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Surgical Treatment of Olecranon Fractures

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Since the olecranon fractures are caused by relatively low-energy injuries, such as a fall from standing height, they are usually found without comminution. Less commonly they can be developed by high-energy injuries and have severe concomitant comminution or injuries to surrounding structures of the elbow. Because the fracture by nature is intra-articular with the exception of some avulsion-type fracture, a majority of olecranon fractures are usually indicated for surgical treatment. Even if there is minimal displacement, surgical treatment is recommended because there is a possibility of further displacement by the traction force of triceps tendon. The most common type of olecranon fracture is displaced, simple non-comminuted fracture (that is, Mayo type IIA fractures). Although tension band wiring was the most widespread treatment method for these fractures previously, there is some trends toward fixation using locking plates. Primary goal of the surgery is to restore a congruent joint and extensor mechanisms by accurate reduction and stable fixation so that range of motion exercises can be performed. The literature has shown that good clinical outcomes are achieved irrespective of surgical fixation technique. However, since the soft tissue envelope around the elbow is poor and the implants are located at the subcutaneous layer, implant irritation is still the most common complication associated with surgical treatment.

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Key Words: Olecranon process; Fracture fixation; Review

Introduction

Direct blows to the elbow, and less frequently, indirect tensional force, is the most common mechanism of injury in olecranon fractures, which are fundamentally intra-articular fractures. Because they are induced by relatively low-energy injuries such as those from a fall at standing height, most olecranon fractures are simple fractures without severe comminution. Further, because of persistent tension force created by the triceps, even simple olecranon fractures are often displaced. Even if there is no displacement at the time of injury, these fractures may progressively develop into displaced fractures. Thus, surgical treatment should be one of the options considered for simple fractures with concomitant displacement or with risk of displacement, as well as for those combined with severely comminuted fractures, coronoid process fractures, or radial head fracture around the elbow. The general consensus is that most olecranon fractures should be considered for surgical treatment. The two most important goals of surgery are an accurate anatomical reduction that restores the articular surface and a strong fixation that facilitates early rehabilitation, although the choice of surgical treatment differs among surgeons. They include tension band wiring (TBW), precontoured locking plate fixation, and suture repair. This review article evaluates the current literature relating these surgical approaches for olecranon fractures.

Anatomy

The olecranon and the coronoid process are separated by an area called as the "bare spot" and compose a single bony structure of greater sigmoid notch. It enables highly congruent motion of the elbow by forming hinge joint together with the trochlea of the distal humerus.

The aim of surgical treatment for olecranon fractures is to

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reposition the separated olecranon with respect to the proximal ulna to restore joint congruence. Interestingly, recent studies on the anatomy of the proximal ulna have revealed that proximal ulna is not straight. Although many surgeons tended to regard the proximal ulna as a straight bone, there is an average of 5.7 degrees of dorsal angulation and 14 degrees of varus angulation (Fig. 1).[1-3] The unique anatomy of proximal ulna should be considered in reduction of fracture and the selection of metal plate. Proper understanding of anatomy will prevent mal-reduction of fracture and help reconstruction of congruent elbow joint without subluxation or dislocation of radial head.[4,5]

Classification

Olecranon fractures are classified using either the AO or the Mayo classification systems. The AO classification defines proximal radius and ulna fractures as the 'fracture site 21' and divide it into three groups: 1) extraarticular fractures are classified as type A; 2) articular fractures in either the ulna or the radius, type B; and 3) articular fractures in both the ulna and the radius, type C.[6] In addition, it has subtype based on the comminution, displacement, and location of fracture fragments. Although the AO classification is not commonly used in clinical practice, it is often used for research purposes.

