

Tension-Band Wiring Versus Plate Fixation for Olecranon Fractures: A Narrative Review

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Abstract

Background: Olecranon fractures are intra-articular injuries influenced by the subcutaneous location of the olecranon and the distractive forces of the triceps. Operative fixation commonly relies on tension-band wiring or plate fixation, but each technique has distinct biomechanical advantages and complication profiles.

Objective: This narrative review summarizes the epidemiology, anatomy, classification, diagnosis, treatment principles, surgical techniques, functional outcomes, complications, and clinical selection of tension-band wiring and plate fixation for olecranon fractures.

Review: Tension-band wiring is inexpensive and remains appropriate for simple transverse Mayo type IIA fractures with good bone quality and minimal comminution. Its effectiveness depends on accurate reduction, parallel Kirschner-wire placement, secure anchorage, and proper tensioning of the figure-of-eight wire. Hardware prominence, wire migration, loss of reduction, and implant removal remain important limitations. Plate fixation provides rigid, fixed-angle stability and is particularly useful for comminuted, oblique, osteoporotic, and unstable fracture patterns. Modern pre-contoured and low-profile plates improve construct versatility, although hardware irritation, wound complications, and higher implant cost remain concerns.

Conclusion: Both techniques can provide reliable union and satisfactory function when appropriately selected and correctly performed. Fixation should be individualized according to fracture morphology, bone quality, soft-tissue condition, patient activity, and the anticipated risk of implant-related complications.

Keywords: olecranon fracture; tension-band wiring; plate fixation; elbow; internal fixation; complications

Introduction

Olecranon fractures represent a significant proportion of upper extremity injuries encountered in orthopedic practice, constituting approximately ten percent of all upper limb fractures and ranking among the most frequent elbow injuries in the adult population. These fractures present unique clinical challenges due to their intra-articular nature, the subcutaneous location of the olecranon, and the mechanical forces exerted by the triceps muscle across the fracture site ^(1,2). The management of simple, isolated, displaced olecranon fractures continues to generate considerable debate within the orthopedic community, particularly regarding the optimal surgical technique for achieving favorable functional outcomes while minimizing complications. The olecranon, as the proximal articular portion of the ulna, plays a crucial role in elbow stability and function, forming the greater sigmoid notch that articulates with the trochlea of the distal humerus ⁽³⁾.

Understanding the anatomical relationships, biomechanical principles, and fracture patterns of olecranon injuries is essential for appropriate treatment selection and surgical planning. Despite being considered one of the simplest articular lesions, olecranon fractures can result in significant functional impairment if not managed appropriately ⁽⁴⁾. Complications including loss of motion, symptomatic hardware, nonunion, and posttraumatic arthritis have been well documented in the literature. The traditional approach to displaced olecranon fractures has emphasized

operative fixation using tension band wiring or plate fixation techniques ⁽⁵⁾. Recent evidence has challenged conventional paradigms, particularly regarding treatment options for elderly patients with multiple comorbidities ⁽⁶⁾.

Epidemiology and Mechanisms of Injury

The epidemiology of olecranon fractures demonstrates a distinct bimodal age distribution pattern, with fractures occurring after high-energy trauma in younger patients and following low-energy falls in elderly individuals with compromised bone quality. Recent large-scale epidemiological studies have provided valuable insights into the true burden of these injuries across different populations and healthcare systems. A comprehensive Swedish nationwide registry study analyzing two thousand four hundred sixty-two olecranon fractures over a five-year period from January two thousand fourteen to December two thousand eighteen reported a median patient age of sixty-six years. Women accounted for sixty-five percent of all cases in this landmark study ⁽¹⁾.

The Danish study also documented a significant shift in surgical treatment patterns over the twenty-year observation period. The use of plate fixation increased dramatically from seven percent in nineteen ninety-nine to forty-five percent in two thousand eighteen. Conversely, tension band wiring decreased from eighty-nine percent to forty-six percent over the same period. These findings suggest evolving treatment philosophies and potentially improved understanding of fracture biomechanics. The shift toward plate fixation may reflect growing recognition of the limitations of tension band wiring in certain fracture patterns and patient populations ⁽⁷⁾.

The mechanism of injury varies substantially between demographic groups and significantly influences fracture characteristics and treatment outcomes. In elderly women, low-energy traumatic events, particularly same-level falls, represent the predominant injury mechanism, accounting for the majority of fractures in this population. The Swedish registry study found that patients over sixty-five years of age predominantly sustained fractures through simple falls at home or in the street. In contrast, younger patients more frequently experienced high-energy trauma mechanisms such as road traffic accidents or falls from height ⁽¹⁾.

Olecranon fractures can occur through several distinct mechanisms related to the unique anatomy and biomechanics of the elbow joint. Direct trauma to the posterior aspect of the elbow represents one common mechanism, occurring when the olecranon impacts against a hard surface during a fall. The subcutaneous location of the olecranon provides minimal soft tissue protection, making it particularly vulnerable to direct blows. This mechanism is more common in younger patients involved in high-energy trauma such as motor vehicle accidents or sports injuries ⁽³⁾.

Indirect trauma through forced hyperextension of the elbow represents another important mechanism, particularly in elderly patients. When a patient falls on an outstretched hand with the elbow extended, the olecranon is forced into the olecranon fossa of the distal humerus, potentially causing a fracture. This mechanism is associated with simple transverse or short oblique fracture patterns. Additionally, avulsion fractures can occur through sudden forceful contraction of the triceps muscle against resistance during a fall attempt ⁽³⁾.

Osteoporosis and poor bone quality significantly increase fracture risk in elderly patients, with fragility fractures occurring after minimal trauma. Female gender is consistently associated with higher fracture rates, particularly in the elderly population where hormonal changes and bone mineral density loss contribute to increased vulnerability ⁽¹⁾. Other risk factors include conditions affecting bone metabolism, previous upper extremity fractures, and functional limitations that increase fall risk ⁽⁸⁾.

