RESEARCH ARTICLE

Complications in Olecranon Fracture Surgery: A Comparison of Tension Band Vs. Plate Osteosynthesis

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Received: 17 September 2021 *Accepted: 13 December 2021*

Abstract

Background: The purpose of this study is to compare the incidence of complications associated with tension band wiring (TBW) versus plate osteosynthesis (POS) in the treatment of olecranon fractures.

Methods: We performed a retrospective cohort study of operatively treated adult olecranon fractures from an integrated healthcare system by multiple surgeons from January 2008 to December 2011. Patients were divided into two cohorts: fractures fixed using the tension band technique and fractures fixed using plate osteosynthesis. The study was limited to the Orthopedic Trauma Association classification of olecranon fracture type 21-B1, with subtypes 1-3. Outcome measures were loss of fracture fixation requiring revision, postoperative infection, stiffness requiring surgery, and symptomatic hardware removal (HWR). Univariate and multivariable logistic regressions were performed to test the associations between the type of internal fixation and outcomes.

Results: A total of 321 olecranon fractures were included (median age: 61 years old, 57 % female); 153 participants were treated with TBW, and 168 patients with POS. There was one failure in the TBW group and two in the POS group (*P=0.62*). There were no significant differences in the infection rates (TBW 5%, POS 9%, *P=0.20*) and no reoperations for stiffness. The HWR occurred significantly more often in TBW (29%) than in POS (14%) (OR=0.39, *P=0.001*). The association between POS and decreased HWR remained highly significant (OR=0.40, *P=0.003*) after adjusting for clinical variables.

Conclusion: In this large study comparing POS and TBW for 21-B1 olecranon fractures, no difference in fixation failure, infection, or postoperative stiffness was noted. A significantly greater risk of symptomatic hardware occurred in TBW. These findings may assist surgeons and patients in considering the risks and benefits of TBW and POS as treatment options for displaced olecranon fractures.

Level of evidence: III

Keywords: Fixation failure, Hardware removal, Infection, Multifragmentary, Skin breakdown

Introduction

Olecranon fractures comprise approximately 10% of all adult upper extremity fractures.[1] Due to the intra-articular nature of most of these injuries, open reduction and internal fixation with anatomic reduction of the articular surface is generally recommended.[2] Numerous methods of fixation have been described including figure-of-eight tension band wire fixation (TBW), plate osteosynthesis (POS), intramedullary screw fixation, and fragment excision with triceps advancement.[3]

The TBW has traditionally been used for isolated noncomminuted fractures. A recent increase in the application of plate fixation has been reinforced by evidence of superior performance during biomechanical

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THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

testing.[4-6] Plate fixation is commonly used for comminuted fractures, though recently it has also been recommended for simple transverse fractures due to the high complication rates associated with tension band fixation.[7] Other studies reviewing TBW, and POS have included small sample sizes or focused on a subset of noncomminuted olecranon fracture patterns.[7, 8]

The goal of this study is to provide a large-scale comparison of complications associated with TBW versus POS in the treatment of intra-articular olecranon fractures. Additionally, this study includes an analysis of patient or surgeon factors that may contribute to differences in complication rates between the two surgical techniques. These findings may hopefully assist both surgeon and patient in weighing the risks and benefits of each procedure when choosing a treatment plan.

Materials and Methods

This study is a retrospective, comparative review of a cohort of patients within a single integrated healthcare system, with institutional review board approval.

Patients

Data were obtained from the database of an integrated healthcare system from January 1st, 2008, to December 31st, 2011. The database uses diagnosis codes from the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), and procedure codes from the Current Procedural Terminology (CPT). All patients who had a primary diagnosis of closed or open fracture of the olecranon process of the ulna (ICD-9-CM diagnosis codes 813.01 and 813.11) and underwent open treatment of the olecranon process, with or without internal or external fixation (CPT 24685) were identified.

