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Treatment of olecranon fractures using an intramedullary cancellous screw and suture tension band: minimum 2-year follow-up

Julio J. Contreras Fernández, MD [a,b,*], Manuel Beltrán, MD [a,b], Carlos Córdova, MD [a,b], Sergio Benavente, MD [a], Cristóbal Díaz, MD [a,b], Nicolás Rojas, MD [a,b], Sebastián Vial, MD [a,b], Alonso Díaz, MD [a,b], Eduardo Otero, MD [a,b], Héctor Palomo, MD [a], Rodrigo Liendo, MD [c,d], Francisco Soza, MD [c,d]

[a] *Shoulder and Elbow Unit, Instituto Traumatológico, Santiago, Chile*
[b] *Department of Orthopedics and Trauma, Universidad de Chile, Santiago, Chile*
[c] *Shoulder and Elbow Unit, Pontificia Universidad Católica de Chile, Santiago, Chile*
[d] *Department of Orthopedics and Trauma, Pontificia Universidad Católica de Chile, Santiago, Chile*

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Background: Tension band wiring and plates are the most widely used treatments for transverse displaced fractures of olecranon despite high rates of hardware complications, subsequent implant removal, and associated costs. The purpose of this study was to report the outcomes of displaced transverse olecranon fractures treated with intramedullary screw and suture tension band.

Methods: We performed an observational, retrospective, consecutive, monocentric, continuous multi-operator study. We reviewed 31 Mayo type IIA displaced olecranon fractures treated in our institution with intramedullary 6.5 mm AO cancellous screw and high-strength suture tension band (No. 2 FiberWire®) from 2016 to 2018. Inclusion was limited to functionally independent patients with Mayo type IIA fractures and minimum 24-month follow-up for implant removal. We assessed clinical outcomes including range of motion; QuickDASH score; and Mayo Elbow Performance Score. Categorical data were analyzed with Fisher's exact test when appropriate. Continuous data were analyzed with the Student t-test or Mann-Whitney U test after assessment for normality. Statistical analysis was performed with STATA 16 software.

Results: Twenty-seven patients with a mean follow-up period of 38.4 ± 6.2 months (range, 24.1-50 months) were included in the study. The average flexion was 134.5° ± 14.8° (range, 70°-140°) and the mean extension was −5.9° ± 7.0° (range, −20°-0°). Mean pronation and supination were 85.8° ± 11.9° (range, 45°-90°) and 86.9° ± 14.3° (range, 20°-90°), respectively. The mean Mayo Elbow Performance Score was 90.8 ± 9.6 (range, 70-100) with 92.3% good and excellent results. The mean QuickDASH score was 17.1 ± 16 (range, 0-54.5). There were 3 hardware-related removals (11.1%). The overall removal rate was 18.5%. Univariate analysis of the factors associated with implant removal were pain in relation to the implant (60% vs. 11%, $P = 0.0482$), proximal screw migration (3.7 mm vs. 1.7 mm, $P = 0.05$), articular angle (22.5° vs. 27.7°, $P = 0.0353$), and olecranon width (22.2 mm vs. 24.4 mm, $P = 0.0166$). In total, 26.1% of the cases presented some degree of proximal migration of the implant (2.7 ± 1.8 mm of migration; range, 1.5-6.2 mm). Univariate analysis of the factors associated with implant proximal migration were proximal ulnar dorsal angulation (1.7° vs. 6.4°, $P = 0.0179$), anteroposterior endomedullary canal (7.3 mm vs. 6.0 mm, $P = 0.0369$), and lateral endomedullary canal (7.2 mm vs. 5.0 mm, $P = 0.0219$).

Conclusion: The functional outcomes of simple transverse olecranon fractures treated with an intramedullary cancellous screw and a suture tension band are excellent, associated with a low rate of complications and material removal.

The Clinical Research Ethical Committee of Instituto Traumatológico "Dr. Teodoro Gebauer Weisser" approved the patient registry. All patients provided informed consent before participation.

[*] Corresponding author: Julio J. Contreras Fernández, MD, Shoulder and Elbow Surgeon, Instituto Traumatológico de Santiago, Assistant Professor, Department of Orthopedics and Trauma, Universidad de Chile, Pocuro #2170, D63, Santiago PC 7510664, Chile.

E-mail address: juliocontrerasmd@gmail.com (J.J. Contreras Fernández).

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Fractures of the proximal ulna range in severity from simple olecranon fractures to complex fractures involving damage to stabilizing structures of the elbow.[21,32]

Olecranon fractures account for 0.9% of all fractures and 10% of all upper extremity fractures.[13,31,35] Concerning isolated fractures of the olecranon, the Mayo classification is that the most useful in clinical practice.[25] It not only describes fracture morphology but also includes fracture stability and, therefore, serves as a guide for choice of surgical approach.

