

Original Article

An implant positioning score for tension band wiring in olecranon fractures

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ABSTRACT

INTRODUCTION. Tension band wiring (TBW) is one of the most commonly used methods of fixation for displaced olecranon fractures. This study aimed to assess whether implant positioning (IMPO) of TBW for olecranon fractures was associated with complications.

METHODS. This was a multicentre cohort study. Eligible patients were retrieved from the hospitals' administrative databases using diagnosis codes for elbow and olecranon fractures. The patients' healthcare files were reviewed for demographics and complications. A major complication was defined as any reoperation within eight weeks or deep infection. Any loss of fixation was added to define surgical complications. Preoperative X-rays were classified according to the Mayo classification. Post-operative X-rays were evaluated, and the IMPO of TBW was rated on a 0-10 scale, yielding 10 points if all conditions were met. A high IMPO score was 9-10 points, a low score was eight points or less.

RESULTS. A total of 307 patients were included: 76% with Mayo type 2A and 20% with type 2B. The TBWs were rated with a median score of eight points (range: 3-10), and 11.8% had major complications. There was a 5% complication rate with a high IMPO score, compared with 15% with a low score ($p = 0.010$). A total of 105 patients (34%) had surgical complications: 21% with a high IMPO score and 44% with a low IMPO score.

CONCLUSIONS. The IMPO score after TBW for olecranon fractures has a clear correlation with post-operative complications. We propose that at least nine out of ten points should be achieved before surgery is acceptable.

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Fracture of the olecranon is the most common elbow fracture, accounting for approximately 1% of upper extremity fractures and about 20% of all proximal forearm fractures [1-3]. Tension band wiring (TBW) was first described in 1963 and is the most frequently used fixation for displaced olecranon fractures [4-6]. TBW is, in general terms, a simple method that can be performed by most orthopaedic surgeons, with satisfactory results leading to a well-functioning elbow after surgery [6, 7]. Even so, studies report wide variation in complication rates, ranging from 46% to 80% [6-12]. A possible explanation for the variation in complications could be the quality of the TBW osteosynthesis.

It is well known that there is an association between the quality of osteosynthesis and subsequent complications [13-15]. For olecranon fractures, one study [9] described ten criteria for evaluating TBW treatment based on ten

operative imperfections, including nonparallel or long K-wires, insufficient fixation of the proximal ends of the K-wires, perforation of the joint surface, loose figure-of-eight configuration and incorrect repositioning [9]. So far, no studies have investigated whether an association exists between implant positioning (IMPO) of TBW in olecranon fractures and complications.

The aim of this study was therefore to assess whether an IMPO score of TBW for displaced olecranon fractures in adult patients was associated with complications.

Methods

Level of evidence

Retrospective cohort study, evidence level 3.

Study design

This was a multicentre retrospective cohort study involving adult patients with a displaced olecranon fracture treated surgically, including a one-year follow-up. This study was approved by the Danish Patient Safety Authority (case no. 3-3013-3121/1). Reporting was conducted according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [16].

Setting

The present study was performed in four independent public hospitals in the Region of Southern Denmark (1.22 million inhabitants) [17]. All patients with olecranon fractures in the Region of Southern Denmark are admitted to one of these four hospitals, as the Danish National Health Service provides tax-supported, free healthcare and general hospital care for all Danish citizens [18]. It is therefore unlikely that patients with an olecranon fracture have been admitted to the few private hospitals in the region, and thus the study is very likely to present a complete and consecutive cohort.

