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Research article

Clinical outcomes of olecranon sled fixation in patients with Mayo type II olecranon fractures

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ABSTRACT

Background: Tension band wiring and plate fixation are common internal fixation methods used for olecranon fractures, but complications and reoperations are common. The purpose of this study is to investigate the clinical outcomes of displaced olecranon fractures treated with olecranon sled internal fixation.
Methods: The data of 39 patients with olecranon fractures treated with olecranon sled in the Department of Traumatology of Beijing Jishuitan Hospital between May 2018 and April 2020 were retrospectively analyzed. There were 17 males and 22 females; the mean age was 44.0 ± 15.8 (range, 18–68 years). Preoperative olecranon fractures were classified according to the Mayo classification: 24 cases were type IIA and 15 cases were type IIB. Elbow range of motion (extension and flexion) and forearm rotation (protonation and supination) were observed at the last follow-up. The Mayo elbow performance score (MEPS), Disabilities of the arm, shoulder and hand (DASH) and visual analogue scale (VAS) scores were used to evaluate elbow function and pain, and complications were also recorded.
Results: Thirty-nine patients were followed up for 33.6 ± 8.3 months (range, 25–51 months) after the operation. At the last follow-up, the mean flexion-extension arc was 137° ± 15° (range, 60°–160°), and the mean pronation-supination arc was 178° ± 4° (range, 160°–180°). The mean MEPS was 94.9 ± 9.9 (range, 50.0–100.0). The mean DASH score was 5.4 ± 4.3 (range, 0–18.3). The mean VAS score was 0.4 ± 0.8 (range, 0–3). Seven patients developed olecranon skin irritation, and 3 of them had the internal fixation device removed. Two patients developed heterotopic ossification, of whom 1 patient suffered elbow stiffness.
Conclusion: Olecranon sled internal fixation has good clinical outcomes in the treatment of Mayo type II olecranon fractures with a low rate of reoperations.

Olecranon fractures are one of the most common types of elbow fractures, accounting for approximately 10 % of upper limb fractures [1]. Common mechanisms of injury include indirect force from falls and direct trauma from high-energy trauma [2]. Due to the traction of the triceps brachii muscle, olecranon fractures can easily become displaced. Conservative treatment is difficult to

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achieve a good outcome, so surgical treatment is recommended in most cases. At present, the commonly used surgical methods are mainly tension band wiring (TBW) and plate fixation [3].

The clinical effect of these surgical methods for treatment of simple olecranon fracture was generally satisfactory. However, when using TBW, the Kirschner wire is easily displaced proximally, resulting in a high rate of internal fixation device removal [3]. Plates are relatively bulky, tending to provoke internal fixation irritation and hardware removal, especially in thin Asian people [4]. Olecranon sled (TriMed Inc. Valencia, CA) is a novel internal fixation technique used to treat olecranon fractures, and because the olecranon sled is low profile and the technique employs the use of a continuous single-wire loop design, it may effectively reduce the rate of hardware removal (Fig. 1) [5]. However, only 1 study have reported the clinical outcomes of olecranon sled in treatment of olecranon fracture, and the number of included patients is relatively small [6].

This study not only focused on the functional results and complications, but also discussed the difference of curative effect between Mayo type IIA and type IIB. The purpose of this study was to analyze the clinical outcomes of Mayo type II olecranon fracture patients treated with olecranon sled.

1. Materials and methods

We have retrospectively studied a group of Mayo type II olecranon fracture treated with olecranon sled. Among 676 patients with an olecranon fracture who were admitted in our hospital from May 2018 through April 2020, we collected those who had been diagnosed as “Mayo type II olecranon fracture” by a senior surgeon during the admission. Overall, 548 patients were identified. Only 63 patients were treated with an olecranon sled by the same surgeons (Zha.Y. and Chen.C.)

