. Level II-III evidence show both techniques have high union rate and good outcomes, however, they are associated with complications and high re-operation rates[79, 80]. Biomechanical studies show no difference between TBW and PO in fracture displacement with transverse olecranon fractures, however, PO provides better compression at the fracture site, particularly the articular surface[81, 82]. The largest RCT to compare TBW and PO has evaluated their use in simple displaced (Mayo 2A) fractures and shown no difference in the functional outcomes and ROM[44]. TBW was associated with higher risk of complications due to the higher risk of implant removal. More important complications including revision surgery and infection only occurred in the PO group, however, this did not reach statistical significance (Table 2). Two recent meta-analyses have been published comparing the outcomes of TBW to PO[83, 84]. Koziarz et al. was marked as level II evidence because it had 3 RCTs and numerous observational studies with dramatic effects[84]. Ren et al was ranked as level III evidence because it had only 1 RCT with small sample size and was predominately a review of level III evidence[83]. Both meta-analyses show the outcomes from TBW and PO are satisfactory with no significant difference in the functional outcomes and flexion/extension and pronation/supinations ROM. They also show that TBW is associated with higher re-operation and complications rates. This finding is not present in all studies and two large retrospective cohort-studies showed no significant difference in re-operation rates between PO, TBW and IM fixation methods[41, 85].

It is important to highlight that the evidence in the literature mainly supports using PO in the management of multifragmentary and unstable olecranon process fractures with good outcomes.

Suture repair:

SR methods have been introduced more recently to address the high risk of implant prominence and removal associated with TBW and PO. Five techniques have been discussed in the literature with three techniques using anchor fixation and two use all-suture method[86-89]. The all-suture technique may have economic advantage by not using any anchors. Biomechanical studies show that SR is not inferior to TBW during cyclical load and ultimate fixation strength[90-94]. Clinical studies also show promising results with high union and low complication rates, however, these studies are limited to relatively small retrospective observational studies[87, 89, 91, 95, 96]. Only one comparative study compared re-operation rates and radiological findings between SR, TBW and PO. Most patients (78%) in this study had Mayo type 2A fracture, 30 patients had an olecranon osteotomy and 138 had an olecranon fracture. This study showed lower re-operation rate in the SR group that was only statistically significant when compared to TBW. The SR group had two complications after olecranon osteotomy, one radiological non-union not requiring further surgery and one failed fixation. None of the patients had suture irritation[97]. **Currently, there is a multi-centered RCT in the UK comparing SR to TBW called the SOFFT trial.**

Intramedullary fixation

Currently IM methods are categorized into two types, intramedullary screw fixation (IMS) and Intramedullary nailing system (IMN). IMS was popularized by Johnson et al. in 1986 and entail the use of a cancellous bone screw[98]. It was mainly used in nonfragmentary fractures. Cadaveric studies have shown that using IMS alone has a higher risk of fracture displacement compared to TBW supplementation (S-TBW)[99]. The most important technical consideration in this procedure is to ensure the screw entry point and insertion is along the axis of the ulna medullary canal. The surgeon must consider the VA, described in the anatomy section[100]. If the entry point is away from the axis, then there is a higher risk of losing reduction during screw insertion. Most studies assessing the outcomes of IMS are retrospective series with a very small sample size and were published before 1990[98]. In the last 30 years we can only find one retrospective case-series of 15 patients to evaluate the outcomes of IMS showing a union rate of 93%, a flexion/extension arc of 134° and a DASH score of 16[101]. The only comparative study comparing IMS to TBW show a significantly higher risk of fracture displacement associated with the IMS[99].

IMN is an alternative technique which has the advantage of not having a protruding hardware (unlike the screw head) and a locking construct that can be used for interfragmentary fractures. Several types of nails have been discussed in the literature including intermedullary olecranon nail (ION), Olecranon osteotomy nail (OIeON), OlecraNail and the XS-Nail. Biomechanical studies have shown the IMN systems to be significantly stronger, stiffer, more stable and have lower risk of loosening than TBW and have shown to have less micromotion than PO[102-104]. Retrospective analysis of the XS-nail shows good outcomes with one study showing an average MEPS of 92 and DASH score of 21 and another study reported the Murphy score in 73 patients, with 68 (93%) having good to excellent outcomes[105, 106]. One study has examined outcomes following OIeON nail in 7 patients with olecranon fractures and all patients achieved union and MEPS score of 100. In the same study 14 patients had olecranon osteotomy and there was one patient with delayed union and implant failure and 3 patients with heterotopic ossification[107].

Fragment excision and triceps advancement.

Fragment excision and repair of the triceps was first described in 1918 by Follie. Since then, several reports supported the use of this procedure mainly as a primary treatment for displaced olecranon fractures in the elderly[37]. The proportion of olecranon that can excised safely without causing elbow instability has been debated in the literature and ranged between 50-80%, however, a detailed anatomical study by An et al concluded that excision of >50% of the olecranon can lead to defunction of the elbow static stabilizers leading to instability[21, 108]. Other than instability, fragment excision causes elevated joint stresses, the clinical impact of this is not understood[109]. Clinical outcomes of this procedure are historic, and the 'most recent' paper was published in 1993 evaluated the outcomes of 12 patients using Murphy's outcomes scores and reported 11 patients to have good to excellent outcomes and no reoperations. In 1981, Gartsman et al. compared the outcomes of surgical fixation to fragment excision and showed no difference in the elbow extensor performance and lower re-operation rates associated with excision procedure. This procedure may still have a role in salvage situations.

Summary:

The literature evaluating the management of olecranon fractures consists mainly of level III and level IV studies. There are 5 low-quality and 2 moderate-quality RCTs with a small sample size published in this field and 3 Meta-Analysis of largely low-quality studies. The current literature suggest that non-operative management is appropriate for non-displaced fractures (Mayo 1) and displaced stable fractures in the elderly (Mayo 2). Simple displaced fracture (Mayo 2A) can be managed with PO or TBW, however, patients need be counselled about the high risk of complications and re-operation rates. **The outcomes of SR are promising but need an evaluation in a large prospective trial.** The limited evidence also shows good outcomes associated with PO in managing multifragmentary fractures and fractures in an unstable elbow (Mayo 2B and 3).

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Figure legends:

Figure 1: Anatomy of the olecranon process 1a) The four facets of the proximal ulna 1b) The hull of a boat out of the water concept

Anterior articular surface AL: anterolateral facet, AM: anteromedial facet, Posterior articular surface PM: posterolateral facet, PM: posteromedial facet. The area in the green is the four facet. The area in the yellow is the non-loadbearing bare area.

Figure 2: Anterior "V" sign

Figure 3: Management algorithm

Figure 4: Failure of osteosynthesis of olecranon fracture with elbow instability (Mayo type 3) using TBW

Figure 5: Plate osteosynthesis with mal-reduction of the four facets of the greater sigmoid notch leading to joint incongruency

Figure 6: Suture augmentation with plate fixation

CME-1 Figure: Failure of osteosynthesis of olecranon fracture with elbow instability (Mayo type 3) using TBW

CME-2 Figure: The Mayo classification of olecranon fractures

CME-3 Figure: Proximal Ulna Dorsal Angulation (PUDA)

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