



Tension band wiring through double-cannulated screws as a new internal fixation method for treatment of olecranon fractures: a randomized comparative study

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Objective: The aim of this study was to assess the therapeutic effects and complications of tension band wiring (TBW) through the use of double-cannulated screws versus conventional TBW in the treatment of olecranon fractures.

Methods: Eligible participants were randomly assigned to 2 groups to undergo different methods of fixation. The related indices and data of the 2 groups were collected for comparative analysis after an average follow-up of 32.7±6.6 months.

Results: Average fracture healing time was 11.4 weeks in the double-screw TBW group and 12.6±1.8 weeks in the conventional TBW group (p=0.000). There was significant difference in complications related to fixation between the 2 groups. In the double-screw TBW group (42 patients), 2 patients felt screw head prominence with no pain and requested no further intervention; in contrast, 21 patients experienced complications associated with internal fixation in the conventional TBW group. Mean Mayo Elbow Performance Score (MEPS) score was 87.90±6.0 in the double-screw TBW group, compared to 83.67±6.6 in the conventional TBW group at 24-month follow-up (p=0.002). The rate of elbow function in the double-screw TBW group (29/42, 69.05%) was higher than that of the conventional TBW group (16/46, 34.78%) (p=0.000).

Conclusion: In comparison with conventional TBW, TBW with double-cannulated screws can significantly reduce complications, lower reoperation rate, improve elbow function, shorten healing time, as well as diminish surgical trauma.

Keywords: Cannulated screw; internal fixation; olecranon fracture; tension band wiring.

Level of Evidence: Level I Therapeutic Study

Olecranon fractures are common in adults, accounting for 10% of fractures related to the elbow joint.^[1] When displacement is larger than 2 mm, olecranon fractures require operation.^[2] Tension band wiring (TBW) is the most common method of fixation and is considered to be

the gold standard for treatment of olecranon fracture.^[3–6]

However, postoperative complications such as Kirschner wire (K-wire) migration, symptomatic prominence of K-wires, and higher reoperation rate for implant removal occur in a substantial proportion of patients.^[1,5–10]

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Fig. 1. Postoperative radiographs of olecranon fractures of conventional TBW in the treatment of olecranon fractures.

These complications are directly or indirectly correlated with K-wires. Therefore, this study introduces a new internal fixation method using double-cannulated screws instead of K-wires for TBW, in an attempt to reduce complications, decrease reoperation rate, and achieve good curative efficacy.

To our knowledge, there have been no reports published on this new fixation method in the treatment of olecranon fractures.

The purpose of this randomized comparative study is to assess the therapeutic effects and postoperative complications of the new fixation method by comparing it with conventional TBW.

Patients and methods

There were 2 participating regional medical centers: Taizhou People's Hospital (Hospital Affiliated to Nantong University) and The First Affiliated Hospital of Soochow University.

From July 2009 to December 2010, consecutive olecranon fracture patients treated in the 2 medical centers were enrolled in this study. Inclusion criteria were patients aged between 20 to 70 years old who had non-comminuted or short oblique fractures which were unilateral, fresh, closed, and with a displacement <2 mm. Exclusion criteria were pathological fractures accompanied by other associated injuries which could impact treatment and postoperative function exercise, and refusal to participate in the study.

Eligible participants were randomly assigned to 2 groups for different methods of fixation: TBW through double-cannulated screws (double-screw TBW group) and conventional TBW (conventional TBW group). All participants gave written informed consent.

This study was approved by the human research eth-

ics committee of the 2 participating medical centers, in compliance with China's relevant laws and regulations.

In conventional TBW, after exposing the fracture site through posterior approach, the olecranon fracture was accurately reduced with bone clamps (Figure 1). Two 2.0-mm diameter parallel K-wires were inserted through the fracture site into the ulnar intramedulla from the tip of the olecranon, parallel to the long axis of the ulna. A figure-eight pattern was formed with a 1.0-mm stainless steel wire, passing through a 2.0-mm diameter hole that was drilled perpendicular to the long axis of the ulna on the posterior cortex of the ulna, crossing in a figure-eight, then bypassing the end of the K-wires, and twisted together. The figure-eight construct was tightened through twisting the steel wires on both sides to achieve the appropriate tension.

