Eur J Orthop Surg Traumatol (2016) 26:153–159
DOI 10.1007/s00590-015-1724-0

ORIGINAL ARTICLE • ELBOW - FRACTURES

Outcome after olecranon fracture repair: Does construct type matter?

Edward M. DelSole[1] · Christian A. Pean[1] · Nirmal C. Tejwani[1] · Kenneth A. Egol[1]

Received: 18 August 2015 / Accepted: 25 October 2015 / Published online: 16 November 2015

Abstract
Purpose This study compares clinical and functional outcomes of patients with displaced olecranon fractures treated with either tension band wiring (TBW) or a hook plate construct.
Methods We performed a retrospective review of olecranon fractures operatively treated with either TBW or plate fixation (PF) using a hook plate over a 7-year period. Patient demographics, injury information, and surgical management were recorded. Fractures were classified according to the Mayo system. Measured outcomes included range of elbow motion, time to union, and development of postoperative complications. Mayo Elbow Performance Index (MEPI) scores were obtained for all patients. All patients were followed for a minimum of 6 months.
Results A total of 48 patients were included in this study, 23 treated with TBW and 25 treated with hook PF. Groups did not differ with respect to patient demographics, Mayo fracture type, or duration of follow-up. Patients undergoing PF had less terminal extension than TBW patients ($-8.6° \pm 7°$ vs. $-3.5° \pm 9.3°$, $p = 0.036$) and a longer time to radiographic union (19 ± 8 vs. 12 ± 6 weeks, $p = 0.001$). There were no differences in rates of symptomatic hardware, MEPI scores, or other clinical outcomes. Two patients in each group required a second surgery.
Conclusions TBW and PF of olecranon fractures had similarly excellent functional outcomes in this study. Patients undergoing PF had a longer time to union and slightly worse extension at final follow-up. TBW remains an effective treatment for appropriately selected olecranon fractures and in this cohort outperformed plate osteosynthesis.

Keywords Olecranon fracture · Olecranon fixation · Tension band wiring · Hook plate · Clinical outcomes

Introduction

Fractures of the olecranon process of the ulna are intra-articular injuries that benefit from anatomic reduction and early range of motion in order to restore functional elbow motion and strength. Controversy exists regarding the optimal surgical treatment of displaced olecranon fractures. To date, the body of literature has argued both for and against the use of the tension band wire (TBW) technique for the treatment of displaced olecranon fractures. The tension band is a simple, inexpensive, and reliable technique, which has achieved excellent clinical outcomes and low rates of failure and complication [1, 2]. Others, however, have suggested that plate and screw fixation is superior to the tension band in terms of its mechanical strength, ability to maintain reduction, and postoperative complications [3, 4].

The purpose of this study is to compare the clinical and functional outcomes of patients who have sustained a displaced olecranon fracture and were treated with either a tension band wire or a plate and screw fixation, specifically a one-third tubular hook plate construct.

✉ Christian A. Pean
christian.pean@gmail.com

Kenneth A. Egol
kenneth.egol@nyumc.org

[1] Department of Orthopaedic Surgery, NYU Hospital for Joint Diseases, 301 East 17th Street, New York, NY 10003, USA

Patients and methods

After obtaining the approval of our institutional review board, we performed a retrospective review of case logs of two board-certified orthopedic traumatologists, for patients who underwent open reduction and internal fixation (ORIF) for olecranon fractures from the year 2005 to 2013. After identification, all patient charts, anteroposterior, and lateral injury X-rays were carefully reviewed for fracture pattern and concomitant injuries. Operative reports were reviewed to determine the implants utilized in each case. All data were maintained in a de-identified database. Postoperative radiographs were reviewed to ensure that adequate reduction and fixation was obtained. Each patient's final office follow-up visit was used as the benchmark for clinical and functional outcomes.

