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Original Research

Double-Bending Tension Band Wire for Olecranon Fractures: A Novel Technique

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Purpose: This retrospective study aimed to compare the clinical outcomes and complications of conventional tension band wire (TBW), TBW with penetrating technique, and double-bending technique.
Methods: A total of 40 patients (17 men and 23 women; mean age: 64.0 ± 19.0 years) who underwent surgery for displaced olecranon fractures between January 2018 and December 2021 were included and divided into three groups based on the surgical method used (group A, conventional TBW; group B, TBW with penetrating technique; and group C, double-bending technique). Thirteen patients were assigned to group A, 17 to group B, and 10 to group C, including 2 Mayo type IB, 30 Mayo type IIA, and 8 Mayo type IIB fractures. Postoperative outcomes (elbow extension and flexion arc) and complications, such as backing out of the Kirschner wire (K-wire), were retrospectively evaluated.
Results: No significant difference was found in the general characteristics of the patients and fracture type among the three groups. The mean elbow extension arc values were 6.2°, 10.9°, and 0° in groups A, B, and C, respectively; it was significantly better in group C than in group B ($P = .001$). The rates of backing out of the K-wire were 84.6% (11/13) in group A, 41.2% (7/17) in group B, and 0% (0/10) in group C; the rate was significantly lower in group C than in group A ($P < .001$).
Conclusions: The double-bending technique may be the best procedure for preventing the backing out of the K-wire and postoperative complications, such as range of motion restriction, for treating olecranon fractures that are treatable by TBW.
Type of study/level of evidence: Therapeutic IV.

Olecranon fractures are one of the most common elbow fractures and comprise approximately 10% of all upper extremity lesions.[1] Open reduction and internal fixation (ORIF) using a tension band wire (TBW) is a common surgical technique for treating such fractures, especially simple isolated displaced fractures. Although TBW is a simple and effective fixation method, backing out of the Kirschner wire (K-wire) is the main complication of the procedure and requires metalwork removal. A few studies have reported no significant differences in clinical outcomes between TBW and plate fixation; however, high complication rates due to backing out of the K-wire have been observed in TBW.[2–5]

A unique technique used in Japan is the double-bending technique, which is effective in preventing the backing out of K-wires. However, no study has compared the outcomes and complications of the conventional TBW technique with this technique. This study compared clinical outcomes and complications, such as backing out of the K-wire and related issues, between conventional TBW and the double-bending technique.

Materials and Methods

In total, 58 patients (26 men and 32 women; mean age: 62.7 ± 18.9 years; range, 11–90 years) who underwent surgery for

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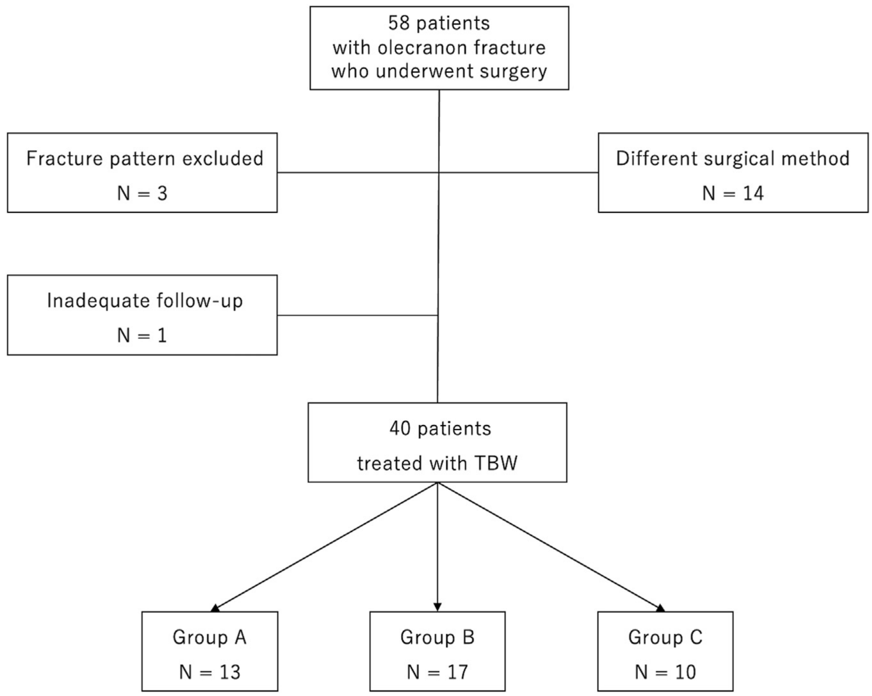