The most commonly used classification in clinical practice is the Morrey's Mayo classification. Fractures are classified according to stability, comminution, and displacement, and a treatment algorithm has been proposed based on this classification system.[7] In Mayo classification, olecranon fractures are divided into 3 subtypes: type I undisplaced fractures; type II displaced-stable fractures (which are further subdivided into either type IIA non-comminuted or type IIB comminuted fractures); and type III unstable fractures. Among the three fractures, type II fractures are the most common type of fractures. Although these fractures show 3-mm or greater displacement, they have intact collateral ligaments so that the forearm is stable with respect to the humerus. Conversely, type III fractures are unstable, displaced fractures and can be considered as a type of fracture-dislocation. Olecranon fractures are multifragmented, complex injuries especially when they occur concomitantly with subluxation of the radial head and/or coronoid process fractures. Although reduction of anterior olecranon fracture dislocations, where the radial head and the forearm are anteriorly dislocated, are generally successful, reduction of posterior olecranon fracture dislocations, where the radial head is posteriorly dislocated (as in Bado type II Moteggia fractures), have been shown to be associated with elbow instability and dysfunction of forearms in spite of successful reduction.[8]

Treatment

Nonoperative Treatment

The olecranon is structurally connected to the triceps tendons and therefore contributes as an essential anatomical structure to the extensor mechanism. Therefore, only non-displaced fractures of the olecranon are indicated for conservative treatment. However, most olecranon fractures are found as displaced fracture. Even if no evidence of displacement is seen at the time of injury, there is a possibility of displacement over time. Moreover, stiffness from prolonged immobilization in conservative treatment can be another concern. Thus, surgical treatment is considered the safest option in most cases of olecranon fractures.[9,10]

Operative Treatment

The important aim of surgical treatment is to restore articular congruity and extensor mechanisms by achieving stable fixation that facilitates early range of motion (ROM) exercises. At current, there are several surgical options to choose. Plain radiographs are enough to identify fracture pattern in most cases, computed tomography scans are used for unrecognized articular impaction or potential comminution. In a previous study, intermediate fracture fragments were identified in more than half of patients with

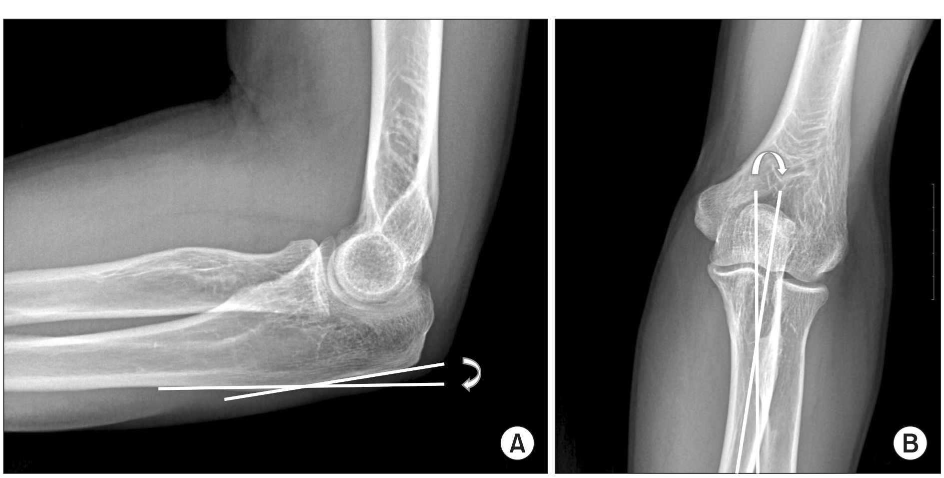

Fig. 1. Posterior dorsal angulation (A) and varus angulation of the proximal ulna (B).

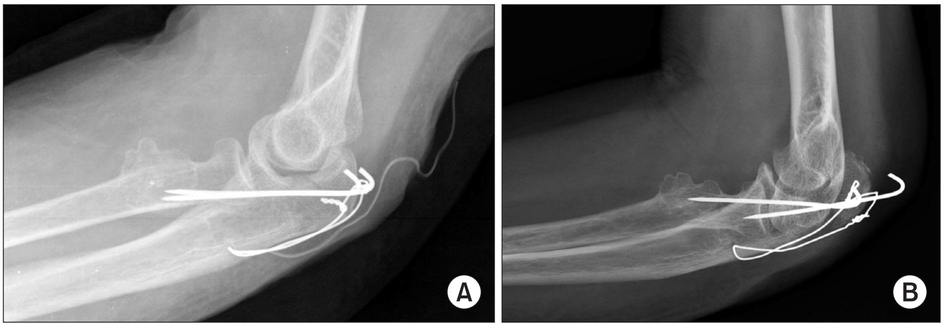

Fig. 2. (A) One of two K-wires is found impinged on the radius in tension band wiring for an olecranon fracture. (B) Impingement of a protruded K-wire causes restricted rotation and eventually back-out.