All fractures were classified according to the Mayo Clinic Classification [5]. All fractures regardless of subtype were included in the analysis. Patients were included in this study if they presented within 1 week of injury, sustained a displaced olecranon fracture, underwent ORIF for fracture treatment with either TBW or hook plate, and had a minimum 6 months of follow-up. Demographic data collected included patient age, sex, laterality of injury, associated injuries, type of plate construct, and duration of follow-up. Clinical outcomes included range of motion, change in work status after surgery, hardware-related pain, and need for reoperation for any reason. A change in work status was defined as the inability of the patient to return to the work that they performed prior to their injury. Functional outcomes were assessed using the Mayo Elbow Performance Index (MEPI). The MEPI is a validated, physician-completed measure of elbow function which takes into account postoperative elbow pain, range of motion, ulnohumeral stability, and the ability to complete five specific activities of daily living: combing hair, eating, performing hygiene, donning a shirt, and donning a shoe. The score ranges from 5 to 100 points, with scores between 90 and 100 being considered excellent [6]. In this study, the MEPI scores were determined from the data documented in the clinical note from the last office follow-up visit. If the data in this note were inadequate for MEPI determination, patients were contacted via telephone, verbally consented for participation in the study, and asked to provide the information necessary to determine the score. Radiographic outcome was assessed for fracture union, hardware migration/failure, and post-traumatic osteoarthritis.

A total of 59 patients treated with either hook plate or tension band wire were identified and directly compared. A total of 48 patients treated with either TBW or hook plate, with complete medical records and follow-up of at least 6 months, were included for analysis. There were 11 patients excluded due to incomplete follow-up. Demographic information for this cohort is provided in Table 1. The study group consisted of 23 patients treated with tension band wire and 25 patients treated with hook plate fixation. There were a total of 11 males and 37 females within both groups with no difference in composition between cohorts ($p = 0.85$). Three of these patients sustained concomitant fractures of the radial head, radial shaft, or proximal humerus.

All tension band constructs were applied by one surgeon using two parallel 1.6-mm K-wires with a supplemental 1.25 mm figure of eight tension band through the triceps proximally and ulna distally. The plate fixation technique utilized a one-third tubular hook plates contoured intraoperatively and applied dorsally by a single surgeon using a previously published hook plate technique (Fig. 1) [7]. The surgeon who applied plates preferentially uses plates for all olecranon fractures regardless of subtype. The surgeon who applied TBW in this study preferentially uses TBW for all but the most comminuted olecranon fractures. After surgery, patients in undergoing both procedures were immobilized for 1 week in a posterior splint and then allowed to begin active range of motion exercises in therapy.

Table 1 Patient demographics

	Male *N* (%)	Female *N* (%)	Mayo class	*N* (%)	Follow-up duration (months) Mean ± 1 SD	Age (years) Mean ± 1 SD
TBW group	5 (21.7)	18 (78.3)	IA	1 (4.3)	13.5 ± 9.7	64.5 ± 20.0
			IIA	18 (78.3)		
			IIB	3 (13.0)		
			IIIA	1 (4.3)		
Hook plate	6 (24)	19 (76)	IA	0 (0)	14.4 ± 11.6	65.76 ± 17.2
			IIA	15 (60)		
			IIB	10 (40)		
			IIIA	0 (0)		
p value (TBW vs. hook plate)		0.85		0.11	0.78	0.81
Overall population	11 (22.9)	37 (77.1)		48	14.0 ± 10.6	65.15 ± 18.5

Fig. 1 Pre- and postoperative films of two Mayo IIA fractures fixed with TBW (*top*) and hook plate fixation (*bottom*)

Statistical analysis was performed using SPSS Software, version 20 (SPSS Inc., Chicago, IL). A power analysis was performed based upon the goal of identifying a significant decrease in the rate of hardware-related pain among patients having plate fixation compared with TBW. Using previously published data, an alpha of 0.05 and a beta of 0.80, the sample size needed to achieve adequate power is to have 753 patients in both the TBW and hook plate arm of the study [2]. Statistical differences in outcome measures were assessed using the Pearson Chi-square or Fisher exact test for categorical variables and the Student *t* test for continuous variables. The Mann–Whitney *U* test was used for comparison of outcomes, which did not meet the condition of normality as assessed by Shapiro–Wilk's test. Significance was defined as $p < 0.05$.