Inclusion criteria required that the patients had both pre and postoperative digital radiographs as well as operative notes available for review. Upon review of the preoperative radiographs, only patients who sustained a fracture of the olecranon process with an Orthopedic Trauma Association classification of 21-B1.1-3 were included.[9] Postoperative radiographs were reviewed to assess the type of internal fixation that was used, either TBW or POS. Of those patients that were treated with TBW, only those that utilized the figure of eight constructs with Kirschner wires were included.

Outcome Measures

Electronic medical records and digital radiographs were used to determine all variable outcomes. The dependent variables recorded included loss of fixation requiring revision surgery, stiffness requiring surgery, infection requiring surgery, and symptomatic hardware requiring hardware removal. For the primary outcome of loss of fracture fixation, a review of the operative notes and radiographs of patients was performed to identify any patients that required revision surgery. A second search using a combination of ICD-9-CM and CPT codes was performed to identify possible postoperative complications for assessment of the secondary outcomes. Diagnoses of surgical site infection and symptomatic hardware (ICD-9-CM codes 998.59, 959.3, and 996.67) and procedural codes for hardware removal, manipulation under anesthesia, and arthroscopic procedures of the elbow (CPT codes 20670, 20680, 24300, 24006, 29830, 29835, 29836, 29837, and 29838) were included in the search. Attending orthopedic surgeons and third and fourth-year orthopedic residents performed all chart and x-ray reviews. Infections were defined as superficial requiring only antibiotics or deep requiring incision and drainage with occasional hardware removal. The minimum follow-up for all patients was three months from the date of the index procedure.

Independent variables recorded included patient demographics, fracture pattern by Orthopedic Trauma Association classification, and open vs. closed fracture. Patient demographics recorded included age, sex, body mass index (BMI), American Society of Anesthesiologists Physical Classification System (ASA Class), smoking history, and history of diabetes. The diagnoses of diabetes included patients with any history of type1, type2, and/or diet-controlled diabetes. Smoking history was noted as "current", "former" if the patient had quit smoking, "never" or "unknown" without any differentiation as to the duration of smoking. The ASA was classified according to four different classes. Class one represented normal healthy patients. Class two represented patients with mild systemic disease. Class three represented patients with severe systemic disease. Class four or greater represented patients with severe systemic disease that is a constant threat to life or a patient who was not expected to survive without the operation. Missing BMI and ASA were filled in using a multiple imputation procedure implanted in Statistical Analysis System. No other comorbidities were included in the data set.

Statistical Analysis

All demographic characteristics of the patients were summarized according to the TBW and POS group and described by counts (proportion) or median (including the 25th and 75th percentile). The two groups were compared regarding each characteristic using a two-sample t-test for continuous variables and Fisher's exact test for categorical variables. The BMI was log-transformed before converting to normal data distribution. The Wilcoxon rank-sum test was performed for follow-up days due to its non-normal distribution. The differences in the distribution across the treatment methods were examined with Fisher's exact test for the different fracture patterns if the injury was an open or closed fracture, and for both primary and secondary outcomes. Univariate logistic regression was performed to assess the independent effect of each patient characteristic on total complications that included both primary and secondary outcomes. The association between fixation type and outcomes was tested by using a univariate and multivariable logistic regression model to estimate the odds ratio, with corresponding 95% confidence intervals (CI). The multivariable model was adjusted for age, gender, smoking status, diabetes status, BMI, SAS classes, fracture pattern, and if the fracture was open or closed. A *P value* of <0.05 indicated significance. SAS version 9.2

(SAS Institute, Cary, North Carolina) was used for the management of the data and statistical analysis.

Source of Funding

There were no external sources of funding for this retrospective review.

Results

A total of 621 patients were identified and underwent a review of available electronic medical records and digital radiographs. Additionally, 98 patients were excluded because the olecranon was not an isolated fracture, or the fracture was extra-articular. Radiographs were missing in 184 patients, with 129 patients missing both pre and postoperative radiographs, and 55 patients missing either one or the other type of radiograph. nine patients were treated with a compression screw, four had internal fixation following olecranon osteotomy for distal humerus fractures, four others had ligamentous repairs, and one patient had total elbow arthroplasty; these were all excluded from the study.