Figure 1. Flowchart of all study populations. From an initial cohort of 58 patients with olecranon fractures who underwent surgery, 40 patients met the inclusion criteria. The patients were divided into group A (13 patients), B (17 patients), and C (10 patients).

displaced olecranon fractures between January 2018 and December 2021 at two different hospitals were retrospectively examined. The inclusion criteria were acute disease (within 2 weeks of surgery), Mayo classification type I or II, ORIF using TBW, and at least 12 months of follow-up. According to these inclusion criteria, 18 patients were excluded from this study (1 patient with Mayo classification type IIIB, 1 patient with a follow-up period of <12 months, 2 patients with the use of cannulated cancellous screw, 2 patients with concomitant fractures, and 12 patients with use of the anatomical locking plate). Patients were divided into three groups based on the surgical method used. Thirteen patients with a mean age of 68.9 (range: 40–85 years), 12 with Mayo type IIA, and 1 with Mayo type IIB were included in group A; 17 patients with a mean age of 63.8 (range: 11–88 years), 2 with Mayo type IB, 12 with Mayo type IIA, and 3 with Mayo type IIB were included in group B; and 10 patients with a mean age of 57.7 (range: 12–79 years), 9 with Mayo type IIA, and 1 with Mayo type IIB were included in group C (Fig. 1).

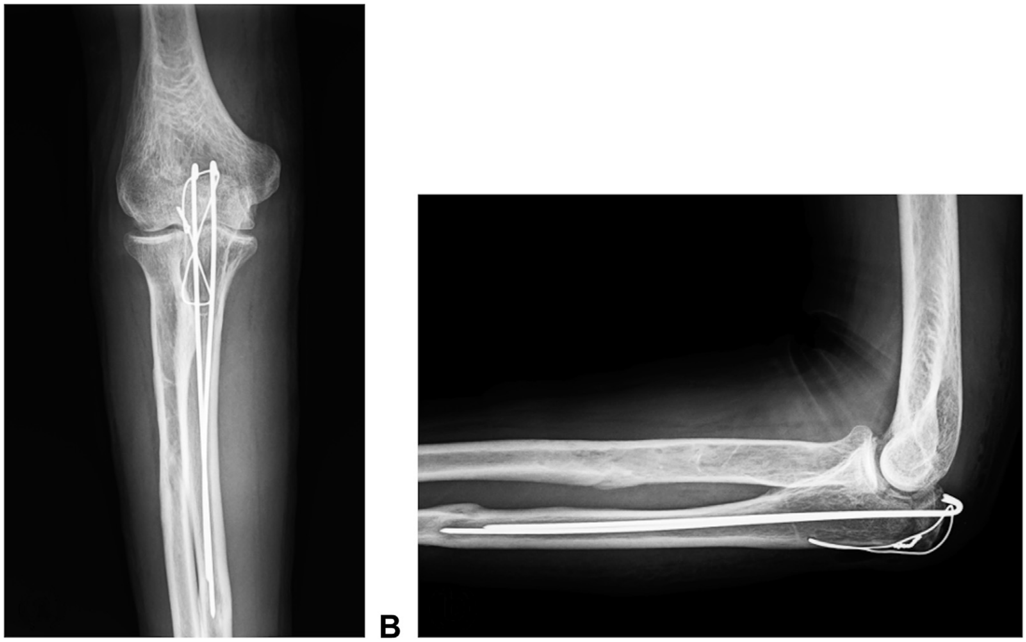
Patients in group A underwent TBW using a conventional bending technique. Subsequently, a K-wire was inserted into the intramedullary space across the fracture line (Fig. 2). Patients in group B underwent TBW with a K-wire penetrating the anterior cortex of the ulna (Fig. 3), whereas those in group C underwent TBW using the double-bending technique (Fig. 4). A total of 10 orthopedic surgeons performed surgeries under the guidance of senior orthopedic surgeons. The choice of the fixation method was made by the attending surgeons.

All the patients were evaluated during a mean follow-up period of 18 months (range: 12–28 months). The mean extension and flexion arcs of the elbow were measured by three senior surgeons using a goniometer and evaluated as clinical outcomes. Additionally, the mean operative time (OT) and estimated blood loss (EBL) were evaluated. Complications, such as backing out of the K-wire (defined as backing out by 5 mm or more [Fig. 5]), restrictions in range of motion (ROM), nonunion, correction loss, refracture, surgical site infection (SSI), pain, and metal irritation, were retrospectively evaluated. Asymptomatic metal removal performed at the request of the patient was not considered a complication. Bone union was confirmed by plain radiography.