Results

A total of 48 patients were included in this study, 23 treated with TBW and 25 treated with hook plates. The average patient age in the TBW group was 64.5 ± 20.0 compared with 65.76 ± 17.2 in the plate fixation (PF) group ($p = 0.81$) (Table 2). Groups were similar with respect to patient sex ($p = 0.85$). Duration of follow-up was also similar between groups with mean follow-up for TBW and PF groups 13.5 ± 9.7 and 14.4 ± 11.6 months, respectively ($p = 0.78$). Fracture pattern distribution according to the Mayo classification was similar as well ($p = 0.11$; Table 2).

Among the TBW group, the rates of clinical and radiographic union were both 100 %. Time to radiographic union was 14 ± 10 weeks. Patients had a mean extension

Table 2 Comparison of patient clinical outcomes between treatment groups

	MEPI	Range of motion (°)				Time to union (weeks)
		Flexion	Extension	Pronation	Supination	
TBW	97.0 ± 5.8	135.4 ± 6.7	3.5 ± 9.3	85 ± 0	70 ± 0	12.2 ± 5.5
Hook plate	93.6 ± 7.1	134 ± 11.2	8.6 ± 7	84.6 ± 2	69.8 ± 1	19.1 ± 7.7
p value	0.082	0.597	0.036*	0.343	0.343	0.001*

MEPI Mayo Elbow Performance Index

* Statistical significance set at *p* value <0.05. *t* test used for continuous variables

Table 3 Complications and outcome analysis

	Symptomatic hardware *N* (%)	Removal of hardware *N* (%)	Infection *N* (%)	Nonunion *N* (%)	Best outcome *N* (%)
TBW	7 (30.4)	2 (9)	0 (0)	1 (4.3)	16 (69.6)
Hook plate	5 (20)	0 (0)	1 (4)	0 (0)	18 (72)
p value	0.404	N/A	N/A	N/A	0.853

of 4° ± 9.4° and flexion of 135° ± 6.7°. Mean supination and pronation were 70° and 85°, respectively. The mean MEPI was 97.08 ± 5.8 with a range of 85–100.

Sixteen patients (70 %) had a completely uncomplicated postoperative course with return of painless elbow motion and good-to-excellent MEPI score (Table 3). Seven TBW patients (30 %) reported symptomatic hardware. Of those, two reported pain during the first 6 months postoperatively, which then resolved spontaneously by the 1-year mark. Two patients (9 %) had a symptomatic K-wire removed under local anesthesia in the office, one at 6 months postoperatively and the other at 6 weeks. Neither of these patients had loss of fracture fixation; however, one of these had radiographically persistent fracture line at last follow-up although was clinically healed. Three of these patients reported a desire for hardware removal at their last follow-up visit, but no formal removal procedure had been performed to date. One TBW patient developed heterotopic ossification, which was associated with a 40 flexion contracture of the operative elbow. This patient's flexion arc was 80° at last follow-up. One patient developed adhesive capsulitis in the ipsilateral shoulder at 1-year follow-up. This was the only patient to suffer a change in work status after injury; however, this episode of adhesive capsulitis was remote from the injury, and we suspect unrelated to the injury or surgery. Among the TBW cohort, there were no infections.

Among the PF group, the rates of radiographic and clinical fracture union were both 100 %. Time to radiographic union was 19 ± 8 weeks. Patients had mean extension of 8.6° ± 7° and flexion of 134° ± 11.2°, which were significantly worse than those in the TBW group ($p = 0.036$). Mean supination and pronation were 70.1° ± 1° and 84.6° ± 2.0°, respectively. The mean MEPI was 93.6 ± 7.2 with a range of 85–100. This did not differ significantly from the MEPI of the TBW group ($p = 0.08$).