Simple displaced transverse intra-articular fractures (Mayo type II) are the foremost common, accounting for up to 85% of all olecranon fractures.[13] These fractures typically occur as a result of standing height falls (67%)[13]; however, higher energy injuries may end in articular comminution (Mayo type IIB) or elbow instability (Mayo type III).[18]

Disruptions of the extensor mechanism, articular incongruity, instability of the ulnohumeral joint, or compromised soft tissue all require operative intervention.[12,38] The goals of surgery are (i) to exact reconstruction of the olecranon alignment,[32,36] (ii) to neutralize the displacing force of the triceps, (iii) to allow an early range of motion,[32] and (iv) to avoid complications or reoperation.[28]

Commonly used techniques include tension band wiring (TBW), plate, and intramedullary fixation.[4,22,28,33,37] The most common complication related to all olecranon fracture surgery is the prominence of hardware causing pain, soft tissue irritation, wound breakdown, and/or reoperation for implant removal.[16,28] This has been reported to be as high as 75% for TBW and 50% for plate fixation.[5,23,34] Apparently, the utilization of an intramedullary screw is related to lower removal rates, ranging from 0 to 33%.[4,33,37]

Regarding the functional results of the surgical approach of isolated, displaced olecranon fractures, no difference was found between TBW and plate fixation within the short-term follow-up.[14] Although it has been accepted that TBW may have a lower profile than plating, hardware removal rates of 65% to 80% are no lower than the rates observed with plates.[23]

Braided suture, such as FiberWire®, may be used instead in an attempt to avoid the soft-tissue irritability of the metal wire. Although one biomechanical study has shown equivalent stability between the two in a cadaver model, no clinical data aside from case reports and case series have been published.[20,26,37] Some evidence suggests that a single 7.3-mm intramedullary screw, with or without tension band wiring, may be biomechanically superior to K-wire tension banding in terms of compression at the articular surface and resistance to gapping.[18] Clinical information with intramedullary screws between 4.5 mm and 7.3 mm reveals good and excellent results associated with a low complication rate.[4,37]

To address the problems related to prominent implants and reoperation, we have developed, for this type of fracture, a novel technique that uses a high-resistance braided suture with an intramedullary cancellous screw; we hypothesize that this technique reduces the incidence of implant removal and maintains good functional results, being able to replace the classic TBW in some indications.

Thus, the primary objective of this study was to assess the clinical and functional outcomes of simple transverse olecranon fractures treated with an intramedullary cancellous screw and suture tension band with a minimum two-year follow-up. The secondary objective was to analyze the factors associated with implant removal and proximal implant migration to improve the surgical technique.

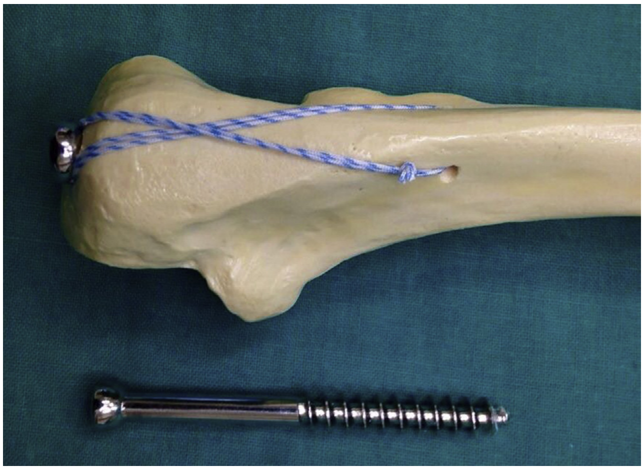

Figure 1 Intramedullary screw and suture tension band. Intramedullary 6.5 mm AO cancellous screw and high-strength suture tension band with nonabsorbable braided polyester polymer with a long-chain polyethylene core No. 2 FiberWire® (Arthrex, Naples, FL, USA).

Materials and methods

Patient selection and study design

Our study was performed following the STROBE statement for cohort studies and the Declaration of Helsinki. Our ethical committee approved a patient registry, and all patients provided informed consent before participation. This was an observational, retrospective, consecutive, monocentric, continuous multioperator study. We reviewed 31 consecutive Mayo type IIA displaced olecranon fractures treated in our institution with intramedullary 6.5 mm AO cancellous screw and high-strength suture tension band with nonabsorbable braided polyester polymer with a long-chain polyethylene core No. 2 FiberWire® (Arthrex, Naples, FL, USA) (Fig. 1) from May 2016 through July 2018 by the Shoulder and Elbow Unit of our institution.

Inclusion was limited to closed, transverse, isolated, unilateral, displaced olecranon fractures in functionally independent patients at the time of injury and at least two years of follow-up for implant removal. The intramedullary screw and suture tension band were used by our team for most Mayo type IIA fractures treated during the study period.

We excluded patients with symptomatic degenerative pathology of the ipsilateral upper extremity; simultaneous traumatic lesions of the ipsilateral upper extremity; Mayo type I, IIB, and III olecranon fractures; fracture with metaphyseal and diaphyseal extensions; and simultaneous additional injuries to structures associated with elbow instability to minimize possible confounding injuries and, thus, to focus on the olecranon fracture itself. Two patients were excluded from the analysis because they did not attend the postoperative controls, whereas one patient was excluded for an open fracture. One patient with an excellent clinical and imaging result, discharged at two-and-a-half months, was excluded because the patient died after three postoperative months (undiagnosed aggressive non-Hodgkin's lymphoma) and, thus, did not complete the follow-up for implant removal.

