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Augmented intramedullary screw tension band construct for olecranon fracture reduction and fixation: a review of literature and surgical technique

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Olecranon fractures, which make up 10% of upper extremity fractures in adults, often require anatomic reduction and stable internal fixation. Successful olecranon fracture osteosynthesis has classically been achieved via tension band wiring or plate fixation. This article reviews the indications, outcomes, and a surgical technique as an alternative construct for tension band wiring of olecranon fractures. The technique involves placement of an ulnar intramedullary partially threaded screw that is used as a proximal point of attachment for tension band wiring of the olecranon. Although infrequently used by orthopedic surgeons, this construct has been shown to be biomechanically and clinically superior to classic Kirschner wire tension banding techniques. This review is intended to familiarize surgeons with a surgical technique that can be applied to a variety of proximal ulna fractures.

Epidemiology of olecranon fractures

The ulnohumeral joint provides static mechanical stability to the elbow throughout a full range of motion.[4] The proper function of the ulnohumeral articulation depends heavily on the congruency between the distal humerus and the greater sigmoid notch, which is made up of the olecranon and coronoid processes.[4,26] Olecranon fractures, which make up 10% of upper extremity fractures in adults, can result in uncoupling of this articulation via incongruity of the greater sigmoid notch and disruption of the elbow extensor mechanism.[26] Olecranon fracture morphology occurs on a spectrum, ranging from simple nondisplaced fractures to comminuted fracture dislocations, with fracture complexity often guiding operative treatment. The Mayo Classification of olecranon fractures is commonly used to describe and categorize these injuries.[6] Simple displaced fractures of the olecranon, classified as Mayo Type IIA fractures, represent the most common fracture morphology encountered clinically.[2] These injuries can result from a direct blow to the dorsal proximal ulna as well as from sudden, substantial tension from the triceps insertion on the olecranon. The majority of olecranon fractures typically occur secondary to low-energy, ground-level falls.[4]

Olecranon fracture osteosynthesis

Multiple surgical treatments have been described for olecranon fractures, including tension band wiring (TBW), plate fixation (PF), intramedullary (IM) screw fixation, IM nail fixation, and fracture excision with triceps advancement.[2,26] Articular stepoff within the ulnohumeral joint or a decrease in articular surface area, as is seen in partial olecranonectomy and triceps advancement, can result in asymmetric joint pressures and post-traumatic osteoarthritis.[19] As such, displaced olecranon fractures require anatomic reduction and stable internal fixation.[2,19,26,28] Nondisplaced fractures may be treated nonoperatively with immobilization and serial radiographs to monitor for displacement.[2,21,26] In these cases, patient compliance is necessary and patients must be advised that subsequent elbow stiffness is probable.[2,21] Nonoperative management of displaced fractures may be a reasonable option in the infirm or elderly patient.[28] There will be obvious loss of elbow extension strength, but some patients will maintain active elbow extension through soft tissue connections and fibrous fracture union. Patients who lose active elbow extension can often still achieve extension with the aid of gravity.[21,28]

Institutional review board approval was not required for this technique study.

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Figure 1 A posterior incision just lateral to the tip of the olecranon is used for exposure of the proximal ulna and triceps insertion.

Although new implant designs are being implemented in the treatment of these injuries, olecranon fracture osteosynthesis has classically been achieved via TBW or PF.[2,21,28] These techniques remain the most commonly employed by orthopedic surgeons and are largely used based on fracture morphology and surgeon preference.[21,28] Each technique provides unique advantages, risks, and variable costs that should be considered and applied based on patient characteristics and fracture patterns. Locking PF constructs offer rigid fixed-angle fixation but are more costly, require more extensive dissection, and often fail to match the anatomic proximal ulna dorsal angulation, which may lead to fracture malreduction.[13,21] TBW constructs are lower-profile and cheaper in comparison to PF constructs but offer less stability.[13,21]

Olecranon TBW indications

TBW constructs can be used in most simple olecranon fractures with minimal to no comminution and an intact articular margin (ie, Mayo Type I and Mayo Type IIA fracture patterns). Contraindications to TBW of the olecranon include olecranon fractures with significant articular comminution, fractures extending distal to the semilunar notch, and olecranon fracture dislocations (ie, Mayo Type IIB and Mayo Type III fracture patterns).[2,21] PF, which can offer increased stability across a fracture site vs. classic TBW, is often the preferred method of fixation in these fracture patterns.[5,21,27-29] Although the use of TBW constructs are limited to simple olecranon fracture patterns, IM screw placement can be used in conjunction with PF for a wide variety of ulna fracture patterns.[12]