Within the PF group, 18 patients (72 %) had completely uncomplicated postoperative course with return of painless elbow motion and good-to-excellent MEPI scores. In this group, five of the 25 patients (20 %) had symptomatic hardware. One patient (5 %) underwent hardware removal 18 months after index surgery due to hardware prominence. Two patients discussed the option of hardware removal due to pain but ultimately did not pursue this with our surgeons. Three patients developed painful hardware which then resolved by final follow-up at 18 months. One patient developed an infection, which occurred after radiographic union, and required irrigation, debridement, and removal of hardware. She was treated with a course of oral antibiotics and recovered well, with ROM of 10°–140° and good Mayo score at final follow-up. One patient fell 3 months post-op and sustained a non-displaced fracture of the ulna at the proximal end of the plate, which was treated non-operatively.

Discussion

This study evaluated the clinical and functional outcomes of patients with olecranon fractures treated with tension band wire and plate and screw fixation. In our cohort, we found that both fixation strategies yielded similar good-to-excellent elbow range of motion, functional outcome, and hardware symptomatology. Patients undergoing plate fixation demonstrated slightly less terminal extension, lower absolute MEPI, and longer time to union. The clinical significance of these differences is debatable. No difference was observed in rates of reoperation for any reason.

The figure of eight tension band wire, as originally described by Weber and Vasey [8], is a dynamic construct that converts the triceps' tensile forces into fracture site compression. This technique gained widespread acceptance and has traditionally been the treatment of choice for simple, displaced olecranon fractures. The use of the tension band came under scrutiny largely in the 1980s as patients began reporting high rates of symptomatic metal prominence from the subcutaneous K-wires [9, 10]. Subsequently, the prospective, randomized trial of Hume and Wiss argued that plate and screw osteosynthesis provided more anatomic and more durable reduction than tension bands, as well as less hardware-related pain [4].

The majority of clinical results have been mixed, with data supporting the use of both fixation methods. A Cochrane review [12] acknowledges the need for more randomized, blinded clinical studies, as well as more reports using validated clinical and functional outcome measures. The most recent original study comparing the two fixation methods was that of Tarallo et al. [2], who found no significant clinical or functional differences

between groups, and that hardware removal was more common among those receiving tension band wire. They concluded that both methods were viable options for treatment that yielded excellent outcomes with little residual disability.

Hardware-related pain after surgery is a troubling endpoint to quantify clinical outcomes because symptoms are likely governed by a multitude of variables including surgeon experience, patient bone quality, and the thickness of the overlying soft tissue. Conceivably, these variables would leave both TBW and plate constructs at risk to cause postoperative pain, for instance due to a deficit of subcutaneous fat to act as padding. These patient- and surgeon-specific variables may explain the lack of consensus in the literature as both constructs have been reported to have high rates of hardware-related pain as well as high rates of clinical success.

Several authors retrospectively report that TBW cause more hardware-related complications than plates [2, 4, 11]. It is argued that this is caused by proximal migration of the K-wires out of the proximal ulna, causing symptomatic prominence of the wire tip [9, 12]. This phenomenon could be affected by a deficit of subcutaneous soft tissue. Additionally, proximal migration may be promoted by bone of poor quality, which is unable to provide adequate friction for K-wires to hold their position against the triceps pull. Plate constructs too generate surgical site pain. Buijze [13] reported that almost 50 % of patients in their cohort had postoperative pain at the plate site that required subsequent removal of hardware. Plate constructs have also been known to pull out of osteoporotic bone, similar to the K-wire of the TBW construct [14]. For these reasons, while it is a clinically significant complication, hardware pain may be a poor independent parameter to evaluate patient outcome. Furthermore, the reliability of surgeon-reported data must be questioned due to the work of Edwards et al. [15], who reported that 78 % of patients who underwent removal of TBW or plate had their hardware removed by a surgeon other than the one who performed the index procedure. If this is the case, these studies may grossly underestimate the rates of hardware removal for both implant types. We believe more research must be done to in order to understand whether the intrinsic properties of one construct make it more likely to become symptomatic than the other.