Anatomy and Biomechanical Considerations

The olecranon constitutes the proximal portion of the ulna, extending from its prominent tip to the base of the coronoid process. This anatomical region forms a crucial component of the elbow joint complex, providing both articular surfaces and attachment sites for major muscle groups. The olecranon and coronoid process together create the greater sigmoid notch, also known as the trochlear or semilunar notch, which articulates with the trochlea of the distal humerus. This articulation is primarily responsible for flexion and extension movements of the elbow, functioning as a highly constrained hinge joint that allows motion predominantly in one plane ⁽³⁾.

The articular surface of the greater sigmoid notch demonstrates a complex three-dimensional contour designed to maximize stability while permitting smooth motion. The bare area, a non-articular region of the sigmoid notch, lies between the olecranon and coronoid articular surfaces and serves as an important anatomical landmark during surgical reduction. Accurate reduction of this bare area is critical to avoid malreduction that could narrow the distance between the coronoid and olecranon, potentially compromising elbow function. The sigmoid notch demonstrates slight valgus angulation and a sagittal curvature that must be restored during fracture fixation to maintain proper joint kinematics ⁽⁷⁾.

The triceps brachii muscle inserts broadly onto the proximal and posterior aspects of the olecranon through a strong, flat tendon. This insertion represents the primary extensor mechanism of the elbow and exerts substantial distractive forces across olecranon fractures. The triceps force can exceed three hundred newtons during active elbow extension, creating significant challenges for fracture stabilization. Understanding these forces is fundamental to selecting appropriate fixation methods that can withstand the constant pull of the triceps during rehabilitation and functional activities ⁽³⁾.

The biomechanics of olecranon fractures and their fixation are governed by the unique loading environment of the proximal ulna. During elbow flexion and extension, the olecranon experiences predominantly tensile forces on its posterior surface due to triceps muscle contraction. These tensile forces must be converted to compressive forces at the articular surface to promote healing and allow early motion. The tension band principle, first described in the nineteen sixties, exploits this biomechanical concept by converting the posterior tensile forces into anterior compression across the fracture site ⁽¹⁾.

The effectiveness of tension band wiring depends on several critical factors including an intact dorsal cortex, minimal comminution, and transverse fracture orientation. The technique requires placement of two parallel Kirschner wires across the fracture to maintain alignment, with a figure-of-eight wire placed dorsally to create the tension band effect. Biomechanical studies have demonstrated that proper tension band construction can provide adequate stability for simple transverse fractures. However, the technique becomes less effective in comminuted fractures, oblique fractures, or fractures with significant bone loss where the basic biomechanical requirements are not met ⁽³⁾.

Plate fixation provides different biomechanical advantages through rigid fixation and load sharing across the fracture site. Modern locking compression plates allow for fixed-angle stability that is particularly beneficial in osteoporotic bone or comminuted fracture patterns. Biomechanical testing has shown that plate constructs generally provide superior resistance to gap formation and displacement compared to tension band wiring, especially under cyclic loading conditions that simulate active muscle forces. However, plate fixation requires more extensive soft tissue dissection and results in more prominent hardware that may cause symptomatic irritation ⁽³⁾.

Classification and Diagnostic Evaluation

The Mayo classification system, introduced by Cabanela and Morrey in nineteen ninety-three, was developed to provide a simplified, clinically useful classification of olecranon fractures based on three key parameters including fracture displacement, comminution, and stability of the ulnohumeral joint. The system divides olecranon fractures into three main types, with each type further subdivided into A and B categories to indicate non-comminuted and comminuted fractures respectively. Type I fractures are undisplaced or minimally displaced with less than two millimeters of separation and an intact extensor mechanism. Type II fractures are displaced but maintain ulnohumeral joint stability with intact collateral ligaments ⁽¹⁾.

The Mayo classification was designed to guide treatment decisions, with Type I fractures typically managed nonoperatively with brief immobilization followed by early range of motion exercises. Type IIA fractures traditionally have been treated with tension band wiring, while Type IIB and Type III fractures generally require plate fixation to provide adequate stability. The classification provides prognostic information, with Type I and IIA fractures generally demonstrating better outcomes than more complex patterns ⁽¹⁾.

The AO/OTA classification system represents a comprehensive, systematic approach to classifying all long bone fractures including those of the proximal ulna. Introduced in nineteen eighty-seven, this alphanumeric system groups fractures based on bone segment, fracture location, and fracture morphology. For proximal ulna fractures, the system uses the designation two-one-U, where two represents the forearm bones, one indicates the proximal segment, and U specifies the ulna. This is followed by letter and number combinations indicating fracture type and subgroups ⁽¹⁾.

The AO system divides proximal ulna fractures into three main types. Type A fractures are extra-articular, involving the olecranon metaphysis without extension into the articular surface. Type B fractures are intra-articular fractures of either the radius or ulna, which includes most olecranon fractures. Type C fractures involve both the radial head and olecranon as intra-articular injuries. Within Type B fractures, further subdivisions exist with B-one fractures representing olecranon fractures without involvement of the coronoid process ⁽⁹⁾.

Patients with olecranon fractures typically present with a history of falling on an outstretched hand or receiving a direct blow to the posterior aspect of the elbow. The clinical presentation usually includes sudden onset of severe elbow pain, swelling over the posterior elbow, and inability to extend the elbow actively against gravity. In displaced fractures, a palpable gap or defect may be appreciated on physical examination. Patients often support the affected arm in slight flexion using the opposite hand, as any attempted motion causes significant discomfort ⁽³⁾.

