



Complications and reoperations related to tension band wiring and plate osteosynthesis of olecranon fractures

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Background: Olecranon fractures are common and usually treated operatively either by tension band wiring (TBW) or plate fixation (PF). The aim of this study was to assess early complications and reoperations and their predictive factors related to those operative methods.

Methods: A retrospective analysis of all patients with an operatively treated olecranon fracture between 2007 and 2017 at Turku University hospital was performed. Reoperations, postoperative complications, and potential risk factors for these were recorded.

Results: A total of 434 patients (387 TBW and 47 PF) were identified. There was no statistically significant difference in the rate of early complications (49% vs. 62%, $P = .262$) or reoperations (38% vs. 53%, $P = .079$) between patients treated with TBW and PF. In the TBW group, the intramedullary placement of Kirschner (K)-wires predisposed patients to complications compared to transcortical placement of the K-wires according to multivariate analysis (odds ratio [OR] 1.94, $P = .026$). Younger age was associated with the frequency of reoperations, the odds decreasing 24% for every 10 years of age ($P < .001$). Further, patients with high-energy trauma mechanisms were reoperated more often compared to patients with low-energy trauma (OR 2.99, $P = .002$). Also, excellent postoperative reduction was associated with higher reoperation rate than good or fair reduction (OR 0.48, $P = .033$).

Conclusion: There is a high risk of early complications and reoperations associated to both TBW and PF. Transcortical positioning of K-wires may reduce the rate of complications in TBW.

Level of Evidence: Level III; Retrospective Cohort Comparison; Treatment Study

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Keywords: Olecranon fracture; tension band wire; plate fixation; complication; reoperation; Mayo classification; Kirschner wire placement

Olecranon fractures account for approximately 1% of all upper extremity fractures. Current epidemiologic data show that the incidence of olecranon fractures is increasing,

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

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especially in the elderly population,^{8,10} and these fractures seem to have osteoporotic features such as age-dependent low bone attenuation and low-energy trauma as a cause of injury.²² Traditionally displaced olecranon fractures have been treated operatively either by tension band wiring (TBW) or plate fixation (PF).²³ Current literature supports the use of these methods but does not support one implant over another^{18,24,25} because significant differences between

these 2 methods have not been found concerning patient satisfaction, improvement rate, range of motion, operation time, or blood loss.²⁵

Both operative TBW and PF methods may lead to reoperations because of prominent hardware and also because of infections and loss of reduction.^{6,9,18,24,25} These reoperations are costly and increase patient morbidity. Reported reoperation rates vary, reaching up to 16%-50% for TBW and 15%-33% for PF.^{6,9,11,12,17} American Society of Anesthesiologists Physical Status Classification System grade, comminuted fracture pattern, as well as poor bone quality are reported to predict an overall poorer long-term outcome.^{6,7,14} Furthermore, younger patients and women more often suffer from prominent and symptomatic hardware leading to hardware removal than older patients and men.^{4,7} Finding all those risk factors for complications and reoperations that are not yet known would help the patients and clinicians in shared decision making to optimize the treatment of olecranon fractures and reduce the reoperation rate.

The aim of this study was to assess the complication and reoperation rates for patients treated with TBW or PF and to find possible patient-, fracture-, or operation technique-related predictive factors for complications and reoperations. Our hypothesis was that patients with complicated and comminuted fracture patterns as well as older patients would suffer more complications and be reoperated more often.

Material and methods

Hospital District of Southwest Finland granted the research permission on February 14, 2018 (TO1/001/18). Patients were identified retrospectively from Turku University Hospital's (Turku, Finland) electronic patient record systems, which were searched for proximal ulnar fracture diagnosis S52.0 according to *International Statistical Classification of Diseases and Related Health Problems 10th Revision* and the type of surgery NCJ62 or NCJ64 according to the *NOMESCO Classification of Surgical Procedures, Version 1.14*, by the Nordic Medico-Statistical Committee for the 11-year period between 2007 and 2017. All data were manually extracted from electronic patient record systems in May 2019.