Demographic data

Fifteen patients were women and 12 were men (n = 27). Their average age at the time of surgery was 43.1 years (range, 17-78

Table I
Demographic characteristic and injury mechanism.

Demographic characteristic	
Age, mean ± SD, years	43.1 ± 21.1
Sex	
Female, n	15
Male, n	12
Follow-up, mean ± SD, months	38.4 ± 6.2
Injury mechanism	
Fall to the level, n	10
Direct blow, n	6
Bicycle fall, n	6
Motorcycle accident, n	3
Fall from heights, n	1
Hit by a car, n	1

SD, standard deviation.

years). Ten patients had a fall onto an outstretched hand (37%), six suffered a direct blow, six had a bicycle fall, three had a motorcycle accident, one had a fall from heights, and one was hit by a car (Table I).

Surgical technique

After induction of regional anesthesia, the patient is positioned supine on the operating table with the affected extremity and with the shoulder adducted and the elbow flexed across the torso, stabilized by an assistant, a well-padded armrest, or a cushion. The upper extremity is prepared and draped in standard orthopedic fashion, and a tourniquet is placed on the upper arm. A curved posterior incision is used, starting a few centimeters proximal to the tip of the olecranon, as needed for access to the injured area. Then it is curved slightly laterally around the tip of the olecranon and extending distally in line with the posterior cortex of the ulna as needed to provide access to the injured area (Fig. 2A). In the proximal portion, dissection is carried down to the level of the triceps fascia, with care taken to not develop significant flaps. Over the olecranon, the bursa is removed and the triceps aponeurosis incised, exposing the bone. At the fracture site, there is minimum detaching of the flexor carpi ulnaris muscle on the medial side, and the anconeus muscle on the lateral side as far as necessary to expose the involved articular surfaces for an anatomical reduction and stable fixation (Fig. 2B). There is exposition of the fracture site with minimal soft tissue dissection off the bone. The hematoma is removed and the fracture site is irrigated. The fracture is reduced with the help of reduction forceps and provisionally fixed with two 2.0 K-wires toward the anterior cortex, leaving at least 10 mm of space between the K-wires in which to put the intramedullary screw (Fig. 2D). Reduction is confirmed with direct visualization and fluoroscopic imaging. The length of the screw is measured with preoperative radiographies and/or visualization with fluoroscopy to obtain a good purchase in the ulna shaft (in this series, the average screw length was 89.8 ± 15.3 mm (range, 65-110 mm)). A transverse drill hole for the long axis of the ulna is made with a 2.0-mm bit, just beneath the posterior cortex through the medial and lateral cortices, 4 cm distal to the fracture site, to pass the suture for the tension band (Fig. 2C). Longitudinal opening is performed with the scalpel in the axis of the fibers of the tricipital tendon, and blunt dissection is made with scissors or clamps (Fig. 2D). No additional incisions are made in the triceps to preserve the soft tissue attachments. The intramedullary canal of the ulna is drilled with a 3.2-mm drill, and a 4.5-mm drill is used to predrill the proximal part of the olecranon. The starting point is positioned center to center on the proximal ulna in two planes and the direction should be in line with the ulna axis, considering varus angulation. Fluoroscopic assistance is recommended. Tapping of the ulna shaft with the 4.5-mm cortical tap is performed with the protection sleeve. The olecranon cortex is slightly countersinked to decrease the prominence of the screw in patients without osteoporotic bone. The 6.5-mm cancellous screw with partial thread (32mm) is inserted and carefully tightened, ensuring that the fracture stays reduced and is compressed (in two cases, a 16 mm partial thread was used). The correct position of the screw is checked with fluoroscopy. In case of a difficult passage of the screw, it is suggested that the screw be removed and its length reduced. In total, 5 mm of screw head is left without advance to pass the suture below the screw. Two strands of No. 2 FiberWire® are passed transversely using a manual method and configured in a tension band fashion with an eight-shape, passing the proximal end through the tricipital tendon and below the screw head (in two cases, FiberTape® suture tape was used) (Fig. 2E). Depending on surgeon preference, an additional washer can be used (used in only two cases). The suture is progressively knotted with the Nice double-suture knot technique to control compression (Fig. 2F). Finally, the screw is fully inserted, the suture is tightened again, and a final check with fluoroscopy is performed to evaluate the final position of the screw head and avoid hardware irritation. Excellent compression at the fracture site was noted. The fracture was determined to be anatomically reduced by visual inspection and intraoperative fluoroscopic imaging. This technique is available in Vumedi® (https://www.vumedi.com/video/orif-for-transverse-olecranon-fracture-mayo-ii-a-with-endomedullar-cancellous-screw-and-fiberwire-te/). Postoperatively, patients were immobilized in a sling for two weeks. All elbows were allowed to start active and passive movement immediately after surgery but were limited to non-weight-bearing activities for the first six weeks. Therapy was not routinely prescribed. The same therapy protocol was applied to all patients by our institution's therapy team.