1.1. Inclusion & exclusion criteria

The study’s inclusion criteria were as follows: (1) Mayo type II olecranon fractures, (2) treated with olecranon sled only, (3) age≥18 years, (4) follow-up for more than 24 months. Exclusion criteria were as follows: (1) patients with open fractures, (2) associated fractures in the same limb, (3) tumor-related pathological fractures, (4) refused to follow up. The study protocol was approved by the hospital ethics board and written informed consent was obtained from all participants prior to their involvement. The series included 39 Mayo type II olecranon fractures treated with the olecranon sled.

1.2. Data collection

Demographic characteristics and radiographic data were retrieved from electronic medical records and then reviewed. All patients underwent standard anteroposterior and lateral elbow radiography at the follow-up. Elbow arc of motion (extension and flexion) and forearm rotation (protonation and supination) were measured in the outpatient department. The clinical outcomes were also evaluated using the Mayo Elbow Performance Score (MEPS), the visual analogue scale (VAS) score and the Disabilities of the arm, shoulder and hand (DASH) score [7]. In the MEPS, a total score of 90–100 points indicates excellent outcome; 75 to 89 points, good; 60 to 74 points, fair; and 0 to 59 points, poor. Complications such as nonunion, infection, neurovascular injury, implant irritation, internal fixation device removal and other reoperations were recorded.

1.3. Surgical technique

All patients were operated under brachial plexus block anesthesia. All patients were placed in the supine position with the affected

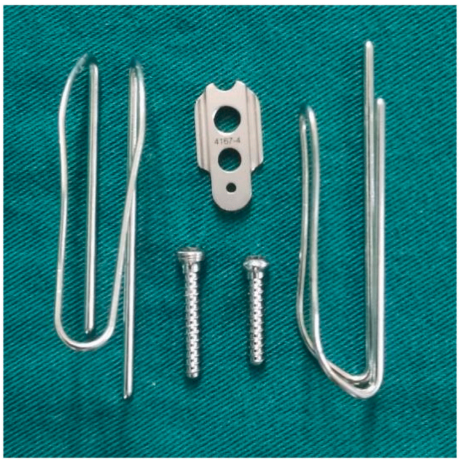

Fig. 1. Configuration of olecranon sled: head-on view of the sled (left), washer and two screws (middle), and side view of the sled (right).

side padded above the chest. A standard posterior approach was used to expose the olecranon fractures. The collapsed articular surface was reduced. If there was any free bone fragment, it was fixed with screws. The sled drill guide was attached to the proximal olecranon. Through the drill guide, two holes were drilled with the 2.0 mm drill bit, and then two 0.9 mm guide pins were inserted. The tips of the olecranon sled are hollow so that the tips could be placed on the guide pins and then pushed into the predrilled holes in the olecranon. Standard impactors were then used to fully seat the olecranon sled against the bone. The groove of the washer drill guide was engaged to the distal loop of the sled, and the compression force was applied by pushing distally. Three holes were drilled using a 2.3 mm long drill on the dorsal proximal ulna. The washer was applied, and two 3.2 mm screws were inserted in the two most proximal holes on the washer, loosening each screw by one-quarter turn to allow the sled to glide along the washer. A 3.2 mm cortical screw was inserted into the distal hole. When the distal screw was fully seated, the sled was further moved distally, which compressed the fracture. The final fixation was achieved by replacing locking screws in the middle hole.

1.4. Post-operation rehabilitation

Functional exercise was performed on the second day after the operation, which mainly included flexion and extension of the elbow and rotation of the forearm. Active exercise and mild passive exercise were both performed. Appropriate active strength exercise was allowed after 1 month.

1.5. Statistical analysis

IBM SPSS 24.0 for Windows (IBM, Armonk, NY, USA) was used to perform all statistical analyses. Categorical data were analyzed with the $\chi 2$ test or Fisher's exact test as appropriate. Continuous variables were described as the mean ± standard deviation or median (25th percentile, 75th percentile) and compared by the *t*-test or Mann−Whitney *U* test (if they did not follow a normal distribution), respectively. The level of significance was set as $P < 0.05$.