This study was approved by the Institutional Review Board of the Clinical Research Support Center of our hospital and the Institutional Review Board of the other participating hospital. All the study procedures were conducted in accordance with the relevant guidelines and principles of the Declaration of Helsinki. All participants provided informed consent to participate in the study, including their consent for publication, and they were free to withdraw from the study at any time.

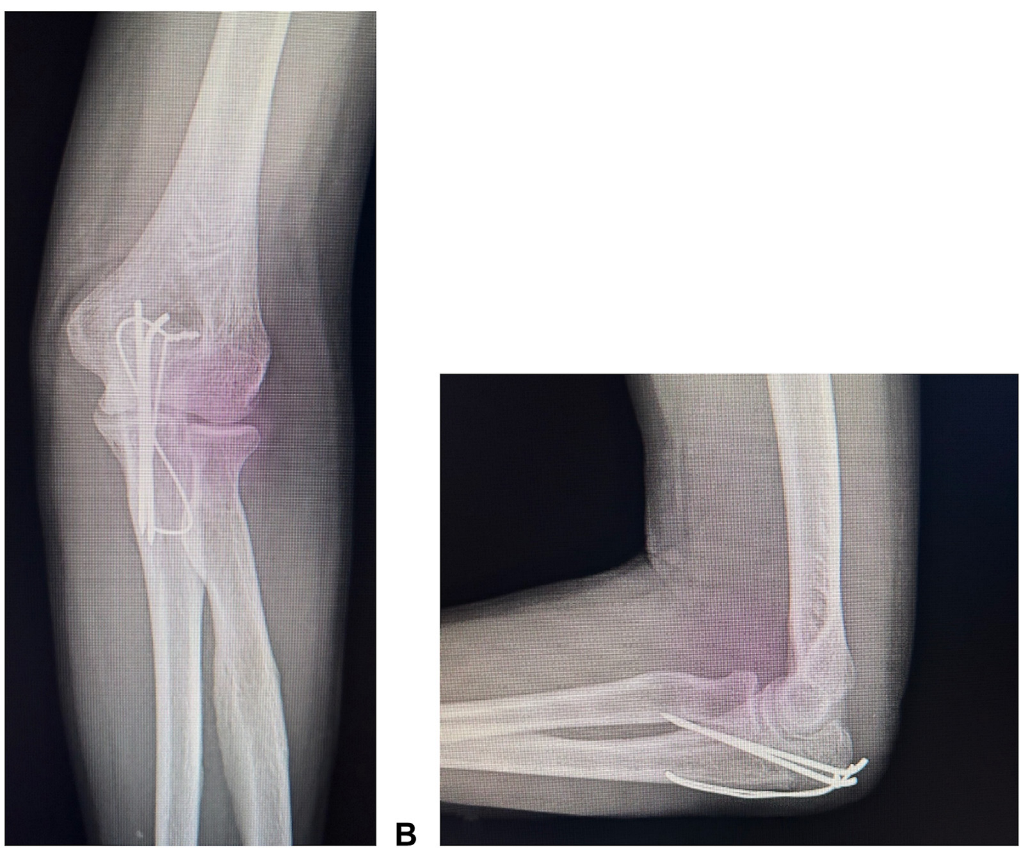
Surgical technique and postoperative treatment

All surgeries were performed under general or regional anesthesia (axillary nerve block) with sedation in the prone or lateral position. A posterior midline incision was made along the ulnar axis to expose the site of the fracture. The reduction was performed under fluoroscopic imaging using a bone clamp. In patients with Mayo type IIB fractures, the intermediate fragment was first reduced and fixed using a K-wire (1.4 mm in diameter); subsequently, the main fragment was reduced. After reduction, the fractured fragment was fixed using a K-wire, and a soft wire was attached to the K-wire. The diameter of the K-wire was 1.8 mm and those of the soft wires were 0.97 mm or 1.0 mm. The K-wire was inserted into the intramedullary space across the fracture line in groups A and C and passed antegrade no further than 10 mm through the anterior cortex in group B. The apex of the K-wire was bent 180° into a U-shape and stuck in the cortex in group A (Figs. 2, 3, and 6). In group C, the apex of the K-wire was bent in two different directions, forming a shape similar to that of a question mark, and the soft wire was hooked to the apex of the bent K-wire (Figs. 4 and 7). Finally, the tips of the bent K-wires were buried in the triceps muscles. In this technique, when the K-wire is forced to back out, the soft wire hooked to the apex of the bent K-wire blocks it mechanically, preventing the K-wire from backing out.