Olecranon TBW construct design and biomechanics

TBW constructs convert tensile forces (generated by the contraction of the extensor mechanism at the elbow) into compressive forces at the fracture site.[2] There are multiple proposed tension band techniques of the olecranon.[9,11,18] The most commonly used construct involves placement of 2 bicortical Kirschner wires (K-wires) from proximal to distal, exiting the volar ulna distal to the coronoid process.[9,11] This is a technically demanding construct, as erroneous K-wire positioning or length can result in a mechanical block to forearm rotation or injury to anterior neurovascular structures, most notably the anterior interosseous nerve.[7,14,22,25] Alternatively, surgeons may place these Kirschner (K) wires unicortically, terminating in the medullary canal. Unicortical wires have been found to have a significantly higher incidence of instability and proximal hardware migration.[9,22,25] Recent biomechanical analysis has questioned whether olecranon TBW constructs function as a true tension band.[7,29] Wilson et al[29] carried out a biomechanical study evaluating static and dynamic compression of olecranon fractures treated with PF and standard K-wire TBW and found that TBW constructs introduced negligible dynamic compression at the fracture site with simulated cyclical triceps contraction. Additionally, K-wire TBW constructs were found to impart significantly decreased static compression at the fracture site compared with PF (PF, 819 N; TBW, 77 N; $P = .039$).[29] Brink et al[3] carried out a similar biomechanical analysis and found that olecranon K-wire TBW constructs created a small but likely inconsequential amount of dynamic compression at the articular surface with extension of the humerus in the upright position in 30°-120° of elbow flexion.

IM screw TBW

An alternative construct for TBW of olecranon fractures that introduces improved fracture compression has been described.[12] This technique involves placement of an ulnar IM partially threaded screw that is used as a proximal point of attachment for TBW of the olecranon (IM screw TBW).[12] Interestingly, this construct is infrequently used by orthopedic surgeons. Edwards et al[11] observed use of this technique in approximately 6% of the cases in their

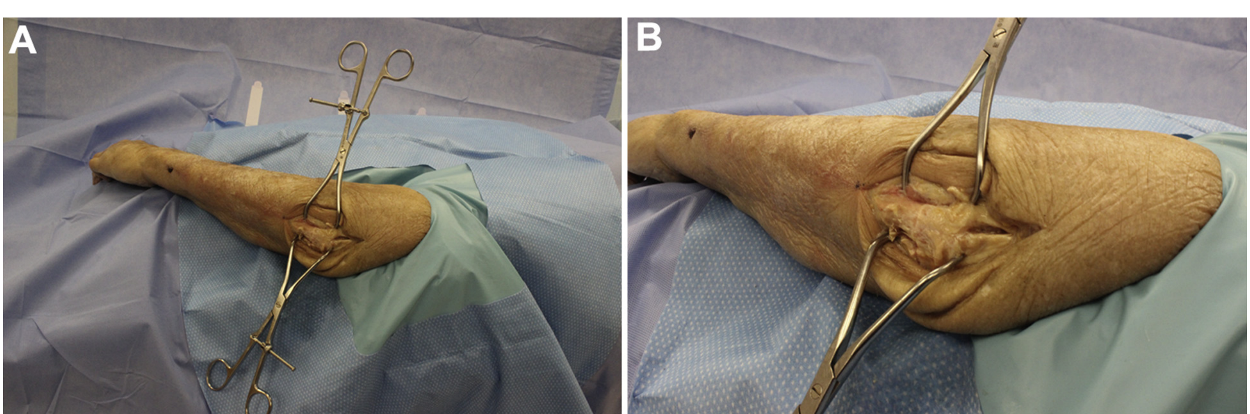

Figure 2 (**A**) The fracture is anatomically reduced and provisionally held with the use of modified point-to-point reduction clamps placed on the medial and lateral aspects of the proximal ulna. Unicortical drill holes are placed in the proximal ulna at the site of proposed tine application to allow adequate clamp purchase in fracture fragments. (**B**) A single longitudinal incision is made in the central, distal aspect of the triceps insertion to allow drilling of the proximal ulna at the center-to-center position for the intramedullary screw starting point. The incision in the triceps must be large enough to allow passage of a 6.5-mm screw and 13-mm washer.

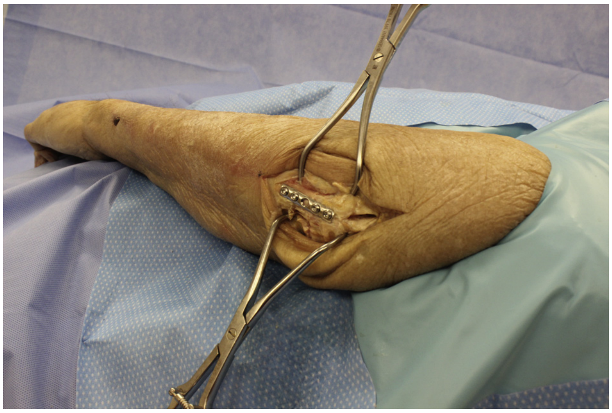

Figure 3 Before drilling and tapping of the ulna, a 5-hole 2.0-mm minifragment plate is placed over the dorsal ulna with 4 × 10-mm screws placed distal and proximal to the fracture site. This plate can provide additional resistance to fracture fragment displacement during proximal ulna drilling and tapping as well as during intramedullary screw placement. Surgeons may incorporate this plate into the final construct or use it for augmenting provisional fixation.