olecranon fractures.[11)]

1) Excision

For fractures with severe comminution, where anatomical reduction cannot be achieved, fracture fragments may be excised. It can be intercalary fragment or proximal fragment. Although early studies have reported that excision of up to 80% of the olecranon is acceptable,[12)] a recent biomechanical model has shown that even a 12.5% excision negatively influences joint stability.[13)] Thus, every effort to obtain congruity and extensor mechanism should be done and the excision of the olecranon should only be considered as a last resort.

2) Tension band wiring (TBW)

TBW involves a dynamic compression mechanism that converts tension force at the outer cortex into a compressive force at the inner cortex. An ideal indication for TBW is simple transverse fractures without comminution especially at the articular side. In order to perform tension band wiring, a rigid fixation that can withstand tensile force must be obtained. The articular side should have an intact buttress enough to withstand compression force converted from the posterior tension force. Transverse fracture rather than oblique fracture would be better for compression and ideal for TBW. However, the classic theory that the TBW converts posterior tension forces to articular compression has not been validated clinically or in multiple biomechanical studies.[14)] Some evidence suggests that a intramedullary screws instead of K-wires may be superior to the classic TBW using K-wire tension banding in terms of compression at the articular surface and resistance to gapping.[15)]

There are several tips to minimize complications by the use of TBW. For instance, it is better to position K-wires in parallel or diverged fashion. K-wires inserted towards radius can cause impingement of the K-wire with the radius and induce limitation of forearm rotation (Fig. 2). The use of K-wire more than 18-gauge will lessen the possible wire breakage. Two K-wires should be inserted taking care to engage the anterior cortex of ulna and travel through the subchondral bone. This step has been shown to minimize the back-out of K-wires and found safe with the K-wires can be placed at least 10 mm away from the median nerve and the ulnar artery.[16)] Furthermore, the incidence of skin irritation and back-outs of K-wires can be lowered by cutting K-wires in an oblique fashion and rotating them 180° before insertion.

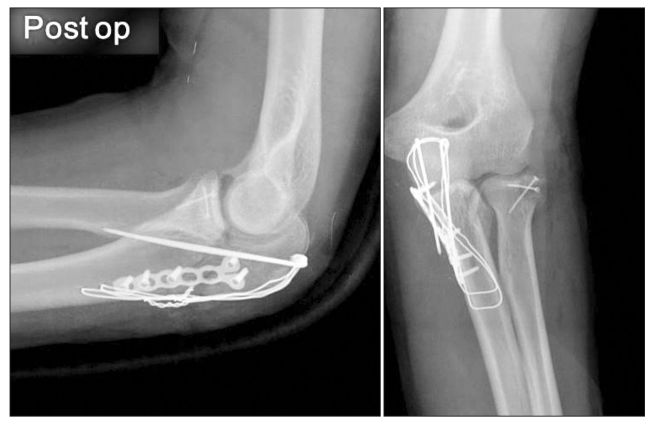

Fig. 3. An oblique fracture without comminution is treated by tension band wiring after preliminary fixation with small plate and screws.
Post op: postoperative.

In olecranon fractures with oblique patterns, TBW can be performed after the interfragmentary fixation using lag screws or small plates (Fig. 3). In addition, commercially available tension band plates have been developed to reduce complications associated with TBW and to provide biomechanically superior outcomes. The new tension band plates are designed to make the screw instead of K-wires pass across the fracture site and purchase the ulna bicortically. Compared to existing TBW techniques, the tension band plate was reported to have more superior biomechanical properties and fewer wire-related complications.[17)]