A B

Figure 2. Postoperative anteroposterior (**A**) and lateral (**B**) plain radiographs of group A. The K-wire is inserted into the intrathecal space across the fracture line. The apex of the K-wire is bent 180° into a U-shape and stuck into the cortex.



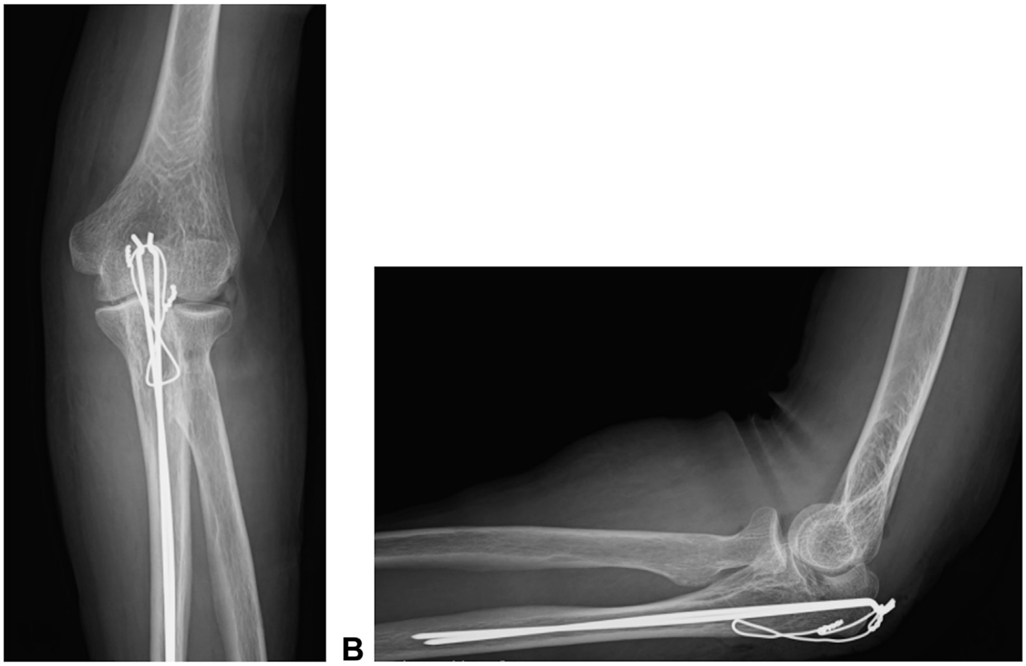
A B

Figure 3. Postoperative anteroposterior (**A**) and lateral (**B**) plain radiographs of group B. The K-wire is passed antegrade no further than 10 mm through the anterior cortex of the ulna.

After the surgery, the elbows were placed in 90° flexion in a long-arm splint, which was removed a week after the surgery. Furthermore, active elbow flexion and extension exercises were initiated.