Range of motion and function are important and reliable outcome parameters for these constructs. Functional elbow range of motion is related to the task performed and may be different for every individual depending upon occupation and daily activities. Morrey et al. [16] pioneered this work, determining that a 100° flexion arc from 30° to 130° and a supination/pronation arc of 50° to 50° are required for personal hygiene and secondary tasks. Modern tasks, such as using a cell phone, elbow flexion of up to 142° may be

Fig. 2 Pre- and postoperative films of two Mayo IIB fractures repaired with TBW (*top*) and hook plate fixation (*bottom*)

required [17]. In our study, both cohorts had a final flexion arc of greater than 100° and no reported functional limitations.

Construct choice in olecranon fracture fixation is often a factor of the fracture pattern. Classically, the tension band wire has been used for only simple displaced fractures, whereas plates and screws have been employed for fixation of more comminuted fractures in order to prevent over-compression of the articular surface. Although not included in this series, locking plates have also been employed with success in cases of olecranon fractures with extensive comminution and osteopenic bone, although in some series clinical results do not seem to differ from fracture treated with non-locked plating [13, 18–20]. Similarly, cadaveric studies have explored these constructs and demonstrated that both locked and non-locked implants have similar stiffness and fixation strengths under bending loads [21] [14]. The use of locking plates, however, is associated with a high cost, and therefore, they should be used judiciously, with preference given to those patients with complex fracture patterns, extensive comminution, and osteoporosis [19]. In this study, TBW was used on several Mayo IIB fractures with no complication in clinical or functional outcomes (Fig. 2). These results suggest that TBW can be used in select comminuted fractures as long as anatomic reduction can be achieved and confirmation is obtained intraoperatively that overcompression of the articular surface does not occur.

The weaknesses of this study are in its retrospective design. Many patients were excluded due to follow-up of less than 6 months. In most of those cases, patient clinical status was stable, and follow-up was made on an as-needed basis. Additionally, the study was underpowered based upon our analysis. However, based on our analysis, the need for 1506 patients makes a single-center study of this topic challenging. Future multicenter studies may be necessary to achieve adequate power. The composition of the cohorts was heterogeneous within each cohort and asymmetric between cohorts, which may introduce bias into these results. Careful inspection of the cohort composition reveals that more IIB fractures are in the plate fixation group and one IIIA fracture is in the tension band group. Despite these differences, the groups were matched for fracture type, and the differences did not reach statistical significance. We also acknowledge that some patients with symptomatic hardware who did not report back for removal may have sought management elsewhere.

In conclusion, for patients with Mayo IA–IIIA fractures of the olecranon, fixation using tension band wire and plate–screw constructs achieved similarly excellent results. In this cohort, tension band wire was superior to plate–screw construct with respect to time to union as well as postoperative range of motion. The clinical significance of these outcomes may not be important to the patient. We feel these data support the use of the tension band wire for operative care of olecranon fractures.

Compliance with ethical standards

Conflict of interest None.