Clinical evaluation

Electronic medical records and functional evaluations were reviewed for demographic data, physical examination findings, and radiographic data. Complications including wound dehiscence, infection, nonunion, neurovascular injury, stiffness, hardware removal, and reoperation were recorded.

Twenty-six patients were assessed at a minimum of 6 months follow-up for subjective functional outcomes. The range of elbow motion was checked, and the degree of pain was evaluated with a visual analog scale score from 0 to 10. Overall functional status was evaluated using the Mayo Elbow Performance Score (MEPS) and the Quick Disabilities of the Arm, Shoulder and Hand score (QuickDASH).[2] If patients were unable to undergo follow-up in the office, their elbow range of motion was assessed via digital photography[24,27] and the MEPS and QuickDASH questionnaires were filled out electronically. Of the 27 patients included in the study, only one patient did not attend the functional evaluation in person or electronically, although there was an electronic medical record of the other clinical variables. The presence of implant removal was evaluated after two years of follow-up in the entire sample.

Radiologic evaluation

Bony union, implant failure, loss of reduction, and anatomical measurements were evaluated retrospectively based on the available postoperative follow-up radiographs and medical records (Fig. 3). All radiographs were obtained using a digital imaging system (DigiRAD-FP (ST-5000C), Gyeonggi-do, Korea). Commercially available imaging software (Vue PACS, Carestream) was used to enlarge images and to conduct measurements. One surgeon,