2. Results

We identified 63 patients with Mayo type II olecranon fracture treated with olecranon sled over a three-year period. Following a further review, 24 patients were excluded, including 4 younger than 18 years, 7 with associated fractures in the same limb, 2 with open fractures, and 11 patients' refusal. Finally, 39 patients (17 males, 22 females; mean age 44.0 ± 15.8 years; range, 18–68 years) were enrolled in the study (Fig. 2). Twenty-eight patients sustained injuries after falls on the ground. Ten patients were injured in motor vehicle accidents, and one patient was struck by a heavy object.

Thirty-nine patients, 24 with Mayo type IIA fractures and 15 with Mayo type IIB fractures, were followed up for 33.6 ± 8.3 months (range, 25–51 months) after the operation (Table 1). The average BMI of the patients was 22.5 ± 3.2 (range, 16.0–28.4). At the last follow-up, the flexion-extension arc of the 39 patients was 137° ± 15° (range, 60°–160°) with a mean elbow flexion of 142° ± 10° (range, 90°–150°) and a mean elbow extension of 4° ± 6° (range, −10°-30°). The mean forearm protonation was 89° ± 8° (range,

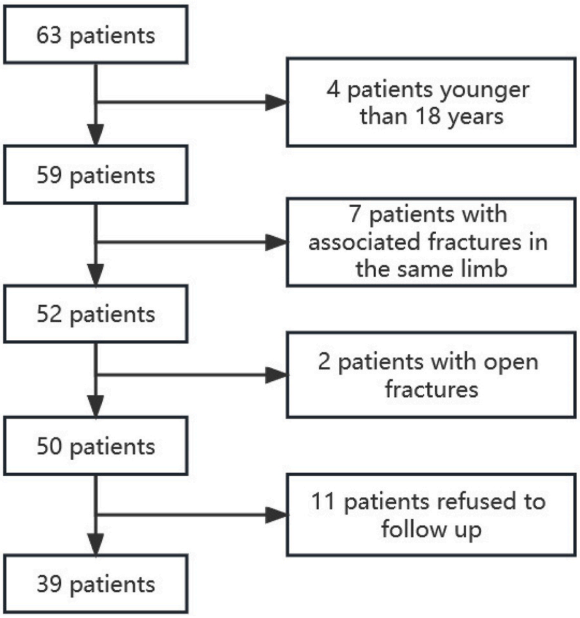

Fig. 2. Selection of patients for the study.

Table 1
Patients' demographics, clinical characteristics, and postoperative results.

