Short-Term Outcomes of Herbert Screw Fixation for Isolated Olecranon Fractures in Children: A Single-Institution Retrospective Study

Yang Li1 · Kelai Wang1 · Dong Sun1 · Yakun Liu1 · Zhe Wang1 · Aiwu Li1

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Abstract
Background The aim of this study was to assess the clinical and radiological outcomes of closed reduction with percutaneous Herbert screw fixation in children with isolated olecranon fractures.

Methods We retrospectively reviewed the records of children treated at our center for isolated olecranon fractures (Mayo type IIA) with closed reduction and percutaneous Herbert screw fixation. The related indices and data of the group were collected for comparative analysis after an average follow-up of 6–8 months. The Herbert screws were removed by a second operation.

Results Overall, 14 patients with an average age at the time of injury of 11.36 (range 10–14) years were included. All patients had good radiological and clinical outcomes at 6–8 months postoperatively; all had normal elbow ranges of motion and showed complete bone healing on radiographs. There were no foreign body irritation, implant migration, or osteoarthritis cases. Premature epiphyseal closure was noted in six patients. The average QuickDASH score was 1.58.

Conclusions Fixation of olecranon fractures with Herbert screws is a safe and easy method in young patients, leading to good functional and radiological results. Nonetheless, determination of the effects of this treatment method on the olecranon ossification center requires long-term follow-up.

Keywords Isolated olecranon fractures · Herbert screw fixation · Children · TBW

Introduction
Elbow fractures are common in children, accounting for 5–10% of all pediatric fractures. Contrarily, only 1.7% of healthy children are likely to have olecranon fractures [1]. Pediatric patients are likely to have injuries related to a high-energy injury mechanism. Olecranon fractures may occur when the elbow is extended or flexed by external forces, with a varus or valgus stress on the joint. The posterior surface of the olecranon is mainly affected by the intense extension of the triceps brachii muscle and the flexural stress generated by the biceps brachii muscle, which often leads to olecranon fractures [2]. The anatomic site and pattern of the fracture, extensor mechanism integrity, and in particular, fracture displacement and stability are the determining factors in the treatment of olecranon fractures.

Most olecranon fractures in children can be treated conservatively with good results. Fractures with a displacement of less than 2 mm are typically treated with cast immobilization, and long-term follow-up is performed to ensure good results [1, 3]. Conversely, fractures with a displacement of more than 4 mm are treated surgically. Evans and Graham suggested that displacements of 2–4 mm represent a gray zone in which the choice for surgical or non-surgical treatment has to be individually considered depending on the biomechanical stability, as assessed clinically by an experienced surgeon [4].

Numerous classification systems have been described in the literature for olecranon fractures, but the most commonly used is the Mayo classification. Although various fixation methods can be used for the treatment of displaced olecranon fractures, such as isolated pinning, percutaneous screw fixation, cerclage with Kirschner wires, pinning with threaded pins with adjustable lock, and tension band wire (TBW) fixation [1, 5, 6], there are no clear indications in the current literature regarding which surgical technique should be adopted for the treatment of Mayo type IIA olecranon fractures. The most commonly used surgical techniques for...
simple olecranon fractures are TBW and tension band suture (TBS) fixation, which produce good outcomes with union occurring in nearly 90% of fractures with a single surgical procedure [3, 7]. However, these techniques are associated with many complications that are directly or indirectly correlated with the use of Kirschner wires, such as hardware irritation, Kirschner wire migration, and high reoperation rates for implant removal in a substantial proportion of patients (approximately 80%) [8]. Furthermore, the open reduction and extensive exposure increase the risk for ischemic insult of the growth plate [9].

In 1942, MacAusland described the treatment of olecranon fractures by intramedullary screw fixation, but subsequent reports noted that the technique was challenging and unreliable [10, 11]. Persiani et al. reported the outcomes of treatment of olecranon fractures in children affected with osteogenesis imperfecta (OI) type I by screw fixation. Although screws provided good fixation, there was a high risk for implant migration; displacement of the internal fixation device occurred in three of the 10 patients [12]. However, limited studies have reported on the use of screws for isolated olecranon fractures in healthy children and skeletally immature patients. Hence, the indications and type of surgical treatment for these fractures in these populations are not clear.