References

1. Wolfgang G, Burke F, Bush D et al. (1987) Surgical treatment of displaced olecranon fractures by tension band wiring technique. Clin Orthop Relat Res 224:192–204
2. Tarallo L, Mugnai R, Adani R et al (2014) Simple and comminuted displaced olecranon fractures: a clinical comparison between tension band wiring and plate fixation techniques. Arch Orthop Trauma Surg 134:1107–1114. doi:10.1007/s00402-014-2021-9
3. Hutchinson DT, Horwitz DS, Ha G et al (2003) Cyclic loading of olecranon fracture fixation constructs. J Bone Joint Surg Am 85-A:831–837
4. Hume MC, Wiss DA (1992) Olecranon fractures. A clinical and radiographic comparison of tension band wiring and plate fixation. Clin Orthop Relat Res 285:229–235
5. Morrey BF (1995) Current concepts in the treatment of fractures of the radial head, the olecranon, and the coronoid. Instr Course Lect 44:175–185
6. Longo UG, Franceschi F, Loppini M et al (2008) Rating systems for evaluation of the elbow. Br Med Bull 87:131–161. doi:10.1093/bmb/ldn023
7. Tejwani NC, Garnham IR, Wolinsky PR et al (2002) Posterior olecranon plating: biomechanical and clinical evaluation of a new operative technique. Bull Hosp Jt Dis 61:27–31
8. Weber BG, Vasey H (1963) Osteosynthesis in olecranon fractures. Z Unfallmed Berufskr 56:90
9. Helm RH, Hornby R, Miller SWM (1987) The complications of surgical treatment of displaced fractures of the olecranon. Injury 18:48–50. doi:10.1016/0020-1383(87)90386-X
10. Horne JG, Tanzer TL (1981) Olecranon fractures: a review of 100 cases. J Trauma 21:469–472
11. Snoddy MC, Lang MF, An TJ et al (2014) Olecranon fractures: factors influencing re-operation. Int Orthop (SICOT) 38:1711–1716. doi:10.1007/s00264-014-2378-y
12. Chalidis BE, Sachinis NC, Samoladas EP et al (2008) Is tension band wiring technique the "gold standard" for the treatment of olecranon fractures? A long term functional outcome study. J Orthop Surg Res 3:9. doi:10.1186/1749-799X-3-9
13. Buijze G (2009) Clinical evaluation of locking compression plate fixation for comminuted olecranon fractures. J Bone Joint Surg Am 91:2416. doi:10.2106/JBJS.H.01419
14. Edwards SG, Martin BD, Fu RH et al (2011) Comparison of olecranon plate fixation in osteoporotic bone: Do current technologies and designs make a difference? J Orthop Trauma 25:306–311. doi:10.1097/BOT.0b013e3181f22465
15. Edwards SG, Cohen MS, Lattanza LL et al (2012) Surgeon perceptions and patient outcomes regarding proximal ulna fixation: a multicenter experience. J Shoulder Elbow Surg 21:1637–1643. doi:10.1016/j.jse.2011.11.024
16. Morrey BF, Askew LJ, Chao EY (1981) A biomechanical study of normal functional elbow motion. J Bone Joint Surg Am 63:872–877
17. Sardelli M, Tashjian RZ, MacWilliams BA (2011) Functional elbow range of motion for contemporary tasks. J Bone Joint Surg Am 93:471–477. doi:10.2106/JBJS.I.01633

18. Siebenlist S, Torsiglieri T, Kraus T et al (2010) Comminuted fractures of the proximal ulna—preliminary results with an anatomically preshaped locking compression plate (LCP) system. Injury 41:1306–1311. doi:10.1016/j.injury.2010.08.008
19. Erturer RE, Sever C, Sonmez MM et al (2011) Results of open reduction and plate osteosynthesis in comminuted fracture of the olecranon. J Shoulder Elbow Surg 20:449–454. doi:10.1016/j.jse.2010.11.023
20. Simpson NS, Goodman LA, Jupiter JB (1996) Contoured LCDC plating of the proximal ulna. Injury 27:411–417
21. Buijze GA, Blankevoort L, Tuijthof GJM et al (2009) Biomechanical evaluation of fixation of comminuted olecranon fractures: one-third tubular versus locking compression plating. Arch Orthop Trauma Surg 130:459–464. doi:10.1007/s00402-009-0980-z