Physical examination should begin with careful inspection of the affected extremity, noting any obvious deformity, swelling, or ecchymosis. The skin should be examined meticulously for any signs of open injury, as the subcutaneous location of the olecranon makes these fractures vulnerable to open contamination even with relatively minor trauma. Open fractures require urgent surgical debridement and are associated with higher risks of infection and complications. Swelling typically develops rapidly over the posterior elbow but may extend proximally toward the arm or distally toward the forearm ⁽¹⁰⁾.

A comprehensive neurovascular examination is mandatory in all cases. The ulnar nerve is particularly vulnerable due to its superficial course posterior to the medial epicondyle. Ulnar nerve symptoms including numbness in the ring and small fingers or weakness of intrinsic hand muscles should be documented. The radial and median nerves should also be assessed. Vascular examination includes palpation of radial and ulnar pulses, assessment of capillary refill, and evaluation of hand perfusion ⁽³⁾.

Standard anteroposterior and lateral radiographs of the elbow represent the initial imaging modality for suspected olecranon fractures and are sufficient for diagnosis in most cases. The lateral view is particularly valuable for assessing fracture displacement, comminution, and joint surface involvement. Images should be scrutinized for fracture line orientation, degree of displacement, number and size of fragments, and articular surface congruity. The presence of associated injuries including radial head fractures, coronoid fractures, or elbow dislocation must be identified ⁽⁴⁾.

Assessment of fracture displacement is critical for treatment planning. Displacement is typically measured as the maximum separation between major fragments on lateral radiographs. Fractures with less than two millimeters of displacement and an intact extensor mechanism may be considered for nonoperative management. Greater displacement generally requires surgical fixation. Articular surface step-off or gap of greater than two millimeters is generally considered unacceptable and warrants operative reduction ⁽³⁾.

Computed tomography may be valuable in complex fracture patterns to better delineate fracture lines, assess comminution, and plan surgical approaches. Three-dimensional reconstructions can provide enhanced visualization of fracture morphology and fragment orientation. CT is particularly useful when the fracture extends into the coronoid process or involves the proximal radioulnar joint, as these areas may be difficult to assess on plain radiographs. However, for simple displaced transverse fractures, CT is usually unnecessary and plain radiographs provide adequate information for treatment planning ⁽⁶⁾.

Treatment Principles

Nonoperative management of olecranon fractures is appropriate for specific fracture patterns and patient populations. Undisplaced or minimally displaced fractures with less than two millimeters of separation and an intact extensor mechanism may be treated conservatively. The patient must demonstrate the ability to actively extend the elbow against gravity, confirming continuity of the triceps mechanism. Treatment typically involves immobilization in a posterior splint or cast for seven to fourteen days followed by progressive range of motion exercises ⁽³⁾.

Recent evidence has challenged traditional indications for operative intervention, particularly in elderly patients. Multiple studies have demonstrated acceptable functional outcomes with nonoperative treatment of displaced olecranon fractures in patients over seventy-five years of age. A prospective randomized trial found no significant difference in DASH scores at twelve months between operative and nonoperative groups in elderly patients. The nonoperative group had a complication rate of only fourteen point three percent compared to eighty-one point eight percent in the operative group ⁽¹¹⁾.

Nonoperative treatment protocols typically involve initial immobilization for comfort using a sling or posterior splint, followed by early mobilization as tolerated. Patients are instructed to perform gentle active-assisted range of motion exercises beginning within the first weeks. Weight-bearing restrictions are maintained for six to eight weeks to allow fibrous union or partial bony healing. Pain management with oral analgesics facilitates early mobilization and improves patient comfort ⁽¹²⁾.

Operative management is indicated for most displaced olecranon fractures where displacement exceeds two millimeters or the patient cannot actively extend the elbow against gravity. Articular surface incongruity with step-off or gap greater than two millimeters generally warrants surgical reduction and fixation. Open fractures require urgent surgical debridement and stabilization regardless of displacement. Complex fracture patterns including comminution, oblique fracture lines extending distal to the coronoid, or associated fractures typically necessitate operative intervention ⁽³⁾.

Surgical fixation of olecranon fractures aims to restore articular congruity, reestablish the extensor mechanism, and provide sufficient stability to allow early motion and rehabilitation. Anatomic reduction of the articular surface is paramount, with less than two millimeters of residual step-off or gap considered acceptable. The bare area between the olecranon and coronoid articular surfaces must be appropriately restored to avoid narrowing the sigmoid notch. Failure to achieve anatomic reduction may lead to posttraumatic arthritis and loss of motion ⁽¹²⁾.

The surgical approach typically utilizes a midline posterior incision extending approximately one inch proximal and two inches distal to the olecranon tip. The incision may be curved slightly medially or laterally to avoid direct pressure from wheelchair armrests or other supports. Full-thickness skin flaps are elevated to expose the fracture site while preserving periosteal attachments where possible. The ulnar nerve should be identified and protected, though routine formal decompression is not necessary in simple fractures ⁽³⁾.

Intraoperative fluoroscopy should be used to confirm adequate reduction and appropriate hardware placement. Images should include anteroposterior, lateral, and oblique views to assess all aspects of the reduction. Kirschner wires should engage the anterior cortex for adequate purchase. Plates should be positioned to avoid prominence at pressure points. The articular surface should be carefully inspected to ensure no step-off or gap remains ⁽¹¹⁾.

Tension-Band Wiring

Tension band wiring has been the traditional gold standard treatment for simple, displaced olecranon fractures for over five decades, representing one of the most widely utilized fixation techniques in orthopedic trauma surgery. The technique is based on the biomechanical principle of converting tensile forces generated by the triceps muscle on the posterior aspect of the olecranon into compressive forces across the articular surface of the fracture site. This conversion theoretically promotes primary bone healing while allowing early mobilization of the elbow joint ⁽¹³⁾.