A total of 321 remaining patients were included in the present study, who were operated on by 67 surgeons. This group included 137 (42.7%) male patients and 184 (57.3%) female patients with a median age of 61 years. Accordingly, 168 patients underwent open reduction internal fixation with POS while 153 (48%) underwent fixation with TBW. The POS group included 74 (44.0 %) male patients and 94 (56.0 %) female patients with a median age of 62 years. The TBW group included 63 (41.2%) male patients and 90 (58.8%) female patients with a median age of 59 years. BMI, smoking status, and the presence of diabetes mellitus were similar in both groups. Most of the patients in the POS group were categorized in the ASA Class II, with fewer in both Classes I and III (P = 0.04) [Table 1]. The review was conducted approximately 24 months after the last case. The average time from the date of surgery to chart review was 1,028 days.

The simple transverse fracture with one fracture line was the most common pattern of injury in both groups with 104 (61.9%) patients in the POS group and 133 (86.9%) in the TBW group. The POS was more commonly used than TBW in patients within the subset of multi-fragmentary fracture patterns (*P<0.0001*). There was a total of 19 patients with open fractures that were similarly distributed between the two groups with 8 (4.8%) in the POS group and 11 (7.2%) in the TBW group [Table 2].

For the primary outcome of loss of fracture fixation, there was only 1 (0.6%) failure in the TBW group and 2 (1.2%) in the POS group. The type of internal

Table 1. Demographic characteristics for patients with Olecranon fractures. Values shown are medians (25th, 75th percentile) unless otherwise specified

	POS	Tension Band	All	*P-value*
	N=168	N=153	N=321	
Age	62 (47,76)	59 (40,77)	61 (43,77)	0.20
Sex (%)				0.60
Male	74 (44.0)	63 (41.2)	137 (42.7)	
Female	94 (56.0)	90 (58.8)	184 (57.3)	
BMI	24.7 (21.6,28.4)	24.2 (21.5,27.2)	24.2 (21.4,27.9)	0.50
ASA Class (%)				0.04
I	23 (13.7)	29 (18.9)	52 (16.2)	
II	116(69.0)	85 (55.6)	201 (62.6)	
III	28 (16.7)	39 (25.5)	67 (20.9)	
≥IV	1 (0.6)	0 (0.0)	1 (0.3)	
Smoking Status (%)				0.96
Never	102 (60.8)	91 (59.4)	193 (60.2)	
Current	13 (7.7)	14 (9.2)	27 (8.4)	
Former	38 (22.6)	33 (21.6)	71 (22.1)	
Unknown	15 (8.9)	15 (9.8)	30 (9.3)	
Diabetes Mellitus (%)				0.84
Yes	21 (12.5)	18 (11.8)	39 (12.1)	
No	147 (87.5)	135 (88.2)	282 (87.9)	
Follow-up (days)	109 (70, 217)	151 (77, 316)	127 (74, 269)	0.05

Table 2. Injury and treatment factors for patients with olecranon fracture

	POS	Tension Band	*P-value*
	N=168	N=153	
Fracture Pattern (%)			<0.0001
Simple transverse one fracture line	103 (61.3)	133 (86.9)	
Transverse with two fracture lines	10 (6.0)	8 (5.2)	
Multifragmentary	54 (32.1)	12 (7.9)	
Undetermined	1 (0.6)	0 (0)	
Open Fracture (%)			0.48
Yes	8 (4.8)	11 (7.2)	
No	160 (95.2)	142 (92.8)	

fixation did not have a significant effect on this primary outcome (*P=0.62*). For the secondary outcomes, there was no significant difference in the infection rates (POS 8.9%, TBW 5.2% OR=1,78, *P=0.2*). However, there were significantly more patients requiring HWR in the TBW group (44, 28.8%) as compared to the POS group (23, 13.7%). The POS group had an approximately 60% less chance of needing HWR (OR=0.39, *P=0.001*). Combining the primary and secondary outcomes, the POS group was significantly associated with fewer combined complications (OR = 0.59, *P=0.04*). In the multivariable model, after adjusting for age, gender, body mass index (BMI), ASA Class, smoking history, and history of diabetes, only the association between the POS group and lower rates of HWR remained significant (OR = 0.40, *P=0.003*). There were no cases of re-operations for stiffness in either group [Table 3].