CaseNo.	Gender	Age, yr	Injuryside	Injury Mechanism	BMI	ASA	MayoClassification	DurationofFollow – Up, mo	Extension – FlexionROM,°	pronation – supinationROM,°	Extension,°	Flexion,°	Pronation,°	Supination,°	MEPS	DASH	VAS	Hardwareremoval	Comlications
1	Female	58	Left	Slip	17.6	I	IIA	25	135	170	5	140	85	85	100	0.8	0	No	
2	Female	55	Right	Slip	25.2	I	IIB	29	60	180	30	90	90	90	50	18.3	1	No	elbow stiffness, HO
3	Female	27	Left	Slip	16.1	I	IIA	27	140	180	10	150	90	90	100	5.0	0	No	
4	Male	37	Left	Slip	24.1	I	IIB	28	140	175	5	145	85	90	100	4.2	0	No	
5	Female	34	Left	Traffic accident	20.8	I	IIA	26	125	180	10	135	90	90	100	1.7	0	No	
6	Male	71	Left	Slip	27.9	I	IIA	25	145	175	0	145	85	90	85	1.7	3	No	
7	Female	49	Left	Traffic accident	23.5	I	IIA	26	150	180	0	150	90	90	85	5.0	1	No	PMI
8	Female	35	Left	Traffic accident	20.2	I	IIA	25	135	180	10	145	90	90	85	5.0	1	No	HO
9	Female	23	Left	Traffic accident	20.8	I	IIA	28	150	180	0	150	90	90	85	5.8	1	No	PMI
10	Female	63	Left	Slip	21.6	II	IIA	28	145	175	0	145	85	90	100	1.7	0	No	
11	Male	64	Left	Slip	21.8	II	IIA	25	145	170	5	150	85	85	85	3.3	1	No	PMI
12	Male	27	Left	Slip	18	I	IIB	27	125	180	10	135	90	90	85	8.3	2	No	
13	Female	62	Right	Slip	22.9	I	IIA	25	130	180	15	145	90	90	85	6.7	1	No	
14	Male	28	Left	Slip	24.2	I	IIA	25	140	180	10	150	90	90	100	0.0	0	No	
15	Female	27	Left	Slip	16.7	I	IIB	26	150	180	0	150	90	90	100	0.0	0	No	PMI
16	Female	63	Right	Slip	25.9	I	IIB	26	140	180	0	140	90	90	100	9.2	0	No	
17	Male	63	Right	Slip	23.6	I	IIA	29	130	180	0	130	90	90	100	10.0	0	No	
18	Female	50	Left	Slip	19.5	I	IIA	27	135	175	5	140	85	90	100	4.2	0	No	
19	Female	40	Right	Slip	19.5	I	IIA	30	150	180	0	150	90	90	100	2.5	0	Yes	PMI
20	Male	45	Right	Traffic accident	26.6	IV	IIB	29	125	180	10	135	90	90	100	10.0	0	No	
21	Female	62	Left	Traffic accident	27.8	II	IIA	33	130	160	10	140	80	80	100	6.7	0	No	
22	Male	68	Left	Slip	23.4	I	IIA	37	140	180	0	140	90	90	100	5.8	0	No	
23	Male	18	Left	Slip	22.7	I	IIB	39	135	180	5	140	90	90	100	6.7	0	No	
24	Male	57	Right	Traffic accident	22.2	I	IIA	42	140	180	0	140	90	90	100	0.0	0	No	
25	Female	42	Left	Slip	23	I	IIB	37	130	180	10	140	90	90	100	1.7	0	No	
26	Male	55	Right	Slip	26	I	IIB	45	135	180	5	140	90	90	100	10.0	0	No	
27	Male	20	Left	Slip	21	I	IIA	46	140	180	0	140	90	90	100	5.0	0	No	
28	Female	18	Left	Slip	22.2	I	IIA	47	135	180	5	140	90	90	100	4.2	0	No	
29	Male	26	Left	Struck by an object	22	II	IIA	50	135	170	0	135	85	85	100	4.2	0	No	
30	Male	51	Left	Traffic accident	22.1	I	IIB	33	140	180	0	140	90	90	100	2.5	0	No	
31	Male	38	Right	Slip	25.6	I	IIA	33	150	175	0	150	85	90	100	0.0	0	No	
32	Male	34	Left	Slip	28.4	I	IIB	35	140	180	0	140	90	90	85	2.5	2	No	
33	Female	51	Right	Slip	16	I	IIB	37	150	180	0	150	90	90	100	8.3	0	Yes	PMI
34	Female	29	Left	Traffic accident	21.7	I	IIA	38	160	180	−10	150	90	90	100	16.7	0	No	
35	Male	51	Left	Slip	25.2	I	IIB	40	130	180	10	140	90	90	85	6.7	2	No	
36	Female	51	Left	Slip	21.5	I	IIA	34	140	180	0	140	90	90	85	10.0	1	No	
37	Female	34	Left	Traffic accident	21.4	I	IIA	45	150	180	0	150	90	90	100	8.3	0	No	
38	Female	62	Left	Slip	28.3	III	IIB	51	130	170	10	140	80	90	100	8.3	0	No	
39	Female	26	Right	Traffic accident	21.1	I	IIA	51	150	180	0	150	90	90	100	0.0	0	Yes	PMI

BMI: Body Mass Index; ASA: American Society of Anesthesiologists Physical Status Classes; ROM: Range of Motion; DASH: Disabilities of the Arm, Shoulder, and Hand; MEPS: Mayo Elbow Function Score; VAS: Visual Analogue Scale; HO: Heterotopic Ossification; PMI: Prominent Metalwork Irritation.