Demographic data and relevant medical comorbidities that could affect the quality of bone, wound healing, or cooperation regarding postoperative rehabilitation and instructions, such as rheumatoid arthritis, diabetes mellitus, dementia, and excessive use of alcohol, were recorded. We also recorded the date of the injury, side of injury, trauma mechanism, the classification of the fracture according to the Mayo fracture classification,^{19,20} and whether the fracture was open or closed; open fractures were classified according to Gustilo Andersson classification.¹⁴ Injury Severity Score³ was calculated to determine the total trauma burden on each patient. Regarding the treatment, the date of the operation, implants used, the level of experience of the operating and assisting surgeon (attending, resident, or intern), and follow-up schedule were recorded. Possible early complications (failure

of the reduction, wound or deep infection, symptomatic prominence of the fixation materials, malposition of fixation material, or nerve damage), reoperations, and their reasons were recorded till the last follow-up visit to the outpatient clinic. The postoperative radiographs were evaluated by one author (I.R.) concerning 2 things: the adequacy of the fixation by AO principles² and method instructions and the quality of reduction of the joint surface by measuring possible gap or step-off. The measurements were graded as follows: excellent for exact joint surface positioning, good or fair if there was 1-2 mm dislocation, and unsatisfactory for dislocation >2 mm. Fixation material was regarded malpositioned if the Kirschner (K)-wires were too long and far out the ulnar cortex in the soft tissues of the forearm or penetrating the joint surface. From the follow-up radiographs, the maintenance of the reduction was evaluated by comparing the joint surface positioning to the postoperative radiographs, and reduction was considered lost if there was ≥ 2 mm redislocation of the joint surface. If a patient had deceased, the date was recorded.

Statistical analysis

Univariate analyses were carried out for all variables to get an overview of the patients and to derive the descriptive statistics. The number and pattern of missing values were also checked. Binary variables were formed for complications and reoperations to represent their occurrence in general and were used in the analyses. Age was rescaled into tens of years for the models.

The association between the occurrences and other variables were studied using simple logistic regression. Based on the results of simple logistic regression models, we decided to investigate the association between the complications and tension band Kirschner (K)-wire placements with multiple logistic regression adjusting for age and gender. Visual inspection of the deviance and partial residuals were used for justification of the analyses. The association between other categorical variables were studied using Fisher exact test.

Odds ratios (OR) with 95% confidence intervals (CIs) and *P* values are reported for logistic regression models and *P* values are reported in conjunction with Fisher exact test. *P* values of $\leq .05$ were considered statistically significant. R, version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria), was used for statistical analyses.

Results

A total of 434 patients who had undergone surgery for olecranon fracture between 2007 and 2017 were identified. Baseline characteristics of the patients are shown in [Table 1](#). Median age of all patients was 64 years (range 16-95), and majority of the patients were female (66.4%). The most common fracture type was Mayo type 2 (94.2%). The most common mechanism of trauma was falling from standing height (61.5%). Majority of the patients got their fractures fixated with TBW ($n = 387$, 89.2%), but PF ($n = 47$) was more often used for Mayo type 3 fractures than TBW, 10.6% vs. 3.1% respectively ($P = .048$). In the TBW group, 274 patients (70.8%) had their K-wires placed

Table I Baseline characteristics

Variable	All	TBW	PF
Patients, n (%)	434	387 (89.2)	47 (10.8)
Female, n (%)	288 (66.4)	260 (60.0)	28 (6.5)
Age, y, median (range)	64 (16-95)	65 (16-95)	59 (16-86)
ISS, median (range)	(4-17)	(4-13)	(4-17)
Fracture type, n (%)			
Mayo 1	8 (1.8)	8 (2.1)	0 (0.0)
Mayo 2	409 (94.2)	367 (94.8)	42 (89.4)
Mayo 3	17 (3.9)	12 (3.1)	5 (10.6)
Trauma mechanism, n (%)			
Falling from standing height	267 (61.5)	244 (56.2)	23 (5.3)
Other*	167 (38.5)	142 (32.7)	25 (5.8)
NA	1 (0.2)		
Open fracture, n (%)			
Gustilo 1	14 (3.2)	10 (2.3)	4 (0.9)
Gustilo 2	10 (2.3)	8 (1.8)	2 (0.5)
NA	1 (0.2)		

ISS, Injury Severity Score; NA, not announced; Mayo, Mayo Fracture Classification TBW, tension band wiring; PF, plate fixation.^{4,19}

* Other trauma mechanisms include falling down stairs, falling with a bicycle, falling from >1 m height, other high-energy mechanism, or unknown.

transcortically through the volar cortex of ulna and 62 patients (16%) had them placed intramedullary. The rest of the TBW patients (n = 51, 13.2%) had different modifications of these options. The median time to the last outpatient clinic visit was 6 weeks (range 1-52).

All together 217 early complications were recorded in 202 (46%) patients. Most common early complications were symptomatic fixation material (n = 125, 29%) and failure of reduction (n = 55, 13%) (Table II). A total of 155 (36%) patients had undergone 173 reoperations. The most common reoperation was removal of hardware (n = 151, 35%) (Table III). Sixteen patients had their fixation materials removed routinely in a reoperation without any mention of a complication.