3) Plate-and-screw fixation

Various design of precontoured anatomical locking plates are available in market and there has been a trend from tension banding toward more rigid fixation using those plates and screws. Although internal fixation using locking plate still shows discomforts caused by hardware prominence, there are less hardware problems including pin back-out or skin irritation than traditional TBW.[18)] Precontoured locking plate fixation was reported to be superior to TBW statistically and during active extension of the elbow. It allows for more compression at fracture site than does the traditional TBW. Furthermore, more complex and comminuted fractures can be managed properly with plating (Table 1).[15] However, there are relatively few studies comparing TBW and plating. This is probably because the indications for plating and those for TBW are not same. In one study directly comparing locking compression plate (LCP) with TBW for Mayo type IIA fractures, 92% of LCP and 77% of TBW were associated with good clinical results. While the plating group needed more surgical time and cost, they showed less complication from hardware irritation. Range-of-motion in the Disabilities of the Arm, Shoulder and Hand Score revealed no difference.[19,20]

Fixation with precontoured anatomic plate is generally recommended for comminuted and complex fractures over TBW. Prior to surgery, a thorough examination is needed to ensure that there are no intermediate fragments or articular impaction of these intercalary fragment. Fragments that seems too small should never be thrown away because loss of those fragments might lead to incongruency. If concomitant comminution of the medial and lateral cortical surfaces exists, a small plate and screws, and in certain circumstances a dual plating, may be used to provide a temporary reduction and final fixation (Fig. 4).[21] Irrespective of the fixation method chosen, understanding the anatomy of the ulna is most important to achieve an accurate reduction. Many of the precontoured plates should be used carefully since considerable variation in proximal ulnar anatomy as we discussed before. Most plates do not accommodate the proximal ulnar dorsal angulation and varus. If a straight plate is used in an ulna with dorsal angulation and varus, it will force the fracture into malreduction. It is vital for joint congruency that the sigmoid notch is anatomically restored. Failure to obtain accurate anatomic reduction will result in subluxation of radial head, loss of motion and posttraumatic arthrosis in the long term. It is common to reduce the posterior cortex first, and then the articular side is indirectly reduced. This technique is generally successful in fractures with a simple pattern. However, in comminuted fractures, articular fragments are often separated with the posterior cortex. Separated articular fragments may lead to malreduction despite a successful reduction of the posterior cortex. As an alternative method, reduction can be performed from anterior to posterior and from distal to proximal. Depending on the fracture pattern, a provisional fixation using K-wires may be made on small fragments prior to the reduction of the posterior cortex.

Although interfragmentary screw fixation is important to achieve union, but excessive compression on articular surfaces of the sigmoid notch can lead to incongruent joint. Subsequently, motion can be restricted with arthrosis. Care must be taken to prevent over-compression of articular fragments especially in comminuted fracture. If there is irreducible intercalary comminution in Mayo type IIB or IIIB olecranon fracture, excision of intercalary fragment and re-establishment of congruent sigmoid notch would be recommended (Fig. 5). In osteoporotic bone catastrophic failure can occur even with the use of locking plate and screws since the bone is too weak and triceps tendon act as deforming force.[22] Suture augmentation has been shown to effectively reinforce the plate construct even in osteoporotic bone. In one study, plate fixation with suture augmentation increased

Table 1. Advantages of Tension Band Wiring and Plating

	Tension band wiring	Plating
Possible advantages	Lower cost	Fewer hardware problems such as pin back-out or skin irritation
	Less bleeding and reduced surgical time	Applicable to more complex and comminuted fracture patterns
	Similar clinical outcome as plating	More rigid fixation

Fig. 4. A small plate and supplementary precontoured locking plate are used in small bone fractures. Use of precontoured plates is useful for comminution of medial and lateral cortical surface or for temporary reduction/fixation. Preoperative (A) and postoperative (B) lateral radiographs.