Figure 5 A long 2.5-mm drill bit with soft tissue protector is used to create the entry point for the intramedullary screw in the proximal ulna. Care must be taken to avoid eccentrically drilling into the endosteal surface of the ulna, which can result in extraosseous screw placement.

multicenter review. This technique introduces interfragmentary compression at the fracture site with lag screw fixation that is subsequently augmented with a tension band wire around a washer. Use of IM fixation as employed in this technique offers the additional biomechanical benefits of a load-sharing device and minimization of stress shielding compared with K-wire TBW and PF constructs.[8,24] Although biomechanical analysis to date has shown that TBW of olecranon fractures likely imparts negligible dynamic compressive forces in vivo, it does appear to introduce superior construct stability compared with IM screw fixation alone.[3,16,29] A biomechanical analysis carried out by Hutchinson et al[16] evaluating cyclic loading revealed a significant decrease in fracture gapping with IM screw TBW compared with IM screw fixation alone ($P = .004$) and K-wire TBW constructs (IM $P = .002$, transcortical $P = .003$).

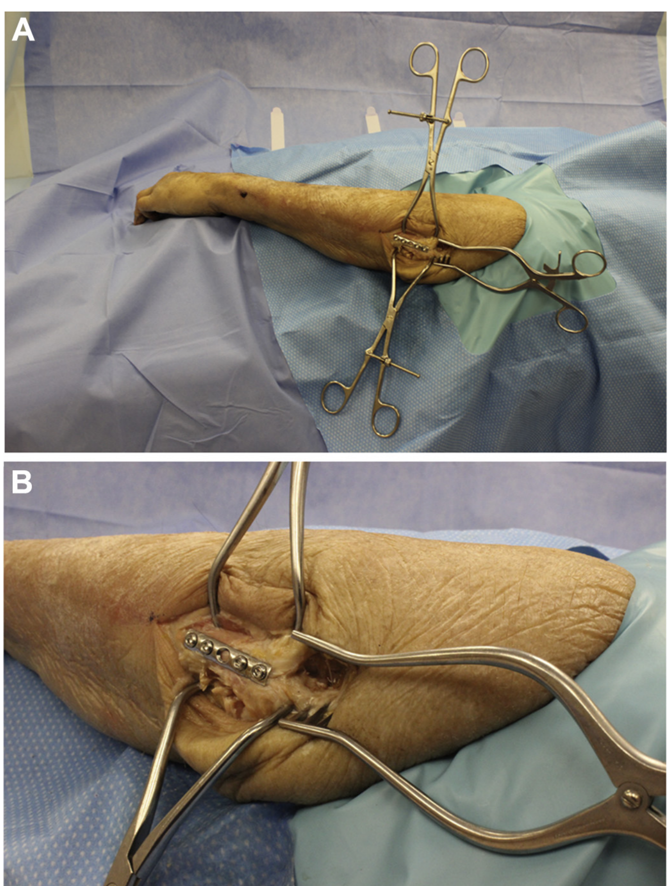

Figure 4 (**A**, **B**) A Weitlaner retractor can be placed in the longitudinal triceps incision to increase visualization and protect the triceps insertion during drilling and instrumentation.

Outcomes and complications

Clinical outcomes following operative fixation of simple transverse olecranon fractures are favorable. Duckworth et al[10] conducted a prospective randomized trial and observed no significant difference in DASH scores following classic TBW compared with PF for simple transverse olecranon fractures. At a 1-year follow-up, 93% of patients reported good or excellent result.[10] Although these techniques have been shown to be successful in achieving olecranon osteosynthesis, both TBW and PF of olecranon fractures are hampered by relatively high rates of hardware prominence and hardware removal.[5,10,11,23,27] Duckworth et al[10] noted a higher rate of symptomatic hardware requiring removal following TBW vs. PF (TBW, 50%; PF, 22%; $P = .021$), but noted that all major complications (defined as infection and revision) occurred after PF. The rate of major complication was 21.8% (4 infections, 3 revisions) vs. 0% in the TBW cohort ($P = .011$). Edwards et al[11] carried out a multicenter retrospective review of 138 olecranon fractures/osteotomies treated operatively and observed no significant difference in hardware removal rates between K-wire TBW and PF constructs (TBW, 63.6%; PF, 62.5%; $P = .50$). Interestingly, the authors did note that average time to hardware removal was later for patients treated with locking plates (TBW, 13.0 months; PF, 22.4 months), which may play a role in the 1-year results reported by Duckworth et al.[10,11] This finding may be a result of surgeon concern for refracture following early plate removal.[15] Literature on outcomes following IM screw TBW of olecranon fractures is limited. Woods et al[30] carried out a multicenter retrospective review analyzing the efficacy of multiple fixation constructs (ie, TBW, IM screw, PF, and IM screw TBW) in osteosynthesis of olecranon osteotomies. The authors reported a statistically increased odds ratio of nonunion and hardware removal