A univariate logistic regression analysis regarding age, sex, smoking status, diabetes mellitus, ASA Class, and BMI was utilized to compare the two groups to assess for any independent effect of any of the complication rates. Taking complications, which include failure of fixation, infection, or need for symptomatic HWR, no significant association was found except for BMI. Patients that experienced complications had a slightly significantly lower BMI (23.7) when compared to patients that experienced no complications (24.6) (*P=0.04*) [Table 4].

A multivariate logistic regression model was used to estimate the association between the fixation types and complications. No significant difference was found in regard to fixation failure between the two groups. Regarding postoperative infection, it was twice as likely to occur in the POS group (OR=2.02, 95% CI = 0.86 -4.74) although this association was not significant. The POS group had an approximately 60% less chance of needing HWR (OR = 0.42, 95% CI =0.23 - 0.74, *P=0.003*) [Table 5].

Table 3. Primary and secondary outcomes for patients with olecranon fracture

	POS	Tension Band	*P-value*
	N=168	N=153	
Primary outcome			0.99
No Failure	166 (98.8)	152 (99.4)	
Failure	2 (1.2)	1 (0.6)	
Secondary outcome			0.20
No Infection	153 (91.1)	145 (94.8)	
Infection	15 (8.9)	8 (5.2)	
Secondary outcome			0.0009
No Hardware Removal	145 (86.3)	109 (71.2)	
Hardware Removal	23 (13.7)	44 (28.8)	
Secondary outcome			
No Reoperation for stiffness			
Reoperation for stiffness			

Table 4. Univariate analysis. Values shown are medians (25th, 75th percentile) unless otherwise specified

	Others N=241	Failure, HWR or Inf N=80	*P-value*
Age	63 (46,78)	59 (31,69)	0.05
Sex (%)			0.77
Male	104 (43.2)	33 (41.2)	
Female	137 (56.8)	47 (58.8)	
Smoking status (%)			0.39
Never	145 (60.2)	48 (60.0)	
Current	20 (8.3)	7 (8.8)	
Former	50 (20.7)	21(26.2)	
Unknown	26 (10.8)	4 (5.0)	
Diabetes mellitus (%)			0.50
Yes	31 (12.9)	8 (10.0)	
No	210 (87.1)	72 (90.0)	
ASA Class (%)			0.79
I	37 (15.3)	15 (18.7)	
II	153 (63.5)	48 (60.0)	
III	50 (20.8)	17 (21.3)	
≥IV	1 (0.4)	0 (0.0)	
BMI	24.6 (21.8,28.2)	23.7 (20.0,26.5)	0.04
Fracture pattern (%)			0.94
Simple transverse one fracture line	178 (73.9)	58 (72.5)	
Transverse with two fracture lines	13 (5.4)	5 (6.3)	
Multifragmentary	49 (20.3)	17 (21.2)	
Undetermined	1 (0.4)	0 (0.0)	
Open fracture (%)			0.27
Yes	12 (5.0)	7 (8.8)	
No	229 (95.0)	73 (91.2)	

Table 5. Multivariable analysis

	Odds ratio	95% CI	*P-value*
Primary outcome: Fixation Failure			
POS vs Tension Band	1.89	0.38-9.55	0.464
Secondary outcome: Postoperative Infection			
POS vs Tension Band	2.02	0.86-4.74	0.114
Secondary outcome: Hardware Removal			
POS vs Tension Band	0.42	0.23-0.74	0.003
Fixation Failure, HWR, or Infection			
POS vs Tension Band	0.65	0.38-1.09	0.102
Secondary outcome: Reoperation for Stiffness			
POS vs Tension Band			

Discussion

Displaced olecranon fractures are typically intra-articular in nature 9 and require anatomic restoration of the articular surface. The goals of operative treatment are to restore articular congruity, maintain joint stability, provide a pain-free functional arc of motion, allow early rehabilitation, and minimize morbidity. Various methods of internal fixation have been described including TBW and POS.