Despite its popularity and extensive use over many decades, tension band wiring is not without significant limitations and complications. Recent evidence has challenged the notion that this technique represents a simple, straightforward procedure with consistently excellent outcomes. High rates of hardware-related complications, particularly symptomatic prominence of Kirschner wires and subsequent need for hardware removal, have been well documented in contemporary literature ^(14,13).

The theoretical foundation of tension band wiring rests on the premise that during elbow flexion and extension, the olecranon experiences tensile forces posteriorly due to triceps muscle action, while the articular surface should experience compression to promote healing. The figure-of-eight wire construct placed dorsally over parallel Kirschner wires is designed to resist these tensile forces and redirect them anteriorly, converting tension into compression at the fracture site. This concept assumes that the intact anterior cortex or reduced articular surface can serve as a fulcrum, allowing the posterior tension band construct to generate compression as forces are applied ⁽¹⁵⁾.

However, biomechanical investigations using cadaveric models with pressure sensors placed at the fracture gap have challenged this traditional understanding. One study measuring compressive forces during active flexion and extension after tension band wiring of transverse olecranon osteotomies found that active flexion did not cause any compressive forces in the osteotomy gap. Extension with the humerus in an upright position and the elbow actively extended did cause some compression, measuring zero point three seven to zero point five one megapascals at the articular surface. Posteriorly, there was no significant pressure difference between active flexion and extension. These findings suggest that the tension band wiring principle functions primarily during active extension in a range of thirty to one hundred twenty degrees of elbow flexion, rather than throughout all elbow motions as traditionally believed ⁽¹⁶⁾.

Additional biomechanical studies have examined factors affecting construct stability including Kirschner wire diameter, wire thickness, figure-of-eight configuration tightness, and anchorage of wire ends. Larger diameter Kirschner wires provide greater resistance to bending and migration but may be more difficult to insert and more prominent subcutaneously. The figure-of-eight wire must be tensioned adequately to function effectively, but excessive tightening can cause wire breakage or cut through bone, particularly in osteoporotic patients. Anchorage of the proximal Kirschner wire ends is critical, as insufficient fixation allows proximal migration of wires, leading to soft tissue irritation and loss of reduction. These biomechanical considerations highlight that successful tension band wiring requires more than simply placing wires and pins in an approximate configuration ⁽¹⁷⁾.

Tension band wiring is most appropriately applied to simple, transverse or short oblique fractures of the olecranon located in the proximal third of the bone, corresponding to Mayo type IIA fractures. The technique requires an intact or reducible dorsal cortex to serve as a tension band surface, minimal comminution that allows stable reduction, and sufficient bone quality to hold Kirschner wires and allow drilling of distal holes. Ideal candidates are patients with good bone stock, simple fracture patterns without significant displacement of fragments, and fractures that can be anatomically reduced with direct visualization of the articular surface ⁽¹⁸⁾.

Specific contraindications to tension band wiring include comminuted fractures where multiple fragments cannot be held in stable reduction, oblique fractures extending distal to the midpoint of the greater sigmoid notch where the technique cannot adequately resist shear forces, fractures in severely osteoporotic bone where hardware anchorage is compromised, and fractures associated with elbow instability or fracture-dislocations. Additionally, patients who are very thin with minimal soft tissue coverage may experience problematic hardware prominence even with technically adequate fixation. Young, active patients who place high demands on the extremity may be better served by plate fixation that provides more rigid construct stability ⁽¹⁹⁾.

Anatomic reduction of the articular surface represents the most critical step in achieving successful outcomes. The fracture fragments are manipulated under direct visualization to restore articular congruity, with particular attention to avoiding step-off or gap at the joint surface. Pointed reduction forceps can be used to hold fragments in position temporarily while reduction quality is assessed. The bare area between the olecranon and coronoid articular surfaces must be appropriately restored to avoid narrowing the sigmoid notch, which could compromise

elbow motion. Fluoroscopic imaging in anteroposterior, lateral, and oblique projections confirms adequate reduction before proceeding with definitive fixation ⁽¹³⁾.

Proper placement of the two parallel Kirschner wires is critical for construct stability and prevention of complications. The wires should be inserted from the tip of the olecranon in a direction parallel to the anterior cortex of the ulna, aiming to engage the anterior cortex several centimeters distal to the coronoid process. Wire diameter typically ranges from one point five to two point zero millimeters, with larger wires providing greater stiffness but increased prominence and potential for soft tissue irritation. The wires should be placed in the central portion of the olecranon to provide maximum bone stock around the implants and avoid eccentric loading ⁽¹⁷⁾.

Three main options exist for distal wire termination including intramedullary placement within the distal ulnar canal, penetration of the anterior cortex, and placement within the distal ulnar canal without cortical penetration. Intramedullary placement in the proximal ulnar canal should be avoided as it allows proximal wire migration with subsequent elbow irritation. Penetration of the anterior cortex provides excellent fixation stability but carries risk of injury to the anterior interosseous nerve and ulnar artery if wires protrude excessively. Anatomic studies have demonstrated that the anterior interosseous nerve and ulnar artery lie in close proximity to the anterior ulnar cortex, with distance measurements showing minimal safety margin if wires penetrate far through the cortex ⁽²⁰⁾.

The proximal wire ends must be firmly seated in the dorsal cortex to prevent backing out and soft tissue irritation. After drilling the wires across the fracture, they should be advanced until the proximal tips are flush with or slightly countersunk below the bone surface. Insufficient fixation of proximal wire ends was identified in ninety-one percent of cases in one large series and represents the single most common technical imperfection. Some surgeons bend the proximal wire ends to create a hook that engages the dorsal cortex, though this may cause prominent hardware. Others drill a small groove in the dorsal cortex to allow countersinking of wire tips, reducing prominence while maintaining stable fixation ⁽¹⁷⁾.