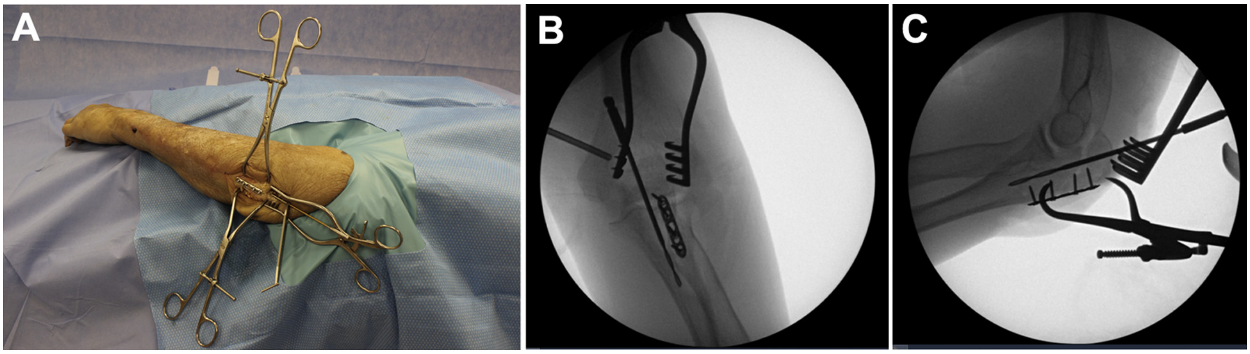

Figure 6 (**A**) The long 2.5-mm drill bit can be uncoupled from power so the intramedullary screw start point can be visualized under fluoroscopy to confirm adequate positioning. (**B**, **C**) Intramedullary screw starting point on the anteroposterior view should be center-to-center on the proximal ulna. The starting point on the lateral view should be at the midpoint between the dorsal cortex and nadir of the ulnohumeral joint.

following K-wire TBW compared with IM screw TBW, IM screw, and PF at 1-year follow-up. Within the 58-patient cohort treated with IM screw TBW (36.3% of study population), 5 patients (8.6%) experienced postoperative infection, 10 patients (19%) underwent subsequent removal of hardware, 3 patients (5.2%) had loss of reduction, and 5 patients (8.6%) went on to nonunion. Compared with all other olecranon fixation constructs in the study, IM screw TB had the lowest incidence of removal of hardware, loss of reduction, and nonunion.[30] Ahmed et al[1] carried out a prospective randomized study of 30 patients with olecranon fractures randomized to IM screw TBW and K-wire TBW construct fixation. The authors noted a trend toward improved postoperative elbow range of motion in the group treated with IM screw TBW although this was not statistically significant ($P = .072$).[1] Functional scores were noted to be significantly higher in the IM screw TBW group although minimum follow-up in this study was 6 months.[1] Raju et al[20] carried out a prospective case series evaluating 1-year outcomes following operative fixation of 25 simple olecranon fractures treated with IM screw TBW constructs. Patients were evaluated using a validated 19-point scale and were noted to achieve excellent results in 60%, good results in 12%, and fair results in 28%. Raju et al[20] observed a superficial infection rate of 8% and symptomatic hardware rate of 8% in their cohort.

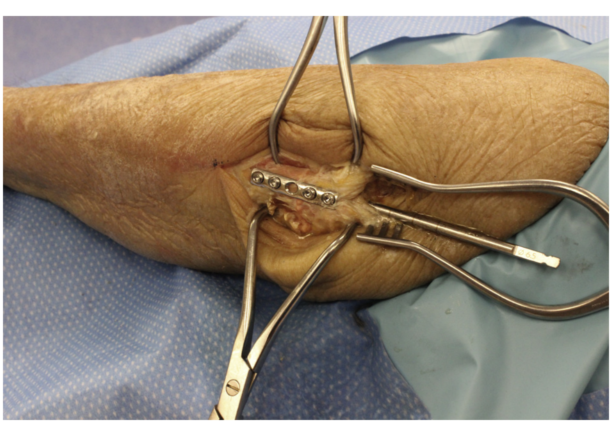

Figure 7 Advancement of a 6.5×150-mm tap into the ulna. Advance the tap under power until some resistance is noted and transition to hand power until the tap meets a firm endpoint. Maintain firm control over the distal ulna while tapping as this introduces significant rotational forces. Be sure to have rotational control of the distal ulna during tap and screw placement. After a firm endpoint is met, use the tap to measure intramedullary screw length. Be sure to select a screw that is slightly shorter than the final tap measurement to allow fracture compression.

Surgical technique: IM screw TBW of olecranon fractures

General anesthesia, regional anesthesia, or a combination can be used. A perioperative multimodal analgesic regimen is recommended.[17] The authors prefer to position the patient in lateral decubitus with an arm post or in the supine position with a sterile padded Mayo stand. The bed is rotated 90° to facilitate intraoperative fluoroscopy and operating room setup. The use of an upper extremity tourniquet is based on surgeon preference. Intraoperative fluoroscopy is brought in from the head of the bed. Radiographs are taken prior to draping to ensure adequate fluoroscopic visualization is obtainable. The operative extremity is prepped and draped in sterile fashion.