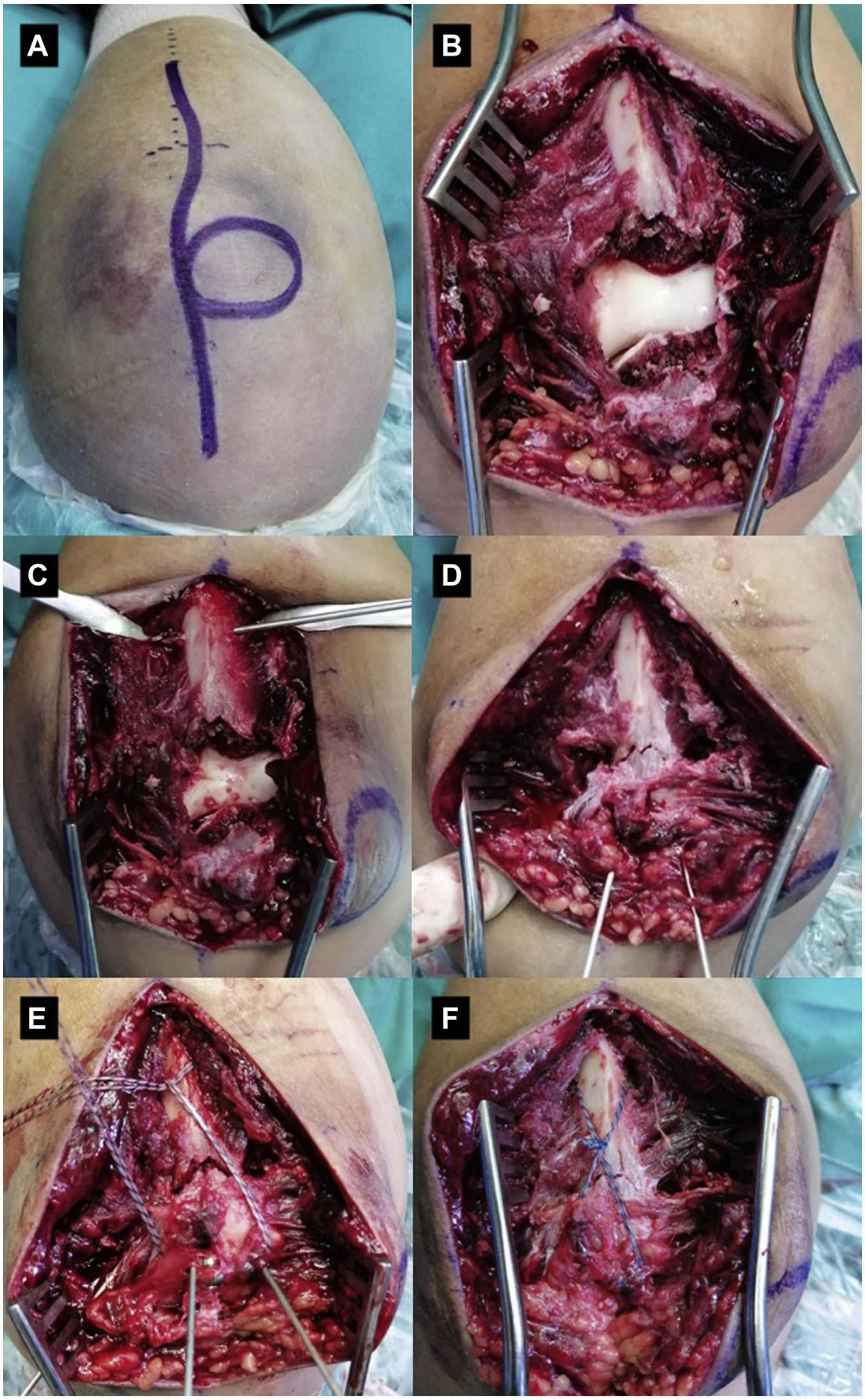

Figure 2 Surgical technique. (**A**) A curved posterior incision is used, starting a few centimeters proximal to the tip of the olecranon. (**B**) At the fracture site, there is minimum detaching of the flexor carpi ulnaris muscle on the medial side, and the anconeus muscle on the lateral side. (**C**) A transverse drill hole for the long axis of the ulna is made with a 2.0-mm bit, just beneath the posterior cortex through the medial and lateral cortices, 4 cm distal to the fracture site. (**D**) The fracture is provisionally fixed with two 2.0 K-wires toward the anterior cortex, leaving at least 10 mm of space between the K-wires in which to put the intramedullary screw. (**E**) Two strands of No. 2 FiberWire® are passed transversely using a manual method and configured in a tension band fashion with an eight-shape, passing the proximal end through the tricipital tendon and below the screw head. (**F**) The suture is progressively knotted with the Nice double-suture knot technique.

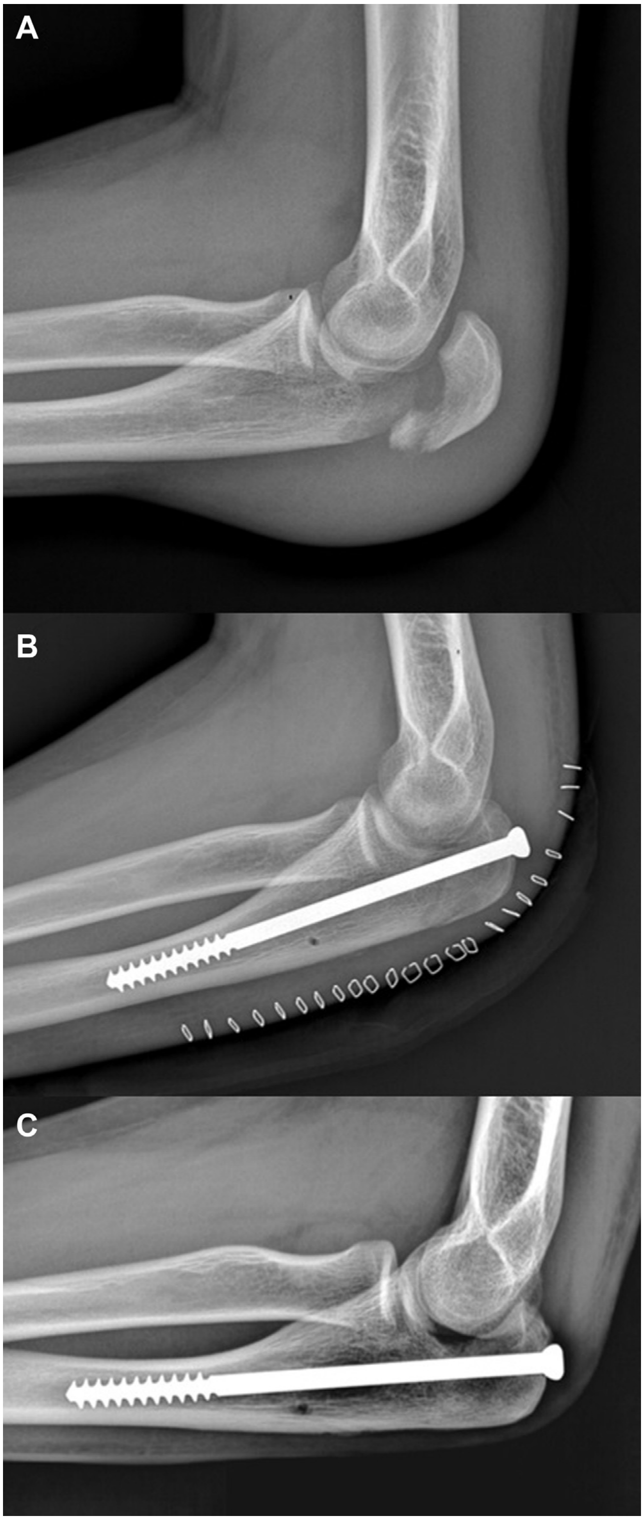

Figure 3 Postoperative follow-up radiographs. (**A**) Preoperative. (**B**) Immediate postoperative. (**C**) Sixth week. Fracture union was defined as more than 3 regions of bone bridging the radial, ulnar, dorsal, and volar cortical aspects of the proximal ulna, which is seen on anteroposterior, lateral, and both oblique projections.

specialized in the care of elbow disorders, examined all radiographs (J.C.F.). These were reviewed to determine the adequacy of reduction (articular step-off), loss of reduction, hardware failure, progression of bony union (delayed union or nonunion was evaluated), proximal migration of the screw, and for the development of heterotopic ossification (including bony spurs or loose bodies). Fracture union was defined as more than 3 regions of bone bridging the radial, ulnar, dorsal, and volar cortical aspects of the proximal ulna, which is seen on anteroposterior, lateral, and both oblique projections.