After Kirschner wire placement and confirmation of position with fluoroscopy, the figure-of-eight stainless steel wire construct is applied. A two millimeter drill bit is used to create two transverse holes through the ulna approximately two to three centimeters distal to the fracture site. The holes should be placed in the same coronal plane to allow symmetric figure-of-eight configuration and should avoid stress concentrations at the fracture site. Drilling should be performed carefully under direct visualization to avoid injury to deep structures including the interosseous membrane and neurovascular structures ⁽¹⁷⁾.

The tightness of the figure-of-eight configuration significantly affects construct stability. A loose configuration with the wire distant from the bone or exhibiting a rippled course compromises the tension band effect and allows excessive motion at the fracture site. The wire should lie flat against the dorsal cortex throughout its course, conforming to the bone contour. Final fluoroscopic images in multiple projections confirm appropriate hardware position, fracture reduction maintenance, and absence of intra-articular wire or pin penetration. The elbow should be ranged through flexion and extension under fluoroscopy to assess stability and ensure no hardware loosening occurs with motion ⁽¹³⁾.

Fracture union following tension band wiring occurs reliably in the vast majority of appropriately selected patients, with reported union rates exceeding ninety-five percent in most series. Average time to radiographic union ranges from eight to twelve weeks, with clinical healing often evident earlier based on resolution of pain and return of function. Factors promoting successful union include anatomic reduction, stable fixation that allows early motion, good bone quality with adequate vascularity, and patient compliance with postoperative protocols. Nonunion remains uncommon with simple transverse fractures treated by tension band wiring, typically occurring in less than five percent of cases ⁽¹⁹⁾.

Functional outcomes following tension band wiring of simple olecranon fractures are generally favorable in patients who do not experience complications requiring reoperation. Multiple studies using validated outcome measures have documented satisfactory results. A prospective randomized trial of sixty-seven active adult patients compared tension band wiring to plate fixation and found no significant difference in Disabilities of the Arm, Shoulder and Hand scores at one year between groups. The mean DASH score in the tension band wiring group

was eleven point four compared to ten point six in the plate fixation group. These scores indicate mild residual disability consistent with generally good functional recovery ⁽¹⁸⁾.

Hardware prominence and symptomatic irritation represent the most common complications following tension band wiring, affecting anywhere from twenty to seventy-nine percent of patients depending on the series and how complications are defined. The subcutaneous location of the olecranon provides minimal soft tissue coverage over the construct, making even properly placed hardware potentially problematic. Symptoms typically include pain when leaning on the elbow, discomfort with direct pressure, visible or palpable prominence of wires or knots, and occasionally skin irritation or threatened breakdown over prominent hardware ⁽¹⁴⁾.

Kirschner wire migration represents a particularly troublesome complication that occurs when the proximal wire ends are not adequately secured and begin backing out through the posterior cortex. Migration rates as high as forty-three point seven percent have been reported with traditional Kirschner wire placement in the proximal ulnar canal. Migrating wires can cause pain, soft tissue irritation, bursitis formation, and in extreme cases can penetrate through skin creating an open wound. Prevention of migration requires proper seating of wire ends flush with or below the dorsal cortex and avoiding placement of wire ends in the proximal ulnar canal where they lack stable anchorage ⁽²¹⁾.

Loss of fracture reduction can occur early in the postoperative period before complete healing or later after initial healing has begun. Early loss of reduction typically results from inadequate initial fixation, hardware failure, or excessive loading before the fracture has healed. Late loss of reduction may occur after hardware loosening or breakage. Reported rates of loss of reduction following tension band wiring range from five percent to fifty-three percent depending on the series, patient population, and definition used ⁽¹¹⁾.

Infection following tension band wiring of olecranon fractures is relatively uncommon but represents a serious complication requiring aggressive management. Superficial wound infections involving only skin and subcutaneous tissue occur in approximately three to five percent of cases and typically respond to oral antibiotics with or without simple wound care. Deep infections extending to the bone or hardware occur less frequently, estimated at one to two percent of closed fractures but substantially higher rates in open fractures. Deep infection usually requires surgical irrigation and debridement, with the decision about hardware retention versus removal depending on timing and fracture healing status ⁽¹⁹⁾.

Nerve complications following tension band wiring occur infrequently but can cause significant morbidity when they occur. The ulnar nerve is most vulnerable due to its superficial course posterior to the medial epicondyle and proximity to the surgical field. Reported rates of ulnar nerve symptoms after olecranon fracture fixation range from one to four percent. Injury may occur from direct trauma during surgical dissection, drilling of distal wire holes too close to the nerve, compression from postoperative swelling or hematoma, or late irritation from hardware prominence or migration. Most ulnar nerve symptoms are transient and resolve spontaneously with observation and symptomatic treatment ⁽¹⁴⁾.

Plate Fixation

Plate fixation has evolved from a secondary option reserved for complex olecranon fractures to an increasingly utilized primary treatment method for simple and complex fracture patterns alike. The growing adoption of plate-based constructs reflects advances in implant technology, improved understanding of biomechanical principles, and recognition of limitations associated with traditional tension band wiring. Modern anatomically pre-contoured locking compression plates offer fixed-angle stability that is particularly advantageous in osteoporotic bone, comminuted fracture patterns, oblique fractures extending distal to the coronoid, and fracture-dislocations where conventional tension band wiring provides inadequate stability. The development of low-profile designs, specialized hook plate configurations, and double-plating techniques has expanded the armamentarium available to surgeons managing these challenging injuries ^(22,23).

The theoretical advantages of plate fixation over tension band wiring include more rigid construct stability allowing early mobilization even in complex fractures, superior fixation in poor quality bone through locking technology, ability to bridge comminution or bone loss, versatility to address various fracture configurations, and

potentially lower hardware removal rates due to decreased prominence with modern low-profile designs. However, plate fixation entails distinct disadvantages including substantially higher implant costs, more extensive soft tissue dissection with greater surgical trauma, technically demanding surgical technique requiring precise plate contouring and positioning, and persistent issues with hardware-related complications despite improvements in implant design ⁽¹⁹⁾.