The authors use a technique previously described by Eglseder.[12] A posterior incision just lateral to the tip of the olecranon is carried out (Fig. 1). Sharp dissection is used to reflect full-thickness skin flaps to expose the dorsal ulna and triceps insertion. Periosteum is reflected at the fracture site to facilitate fracture visualization and cleaning of the fracture site. The fracture is anatomically reduced and provisionally held with use of K-wires or modified point-to-point reduction clamps placed in the medial and lateral aspects of the proximal ulna (Fig. 2, *A*). The authors prefer the use of 2 points of provisional fixation for rotational control. Anteroposterior and lateral radiographs are taken to confirm anatomic reduction. If comminution is noted or provisional fixation is felt to be inadequate, surgeons can use minifragment plate(s) placed over the dorsal ulna with 2×10-mm screws placed both distal and proximal to the fracture site (Fig. 3). In patients with poor bone quality, a minimum of 1 locking screw should be used on each end of the construct. This additional PF can provide further rotational control during subsequent tapping and placement of the IM screw and can be left in place or removed at the conclusion of the case.

A small longitudinal incision along the midsubstance of the triceps tendon at its insertion on the proximal ulna is made that must accommodate passage of a screw and 13-mm washer (Fig. 2, *B*). A small Weitlaner retractor can be placed to hold the tendinous incision open for visualization of the IM screw start point (Fig. 4, *A* and *B*). A long 2.5-mm drill bit is used to create the entry point for the IM screw in the proximal ulna (Fig. 5). The starting point is positioned center-to-center on the proximal ulna, and the trajectory should be in line with the medullary canal of the ulna. On lateral view, the starting point should be at the midpoint between the dorsal cortex and nadir of the ulnohumeral joint. Care must be taken to avoid eccentrically drilling into the endosteal surface of the ulna, which can result in extraosseous screw placement. The long 2.5-mm drill bit can be uncoupled from power to allow the starting point and trajectory

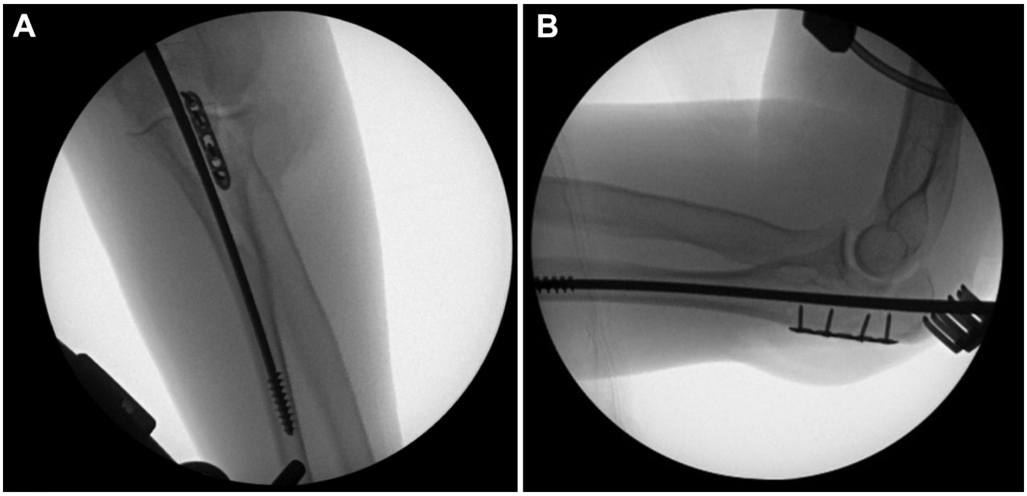

Figure 8 (**A**) Anteroposterior and (**B**) lateral fluoroscopic views should be carried out after final advancement of the 6.5-mm tap to confirm adequate intramedullary positioning and desired screw length. Once the endpoint is obtained and positioning/length is confirmed, the 6.5-mm tap can be removed.

to be visualized under fluoroscopy (Fig. 6, *A*). Proper position of the 2.5-mm drill bit within the ulnar medullary canal should then be confirmed on anteroposterior and lateral fluoroscopic views (Fig. 6, *B* and *C*). Next, overdrill the proximal ulnar fragment with a 4.5-mm drill bit to the level of the coronoid to accommodate the tap and prevent lateralization of the proximal fragment during screw placement. Advance a 6.5$\times$150-mm tap into the ulna under power and transition to hand tightening once slight resistance is noted (Fig. 7). Be sure to have rotational control of the distal ulna during tap and screw placement. This can be obtained by holding the forearm or placing a lobster claw clamp on the ulnar shaft distally. The tap should be advanced until it meets a firm endpoint and cannot be inserted further. Achieving a substantial cortical bite during tap and IM screw placement within the endosteal diaphysis of the ulna is vital to success in this technique. Failure to obtain adequate screw thread purchase in the ulnar diaphysis will result in a weaker construct and potential loss of reduction. If the 6.5-mm tap gains poor endosteal purchase in the distal ulna, remove the tap, place a 7.3-mm cannulated screw guidewire within the canal, overdrill the proximal ulna using a 5.0-mm cannulated drill bit, and advance a cannulated tap. Confirm adequate positioning of the tap on fluoroscopy once fully seated on anteroposterior and lateral views (Fig. 8). Screw length is measured off of the tap. This technique uses a long screw with lengths typically 120-150 mm in range. It is important to place a screw that is slightly shorter than the length of the fully seated tap to allow for fracture site compression. Following tap removal, a 2.0- or 2.5-mm drill bit is used to drill a hole in the dorsal ulnar cortex for placement of the distal TBW limb (Fig. 9). This transverse hole should be drilled 2.5 cm distal from the fracture site and should be placed in the dorsal ulnar cortex immediately adjacent to the medullary canal to avoid TBW notching/failure during screw placement. An 18-gauge wire is placed through this drill hole for use in the distal limb of the TBW construct (Fig. 10). Advance the wire until it is visible on the contralateral side. As described by Eglseder, cannulated screws have a higher modulus of elasticity and will not accommodate the ulnar bow as well as noncannulated screws.[12] As such, a noncannulated 6.5-mm partially threaded (32-mm-thread-length) screw with a 13-mm washer is preferred (Fig. 11). Cannulated 7.3-mm screws can be used in this technique when necessary, but surgeons should be cognizant that this screw will