In double-screw TBW (Figure 2), the olecranon fracture was repaired by making 2 small incisions. The primary incision, approximately 4.0-cm long and located above the olecranon, was made through posterior approach to reveal the fracture site. After the olecranon fracture was accurately reduced, good contraposition was maintained by using 2 towel clamps. From the tip of the olecranon, 2 parallel 1.6-mm guide pins, angled towards the posterior ulna, were inserted through the fracture site, perforating the posterior ulna cortex. After the guide pins perforated the posterior ulna cortex, an incision approximately 1.5-cm in length was made to reveal the position where the guide pins protruded from the cortex. Two 4.5-mm diameter Arbeitsgemeinschaft für Osteosynthesefragen (AO) cannulated screws of suitable length were inserted in place of the 2 guide pins, with their tips placed in the posterior cortex of the ulna and heads inserted in the tendon of the triceps. An anesthetic trocar was placed subcutaneously to connect the proximal and distal incisions, close to the posterior cortex. A 1.0-mm stainless steel wire was threaded through the cannulated screw and the anesthetic trocar, from the head of one screw to the head of the other screw. The above operation was repeated with a 1.0-mm stainless steel wire, threaded through the other screw to a third screw head through the trocar guide. Finally, both wires were twisted together, creating a subcutaneous figure-eight.

External gypsum or orthosis were not used to secure the injured elbow postoperatively, and the elbow was placed in a triangular bandage in a position flexed to 90°. Approximately 3 days later, passive activities of the elbow were initiated. Active flexion and weight-bearing extension were permitted in the second week postoperatively. Exercise intensity was increased gradually, at the same time to avoid rude. Resistance exercises were al-

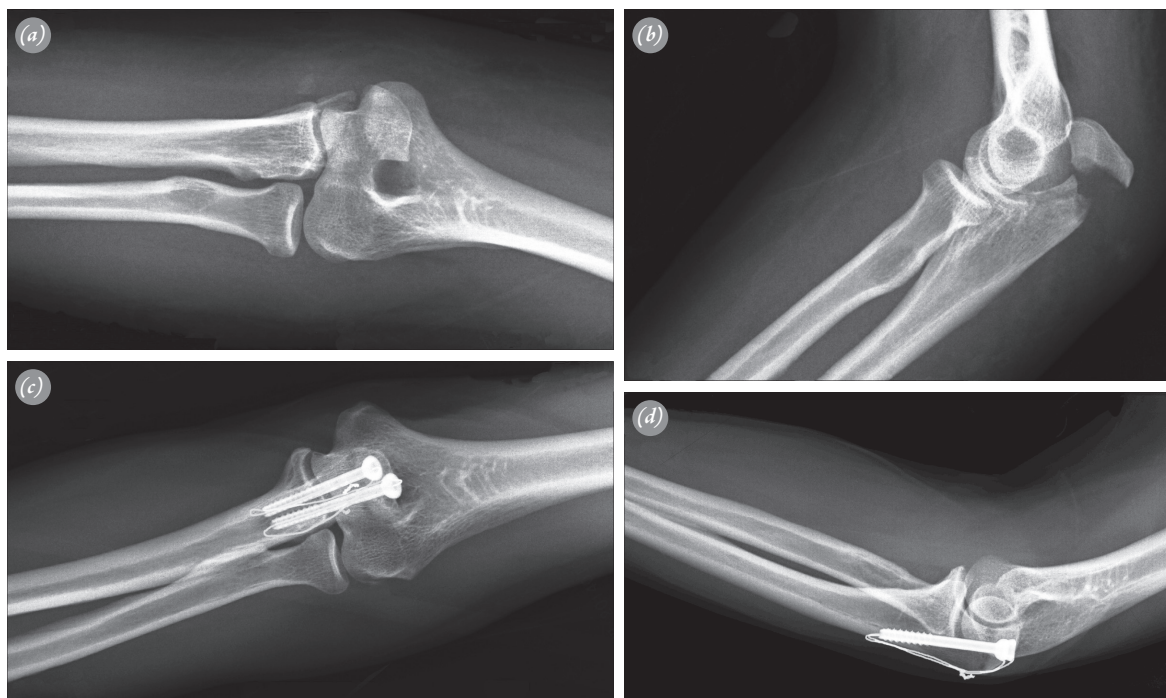


Fig. 2. TBW through double-cannulated screw in the treatment of olecranon fractures. **(a, b)** Preoperative anteroposterior and lateral radiographs of olecranon fractures; **(c, d)** Postoperative radiographs of TBW through double-cannulated screws in the treatment of olecranon fractures.

lowed, depending on the radiological evidence of union at approximately 10 weeks postoperatively. Strenuous activities were not allowed for 3 months postoperatively.