The presence or absence of proximal migration of the implant was evaluated and was measured in mm; the width of the olecranon and the size of the endomedullary canal (anteroposterior and lateral) were calculated at the point that does not present with more narrowing. In addition, the proximal ulnar dorsal angulation (PUDA), articular angle (AA), olecranon–diaphysis angle (ODA), and varus angulation (VA) angles were evaluated. The PUDA was determined by measuring the intersection angle between tangent lines placed on the "flat spot"[15] of the olecranon and the dorsal ridge of the ulnar shaft. The AA was between the axis of the posterior cortex of the olecranon and the line passing through the superior and inferior tips of the trochlear notch.[3] The ODA was between the axis of the mediolateral diaphysis (ulna midshaft axis) and the line passing through the superior and inferior tips of the trochlear notch.[3] The VA was measured between the axis of the mediolateral diaphysis (ulna midshaft axis) and the axis of the olecranon.[3]

Statistical analysis

Results have been presented with averages and standard deviation or percentages as appropriate. A univariate analysis was performed to find statistically significant differences (*P*-value less than 0.05) in accordance with the dependent variables "implant removal" and "proximal screw migration"; for this analysis, normal distribution was verified with the Shapiro-Wilk and Kolmogorov-Smirnov tests (both should be concordant). In those variables with normal distribution, the unpaired t-test with Welch's correction was used, whereas in those variables without normal distribution, the nonparametric Mann-Whitney U test was used. Fisher's exact test was used to compare contingency tables. In addition, a multivariate analysis was performed for the binary dependent variables "implant removal", "proximal screw migration", and "implant-related pain" using logistic regression (independent variables "screw length", "anteroposterior endomedullary canal diameter", "lateral endomedullary canal diameter", and "proximal implant migration (PIM)"; a multiple linear regression was used for the quantitative dependent variable "PIM". Statistical analysis was performed using STATA software (version 16; StataCorp, College Station, TX, USA).

Results

Clinical results

We reviewed 27 consecutive patients treated with an intramedullary cancellous screw and suture tension band; the average follow-up period of the sample was 38.4 ± 6.2 months (range, 24.1-50 months). The average flexion was 134.5° ± 14.8° (range, 70°-140°). The mean extension was -5.9° ± 7.0° (range, −20°-0°). The mean flexion-extension arc was 128.6° ± 17.9° (range, 60°-140°). The mean pronation and supination were 85.8° ± 11.9° (range, 45°-90°) and 86.9° ± 14.3° (range, 20°-90°), respectively. The mean visual analog scale score for elbow pain was 2.1 ± 2.1 (range, 0-7) and the mean MEPS was 90.8 ± 9.6 (range, 70-100) with 92.3% good and excellent results. The mean QuickDASH score was 17.1 ± 16 (range, 0-54.5) (Table II).

In total, 21.7% of patients reported pain in relation to the implant, and the implant removal rate was 18.5%. Three patients had the screw removed due to associated discomfort, one with late

Table II
Clinical results.

Group	Flexion	Extension	Pronation	Supination	QuickDASH	MEPS
Total	134.5° ± 14.8°	−5.9° ± 7.0°	85.8° ± 11.9°	86.9° ± 14.3°	17.1 ± 16.0	90.8 ± 9.6
Implant removal (+)	140.0° ± 0.0°	0.0° ± 0.0°	90.0° ± 0.0°	90.0° ± 0.0°	13.6 ± 17.0	88.0 ± 13.0
Implant removal (-)	133.2° ± 16.4°	−7.4° ± 7.1°	84.7° ± 13.3°	86.1° ± 16.0°	18.0 ± 16.1	91.4 ± 9.0
PIM (+)	128.3° ± 28.6°	−1.7° ± 4.1°	90.0° ± 0.0°	90.0° ± 0.0°	14.0 ± 14.6	95.0 ± 7.7
PIM (−)	137.4° ± 6.8°	−7.3° ± 7.7°	86.6° ± 10.0°	89.7° ± 0.9°	18.5 ± 17.9	89.7 ± 10.6

MEPS, Mayo Elbow Performance Score; *QuickDASH*, Quick Disabilities of the Arm, Shoulder and Hand score; *PIM*, proximal implant migration; (+), presence; (−), absence.
Results have been presented with averages ± standard deviation.

Table III
Radiological results.