80°–90°), and the mean supination was 89° ± 2° (range, 80°–90°) with a mean forearm rotation arc of 178° ± 4° (range, 160°–180°). There was no difference in the flexion-extension range of motion (141° ± 8° and 132 ± 22°, P = 0.06) or forearm rotation arc (177° ± 5° and 179° ± 3°, P = 0.36) between the patients with Mayo type IIA and those with Mayo type IIB fractures.

The mean MEPS was 94.9 ± 9.9 (range, 50.0–100.0), with excellent results in 28 patients, good results in 10 and poor results in 1. The mean MEPS in the type IIA group was 95.8 ± 6.9 (range, 85.0–100.0) and 93.2 ± 14.0 (range, 50.0–100.0) in the type IIB group. The mean DASH score was 5.4 ± 4.3 (range, 0–18.3); it was 4.6 ± 3.9 (range, 0–16.7) in the type IIA group and 6.9 ± 4.7 (range, 0–18.3) in the type IIB group. The mean VAS score was 0.4 ± 0.8 (range, 0–3), with 0.4 ± 0.7 (range, 0–3) in the type IIA group and 0.5 ± 0.9 (range, 0–2) in the type IIB group. There was no difference in the MEPS (P = 0.87), DASH (P = 0.10), or VAS (P = 0.77) score between the patients with Mayo type IIA fractures and those with Mayo type IIB fractures.

All fractures healed during follow-up. Complications were reported in 9 (23.1 %) patients. Seven patients developed prominent metalwork irritation, and three of them had the internal fixation device removed. It is worth mentioning that the average BMI of the 7