The introduction of locking compression plate technology in the early two thousands represented a paradigm shift in fracture fixation principles. Locking screws threaded into the plate create a fixed-angle construct where stability derives from the implant itself rather than solely from bone purchase, providing advantages particularly in osteoporotic or comminuted bone ⁽²⁴⁾. The development of anatomically pre-contoured plates specifically designed for proximal ulna anatomy further improved application ease and fit. These specialized implants account for the natural contour of the olecranon and proximal ulna shaft, reducing the need for intraoperative bending and allowing more predictable screw trajectories ⁽²⁵⁾.

Recognizing that posterior plate position contributes substantially to soft tissue irritation regardless of locking versus non-locking technology, investigators developed alternative plating strategies to reduce prominence. The concept of lateral or posteromedial plate positioning emerged, theoretically allowing soft tissue coverage by the anconeus muscle laterally or flexor carpi ulnaris muscle medially ⁽²²⁾. Double-plate techniques utilizing two low-profile mini-plates applied laterally and medially represent another strategy to distribute fixation forces while minimizing dorsal prominence. These approaches require precise surgical technique and thorough understanding of local anatomy to avoid neurovascular structures ^(23,26).

Locking screw technology fundamentally changes this relationship by creating a fixed-angle construct where screw heads thread into the plate rather than simply passing through. The screw-plate interface rather than the screw-bone interface becomes the primary determinant of construct stability. This design creates an internal fixator where the entire construct acts as a single unit, distributing forces across all screws rather than concentrating stress at individual screw locations. In osteoporotic bone where individual screw purchase may be poor, the fixed-angle relationship prevents screws from toggling or backing out even if bone quality is compromised. Locking technology also eliminates the need for plate-bone compression, preserving periosteal blood supply and potentially enhancing healing biology ⁽²⁴⁾.

Biomechanical studies comparing locking versus non-locking plate constructs for olecranon fractures have demonstrated mixed results depending on testing conditions. Some investigations show superior stiffness and load to failure with locking constructs, particularly under bending loads that simulate physiologic triceps forces ⁽²⁷⁾. Other studies find equivalent mechanical performance between locking and non-locking designs when plate contour and screw configuration are optimized. Clinical outcome studies similarly show variable results, with some series reporting advantages for locking plates while others find no significant differences ⁽²⁸⁾.

Contemporary plate options for olecranon fractures encompass diverse designs addressing specific fracture patterns and surgical philosophies. Standard anatomically pre-contoured dorsal plates represent the most commonly utilized configuration, available in various sizes typically ranging from two point five to three point five millimeters in thickness. These implants feature gentle curvature matching proximal ulna anatomy, multiple hole options for screw placement, and combination locking and non-locking screw options allowing hybrid fixation strategies (De Giacomo et al., 2016). The proximal plate portion typically includes three to six holes to accommodate screw placement in the often-limited proximal fragment, while the distal shaft portion extends variable lengths depending on fracture pattern. Plates designed specifically for olecranon application generally offer right and left specific versions accounting for asymmetric ulnar anatomy ⁽²⁸⁾.

Low-profile double-plate systems represent an innovative approach utilizing two small plates applied laterally and medially rather than a single dorsal plate. The plates measure approximately two point seven to two point eight millimeters in thickness, substantially thinner than standard dorsal plates ⁽²³⁾. Lateral positioning allows coverage by the anconeus muscle while medial positioning permits coverage by flexor carpi ulnaris, theoretically reducing soft tissue irritation. A retrospective comparison of twenty-five double-plate patients versus twenty-two dorsal locking plate patients found comparable functional outcomes but hardware removal rates remained

significant at sixteen percent for double plates ⁽²²⁾. The technique requires careful attention to avoid ulnar nerve injury medially and proper muscle coverage laterally. Multiple screw options enable stable fixation of small proximal fragments that might be challenging with single dorsal plates ⁽²⁶⁾.

Comprehensive preoperative assessment begins with detailed radiographic evaluation to determine fracture pattern suitability for plate fixation. Anteroposterior and lateral radiographs demonstrate fracture displacement, comminution degree, obliquity, and extension into the coronoid or ulnar shaft ⁽¹⁸⁾. Computed tomography with three-dimensional reconstruction enhances understanding of complex fracture morphology, particularly for fracture-dislocations or comminuted patterns where plain radiographs may underestimate injury severity. CT helps identify associated coronoid fractures, radial head involvement, and bone quality assessment through visual estimation of cortical thickness and trabecular density ⁽²⁹⁾.

Patient factors influencing plate selection include age and bone quality, activity level and functional demands, body habitus affecting soft tissue coverage, medical comorbidities impacting surgical risk, and patient preferences regarding multiple procedures versus hardware bulk. Osteoporotic bone favors locking technology providing fixed-angle stability less dependent on bone density ⁽²⁴⁾. Young active patients benefit from rigid fixation enabling early return to demanding activities. Very thin individuals or those with minimal soft tissue may experience prominence regardless of plate type, while obese patients present technical challenges for plate positioning and soft tissue closure. Careful patient counseling regarding realistic expectations, potential complications, and alternative treatment options facilitates informed decision-making ⁽¹⁸⁾.

Implant selection requires matching plate configuration to fracture pattern and patient anatomy. Simple transverse fractures in good bone can be managed with standard dorsal plates or potentially hook plates. Comminuted patterns require plates with sufficient length to bridge the comminution zone, often necessitating six to eight hole constructs. Oblique fractures benefit from lag screw supplementation perpendicular to the fracture line before plate application. Fracture-dislocations may require longer plates extending well into the ulnar shaft to control rotational forces ⁽²⁹⁾.