Thus, the purpose of this study was to assess the clinical and functional outcomes of pediatric isolated Mayo IIA type olecranon fractures treated with Herbert screws using the short version of the Disabilities of the Arm, Shoulder, and Hand (QuickDASH) outcome questionnaire and imaging examination.

## Methods

### Study design and patients

We retrospectively reviewed the records of children treated at our hospital for olecranon fractures by closed reduction with percutaneous Herbert screw fixation from January 2017 to December 2020. The inclusion criteria were as follows: (1) Mayo type IIA isolated and closed olecranon fracture, (2) displacement > 4 mm, (3) no neurovascular injury, and (4) age between 10 and 14 years. The exclusion criteria were as follows: (1) extra-articular ulnar fractures, (2) combined forearm fractures, (3) comminuted olecranon fractures, (4) conservative or TBW or TBS treatment, (4) age < 10 or > 14 years, and (5) non-visible olecranon ossification center or visible epiphyseal closure on radiographs. The following data were collected: patient’s age, sex, mechanism of injury, operation time, side involved, length of postoperative immobilization, and contact information.

### Diagnosis and preoperative evaluation

All patients were initially evaluated in the emergency room. At first contact with the patient, if olecranon fracture was suspected, X-ray examination of the elbow was performed. If olecranon fracture was confirmed, the temporary plaster fixation was performed in the emergency room to avoid aggravation of the fracture displacement. Patients with no surgical contraindications were hospitalized and underwent closed reduction and Herbert screw fixation in the operating room. Figure 1 shows representative preoperative images of a 13-year-old boy. Figure 2 shows postoperative images of the boy.

### Surgical technique

Surgery was performed by an experienced pediatric orthopedic surgeon. After anesthesia induction, the patient was placed in the supine position, and the affected limb was placed on a C-arm X-ray device and sterilized. Because of the extension force of the triceps tendon, the fracture was generally displaced proximally and posteriorly; thus, we generally needed to keep the elbow straight. In some patients, fracture reduction was difficult to perform, and we needed to temporarily place a Kirschner wire into the proximal fracture end and use it to pry the reduction. After fracture reduction, we pressed the fracture block with fingers or a Kirschner wire and implanted two 0.8-mm Kirschner guide wires from the proximal to the distal end. Due to the fracture angle, it was difficult to pass the Kirschner wires through the

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Fig. 1 Preoperative images. a AP and b lateral radiographs in a 13-year-old boy with olecranon fracture.
proximal ulnar bone cortex. Following the direction of the Kirschner guide wires, we implanted two Herbert screws with a diameter of 3.0 mm and withdrew the Kirschner wires. The elbow joint was moved to detect the presence of obstructive sensation or limitation in joint movement. Strong fixation of the olecranon fracture was observed. If the fracture was confirmed to be in good reduction during the surgery—firmly fixed fracture end, no displacement of the internal fixation device, and straight elbow joint with normal flexion activity—the forearm was placed in the functional position with the elbow joint flexed at 45 degrees and fixed with a polyester bandage.

**Postoperative course and follow-up**

All patients were under observation after the surgery to monitor the blood supply to the fingers. In two patients, inlay pressure of the plaster was observed in the early stage, and the plaster was opened and decompressed in the ward. Neither of the two patients showed symptoms of osteofascial compartment syndrome in the later stage. Penicillin was used preoperatively to prevent infection.

Outpatient follow-ups and radiographic examinations were performed in all patients 21 days and 3 and 6 months after surgery. On the first postoperative visit 21 days after surgery, if the fracture line was blurred, we removed the cast and prompted functional activity. If the fracture line was clearly visible, cast removal was delayed until 5 weeks after the surgery. Three of the patients had less callus at the fracture site 3 weeks after surgery, and we delayed the cast removal by 2 weeks. Exercise was assisted by family members or a rehabilitation physician. At the 6-month follow-up, we used the QuickDASH to assess the elbow joint function and recorded forearm muscle strength, elbow flexion and extension range, and bilateral maximum length of the ulna (Fig. 3).