The TBW technique, which relies on the principle of converting posterior tensile forces to articular compressive forces, has been commonly used in the fixation of displaced and minimally comminuted fractures.[10-12] Complications, including soft tissue irritation, olecranon bursitis, wire migration, as well as fracture displacement, have been associated with tension band fixation.[11]

Plating may be complicated by limitations in extension as well as hardware prominence.[13] The incidence of HWR in our study was significantly higher in the TBW group (28.8% in TBW vs. 13.7% in POS). Patients treated with POS had a 58% less chance of requiring HWR, which is similar to results in previous studies.[7, 8, 14] The subcutaneous nature of the K-wires along with the potential migration of the wires may be responsible for the local pain and discomfort.[15] Yet, removal of the implant does not always lead to symptom resolution. Chalidis et al. showed that after HWR following TBW, 66.6% of patients still complained of mild pain or discomfort.[10] In the long term, low levels of pain may occur regardless of whether or not the hardware is removed as degenerative changes develop due to the nature of the injury.[10] In the years following the current study, the emergence of more studies has continued to show higher rates of reoperations due to symptomatic hardware in TBW versus POS in the treatment of olecranon fractures.[16-20] To avoid this complication many researchers have recommended the use of POS for stabilization.[4,21] In this time of healthcare reform and increased expectation of good stewardship with the healthcare dollar, less episodic costly return to the operating room for HWR may become a future sought-after outcome.

Studies analyzing the cost-effectiveness of TBW vs. POS have reported variable results.[16, 20, 22-24] Duckworth et al performed a prospective randomized trial with 67 patients comparing TBW and POS in terms of complications and cost analysis.[16] The study revealed no significant difference in overall cost between the TBW and POS groups despite higher rates of reoperations in the TBW group. Powell et al revealed that POS was less expensive on average when accounting for an increased rate of reoperations when using TBW.[20] In contrast, Francis and Tan performed a cost analysis between TBW and POS and concluded that TBW was more cost-effective.[23, 24] The cost of implant type may be an important factor, as demonstrated by DelSole et al showing the price of the locking plate used in their study was 13 times more expensive than a nonlocking one-third tubular hooked plate.[22]

In this study, both treatment groups performed well in terms of the failure of fixation and prevention of infection. The rate of failure requiring revision surgery was 0.6% in the TBW group and 1.2% in the POS group. Infection rates were slightly higher in the POS group (5.2% in TBW, 8.9% in POS), although this difference was not statistically significant. Five of the patients in the POS treatment group that were complicated by infection had comminuted fracture patterns compared to zero in the TBW group. Patients with comminuted fracture patterns may have suffered higher energy injuries increasing the likelihood of soft tissue compromise. Incisions made through such tissues may lead to future wound breakdown and infection and may explain the higher rate seen in the POS group.[25] Higher infection rates in POS were also seen in the Duckworth randomized trial, which revealed four patients treated with POS suffered from infection compared to zero in the TBW group, although the nature of the fracture in those four patients was not specified.[16]

Increases in plating even for minimally comminuted fractures may be due to biomechanical studies showing that POS provides significantly greater compression at the articular side of the fracture when compared to TBW.[12] In this study, 92.1% of the patients that were fixed with TBW were classified as having one or two fracture lines (141 of 153). A greater proportion of patients with comminution, classified as having a multifragmentary fracture pattern, were fixed with POS (54 of 66 or 81.8%). Greater usage of POS for minimally displaced and comminuted fractures can be seen in our study as well with 67.9% in the POS group falling under the classification of having one or two fracture lines (113 of 168). Another recent biomechanical study compared TBW with POS in the treatment of transverse olecranon fractures in 20 cadaveric elbows. The study revealed no significant difference in fracture displacement or load to failure between the two methods but found hardware failure to be the mechanism of failure in 8 out of 10 TBW trials versus only 1 out of 10 trials in POS.[26] The researchers concluded that POS may be a more reliable method compared to TBW when treating transverse olecranon fractures.