Group	PIM, mm	PUDA	ODA	AA	VA	EMC LAT, mm	EMC AP, mm
Total	2.7 ± 1.8	5.2° ± 4.2°	21.8° ± 7.5°	26.8° ± 6.2°	9.2° ± 3.4°	6.3 ± 1.4	5.6 ± 1.6
Implant removal (+)	3.7 ± 2.2*	2.6° ± 4.0°	18.4° ± 3.2°	22.5° ± 4.7°*	9.3° ± 1.4°	6.5 ± 1.2	5.8 ± 1.6
Implant removal (−)	1.7 ± 0.2*	5.8° ± 4.2°	22.6° ± 8.0	27.7° ± 6.2°*	9.2° ± 3.7°	6.2 ± 1.4	5.5 ± 1.6
PIM (+)	2.7 ± 1.8	1.7° ± 3.3°*	24.1° ± 7.0°	26.6° ± 6.5°	9.3° ± 2.5°	7.3 ± 1.3*	7.2 ± 2.0*
PIM (−)	0.0 ± 0.0	6.4° ± 4.1°*	19.9° ± 7.4°	25.9° ± 6.5°	9.7° ± 3.6°	6.0 ± 1.4*	5.0 ± 1.1*

PIM, proximal implant migration; (+), presence; (−), absence; *PUDA*, proximal ulnar dorsal angulation; *AA*, articular angle; *ODA*, olecranon–diaphysis angle; *VA*, varus angulation; *AP*, anteroposterior; *EMC*, endomedullary canal diameter; *LAT*, lateral.
Results have been presented with averages ± standard deviation.

* *P*-value less than 0.05.

infectious olecranon bursitis, and one with a surgical arthrolysis secondary to elbow stiffness without response to physical therapy management. This patient had no discomfort in relation to the implant. Therefore, the withdrawal rate directly associated with the implant was 11.1%. No other complications were reported.

Radiological results

All fractures achieved union; no nonunion was seen. One loss of reduction was noted (the patient was managed expectantly, with a good final clinical result; 85 MEPS). Reductions were determined to be anatomic without evidence of articular step-off in 88.9% of fractures (24 of 27).

In total, 26.1% of the cases presented some degree of proximal migration of the implant within the serial controls (2.7 ± 1.8 mm of migration; range, 1.5-6.2 mm) (Table III).

The anteroposterior endomedullary canal was 5.6 ± 1.6 (range, 3.2-10.3) and the lateral endomedullary canal was 6.3 ± 1.4 (range, 3.6-8.8). The postsurgical anatomy angles were PUDA 5.2° ± 4.2° (range, −3.1°-12.9°); AA 26.8° ± 6.2° (range, 14.8°-42.6°); ODA 21.8° ± 7.5° (range, 5.8°-36.2°); and VA 9.2° ± 3.4° (range, 3.6°-16°) (Table III).

Associated factors

Univariate analysis of the factors associated with implant removal were pain in relation to the implant (60% vs. 11%, $P = 0.0482$), proximal screw migration (3.7 mm vs. 1.7 mm, $P = 0.05$), AA (22.5° vs. 27.7°, $P = 0.0353$), and olecranon width (22.2 mm vs. 24.4 mm, $P = 0.0166$).

Univariate analysis of the factors associated with implant proximal migration were PUDA (1.7° vs. 6.4°, $P = 0.0179$), anteroposterior endomedullary canal (7.3 mm vs. 6.0 mm, $P = 0.0369$), and lateral endomedullary canal (7.2 mm vs. 5.0 mm, $P = 0.0219$).

The multivariate analysis did not yield significant results.

Discussion

The clinical and functional results of simple transverse olecranon fractures treated with an intramedullary cancellous screw and a suture tension band are excellent, associated with a low rate of complications and material removal, making it a real alternative to the classic tension band and plate in this type of fracture. Duckworth et al[14] performed the first prospective randomized clinical trial to compare the tension band wiring (TBW) and plate. Their functional and disability results were very similar to those found in our series (TBW MEPS 90 ± 14; Plate MEPS 96 ± 6.8), but with a hardware removal rate of 50% for the TBW and 21.9% for the plate. Ren et al[30] performed a meta-analysis that showed no significant differences in DASH, improvement rate, range of motion, operation time, and blood loss between the TBW and plate; owing to the fewer complications, they recommended the plate for olecranon fractures. The OR was 2.61 for more complications associated with the TBW, principally implant irritation (with subsequent implant removal).[30] Wagener et al[37] performed a multicenter study to evaluate the refixation of the Chevron osteotomy with a cancellous screw combined with a suture tension band and the associated complication rate and found no complication, such as infection, pull-out of the screw, or skin necrosis. In none of the cases was hardware removal necessary, showing the least irritation of the screw. Bosman et al[4] treated 15 patients with a type I or IIA Mayo olecranon fracture with an intramedullary cannulated screw (7.3 mm, without tension band) at a single level-2 trauma center between 2012 and 2017. The consolidation and disability results were similar to those of our series but had a higher implant removal rate (33.3%). Interestingly, the authors considered that 4 of 10 patients treated with a washer required implant removal, whereas only 1 of 5 patients treated without a washer required removal, thereby discouraging the use of washer in this technique.[4] In our series, a washer was used only in two cases, without removal of the implant. We also believe that it can cause further irritation and does not contribute to the stability of the tension band. In addition, the nonuse of suture tension bands may be associated with a higher rate of implant removal secondary to proximal screw migration, although these data were not evaluated in this article.[4] The low rate of discomfort and implant removal compared with the literature may be associated with the low profile of the screw head and the fact that it is left under the tendon, associated with a countersink that optimizes its low profile and area of contact with the proximal fragment.