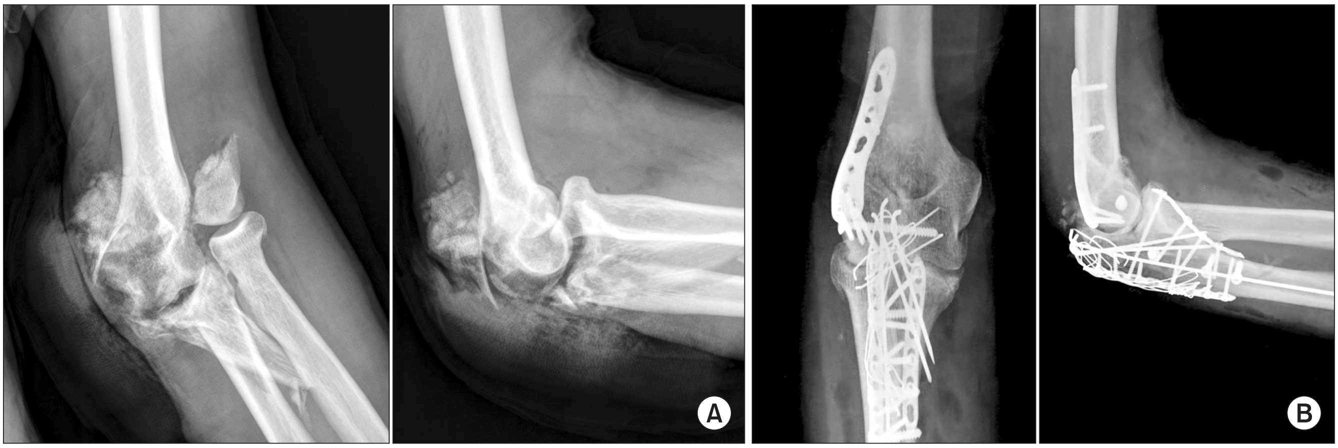

Fig. 5. Small irreducible fragments are excised in a Mayo type IIIB olecranon fracture to re-establish a congruent articular surface preoperative (A) and postoperative (B) radiographs.

fixation strength greater than 200 N above the 500 N it takes to rise from a chair.[23)]

4) Intramedullary nail

Less commonly, some surgeons prefer to use intramedullary nailing over the traditional TBW or plating because it obviates the need for a secondary surgery to remove hardware.[24)] It showed better results than TBW in one biomechanical study.[25)] However, indications for intramedullary nailing must be carefully chosen. Especially all the olecranon fractures are intraarticular fracture and thus accurate articular reduction is critical. When there is significant articular comminution, use of intramedullary nail would be limited Currently DePuy Synthes provide commercially available Intramedullary nailing systems for olecranon fractures.[24-27)]

5) Bioabsorbable fixation

Either TBW or plate fixation, which are two mainstays of operative treatment has been reported hardware-related complications.[28)] Bioabsorbable fixation can obviate those hardware-related complications and completely deviates the need for secondary surgery to remove hardware.[29)] The clinical outcomes of bioabsorbable implants (poly-L-lactide wire with self-reinforced polyglycolide screws or self-reinforced poly-L-lactide plugs) have been shown to be comparable to those of metallic implants, as in K-wires used in TBW.[30)]

6) Suture (anchor) fixation

There is an avulsion-type of posterior tip fracture that cannot be classified into any classification systems. It might be not easy to address this type of fracture with conventional TBW or plating. In addition, even simple transverse fracture found in old age patient can be problematic to obtain sound stability when the bone quality is weak or soft tissue envelope is poor. In such cases, fixation using suture anchors has been suggested as an alternative approach.[31-33)] Although there lack studies that investigate the biomechanical strength of suture fixation in relation to TBW or plating, fixation using suture anchors can be an alternative treatment option in some patients (Fig. 6).

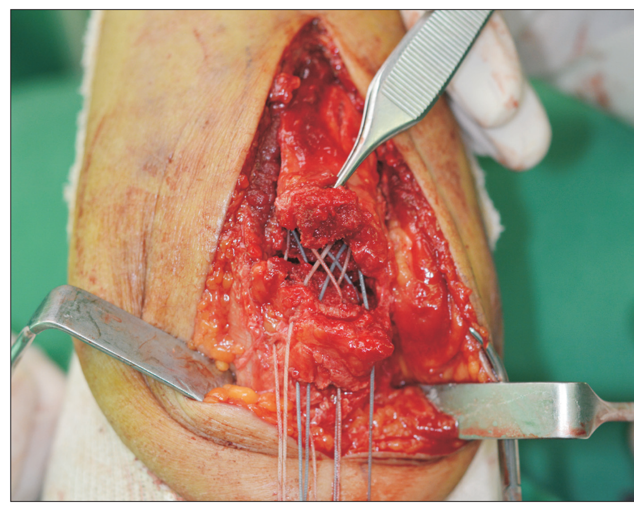

Fig. 6. The suture bridge method for olecranon fractures in an old age osteoporotic bone.