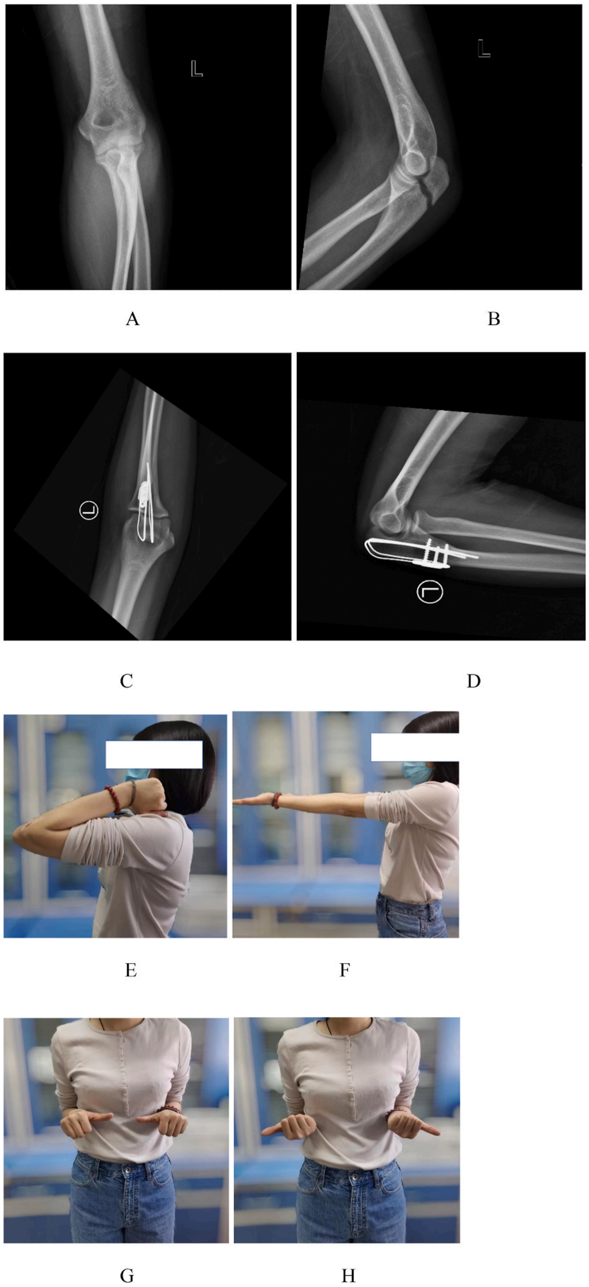

Fig. 3. Female, aged 23, anteroposterior (A) and lateral (B) X-ray showing olecranon fracture preoperatively. Anteroposterior (C) and lateral (D) X-rays showing union of the fracture 28 months after the operation. Clinical photographs (E, F, G, H) showing final full range of motion.

patients was 19.9 ± 2.7, which was lower than that of all patients (P = 0.046). There is no statistical difference between the gender of 7 patients and that of all patients (P = 0.22). Two patients developed heterotopic ossification, of whom 1 patient suffered elbow stiffness with local pain at the last follow-up and planned to undergo elbow arthrolysis. The remaining 30 patients had no complications, such as internal fixation device breakage, screw loosening, incision infection, or neurovascular injury.

3. Discussion

At present, TBW and plate fixation are common methods for olecranon fractures, but implant-related complications and reoperations remain a concern. TBW is prone to loss of reduction and skin irritation [8,9]. As for plate fixation, there is a risk of prominent implant, incision infection, and elbow stiffness [10–12]. To reduce some complications and reoperations, the olecranon sled as a new type of implant has been designed (TriMed Inc., Valencia, CA). The purpose of this study is to investigate the clinical outcomes of Mayo type II olecranon fractures treated with olecranon sled. The data demonstrated that olecranon sled fixation provided satisfactory elbow function recovery, low rate of reoperations and moderate rate of complications. As for the cost of surgery, olecranon sled is higher than TBW and lower than plate, but given the lower reoperation rate of olecranon sled, the total cost of patients may be lower.

TBW converts the longitudinal tension of the triceps into pressure on the articular surface, making the fractures fixed more firmly. However, the Kirschner Wire is smooth and unthreaded. It is easy to slide backward, which can cause skin irritation, leading to skin infection, loss of reduction, traumatic arthritis [13]. Çağlar et al. [3] reviewed 44 patients treated with the TBW, 26 of whom underwent internal fixation removal due to internal fixation irritation. Plate fixation is strong and reliable, allowing early functional exercise of the elbow. But the surgical incision is relatively long, easy to cause infection and other incision complications. Tan et al. [9] conducted a retrospective cohort study, including 53 cases treated with plate. They found the rate of plate internal fixation removal was 22.7 %. Jia et al. [14] evaluated the complications of TBW and plate in the treatment of patients with Mayo II olecranon fractures by Meta analysis. They reviewed complications occurred in 44.5 % of the TBW group and 19.9 % in the plate group. Compared to the previous literature, our study showed lower rate of reoperations than that of TBW and plates group, lower rate of total complications than TBW group and similar rate of total complications with plate group. The olecranon sled technique combines the principle of TBW with plate fixation while using a strong integrated, continuous single-wire loop [5]. The unique design of the sled helps prevent displacement of K-wires, thus avoiding loss of reduction. Its low-profile design creates internal fixation with a low prominence, thereby reducing complications such as skin irritation. In addition, there is a small incision, low blood loss and a moderate rate of incision-related complications. A biomechanical study showed no significant difference in compression between sled and TBW. Six pairs of upper limbs were included in this cadaveric study, and no significant difference was shown in the rate of fracture displacement between the two implants after applying cyclic loading to the biceps and triceps muscles ($P > 0.05$) [13]. However, there were no biomechanical studies comparing the sled and plates.