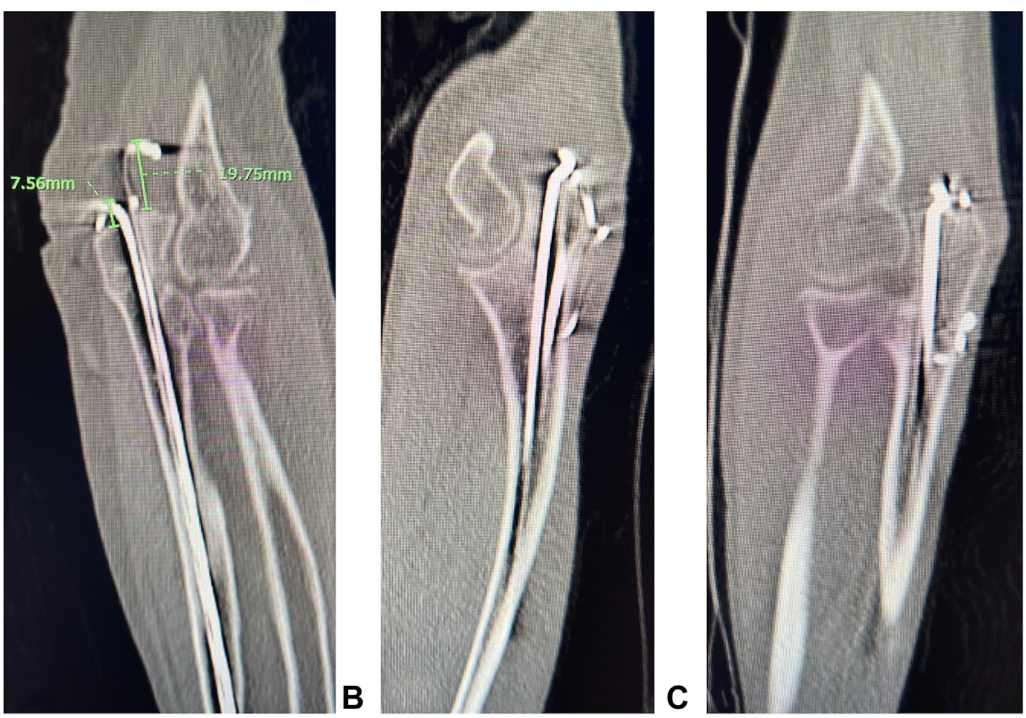
Statistical analyses

Continuous variables, such as age, body mass index, elbow extension arc, elbow flexion arc, OT, and EBL, were summarized as



A B

Figure 4. Postoperative anteroposterior (**A**) and lateral (**B**) plain radiographs of group C. The K-wire is inserted into the intrathecal space across the fracture line. The apex of the K-wire is bent in two different directions similar to a question mark, and the soft wire is hooked to the apex of the bent K-wire.



A B C

Figure 5. Postoperative 3-month CT images of groups A (**A**) and C (**B** and **C**). The measurements in (**A**) indicate a backing out of the K-wire exceeding 5 mm.

the mean, minimum, and maximum, respectively. Data and clinical characteristics were analyzed using one-way analysis of variance and Tukey's multiple comparison tests. Categorical variables, such as backing out of the K-wire and other complications among the three groups, were analyzed using Fisher's exact test and Bonferroni corrections. In the Bonferroni corrections, each P value was tripled, and the significance threshold was set identical to that in the other analyses. Statistical analyses were performed using the R statistical software package (Version 4.2.1; R Development Core Team). The level of significance was set at $P < .05$.

Results

Detailed patient characteristics and fracture types in the three groups are shown in Table 1. No significant difference was found in these parameters among the three groups. Clinical outcomes are

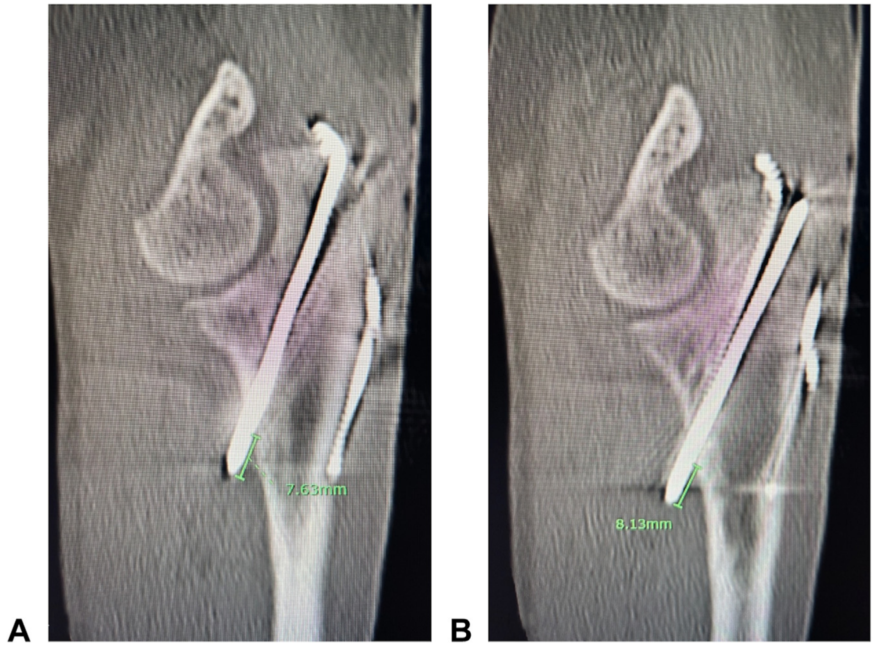


Figure 6. Postoperative CT images of group B. The K-wires are passed antegrade no further than 10 mm through the anterior cortex.