Relevant intraoperative data such as operation time, incision length, and intraoperative blood loss were recorded by 2 nurses. The healing time of fracture, complications such as loosening and migration of implant, and displacement of fracture were confirmed by standard digital anteroposterior and lateral radiographs of the elbow joint, which were taken weekly in the first 3 months postoperatively and once every 3 months thereafter in the subsequent follow-up period. All digital radiographs were assessed by an independent senior radiologist. Evaluation of elbow joint function postoperatively was accomplished by 2 methods: measuring the range of motion (ROM) of the elbow with handheld goniometer (Guangzhou David Technology Co. LTD, Guangzhou, China) and assessing the elbow joint recovery in comparison with the contralateral elbow at 3-month, 6-month, 1-year, and 2-year follow-up; and evaluating comprehensive functional outcome measures, based on the Mayo Elbow Performance Score (MEPS)^[11] index completed by all patients at 2-year follow-up.

Univariate analysis was used for comparative analysis of the pre- and postoperative indices. Independent sample t-test was used for continuous variables, and chi-squared test or Fisher's exact test were used for categori-

cal variables. SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. A p value <0.05 was considered to be statistically significant.

Results

Eighty-eight patients were included in this study from 2 medical centers (48 patients in Taizhou People's Hospital and 40 patients in First Affiliated Hospital of Soochow University).

Fifty-seven patients were male and 31 female, with a mean age of 41.86 ± 12.22 years (range: 21–62 years). According to the Schatzker classification system,^[12] there were 39 cases of type A (transverse) fracture and 49 cases of type C (oblique) fracture. All patients completed follow-up, with mean follow-up of 32.7 ± 6.6 months (range: 24–40 months).

Eighty-eight participants were randomly assigned to the double-screw TBW group (42 patients) or conventional TBW group (46 patients). As shown in Table 1, mean total length of the 2 small incisions in the double-screw TBW group (5.3 ± 0.53 cm) was significantly less than that of the conventional TBW group (8.69 ± 1.29 cm) ($p=0.000$). Besides length of incision, other factors related to operation (type of fracture, operation time, and intraoperative blood loss) and demographic factors (age, gender) showed no differences between the 2 groups.

All patients healed in 3 months. Mean healing time in the double-screw TBW group (11.38 ± 1.2 weeks) was less than that of the conventional TBW group (12.6 ± 1.8 weeks) (Table 2). Statistical difference between the 2 fixation methods was verified ($p=0.000$).

In the 2-year follow-up period, no significant complications occurred in the 42 patients of the double-screw TBW group; 2 patients felt a foreign body sensation caused by prominent screw head, with no pain, and requested no further intervention. However, 21 patients in the conventional TBW group experienced complications associated with internal fixation. Following foreign body sensation with no pain or other complications (10 cases), the most common complication was symptomatic prominence of the K-wires (9 cases). Three of these 9 cases cases with symptomatic prominence had measurable migration of the K-wires (1 case occurred at 4 weeks postoperatively and 2 cases at 7 weeks postoperatively), causing skin ulceration in 2 of the 3 cases and local infec-

tion in 1 case. In addition to the 3 cases of measurable migration of the K-wires, there was 1 other case, occurring 12 weeks postoperatively, but with no pain (migration has no further development through reducing functional activities). Implant loosening occurred in 1 case; this resulted in a mildly displaced fracture at 11 weeks postoperatively, which was healed in 6 weeks through external fixation with gypsum. Hardware removal was performed for symptomatic prominence in 9 cases and implant loosening in 1 case (10/46, 21.74%).