Postoperative Management

Postoperative rehabilitation should be tailored depending on the status of soft tissue and fixation stability. In general, an anterior splint is applied at 30° to 45° for 7 to 10 days to promote soft tissue healing and unload the tension by the triceps tendon. When postoperative pain and swelling alleviates, motion exercises can be started.

Complications

Postoperative complications associated with olecranon fractures include loss of motion, malunion, nonunion, hardware

Fig. 7. Flap surgeries for superficial infection with skin necrosis caused by poor soft tissue envelope.

irritation, wound dehiscence, heterotopic ossification, ulnar nerve symptoms, and posttraumatic arthrosis. Hardware irritation has been shown to be the most common complication after olecranon treatment, showing a prevalence of 75% after TBW and of up to 50% after plate fixation.[34,35] Studies have suggested that fixation using either suture or intramedullary nail may lower the hardware-related complications.[25,31-33] In one study, flexion arc was improved after removal of hardware although there is a question about direct causal relationship.[35] Since the loss of terminal extension is a frequent sequelae in olecranon fractures, patients should be noticed about possibility of some loss of terminal extension. In previous studies, 10% to 15% limitation in arc of motion compared to the contralateral arm was observed in up to 75% of patients.[36-38]

Wound healing is often problematic in high-energy injuries. In case of severe swelling, delayed surgery is inevitable. Posteromedial or posterolateral incision is preferred whenever possible and it avoids having a wound over the maximum tension. Meticulous handling of soft tissue including full-thickness flaps for the exposure should be performed. Postoperatively, a well-padded anterior splinting at 45 degrees is recommended for the one or two weeks to allow healing of the wound. Sometimes a flap surgery may be indicative if there is prominent soft tissue defect or postoperative skin necrosis (Fig. 7).[39] Heterotopic ossification is a relatively common complication after elbow trauma but rare in olecranon fractures. A study by Bauer et al.[40] that investigated the occurrence of heterotopic ossification in 221 fractures of the elbow showed only one case of heterotopic ossification. Heterotopic ossification is more likely to occur in more severe injuries such as trans-olecranon fractures/dislocations, distal humerus fractures, or terrible triad. Therefore, prophylactic radiotherapy should be carefully considered in selected cases since it can increase the possibility of nonunion.

Nonunion may be a concern in patients who sustained higher-energy injuries. It is a very rare complication comprising only around 1% of all postoperative complications in olecranon-related surgeries.[41] Inappropriate initial protection in noncompliant patients or aggressive rehabilitation in unstable fixation can lead to fixation failure. Malunion can occur when the intermediate fragments are improperly managed during the surgery. In severely comminuted fractures, non-anatomical reduction or inappropriate fixation, malunion can lead to joint incongruity, motion loss, and posttraumatic arthritis. As mentioned before, unrecognized proximal ulnar dorsal angulation or varus alignment can lead to fatal consequences such as extra-articular malunion at the junction of the metaphysis and the diaphysis. In such instances, this would appear as a subluxation of the radial head and, thus, may even be misdiagnosed as posterolateral instability.[4,5,42,43]

Ulnar nerve complications have been reported to have a prevalence between 2% and 12%. But these complications are not common in patients with olecranon fractures and most of them resolve spontaneously. However, its prevalence has been shown to increase in fractures that are medially displaced and non-reduced.[44]

Post-traumatic arthrosis reported up to 20% of patients. Typically, initial displacement and intraarticular step-off of greater than 2 mm are associated with posttraumatic arthrosis.[34,45]

Summary

Olecranon fractures are common fractures of the upper limbs and generally require surgical treatment. In one study from Canada, most surgeons have shown a preference for TBW in simple displaced olecranon fractures and for plating in displaced, comminuted olecranon fractures.[28] Although TBW is the most common treatment for simple transverse fractures, current evidence demonstrates that the clinical outcomes of locked plating and TBW are comparable, while the plating provides greater construct stability and fewer symptomatic hardware problems. We should understand the unique anatomy of proximal ulna and the fracture geometry. Regardless of surgical techniques, restoration of congruent joint with strong construct which enable early ROM exercise will lead to good clinical results.

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