We found that patients with a lower BMI were more prone to experiencing complications. Though this difference showed statistical significance it likely has no clinical relevance as the BMI only differed by 0.9. We hypothesize that a thicker, soft tissue envelope might protect against symptomatic hardware but did not quantify this. In regard to age, sex, smoking, diabetes history, and ASA class we found no association with these variables to complication rates.

The strengths of this study include the large sample size and the availability of a comprehensive and integrated electronic medical system to help identify patients with olecranon fractures.

To our knowledge, this population of 321 patients is the largest review of outcomes in the treatment of olecranon fractures. This includes studies of TBW alone, plating alone, and all comparisons of both techniques. Previous studies comparing these procedures have included much smaller sample sizes and only focused on specific fracture patterns.[7,8,14] Tarallo et al., using a smaller sample size of 78 patients, also noted higher incidences of HWR in TBW.[8] An evaluation of confounding clinical factors on outcomes was not conducted. Gathen et al. included Mayo, Schatzker, and AO classifications in a study comparing TBW and POS, although it too had a smaller sample size of 40 patients.[17] At the time of our study, there was only 1 prospective randomized trial comparing TBW and POS with a sample of 41 patients.[14] Plate fixation took longer but required less symptomatic hardware removal, less loss of fixation, and better clinical and radiographic results. This study, published in 1994, may not have been reflective of more recent advancements in plating technology such as lower profile, precontoured implants, and locking technology. Since then, Duckworth et al completed a prospective randomized trial comparing TBW and POS in 67 patients as discussed previously.[16] This study demonstrated similar patient-reported outcomes between the two groups along with less symptomatic HWR but more infections and revision surgeries in the POS group compared to the TBW group. Our study as stated in the results shows no differences in infection or revision rates between POS and TBW.

An inherent limitation of using our data source is reliance on the diagnostic codes to identify patients with olecranon fractures. To minimize the misclassification of our patients, all available medical records and radiographs were reviewed and adjudicated to ensure the accuracy of the database search. Another limitation was the retrospective nature of our study.

The current study also did not look at the position of the K-wires in the TBW group. There have been contradicting studies discussing the importance of the positions of the K-wire with regard to implant loosening. Rommens et al. showed that when the K-wires were placed suboptimally, (K-wires which are not inserted parallel or which do not transverse the volar cortex of the proximal ulna), there was no correlation with the increased rate of loosening or need for a secondary procedure.[1] Van der Linden et al. showed that instability and proximal migration of wires were more common when the wires were inserted intramedullary as compared to transcortical.[27] The current study also did not assess the risk of proximal ulna fracture thru the plate holes, if HWR was performed post-POS. Another limitation is that there were no patient-reported outcomes collected before or after surgery.

One of the indirect goals of the present study was to enhance orthopedic surgeon knowledge during the informed consent process around the relative risks of the two different procedures. The risk of HWR is the most significant difference between the two procedures evaluated. The growing trend of using plates even for simple olecranon fracture patterns was noted in our data as well.

In this large-scale review of outcomes in 321 patients undergoing TBW versus POS, no significant differences were noted in terms of fixation failure (0.6% in TBW, 1.2% in POS), infection (5.2% in TBW, 8.9% in POS) or postoperative stiffness (none). However, the rate of symptomatic hardware necessitating removal was significantly increased with TBW as opposed to POS (0.0011). Clinical factors including age, gender smoking, ASA class, DM, fracture pattern, and open versus closed status were found to have no effect on the association between fixation type and outcome. These findings may assist surgeons and patients in considering the risks and benefits of TBW and POS as treatment options for olecranon fractures.

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