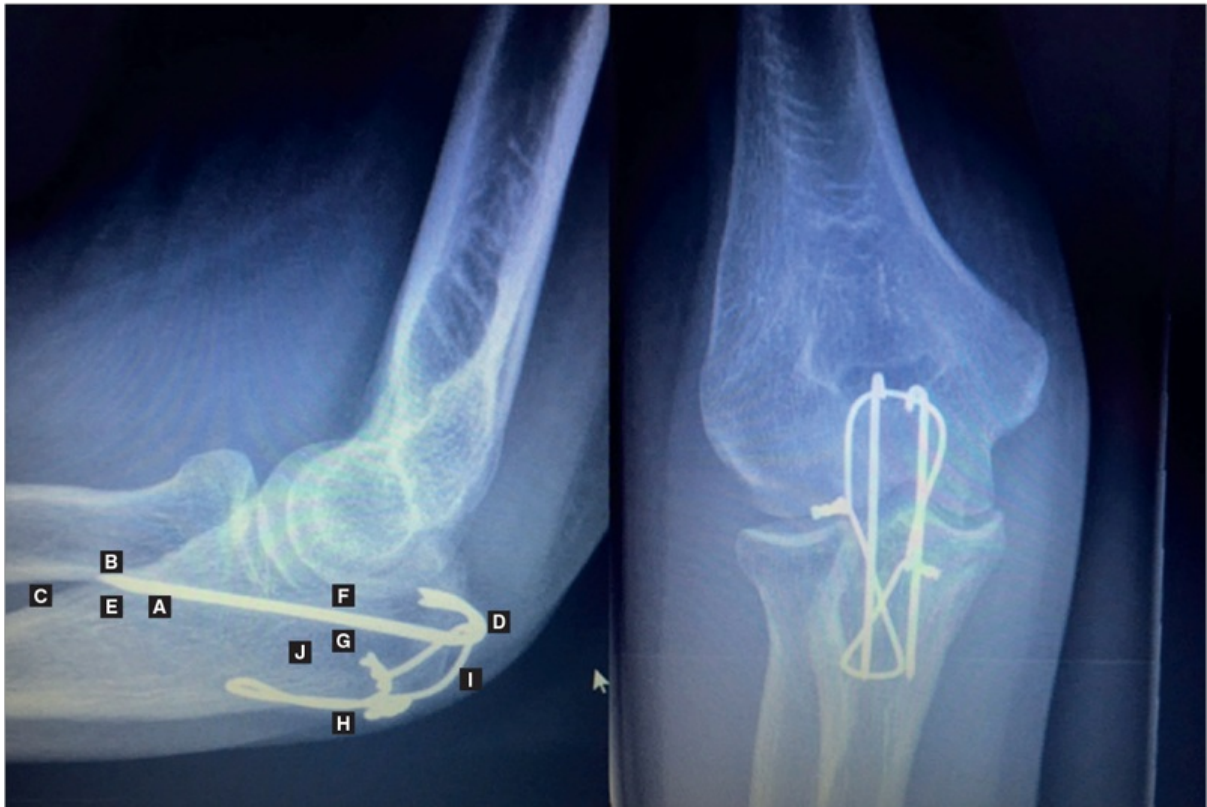
Participants

From 2013 to 2018, eligible patients were identified using International Classification of Diseases, tenth version (ICD-10) diagnosis codes for elbow and olecranon fractures (DS520 and DS520B) from the hospitals' administration databases in the Region of Southern Denmark. Patients with displaced olecranon fractures treated with TBW were included in the study. Patients treated with plate fixation, conservatively treated patients and patients with fractures also involving radius, antebrachium or humerus fractures were excluded. The patients' healthcare records and X-ray images were examined for inclusion and exclusion criteria.

Variables and data sources

Patients' healthcare files were reviewed for demographics, operation details, post-operative treatment and complications. Pre-operative X-rays were reviewed for classification using the Mayo classification [12], and perioperative or early post-operative X-rays were assessed for IMPO of TBW based on the ten imperfections presented by Schneider et al. [9] (**Figure 1**):

FIGURE 1 Antero-posterior and lateral X-ray of the elbow with the ten possible imperfections of tension band wiring. **A.** Nonparallel K-wires. **B.** Long K-wires. **C.** K-wires extending radially outwards. **D.** Insufficient fixation of the proximal ends of the K-wires. **E.** Intramedullary K-wires. **F.** Perforation of the joint surface. **G.** Single-wire knot. **H.** Jutting wire knot(s). **I.** Loose figure-of-eight configuration. **J.** Incorrect repositioning.



The number of imperfections was converted into an IMPO score of ten points, subtracting the number of imperfections; for example, if three imperfections were recorded, a seven-point IMPO score was assigned. Major complications were defined as any reoperation within eight weeks, reoperation due to deep infection, non-union or reosteosynthesis. Surgical complications were defined as major complications and the loss of TBW fixation. Minor complications included simple removal of hardware, defined as removal eight weeks after surgery due to discomfort in the elbow because of the osteosynthetic material.

Quantitative variables

The American Society of Anesthesiologists (ASA) score [19] for physical status classification was dichotomised into low (1-2) and high (3+). A post hoc analysis based on the reoperation distribution and each element of the IMPO score led to dichotomising the IMPO score into a high score with 9-10 points and a low score with eight points or less.

Statistical method

The data were tested for normality and showed a skewed distribution. Median and range were therefore used for descriptive statistics. The χ^2 test was used for group comparison, and a $p < 0.05$ was considered significant. A subanalysis was performed to assess differences between Mayo 2a and 2b based on IMPO scores using the Wilcoxon rank-sum test, and major complications, using the χ^2 test. STATA 16 was used to perform the analyses.

Trials registration: not relevant.

Results

There were 706 eligible patients, and 307 patients were included in the study. A total of 176 patients were excluded due to plate fixation, 140 due to more complex fractures or incorrect diagnosis, 77 due to non-operatively treated fracture and six due to missing follow-up. There were 210 (68%) females; the median age was 64 years (range: 18-98 years), and 20% had a high ASA score. A post-operative cast was applied to 96% of the patients, with a median duration of two weeks (range: 0-6 weeks). There were 76% Mayo type 2A fractures and 20% type 2B.