The advantages of low prominence and secure fixation of the sled may play an important role in reducing the rate of symptomatic metalwork removal [15]. Moreover, it can provide good clinical outcomes for olecranon fractures [Fig. 3(A–H)]. However, there are currently few relative studies, only 2 studies have reported on it, and the number of included patients is small. In a retrospective study, Iorio et al. [5] treated 14 olecranon osteotomy patients with the sled. None of the patients developed complications such as fracture nonunion or delayed union, and only one patient had the internal fixation device removed due to local skin irritation. Lovy et al. [6] used the sled to treat 22 cases of displaced olecranon fractures, and the average MEPS score was 95.5 at the last follow-up. Only one patient had heterotopic ossification, and no patient needed removal of the internal fixation device. They thought the sled worked well for fixing small fracture fragments. In these 2 studies using the olecranon sled, patients obtained good functional results, a low rate of internal fixation device removal and overall satisfactory outcomes, which is similar with our results.

In our study, the rate of metalwork irritation was slightly higher than in previous literature. Moreover, metalwork irritation tends to

Fig. 4. Extreme elbow flexion is more likely to cause prominent metalwork irritation in thinner patients.

occur more often in thinner patients despite ideal recovery of elbow motion, so extreme elbow flexion is more likely to cause skin irritation (Fig. 4). The 7 patients who developed metalwork irritation were generally thin and had a lower BMI, 19.9, than the total patients ($P = 0.046$). There is no statistical difference between the gender of 7 patients and that of all patients ($P = 0.22$). We think that metalwork irritation is related to BMI and not related to gender. Only 23.1 % of the patients in our study developed complications, and 7.6 % chose to have the hardware removed. The results of this study showed that the olecranon sled technique achieved an ideal functional result in patients with olecranon fractures with low rates of complications and reoperation, further demonstrating the efficacy and safety of the sled.

In patients with comminuted fractures, especially those with bone loss, TBW may cause problems [1]. However, the sled can also play an effective supporting role for fractures with mild collapse of the articular surface. If there are longitudinal fracture fragments, screw fixation can be performed intraoperatively. As a result, the sled is more suitable than TBW. For oblique fractures with long fracture lines, the sled cannot appropriately hold fragments, so plate internal fixation is still recommended. Therefore, we believe that the olecranon sled can be applied to both Mayo type IIA and IIB fractures. Although our study also showed no statistical difference in range of motion and function scores between the patients with Mayo type IIA fractures and those with type IIB fractures, the flexion-extension range of motion ($P = 0.06$) and DASH scores ($P = 0.10$) in Mayo type IIA fractures are better than those in type IIB fractures. In terms of surgical techniques, when the 2.0 mm K-wire is used for temporary fixation during the operation, space should be reserved for the drill guide. The drill guide must be flush with the olecranon and fixed securely before drilling and inserting the guide pins; otherwise, the distal loop of the sled cannot be completely attached to the dorsal surface of the olecranon, which easily results in internal fixation irritation.

4. Limitations

There are some limitations of our study. Since it was primarily a retrospective study, no control group with tension band fixation or plate fixation was designed. Some cases need longer follow-up for better results. The sample size is relatively sufficient but could be further expanded. In addition, biomechanical studies on the olecranon sled and plates are needed.

5. Conclusion

In conclusion, olecranon sled had shown satisfactory functional results for olecranon fractures, it had stable fixation, low rates of reoperation and need for removal and moderate rate of complications. A prospective control study with a sufficient number of cases and a long follow-up is needed to further explore the efficacy of the olecranon sled internal fixation for olecranon fractures.

Ethics statement

The use of clinical data obtained ethical approval from the Beijing Jishuitan Hospital ethics committee. (Approved No. 202204-01).

Consent statement

Written informed consent was obtained from all the participants prior to the enrollment of this study.

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Data availability statement

Data included in article/supp. material/referenced in article.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Chen Chen: Writing – review & editing, Supervision, Investigation, Conceptualization. **Jianyu Zhang:** Writing – original draft, Software, Resources, Methodology, Formal analysis, Data curation. **Renwei Cao:** Resources. **Kehan Hua:** Supervision. **Yejun Zha:** Supervision. **Maoqi Gong:** Supervision. **Xieyuan Jiang:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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