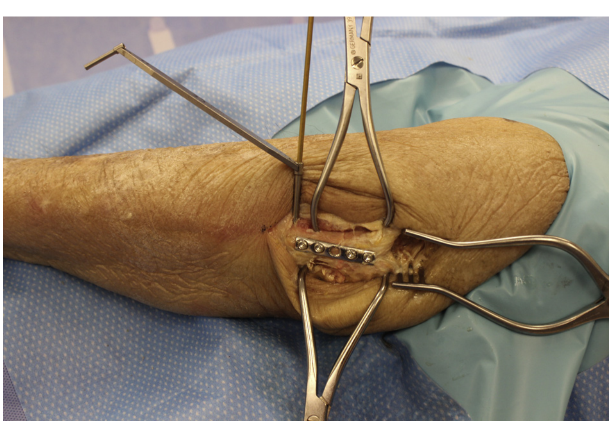

Figure 9 A 2.0- or 2.5-mm drill bit is used to drill a transverse hole in the dorsal ulnar cortex for placement of the distal tension band wiring (TBW) limb 2.5 cm distal from the fracture site. The transverse hole should be drilled immediately adjacent to the medullary canal to avoid TBW notching or failure during intramedullary screw placement.

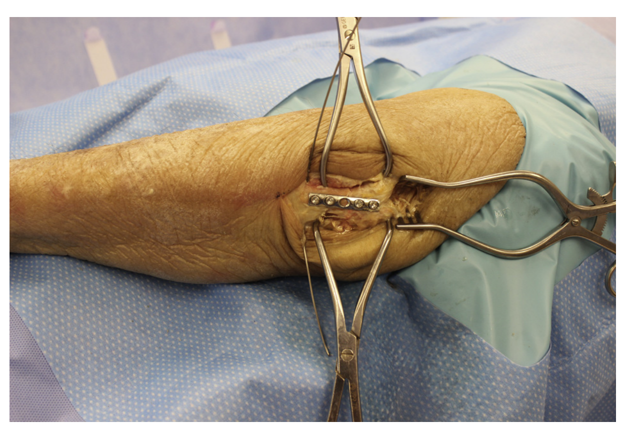

Figure 10 Before screw placement, a length of 18-guage wire should be passed through the dorsal ulnar cortex. This is only partially advanced before screw placement.

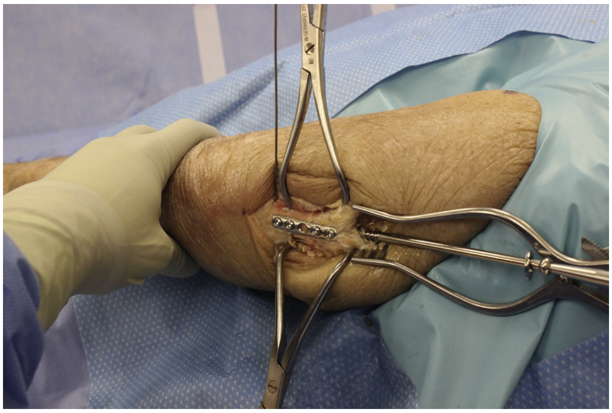

Figure 11 A noncannulated 6.5-mm partially threaded (32-mm-thread-length) screw with a 13-mm washer is placed into the ulna while maintaining rotational control over the distal ulna.