Based on the simple logistic regression, there was no significant difference in early complications ($P = .262$) or reoperations ($P = .079$) between patients treated with TBW and PF (Table IV). Early complications were not associated with age, fracture type, trauma mechanism, open fractures, or the skill level of the operating surgeon (Table IV). In addition, early complications or reoperations were not significantly associated with medical comorbidities or excessive use of alcohol. Patient's sex was not associated with the complication (OR 1.5, 95% CI 0.98-2.25, $P = .065$) or reoperation rate (OR 0.98, 95% CI 0.46-2.0, $P = .96$).

The odds of reoperation decreased by 24% for every 10 years of age (OR 0.76, 95% CI 0.68-0.83, $P < .001$). Patients with a high-energy trauma mechanism were reoperated significantly more often than patients falling from standing height (OR 2.99, 95% CI 1.51-6.22, $P = .002$). We also found that the odds of reoperation was lower if the postoperative quality of the reduction after

primary surgery was good or fair compared to excellent (OR 0.48, 95% CI 0.24-0.95, $P = .033$).

When the configuration of TBW was examined from the postoperative radiographs and patients were divided into groups according to the placement of the TBW K-wires, patients in whom K-wires were placed intramedullary had significantly more early complications when compared with those whose K-wires were placed transcortically through the volar cortex of the ulna. This was shown in multiple logistic regression models, when age and sex were taken into account (OR 1.94, 95% CI 1.1-3.5, $P = .026$). Further analysis of different early complication categories showed a significant difference in symptomatic fixation material problems (OR 2.2, 95% CI 1.2-4.1, $P = .016$) between the intramedullar and transcortical K-wire groups (Table V).

Discussion

TBW and PF are the most frequently used methods for fixation of displaced olecranon fractures.^{5,13,15,23} In this study, we assessed outcomes for 434 patients with an olecranon fracture treated with either TBW or PF. The total rates of early complications and reoperations were high for both TBW and PF, 50% and 40%, respectively. Regarding complications and reoperations, no statistically significant differences between the TBW and PF groups were found. Older age was associated with lower complication and reoperation risks. In the subgroup analysis, patients in the TBW group with intramedullary K-wires were more likely to have problems with symptomatic fixation material.

Table II Early complications

Complication	All, n (%) (N = 434)	TBW, n (%) (n = 387)	PF, n (%) (n = 47)
Failure of reduction	55 (12.7)	47 (12.1)	8 (17.0)
Wound infection	8 (1.8)	8 (2.1)	0 (0)
Deep infection	10 (2.3)	8 (2.1)	2 (4.3)
Symptomatic fixation material	125 (28.8)	110 (28.4)	15 (31.9)
Malposition of fixation material	16 (3.7)	14 (3.6)	2 (4.6)
Nerve damage	3 (0.7)	1 (0.3)	2 (4.6)
Total early complications	217 (50.0)	188 (48.6)	29 (61.7)

TBW, tension band wiring; PF, plate fixation.

Table III Reoperations

Reoperation	All, n (%) (N = 434)	TBW, n (%) (n = 387)	PF, n (%) (n = 47)
Refixation owing to failure of reduction or malposition of fixation material	19 (4.4)	16 (4.1)	3 (6.4)
Removal of hardware	151 (34.8)	129 (33.3)	22 (46.8)
Infection revision	3 (0.7)	3 (0.8)	0 (0)
Total reoperations	173 (39.9)	148 (38.2)	25 (53.2)

TBW, tension band wiring; PF, plate fixation.

Table IV The association of the occurrence of early complications with different variates based on simple logistic regression

Variate	OR	95% CI	P value
Operation method			
Tension band	Reference		
Plate fixation	1.46	0.77-2.64	.262
Tension band Kirschner-wire placement			
Transcortical	Reference		
Intramedullar	1.72	0.98-3.05	.060
Age (continuous)	0.91	0.83-1.00	.054
Fracture type			
Mayo 1	Reference		
Mayo 2	1.99	0.42-14.0	.415
Mayo 3	2.81	0.46-23.7	.285
Open fracture			
Closed	Reference		
Gustilo 1	3.18	1.04-11.7	.054
Gustilo 2	0.16	0.01-0.88	.084
Trauma mechanism			
Falling from standing height	Reference		
High energy	1.42	0.77-2.64	.262
Operating surgeon			
Consultant	Reference		
Resident	1.06	0.71-1.58	.774

OR, odds ratio; CI, confidence interval.