Results of the present study suggest that the new double-screw TBW internal fixation method is beneficial to the recovery of the elbow joint. Compared with the contralateral healthy elbow, the double-screw TBW group was significantly better than the conventional TBW group at follow-up ($p=0.000$) (Table 3). At 24-month follow-up, mean MEPS score in the double-screw TBW group was (87.90 ± 6.0) was higher than that of the conventional TBW group (83.67 ± 6.6 ,

Table 1. Comparison of demographics, fracture classification, and operative outcomes between double-screw TBW group and conventional TBW group for treatment of transverse or oblique olecranon fractures.

	Double-screw TBW group (n=42)	Conventional TBW group (n=46)	p
Gender			
Males	26	31	0.590 ^a
Females	16	15	
Age (years)	39.81 ± 12.7	43.74 ± 11.6	0.133 ^b
Schatzker classification			
Type A	18	21	0.792 ^a
Type C	24	25	
Operation time (min)	48.71 ± 10.1	48.43 ± 9.7	0.895 ^b
Blood loss (ml)	60.35 ± 25.9	55.33 ± 23.25	0.340 ^b
Length of incision (cm)	5.3 ± 0.53	8.69 ± 1.29	0.000 ^b

^aChi-squared test; ^bIndependent-samples t-test.

Table 2. Comparison of fracture healing time and elbow function between double-screw TBW group and conventional TBW group for treatment of transverse or oblique olecranon fractures.

	Double-screw TBW group (n=42)	Conventional TBW group (n=46)	p
Fracture healing time (weeks)	11.38 ± 1.2	12.6 ± 1.8	0.000 ^b
MEPS score	87.90 ± 6.0	83.67 ± 6.6	0.002 ^b
Elbow function (MEPS) ^a			
Excellent	29	16	
Good	12	26	
Fair	1	4	
Poor	0	0	
Excellent rate	69.05% (29/42)	34.78% (16/46)	0.001 ^c

MEPS: Mayo Elbow Performance Score; ^aElbow function: Excellent: ≥ 90 points; Good: 75–89 points; Fair: 60–74 points; Poor: <60 points; ^bIndependent-samples t-test; ^cChi-squared test.



Fig. 3. A 30-year-old woman with left olecranon fracture in the double-screw TBW group obtained excellent functional outcome at 24-month follow-up (MEPS score: 100). [Color figure can be viewed in the online issue, which is available at www.aott.org.tr]

$p=0.002$) (Table 2). The excellent rate of elbow function in the double-screw TBW group (29/42, 69.05%) was higher than that in the conventional TBW group (16/46, 34.78%, $p=0.001$) (Table 2) (Figure 3).

Discussion

A series of complications have been reported related to TBW. Symptomatic metal prominence is the most common complication, with an occurrence rate from 9.75–80%.^[8,10,13,14] Other complications include migration of the K-wire, skin ulceration, and infection,^[8,13] which are responsible for 45.9–81% of cases of hardware removal.^[10,15,16]

These complications may result from K-wires. The bent end of a K-wire is prominent to the bone cortex, which can not only stimulate partial organization but also be easily incarcerated in triceps. Significantly, K-wire, which is unthreaded and cannot firmly fix in bone, has a tendency to be retracted by the triceps during elbow activities. Over time, nonimpacted wires could be pulled out by the action of the triceps during exten-

sion,^[17] causing migration of the K-wire and aggravation of other complications.

Therefore, TBW procedures were improved in an effort to avoid complications. Eliminating the K-wire and directly using figure-eight wiring to fix the fracture was one approach. Karlsson MK^[15] reported that the reoperation rate of hardware removal when using figure-eight wiring alone is far lower than that of TBW (43%:81%). Some scholars believe that changing the K-wire position, especially by penetrating the anterior ulna cortex, enhances the grasping force of the K-wire, thus reducing the risk of migration.^[5,18,19] Since K-wire is unthreaded and prone to migration, replacing K-wire with a single screw to permit tensioning of the band was an improvement on TBW. Johnson RP reported that 6.5-mm cancellous screws assisted with tension band obtained excellent prognosis in patients with osteoporosis and comminuted fracture.^[20] In addition to single-screw fixation, double-screw fixation has been studied in recent years. When compared with TBW, double-screw fixation has equivalent strength and improved

Table 3. Comparison of elbow joint activities between double-screw TBW group and conventional TBW group for treatment of transverse or oblique olecranon fractures.