not contour to the varus bow of the ulnar medullary canal in the same manner. Care must be taken while placing the IM screw. The IM screw is advanced until it is approximately 1 cm proud of being fully seated (Fig. 12). Before fully seating the screw, the length of the 18-gauge TBW wire passed through the distal ulna should be measured to confirm the screw did not break the wire. If the wire is found to have broken, reinsert the wire if possible, or back up the screw and reinsert the wire. Of note, if the dorsal minifragment plate is to be used for augmenting provisional fixation only, it should be removed following IM screw placement and before TBW assembly. The tension band construct can be assembled using a single 18-gauge wire or 2 separate lengths of 18-gauge wire based on surgeon preference. The authors prefer the use of 2 lengths of wire given its ease in TBW assembly. At this time, a second length of 18-gauge wire is passed under the washer and a standard figure-8 tension band construct is formed. Alternatively, 1 or 2 lengths of 20-gauge wire or a 1.0-mm cerclage cable system tensioned to 30 kg can be used in tension band construct formation in an attempt to decrease the overall prominence of the fixation construct. This can be useful in slender, female patients more susceptible to hardware prominence. Before final screw tightening, the TBW construct should be assembled and provisionally tightened according to standard technique (Fig. 13). Depending on the method of provisional fracture reduction and fracture pattern, final screw seating may deform the reduction to some degree. For example, if a dorsal minifragment plate is used to maintain provisional reduction,

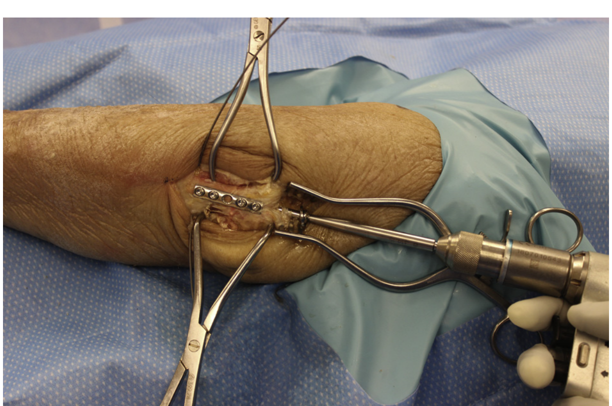

Figure 12 Advance the intramedullary screw until it is approximately 1 cm proud of being fully seated on the proximal ulna.

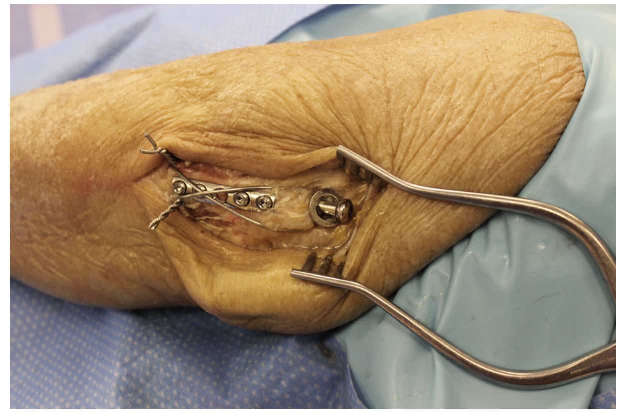

Figure 13 Following intramedullary screw placement, the distal limb of the tension band construct that was partially advanced is now advanced further. Integrity of the 18-gauge wire is checked. A second length of 18-gauge wire is passed under the washer, and a standard figure-8 tension band construct is formed and provisionally tightened. If surgeons wish to use the minifragment plate for provisional fixation only, it should be removed at this time before tension band construct formation. When forming the tension band, be sure to grasp the wires centrally so they twist around one another in a symmetric fashion. Typically, 3 twists are used for provisional tightening on each side. At this time, final intramedullary screw tightening can be carried out.

screw compression may preferentially compress the articular margin as the dorsal cortex is stabilized with the plate. If this occurs, one can loosen the screws or remove the plate to allow uniform compression. After final seating of the screw, the surgeon can carry out final tightening of the tension band wire construct (Fig. 14). At this time, confirm acceptable screw position and fracture reduction with fluoroscopy (Fig. 15). If an intraoperative complication is encountered, the surgeon can transition to an olecranon locking plate. Skin incisions are closed in standard fashion, and a long-arm posterior slab splint is applied. Anteroposterior and lateral radiographs are obtained postoperatively (Fig. 16). The patient is kept nonweightbearing on the operative extremity.

Conclusion

Olecranon fractures are common injuries that often require surgical management. Although multiple techniques are available for olecranon fracture osteosynthesis, IM screw TBW is biomechanically favorable, technically simple, and has fewer complications compared with more commonly used fixation constructs.

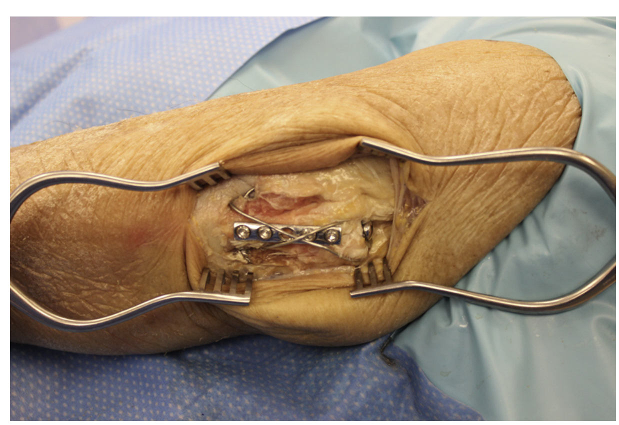

Figure 14 Following placement of the intramedullary screw, the tension band wiring can be finally tightened. At this time, 1 simultaneous twist final tightening while burying the prominent wires along the periosteum. Prior to final tightening of the tension band, prominent wire tips can be trimmed with a wire cutter.