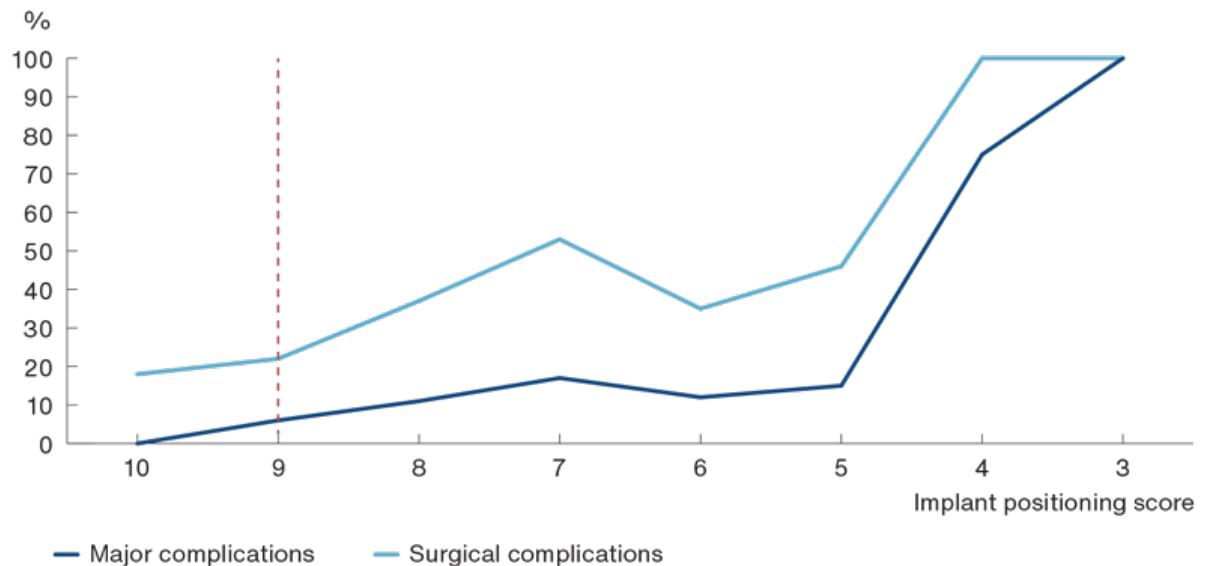
The TBWs were rated with a median score of eight points (range: 3-10) (**Table 1**). A total of 11.8% had major complications. There were no major complications with a ten-point IMPO score, 6% with a nine-point IMPO score; and in 11-17%, the IMPO score was 5-8 points. This revealed a clear relation between a higher score and fewer post-operative major complications ($p < 0.001$). Surgical complications (addition of TBW fixation loss) were seen in 30%, demonstrating a similar relationship between a higher IMPO score and fewer complications ($p < 0.001$).

TABLE 1 The quality of the tension band wiring treatment for displaced olecranon fractures.

Points	Patients, n	Major complications n (%)	Surgical complications n (%)
3	1	1 (100)	1 (100)
4	4	3 (75)	4 (100)
5	13	2 (15)	6 (46)
6	34	4 (12)	12 (35)
7	72	12 (17)	35 (48)
8	83	9 (11)	30 (36)
9	78	5 (6)	15 (19)
10	22	0	3 (14)
Total	307	36 (12)	106 (35)

When the IMPO score was dichotomised, major complications occurred in 5% of patients with a high score versus 15% of those with a low score ($p = 0.010$) (**Figure 2**). For surgical complications, patients with a high IMPO score had 21% complications, while those with a low score had 44% complications ($p < 0.001$).

FIGURE 2 Major and surgical complications depicted by implant positioning score. A cut-off limit is proposed by the dashed red line.



Among the ten IMPO assessments, the most common errors were too long K-wires (48%), insufficient fixation of proximal ends of the K-wires (41%) and a loose figure-of-eight configuration (41%) (Table 2). An association was observed between an intramedullary K-wire, a loose figure-of-eight configuration, incorrect repositioning and major complications. For surgical complications, similar specific associations were observed but the incorrect repositioning was replaced with insufficient fixation of proximal ends of the K-wires.

TABLE 2 The ten assessed imperfections with percentage of correct performances, major and surgical complications.