Anatomic reduction represents the critical foundation for successful plate fixation, requiring restoration of articular congruity, ulnar length, and sagittal plane alignment. Pointed reduction forceps manipulate major fragments into position, applying compression across simple fracture lines ⁽¹⁸⁾. For transverse or short oblique fractures, a single large reduction forceps typically provides adequate control. Comminuted fractures may require multiple forceps or sequential reduction of intermediate fragments. The articular surface must be directly visualized and reduced to within two millimeters, with any step-off or gap exceeding this threshold corrected before proceeding ⁽³⁰⁾.

Plate contouring represents a critical step that significantly impacts final construct stability and hardware prominence. Pre-contoured plates generally match proximal ulna anatomy well but may require minor adjustments for individual variations. Plate bending using specialized bending instruments allows customization to patient-specific anatomy. The plate should sit flush against bone throughout its length without gaps that might allow motion or concentrate stress. Over-contouring creating excessive plate-bone compression can damage periosteum and compromise blood supply. Under-contouring leaves gaps allowing micromotion and stress concentration potentially causing screw loosening or plate fatigue failure ⁽²⁵⁾.

Plate positioning critically affects both biomechanical function and soft tissue tolerance. For dorsal application, the plate centers on the posterior midline of the ulna, though some surgeons prefer slightly lateral or medial positioning to facilitate soft tissue coverage. The proximal plate end should not extend beyond the olecranon tip where it would be maximally prominent and vulnerable to soft tissue irritation. The distal extent depends on fracture pattern, with simple fractures requiring less distal extension than comminuted patterns needing to bridge extensive zones. Plate position is provisionally secured with a single screw before final positioning is confirmed fluoroscopically (De Giacomo et al., 2016).

Screw insertion sequence affects reduction maintenance and construct stability. Most surgeons place a non-locking cortical screw in the oblong hole closest to the fracture first, using the screw to compress the plate against bone and draw fragments together. This maneuver requires the plate to sit slightly proud initially, with screw

tightening pulling the plate down and reducing any residual fracture gap. After achieving compression, locking screws are placed in remaining holes to create fixed-angle stability. Bicortical screw purchase is standard, though unicortical screws may suffice in the thick proximal fragment if bicortical placement risks articular penetration. Fluoroscopy after each screw confirms appropriate length and trajectory without joint penetration or anterior cortex over-penetration risking neurovascular injury ⁽¹⁸⁾.

Plate fixation of olecranon fractures achieves reliable union in the vast majority of cases across diverse fracture patterns. A multicenter evaluation of one hundred eighty-two consecutive displaced olecranon fractures treated with anatomically contoured dorsal plates reported one hundred percent union rate (De Giacomo et al., 2016). A French series of twenty-two complex olecranon fractures managed with pre-contoured locking plates similarly achieved union in all patients within mean ten point six weeks ⁽²⁵⁾. These high union rates reflect stable fixation enabling biological healing combined with preserved blood supply from careful soft tissue handling. Nonunion following plate fixation occurs rarely, typically associated with infection, inadequate fixation stability, or patient factors such as smoking or malnutrition compromising healing ⁽²⁹⁾.

Functional outcomes following plate fixation as measured by validated scoring systems demonstrate generally good to excellent results in most patients. The multicenter series of one hundred eighty-two patients reported mean DASH score of ten point one at minimum one-year follow-up, indicating mild residual disability (De Giacomo et al., 2016). The French locking plate series reported mean Broberg-Morrey score of ninety-six point seven and mean Mayo Elbow Performance Score of ninety-six point six, both indicating excellent function ⁽²⁵⁾. A Chinese comparative study of ninety-five olecranon fractures found mean DASH scores of twelve point nine for three point five millimeter locking plates and eleven point one for double mini-plates, neither significantly different from tension band wiring ⁽²⁶⁾.

Hardware prominence and symptomatic irritation represent persistent challenges with plate fixation despite improvements in implant design and surgical technique. The subcutaneous location of the olecranon provides minimal soft tissue coverage over even low-profile plates, making hardware irritation a common complaint. The multicenter evaluation reported that hardware was asymptomatic in sixty-seven percent of patients, caused pain when leaning on the elbow in twenty percent, and restricted activities in eleven percent (De Giacomo et al., 2016). Overall hardware removal rates ranged from eight to twenty-seven percent across various series, substantially lower than tension band wiring but still representing significant reoperation burden ⁽³¹⁾.

Loss of reduction following plate fixation is uncommon when proper surgical technique is employed, occurring in less than five percent of cases in most series. The randomized trial comparing techniques reported loss of reduction in three percent of plate-fixed fractures versus sixteen percent of tension band wired fractures ⁽¹⁸⁾. This difference reflects superior construct stability of plate fixation particularly in resisting shear forces and controlling rotation. When loss of reduction does occur with plate fixation, it typically indicates inadequate initial reduction, insufficient plate length failing to control all fragments, screw pull-through in osteoporotic bone, or premature loading (De Giacomo et al., 2016).

Wound healing complications including dehiscence, delayed healing, and superficial infection affect approximately five to ten percent of plate fixation cases across various series. The more extensive dissection required for plate application compared to tension band wiring theoretically increases wound complication risk. The French locking plate series reported one infection successfully treated with lavage and antibiotic therapy without hardware removal ⁽²⁵⁾. The geriatric locking plate study reported major wound complications in two of twenty-nine patients requiring operative debridement. Risk factors for wound problems include diabetes mellitus, peripheral vascular disease, tobacco use, malnutrition, and obesity. Thin fragile skin in elderly patients or thick tissue in obese individuals both present challenges for wound healing ⁽³¹⁾.

Nerve complications following plate fixation occur less frequently than with tension band wiring due to different hardware configuration and reduced pin migration risk. The ulnar nerve remains most vulnerable due to proximity to the surgical field, particularly during medial dissection for double-plate application or when placing distal medial screws. Reported ulnar nerve injury rates range from one to three percent. Most injuries represent neurapraxia from traction or manipulation during surgery rather than direct laceration, manifesting as transient

numbness and paresthesias in the ring and small fingers. Full recovery typically occurs within three to six months with conservative management including observation and symptomatic treatment ⁽³¹⁾.