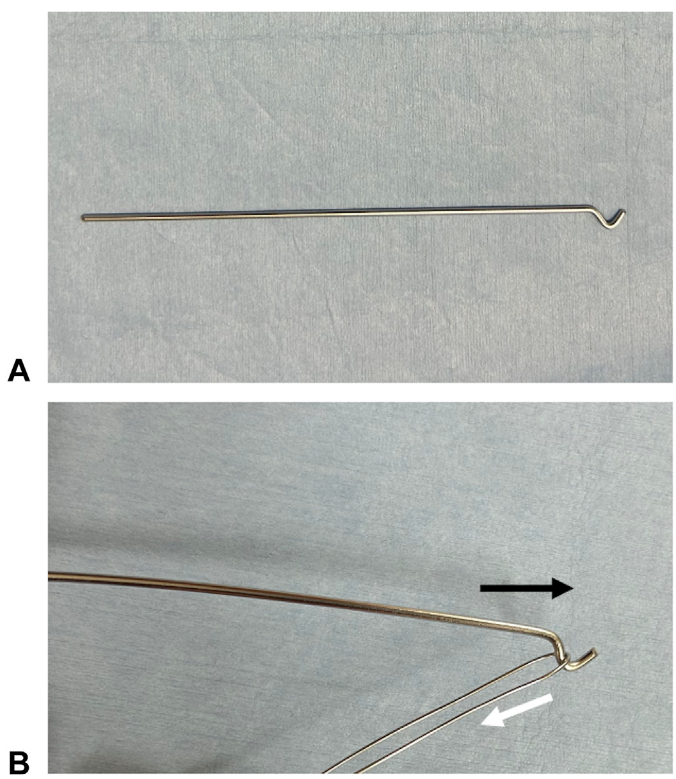


Figure 7. The K-wire is bent according to the double-bending technique. The apex of the K-wire is bent in two different directions similar to a question mark (**A**). The soft wire is hooked at the apex of the bent K-wire. In this technique, when the K-wire is forced to be backed out (black arrow), the soft wire hooked to the apex of the bent K-wire blocks this movement (white arrow) (**B**).

summarized in Table 2. Elbow ROM at the final follow-up before implant removal was evaluated among the three groups. In group A, the mean elbow flexion arc and mean elbow extension arc were 120.4° (range: 80°−140°) and 6.2° (range: 0°−20°), respectively. In group B, the mean elbow flexion arc was 125.9° (range: 70°−140°), and the mean elbow extension arc was 10.9° (range: 0°−40°). In group C, the mean elbow flexion arc was 132.0° (range: 120°−150°), and the mean elbow extension arc was 0° (range: 0°−0°). A significant difference was noted in the elbow extension arc between groups B and C ($P = .001$).

Complications are summarized in Table 3. Eleven patients had backing out of the K-wire in group A and seven in group B; however, no backing out of the K-wire was observed in group C (Fig. 8). In group A, complications included those with restrictions of ROM ($n = 5$), pain ($n = 2$), irritation due to backing out of the K-wire ($n = 5$), correction loss ($n = 1$), nonunion ($n = 1$), SSI ($n = 1$), and implant removal with prominence and discomfort ($n = 8$). Complications, including restrictions of ROM ($n = 14$), pain ($n = 3$), irritation ($n = 1$), and implant removal with prominence and discomfort ($n = 10$), were observed in group B. In group C, a low number of complications, including pain and implant removal in two patients, were observed. A significant difference was observed in the rate of backing out of the K-wire between groups A and C ($P < .001$). The rate of elbow ROM restriction differed significantly between groups B and C ($P < .001$). However, no significant difference was noted between other groups regarding complications, such as pain, irritation, correction loss, implant removal, nonunion, refracture, or SSI.

Discussion

Open reduction internal fixation using TBW is an accepted technique for the surgical treatment of displaced, noncomminuted olecranon fractures with good clinical outcomes and is commonly performed.[4,6,7] Two studies have evaluated the long-term outcomes after TBW for displaced olecranon fractures and reported good clinical and functional outcomes.[8,9] However, recently, the plate fixation technique has been widely used for both simple and comminuted olecranon fractures because of its low complication rate. Few studies have reported no significant difference in clinical outcomes between TBW and anatomical locking plate (ALP),

Table 1
General Characteristics of the Patients Among Three Groups

Demographics	Group A	Group B	Group C	A vs B *P* Value	B vs C *P* Value	A vs C *P* Value
No. of patients	13	17	10			
Sex (M/F)	6/7	4/13	7/3	ns	ns	ns
Mean age, y (SD)	68.9 (14.0)	63.8 (21.3)	57.7 (20.6)	ns	ns	ns
Mean BMI, kg/m^2 (SD)	22.6 (3.5)	20.9 (2.2)	21.4 (3.1)	ns	ns	ns

BMI, body mass index; ns, not significant.