Operative treatment is the gold standard for displaced olecranon fractures. Nonetheless, both of the 2 most frequently used operative methods, TBW and PF, have high

reoperation rates.^{6,9,11,12,17,18,24,25} Our results, with nearly one-half of the patients undergoing some kind of reoperation during this short-term follow-up, are in line with the

Table V Subgroup multivariate analysis of association between placement of tension band Kirschner wires and early complications

Tension band Kirschner-wire placement	All early complications			Symptomatic fixation material		
	Adj. OR	95% CI	<i>P</i> value	Adj. OR	95% CI	<i>P</i> value
Transcortical	Reference			Reference		
Intramedullar	1.94	1.08-3.48	.026	2.17	1.15-4.07	.016

Adj. OR, adjusted odds ratio; *CI*, confidence interval.

Models are adjusted for age and gender.

earlier results. Comparably to previous data, reoperation or complication rates in our material did not differ between the TBW and PF groups.^{6,12}

In earlier studies, American Society of Anesthesiologists grade, comminuted fracture pattern, female sex, and younger age have been associated with inferior outcome after surgical treatment for olecranon fracture.^{6,7} In our data, American Society of Anesthesiologists grade, fracture pattern, or sex did not have an effect on the complication or reoperation rates. We found an association between age and early complications, as well as age and reoperations; the older the patient, the fewer early complications and reoperations. This is comparable to the previous literature where older patients are known to less frequently suffer from symptomatic fixation materials and less frequently have their fixation materials removed.^{4,7} It is plausible that low physical activity and demands for functioning of the elbow reduce the subjective need for revision surgery. Furthermore, the probability of proximal migration of the K-wires most likely decreases because of physical inactivity. Additionally, elderly patients have more comorbidities, which might affect the reoperation decision making. Also, in earlier literature younger patients more likely sustain their fractures with high-energy mechanisms, and the most common mechanism of injury for older patients is falling from standing height.¹⁰ Accordingly, in our material, fractures caused by high-energy trauma more often affected younger persons, who are active and likely to be more demanding with elbow functioning. This may explain our findings that reoperations were more frequently associated with high-energy trauma mechanisms. The association between high-energy trauma mechanism and reoperations has also been noted in young patients suffering a femoral neck or intertrochanteric femoral fracture.^{1,26}

In our analyses, poor or fair postoperative reduction was less frequently associated with reoperations than an excellent reduction. We assume that age can also explain this finding; older patients have poorer bone quality, which often makes an exact reduction challenging or impossible to achieve, and thus lower-quality postoperative primary reductions might have been accepted in these elderly patients and reoperations less frequently found necessary. In young patients, an excellent reduction would more likely be

achieved primarily, but if a failure of the reduction were to occur, the threshold to reoperate might be lower.

TBW is generally performed according to AO recommendations. In these recommendations, the distal part of the K-wires should pass through the volar cortex of ulna; however, in reality, the wires are often positioned intramedullary.² This was also seen in our material, where the K-wires were positioned intramedullary in 16.0% of the TBW cases. Intramedullary placement of the K-wires was associated with significantly more early complications when compared to transcortical placement (OR 1.9). This is in line with previous reports on the matter where intramedullary K-wires have been reported to have more proximal migration compared with transcortical ones.^{16,21} Because this correlation has been shown in multiple studies, including this study, even more attention should be paid to place the K-wires transcortically.

We acknowledge that our study has some limitations. First, the demographic data on the patients were gathered retrospectively from electronic medical records where some information might be erroneously coded or missing. Second, our follow-up is based on outpatient clinic visits, so the follow-up time with some patients is relatively short. However, the Finnish health care system, especially in operative treatment, is strongly public driven, and it is likely that if a patient required a reoperation he or she would have returned to our outpatient clinic. Third, the study cohort is heterogenic and the TBW and PF groups might differ from each other to some extent owing to possibly different indications for the use of different fixation methods, as was seen in our material where PF was more often used for Mayo type 3 fractures than TBW. TBW is known to be more commonly used for isolated and simple olecranon fractures,² whereas PF is reportedly better for comminuted and unstable fractures.^{5,13,15} The fracture pattern did not have a correlation with the complication or reoperation risk, and we think that this has not significantly biased our results. To further diminish the potential selection bias in our material, we performed multiple regression models adjusted for age and sex. Additionally, no clinical assessment of the end result with patient-reported outcome measures was performed, and because of the limited follow-up, we could not address long-term complications

such as loss of range of motion, nonunions, or painful pseudoarthroses. The strengths of our study include the high number of consecutive patients with extensive data and meticulous pre- and postoperative analysis of radiographs.

Conclusions

Both TBW and PF groups had comparably high numbers of complications and reoperations. Older age was associated with lower complication and reoperation rates, likely representing the lower functional needs and higher reoperation threshold of this population. In case of the TBW method, patients were more likely to have a complication if the K-wires were placed intramedullary, and therefore careful attention should be paid to a correct technique during surgery.

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