Group	Motion lag versus contralateral healthy elbow (Flexion/ extension ROM)			
	3 months	6 months	12 months	24 months
Double-screw TBW group	73.45±12.9° (102.17±8.6°/33.57±5.3°)	19.64±6.66° (127.02±5.7°/8.69±4.4°)	10.12±7.5° (134.76±4.4°/6.43±5.1°)	10.24±6.4° (135.12±3.7°/5.57±3.7°)
Conventional TBW group	88.65±12.4° (89.28±9.0°/35.76±6.1°)	38.70±9.57° (121.41±8.5°/15.53±4.8°)	27.50±9.1° (130.54±5.2°/15.01±3.8°)	19.89±7.6° (134.24±4.9°/14.45±4.1°)
p^a	0.000 (0.000/0.079)	0.000 (0.01/0.000)	0.000 (0.000/0.000)	0.000(0.352/0.000)

^aIndependent-samples t-test.

stability in biomechanical study.^[21] In clinical research, double-screw fixation has less frequent hardware removal and better functional results.^[22]

Inspired by the above research, this study proposes an alternative technique for tension band construction that uses double-cannulated screws instead of K-wires. Different from the single-screw fixation technique combined with TBW that has been previously reported,^[20,23–25] TBW is formed through double-cannulated screws rather than passing from the anterior to the head of the screw. Additionally, the tips of the threads of 2 screws were fixed in the cortex of the dorsal ulna but not into the medullary cavity. This structure of new fixation could not only enhance the pullout strength of the screw but also avoid the risk of vascular and anterior interosseous nerve injury.^[7,26,27] More importantly, it forms an integrated structure, which avoids the possibility of wire slippage, strengthens the reliability of fixation, and discards K-wire—the main factors causing complications. The wires go through the tendon of the triceps brachii directly from the smooth screw heads, which reduces the stimulation to local tissue. None of the 42 patients from the double-screw TBW group experienced significant complications, with 2 feeling the screw head but with no pain.

The present study demonstrates that the double-screw TBW group had a shorter healing time (11.38 ± 1.2 weeks, $p=0.000$), which is probably due to the pressure effect of the cannulated screws on the fracture end. Furthermore, wires threaded through double-cannulated screws rather than a hole drilled in the ulna to perform tension band has the advantage of simplifying the operation process, which shortened operation time and made the use of a small incision possible without special equipment. Although the new fixation structure appears to be more complex than that of conventional TBW, there were no statistical differences in operation time between the 2 groups ($p=0.895$), even though the double-screw TBW group had a smaller incision than the conventional TBW group ($p=0.000$).

This study suggests that the new double-screw TBW fixation technique is conducive to the recovery of joint function. Both the excellent results (69.05%) and average MEPS score (87.90 ± 6.0) in the double-screw TBW group are significantly higher than those in the conventional TBW group ($p<0.05$) (Table 2). Loss of motion in terminal extension was a shared adverse consequence. Both groups had a certain degree of extension limitation, but the limitation was significantly higher in the conventional TBW group, except at the 3-month follow-up. Taking into account that the olecranon fracture did not

heal within approximately 3 months postoperatively, the elbow was suspended in triangular bandage for protection, in addition to functional exercise, which may have affected the recovery of elbow joint extension motion in all patients.

Above all, the overall efficacy of the new fixation technique was encouraging, though the clinical indices and time to new fixation could not be greatly improved in absolute terms, compared with conventional TBW. As TBW is the gold standard, it could be very difficult for the new fixation technique to show significant improvement. However, statistical analysis showed a significant difference (Table 2, Table 3).

More importantly, the double-screw TBW group did not develop significant complications, nor did it produce any reoperation cases, which stands in contrast to the high rates of complications and reoperation in the conventional TBW group, and highlights the key advantages of the new fixation technique.

There were some limitations to this study. With only 2 participating hospitals, we were unable to include a wider area with more eligible participants. Collection and measurement of parameters were performed separately, rather than at one place, which increased the probability of error.

In conclusion, compared with conventional TBW, TBW through double-cannulated screws is a more effective and reliable internal fixation method, which could significantly reduce complications, lower reoperation rate, improve elbow function, shorten healing time, as well as diminish surgical trauma through the use of smaller incisions.

Conflicts of Interest: No conflicts declared.

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