Table 2
Comparison of Clinical Outcomes and Operative Factors Among Three Groups

Demographics	Group A	Group B	Group C	A vs B *P* Value	B vs C *P* Value	A vs C *P* Value
Elbow extension arc, degree (SD)	6.2 (8.5)	10.9 (10.9)	0 (0)	ns	.001	ns
Elbow flexion arc, degree (SD)	120.4 (15.6)	125.9 (17.4)	132 (10.3)	ns	ns	ns
Mean OT, minutes (SD)	62.2 (18.1)	58.8 (13.8)	69.1 (28.0)	ns	ns	ns
Mean EBL, mL (SD)	31.7 (55.5)	17.9 (19.5)	9.1 (7.6)	ns	ns	ns

EBL, estimated blood loss; ns, not significant; OT, operative time.

Table 3
Comparison of Complications Among Three Groups

Demographics	Group A	Group B	Group C	A vs B *P* Value	B vs C *P* Value	A vs C *P* Value
Complications, no (%)						
Backing out of the K-wire	11 (84.6)	7 (41.2)	0 (0)	ns	ns	< .001
Elbow ROM restriction	5 (38.5)	14 (82.4)	0 (0)	ns	< .001	ns
Pain	2 (15.8)	3 (17.6)	2 (20)	ns	ns	ns
Irritation	5 (38.5)	1 (5.9)	0 (0)	ns	ns	ns
Correction loss	1 (7.7)	0 (0)	0 (0)	ns	ns	ns
Removal of the implant	8 (61.5)	10 (58.8)	2 (20)	ns	ns	ns
Nonunion	1 (7.7)	0 (0)	0 (0)	ns	ns	ns
Refracture	0 (0)	0 (0)	0 (0)	ns	ns	ns
SSI	1 (7.7)	0 (0)	0 (0)	ns	ns	ns

ns, not significant; SSI, surgical site infection.

although TBW had a higher complication rate, especially hardware removal due to painful hardware irritation, than ALP.[2–5]

Painful hardware irritation is a common complication requiring hardware removal,[10,11] and a higher incidence of painful hardware has been reported after TBW than after ALP.[12,13] Macko et al[14] have reported in a series of 20 patients that 75% of the patients had prominent painful hardware after TBW. Subsequently, hardware removal was indicated in 65% of all patients.[14] Villanueva et al[9] have shown 46% of hardware removal after TBW at a mean 4-year follow-up. Powell et al[2] have stated that although both TBW and ALP had good clinical outcomes with no significant difference, the total complication rate in the TBW group (39%) was higher than that in the ALP group (0%), especially concerning implant removal. Tarallo et al[4] have reported good clinical outcomes for comminuted and noncomminuted olecranon fractures treated with TBW and ALP, with no significant difference between the groups. However, the implant removal rate was higher in the TBW group (30%) than in the ALP group (9%).

The technique recommended by the Arbeitsgemeinschaft fur Osteosynthesefragen group involves passing the end of the K-wire through the anterior ulnar cortex (group B in this study) to prevent backing out of the K-wire.[15] However, other complications, such as ulnar artery injury, interosseous nerve injury, and restriction of ROM, especially for forearm rotation due to penetration of the K-wire, have been reported.[16–21]

Recent studies have demonstrated the efficacy of the TBW technique using eyelet wires. Shimura et al[22] have compared the clinical outcomes and complications of TBW with eyelet wire and ALP fixation for displaced olecranon fractures and observed good outcomes with no difference between the groups. Furthermore, they reported implant removal rates of 2/24 (8%) in the TBW with the eyelet wire group and 12/34 (35%) in the ALP group. Tsujino et al[23] have revealed that 17 patients with displaced olecranon fractures were treated with TBW using an eyelet wire. However, two patients (12%) required removal of the implant owing to the mild local pain and pain on motion at the tip of the eyelet. Okamoto et al[24] have shown satisfactory clinical results for olecranon fractures using TBW with an eyelet wire. According to these studies, TBW using an eyelet wire may be the best procedure for treating displaced olecranon fractures using the TBW technique. However, eyelet wires (Teijin Nakashima Medical Co., Ltd.; 21,100 Japanese yen each [~150 US$]) are more expensive than K-wires (Mizuho Medical Innovation; 496 Japanese yen each [~3.5 US$]). Thus, K-wires are more cost effective than eyelet wires alone.