	Performed incorrectly %	Major complications		Surgical complications	
		%	p value	%	p value
Non-parallel K-wires	33	14	0.461	41	0.084
Long K-wires	48	12	0.953	34	0.730
K-wires extending radially outwards	6	24	0.296	47	0.416
Insufficient fixation of proximal ends of the K-wires	41	14	0.398	41	0.055
Intramedullary K-wires	14	21	0.049	54	0.005
Perforation of the joint surface	4	18	0.514	45	0.438
Single-wire knot	10	21	0.134	48	0.105
Jutting wire knot(s)	20	16	0.054	45	0.060
Loose figure-of-eight configuration	41	22	0.011	45	0.001
Incorrect repositioning	12	23	0.034	40	0.470

The subanalysis comparing Mayo 2a and 2b showed a minor statistical difference between the groups, with a median score of 7.9 (range: 4-10) in the Mayo 2a group and 7.2 in the Mayo 2b group ($p = 0.006$). This did not translate into a statistical difference in major complications with 10.7% in the Mayo 2a group and 14.8% in the

Mayo 2b group ($p = 0.375$).

Discussion

We found a clear relationship between a high IMPO score of the TBW osteosynthesis and fewer complications. In comparison, Rommens et al. [8] conducted a study on the correlation between fracture type, fracture classification and the correctness of the osteosynthesis with the postoperative outcome. Rommens et al. found that 81% had TBW, and they classified suboptimal operational techniques as non-parallel K-wires, unicortically placed K-wires or suboptimal repositioning. They concluded that 9.5% of the patients had implant migration. The overall reintervention rate was 14.7%, with 65% of patients undergoing simple hardware removal. They found no correlation between suboptimal osteosynthesis and implant loosening. In contrast to the present study, Rommens et al. [8] included only three of the ten criteria for optimal osteosynthesis placement and may also have been underpowered. They did present lower complication rates, which could be explained by a lower average age (47.7 years) than in the present study (60.6 years).

Claessen et al. [11] conducted a study to calculate a numerical grading of the technical aspects of TBW for olecranon fractures based on the ten Schneider criteria [9], to determine whether there is a correlation between the technical grading and subjective and objective outcomes. They found 3.0 imperfections per TBW (range: 1.5-4.7). The present study found similar observations with a median of two imperfections per TBW (range: 1-3). In their study, they concluded that no correlation between technical deviations and patient outcomes was found. They suggest that TBW has a wide margin of error and a good outcome even in the face of surgical errors. Furthermore, they proposed that the Schneider criteria are mostly irrelevant from a patient perspective [11]. The results of the study by Claessen et al. [11] conflict with the findings of the present study, as the present study found a significant relationship between higher scores on the Schneider criteria and fewer complications.

When evaluating as many as ten criteria, having only 26 patients limits the ability to achieve statistically significant results. The study by Claessen et al. [11] only included simple transverse noncomminuted fractures, whereas the present study included all fractures treated with TBW. The complication rate is expected to be higher when more complex fractures are included. Another difference between the study by Claessen et al. [11] and ours is the average age: 34 years in theirs, whereas in this study it was 60.6 years.

Schneider et al. [9] found 4.2 imperfections per TBW, compared with 2.3 imperfections per TBW in the present study. In their study, they concluded that the main goal of TBW was to achieve correct repositioning of the fracture. The present study showed similar results, as the step of fracture repositioning is significantly associated with complications. They also concluded that the TBW technique seemed to tolerate imperfections while producing excellent results [9]. In contrast, the present study showed that the rate of complications increases substantially with the amount of imperfections. Our study therefore demonstrates that the surgeon must be very thorough when performing TBW osteosynthesis to reduce postoperative complications.

Based on the present study, we cannot conclude which of the ten steps is most important for avoiding complications. This would require a new, larger study comprising regression analysis.

When comparing complications between Mayo 2A og Mayo 2B fractures, the median IMPO score for 2A fractures was 0.7 points higher than the score for type 2B fractures, which, in our opinion, is of limited clinical relevance. The difference in reoperations was not statistically significant, but 2A fractures were four percentage points lower than 2B, which may suggest a power issue.

Several recent meta-analyses [20] have demonstrated that plate osteosynthesis is associated with fewer complications than TBW. This trend likely contributes to surgeons' increasing preference for plate fixation over

TBW. Consequently, compared with the inclusion period for this study, plate fixation is likely to be used more often in clinical practice. Additionally, studies in the older frail population have also influenced the indication for TBW by promoting a non-operative approach. In the authors' opinion, these trends do not impact the point made in this paper, namely that proper implant positioning is essential when performing TBW.

There are limitations to this study. It does not include inter-/ intra-rater reliability, which could be relevant for further studies. Another limitation is that we have not included patient-reported outcomes, and a lower score may not affect the patients. A strength of the study is the high number of included patients with a ten-point IMPO score on the X-rays.

Conclusions

A total of 11.8% of patients had major complications, and we found a clear relationship between the IMPO score after TBW for olecranon fractures and post-operative complications. We propose that a minimum of nine out of ten points should be achieved before surgery is considered acceptable. Surgeons need to be very thorough when performing TBW to reduce post-operative complications.

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