Postoperative Rehabilitation

Immediate postoperative immobilization varies based on fixation stability, fracture pattern, and surgeon preference. Some surgeons prefer brief immobilization in a posterior splint for seven to fourteen days to allow soft tissue healing. Others initiate immediate range of motion exercises if fixation is deemed sufficiently stable. A bulky dressing with synthetic wool padding provides compression and support while allowing some elbow motion. Elevation of the extremity above heart level minimizes postoperative swelling ⁽³⁾.

Radiographic evaluation is performed in the immediate postoperative period to document reduction and hardware position. Follow-up radiographs are obtained at six weeks, twelve weeks, and six months to assess healing progression and hardware position. Any loss of reduction or hardware failure should be identified early and may necessitate revision surgery. Union is typically evident by organized trabecular bridging visible on radiographs by twelve weeks ⁽¹⁴⁾.

Rehabilitation following olecranon fracture fixation aims to restore range of motion, strength, and functional use of the upper extremity while protecting the healing fracture. Early mobilization has been shown to improve outcomes and minimize stiffness. The specific rehabilitation protocol depends on fracture stability, fixation method, bone quality, and patient factors. Communication between surgeon, therapist, and patient optimizes adherence and outcomes ⁽³²⁾.

For stable fixation in good quality bone, passive and active-assisted range of motion exercises may begin within the first week after surgery. Passive motion generates less distraction force at the fracture site than active motion and should be emphasized initially. Gravity-assisted flexion and extension exercises are performed multiple times daily to maintain joint mobility. Terminal extension is typically the most difficult motion to regain and should be addressed specifically with positioning exercises ⁽¹⁴⁾.

Progressive resistance exercises begin at six to eight weeks postoperatively once radiographic healing is evident. Initial resistance activities use light weights of one to two pounds for strengthening of elbow flexors and extensors. Gradual progression in resistance and repetitions continues over subsequent months. Full strengthening for return to manual labor or athletic activities typically requires three to six months. Some patients, particularly elderly individuals, may never regain full strength ⁽¹⁴⁾.

Functional activities are incorporated progressively into the rehabilitation program based on healing status and patient needs. Activities of daily living including eating, grooming, and dressing are encouraged as tolerated. Patients should avoid heavy lifting and high-impact activities until solid union is demonstrated radiographically. Return to work depends on job demands, with sedentary workers often returning within weeks while manual laborers may require several months ⁽³²⁾.

Management of Complex Fracture Patterns

Complex olecranon fractures including comminution, fracture-dislocations, and associated coronoid or radial head injuries require modified surgical approaches and often benefit from plate fixation capabilities. Comminuted fractures with multiple intermediate fragments challenge fixation stability but plate constructs can bridge comminution zones while controlling major proximal and distal fragments. The strategy involves reduction and provisional fixation of large fragments first, followed by plate application capturing smaller pieces with screws or leaving small fragments out if they cannot be reliably fixed. Intramedullary screws supplement plates by providing central axis stability and controlling rotation, particularly useful in comminuted patterns where cortical continuity is lost ^(31,25).

Transverse fractures with diaphyseal extension require longer plates extending well into the ulnar shaft to achieve adequate distal fixation. The fracture line orientation and location dictate minimum plate length requirements. Generally at least six cortices of screw purchase distal to the fracture are needed for adequate stability, translating to three bicortical screws or six unicortical locking screws. Fractures extending more than five centimeters from

the olecranon tip often benefit from eight to ten hole plates ⁽²⁹⁾. Oblique fracture patterns warrant lag screw placement perpendicular to the fracture before plate application, using the plate as a neutralization device protecting the lag screw fixation from deforming forces. This combined technique optimizes both compression at the fracture site and overall construct stability ⁽¹⁸⁾.

Comparison and Clinical Selection

The choice between tension-band wiring and plate fixation should be based primarily on fracture morphology, bone quality, soft-tissue coverage, and functional demand. Tension-band wiring is best suited to simple transverse or short oblique fractures with an intact dorsal cortex and good bone stock. Plate fixation is more versatile for comminuted fractures, distal extension, fracture-dislocations, and osteoporotic bone because it resists shear and rotational forces and can bridge areas of comminution.

Tension-band wiring offers lower implant cost, wide availability, and shorter operative requirements, but its clinical value is limited by frequent symptomatic hardware and Kirschner-wire migration. Plate fixation requires greater exposure and higher implant cost but generally provides more rigid fixation and lower loss-of-reduction rates. Hardware irritation is not eliminated by plating because the olecranon remains subcutaneous, although modern low-profile and alternative plate configurations may reduce prominence.

No single construct is optimal for every patient. Simple fracture pattern alone should not determine treatment; patient age, activity level, soft-tissue condition, capacity to comply with rehabilitation, and willingness to undergo possible implant removal should also be considered. Careful technique and appropriate rehabilitation are as important as implant selection in achieving stable union and functional recovery.

Conclusion

Olecranon fracture management requires restoration of articular congruity, reestablishment of the extensor mechanism, stable fixation, and early controlled motion. Tension-band wiring remains a reasonable option for carefully selected simple displaced fractures, but meticulous wire and pin placement is essential to reduce migration, prominence, and loss of reduction.

Plate fixation provides greater biomechanical versatility and is preferred for comminuted, oblique, unstable, osteoporotic, and complex fracture patterns. Although plate constructs reduce some limitations of tension-band wiring, wound problems and symptomatic hardware remain possible. Treatment should therefore be individualized, with implant choice guided by fracture characteristics, bone quality, soft-tissue condition, and patient expectations.

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