In this study, a significantly lower rate of backing out of the K-wire was found in the double-bending technique group than in group A (group A, 11/13 [84.6%]; group B, 7/17 [41.2%]; and group C, 0/10 [0%]). Furthermore, the rate of restriction of ROM, especially the mean extension elbow arc, was significantly lower in group C than in group B (group A, 5/13 [38.5%]; group B, 14/17 [82.4%]; and group C, 0/10 [0%]). The tips of the K-wires penetrating the anterior ulnar cortex in group B and the apex of the backed-out K-wires in groups A and B might have caused irritation and pain around the olecranon, leading to restriction of ROM. Although no significant

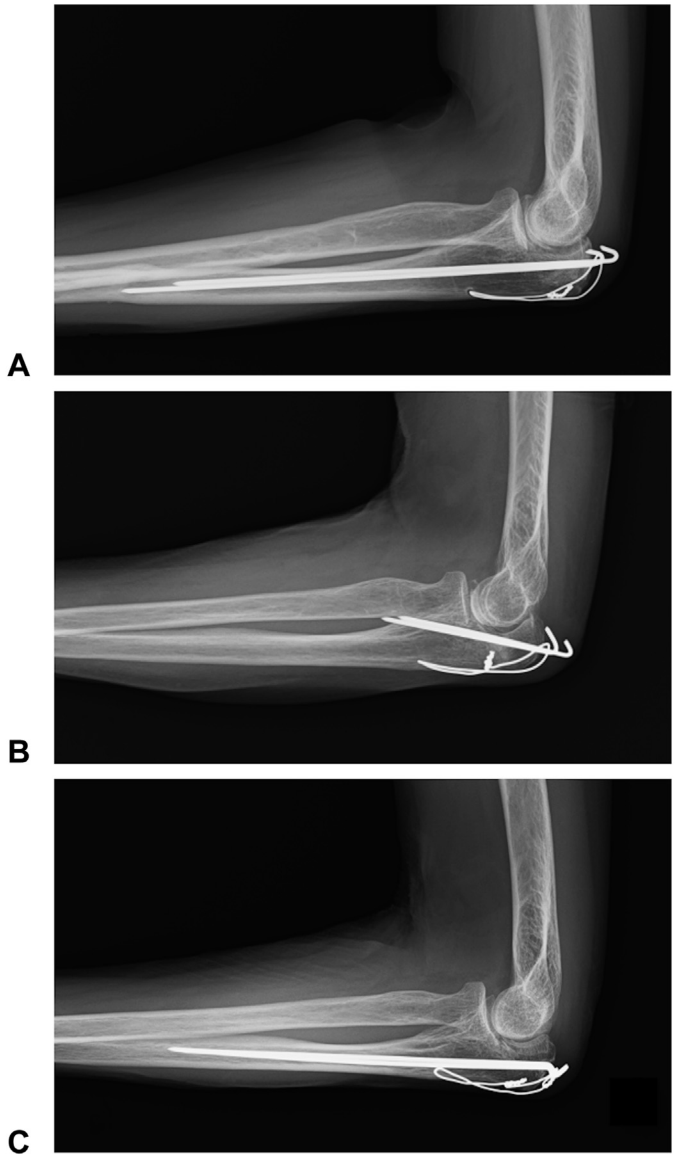


Figure 8. Postoperative 4-week lateral plain radiographs of groups A (**A**), B (**B**), and C (**C**). Backing out of the K-wire is seen in groups A and B.

difference was noted in the rate of backing out of the K-wire between groups B and C and the rate of restriction of ROM between groups A and C, each of those rates was lower in group C.

No significant difference was observed in the rates of implant removal among the three groups. In groups A and B, some patients preferred not to undergo a removal surgery, although the K-wires were backed out because they did not have any complaints such as tenderness of the backed-out K-wires. In group C, two patients had slight pain at the tip of the K-wire while placing their elbow on the table and required additional surgery to remove the K-wire after confirming the union of the fracture site. However, they had no other restrictions and were able to maintain their activities of daily living.

The findings of this study indicate that the double-bending technique is superior to conventional TBW in terms of backing out of the K-wire and complications, such as restriction of ROM. Furthermore, regarding cost-effectiveness, this technique is superior to TBW using an eyelet wire.

This study had several limitations. This retrospective study had a short follow-up period. Moreover, we could not evaluate patient-related functional scores, such as the Mayo Elbow Performance Score or disabilities of the arm, shoulder, and hand. Regarding the choice of implant and surgical method, the selection criteria for plate fixation or TBW were clear. However, the choice of the method in TBW was based on the surgeon's preference and experience, which may have led to selection bias. In group B, 7 of the 17 patients had backing out of the K-wires, which was much higher than that reported in previous studies. This might have occurred because of a technical error. The surgeons might have inserted the K-wires multiple times, and the anterior cortex of the ulna might have been weakened and unable to hold the K-wire and prevent it from backing out.

In conclusion, this report describes the usefulness of the double-bending technique. The double-bending technique is superior to conventional TBW in terms of backing out of the K-wire and postoperative complications, especially restriction of ROM. Hence, this technique may be the best procedure for treating olecranon fractures that are treatable by TBW.

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