Furthermore, the findings of less proximal migration rate of the implant associated with narrow endomedullary canals confirm that the surgical technique can be optimized with an adequate measurement of the screw to reach the narrowest area of the endomedullary canal or consider using larger diameter screws (eg, 7.3 mm).[4] Based on the results of this series, we currently prefer the use of screws closer to 110 mm of length, in most cases. Claessen et al[9] evaluated 392 adult patients who had undergone operative treatment of a displaced olecranon fracture and found only 3% of implant migration, and that technical factors such as the type or configuration of an implant seem to be less important than personal factors in determining who requests a second surgery for implant removal. Di Francia et al[11] evaluated the occurrence of pin migration. They compared classic TBW with expulsion-proof pins (proximal ends are pointed with a curvature of 180° and a concavering that accepts a steel wire 1.5 mm in diameter), finding 43.7% migration at classic TBW and 0% with expulsion-proof pins. The hardware was removed in 24.5% of cases in the expulsion-proof pins group compared with the controls (75%). These results support the importance of proximal implant migration and an increased removal rate; they also serve to demonstrate the low rate of proximal migration of the intramedullary screw with associated suture tension band, which contributes to a low removal rate associated with implant discomfort (11.1% in our series). Wagener et al[37] determined the length of the screw by measuring the length of the tap when adequate fixation was achieved in the ulna; screw length was then measured such that the distal threaded end of the screw would engage the narrow marrow of the proximal ulnar diaphysis. We prefer to complement this technique with radioscopy to ensure that we are in the narrower endomedullary canal.

A lower AA and lower PUDA were also found in those patients with implant removal and implant migration, respectively. Probably, this could be related to the traction vector of the triceps, as in a patient with higher AA and PUDA, there is an increased vector component of bending, reducing the traction vector that directly affects the migration of the screw. This could favor a slightly inclined placement of the screw in a volar to dorsal fashion, although this should be evaluated in biomechanical studies and should not be used in case of generating shear and articular step-off.

However, in this technique, the removal of the screw should not be considered a failure either, as unlike the classic tension band or plate, removal can be a procedure carried out under local anesthetic and a minimal skin incision, as the screw removal is simple. Then the suture is cut and pulled, completely withdrawing it and avoiding a wide incision to remove the wire tension band, which is often associated with preoperative or postoperative soft tissue damage by the skin atrophy in an area of subcutaneous bone. Of the five material withdrawals, only one was performed in the operating room due to the patient's medical conditions.

Bosman et al[4] did not observe complications related to the insertion of a straight rigid intramedullary screw into a bone with a complex curved morphology. They believe this is because the varus curvature begins at approximately 8.2 cm from the olecranon tip, while the used screws were only between 9 and 10 cm[4]. However, the varus angulation point is variable. Recent anatomical studies have measured this point at 73.7 ± 6.8 mm (range, 59.9–91 mm) from the olecranon tip. In our series, we have observed that the screws accommodate to the ulnar bowing, a fact that may favor a lower rate of proximal implant migration. In addition, the technique requires passing the suture through the triceps tendon. Tightening the knot of the tension band generates interfragmentary compression, using the screw as the guiding axis of this effect. These anatomic characteristics highlight the importance of the center-to-center screw insertion.[4,29] Furthermore, the central portion has the highest bone mineral density.[17] Regarding the reduction of the fracture, which in this series was adequate, the position of the screw is key. Malreduction of a simulated olecranon fracture was higher with a medial starting point. A central or laterally starting point was associated with better fracture reduction, probably associated with varus angulation.[29]

From a biomechanical point of view, braided sutures have been tested *in vitro* and *in vivo*, where they have been shown to match the tensile strength and fatigue properties of stainless steel wires.[6,39] In addition, there are several cohorts and series of cases in which the fixation of olecranon fractures is performed with anchors and suture material or only with sutures, obtaining good clinical results without loss of reduction; thus, the use of sutures in this region meets the biomechanical requirements to achieve adequate stability of the fracture site.[1,7,8,10,19,40]

This study has several limitations. In this retrospective and nonrandomized study, patient selection may be biased by the preference of treating surgeons; however, most Mayo IIA fractures during the study period were treated with endomedullary screws and suture tension bands. Regarding the surgical technique, the fact of including several surgeons produced a technical variability in a few cases. Follow-up was adequate, obtaining a response rate of 96.3% to DASH and MEPS, which minimized response bias. In addition, the minimum follow-up for implant removal was 2 years. Finally, we studied a relatively small number of patients, which may have affected the statistical significance of the multivariate analysis. However, the univariate analysis allowed finding statistically significant differences that help to recommend longer or wider screws to decrease the proximal migration rate.

Conclusions

The functional outcomes of simple transverse olecranon fractures treated with an intramedullary cancellous screw and a suture tension band are excellent, associated with a low rate of complications and material removal.

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Conflicts of interest

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