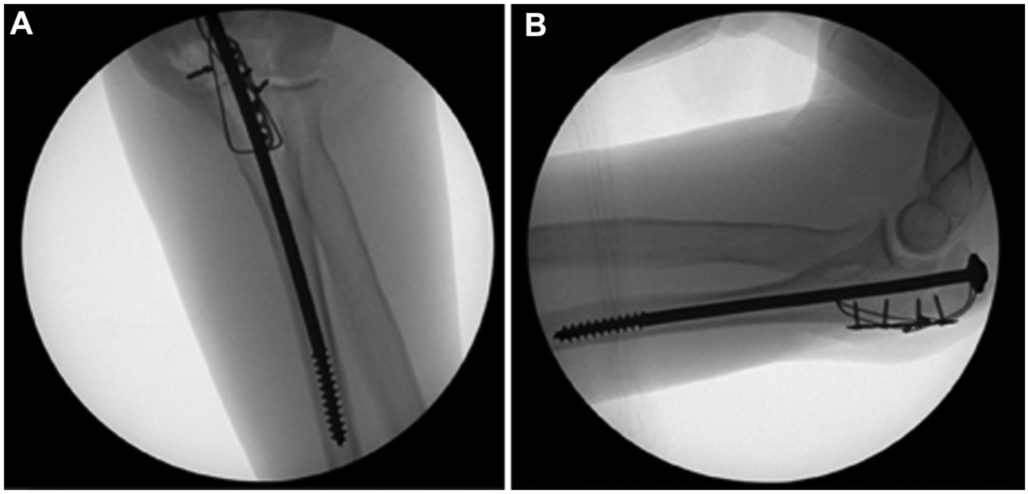

Figure 15 Final (**A**) anteroposterior and (**B**) lateral fluoroscopic views are obtained to confirm maintained fracture reduction and proper hardware placement.

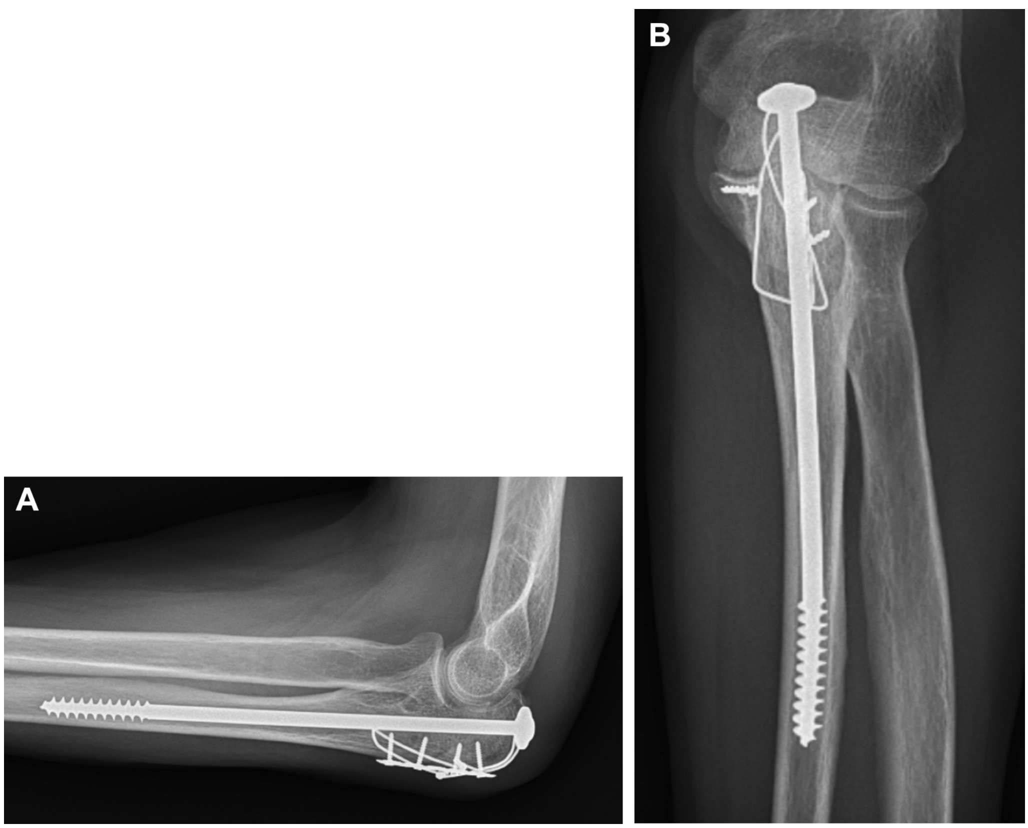

Figure 16 Postoperative (**A**) anteroposterior and (**B**) lateral radiographs are obtained for final evaluation of fracture reduction and later comparison in subsequent follow-up.

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Disclaimer

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