Although none of the patients had foreign body irritation, implant migration, or osteoarthritis, owing to the concern that cannulated compression screws may affect the growth of the epiphyseal or secondary ossification centers, removal of internal fixation was performed in most patients between 6 and 8 months after surgery (Fig. 4).

To remove the Herbert screw, the patients required a second operation. The patient was placed in the supine position, and the affected limb was placed on a C-arm X-ray device and sterilized. A 0.8-mm Kirschner wire was inserted into the skin of the elbow and the Herbert screw; this was confirmed on anteroposterior and lateral radiographs. A 0.5-cm incision was made in the skin around the Kirschner wire, and the Herbert screw was unscrewed in the direction of the Kirschner wire. To avoid bone formation over the screw tip, during the first operation, we implanted Herbert screws and only needed to incise the skin and subcutaneous tissue, not the periosteum, and the end of the screw was buried outside the periosteum rather than in the cortical bone of the olecranon. Moreover, early screw removal is another reason to avoid bone formation over the screw tip.

Fig. 2 Postoperative images from the 1-day follow-up. a AP and b lateral radiographs in the same patient treated with closed reduction and Herbert screw fixation

Fig. 3 Functional outcomes in the same patient at 6 months after surgery. Before removing the cannulated screw, we used the QuickDASH to assess the elbow joint function and recorded forearm muscle strength, elbow flexion and extension range, and bilateral maximum length of the ulna (Fig. 3).
Radiological comparison between the fractured and non-fractured arm to evaluate the effect of the Herbert screw on the epiphyseal and measurement of the maximum length of the ulna (Fig. 5) were performed. Relevant information is still being followed up.

**Statistical analysis**

All analyses were performed using IBM SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). Data are expressed as means ± standard deviations. Comparison between the fractured and non-fractured arms in the same individuals was made using the paired t-test. The threshold for statistical significance was set at \( p < 0.05 \).
Results

A total of 14 patients were included in this study. There were 9 males and 5 females, with an average age at the time of injury of 11.36 (range 10–14) years. All fractures were closed injuries. None of the patients required open reduction. The average follow-up time was 11.9 (range, 8–15) months and the average QuickDASH score was 1.58 (Table 1).

Cast removal was performed at 21 days after surgery in 11 patients, while three patients had their plaster removed at 5 weeks after surgery because of lack of callus growth. X-ray imaging showed that all patients had complete bone healing, and there were no cases of periarticular calcification, foreign body irritation, persistent joint pain, or implant migration. At the 6-month follow-up, we measured the elbow ranges of motion and the maximum length of the ulna both on the fractured and non-fractured arms (Table 2). In the comparison, there was no significant difference between the fractured and non-fractured arms. Internal fixation was removed in all patients 6–8 months after surgery. Radiographs were also obtained from the uninjured side to compare the development of the olecranon epiphyseal cartilage. There were six patients (42.9%) with premature epiphyseal closure.

Discussion

In this study, our results indicated that fixation of olecranon fractures with Herbert screws is a safe and easy fixation method in young patients, leading to good functional and radiological results.

Olecranon fractures are rare in children, representing approximately 5% of all elbow fractures [6]. Because these fractures involve the articular surface of the elbow joint and may affect the development of ulnar bone epiphyses, the standard indication for surgical reduction is generally considered to be a fracture displacement distance greater than 4 mm [13].

In previous studies, TBW and TBS have been described as very effective fixation methods with excellent results, even regarded as the gold standard for simple olecranon fractures [14]. However, because the skin at the proximal ulna is thin with relatively little subcutaneous tissue, although the tension bands maintain a good and stable reduction at the olecranon fracture site, hardware irritation, or persistent joint pain often develop, requiring hardware removal in up to 68–82% of patients [14]. The need for additional surgery is mostly determined by intolerance to the osteosynthesis material due to the prominent Kirschner wires in the elbow [15, 16]. When hollow screws are used for internal fixation, the end of the screws is buried in the ulnar periosteum, and foreign body rejection occurs rarely. Furthermore, soft tissue irritation by the screws during elbow movement can be negligible. In this study, none of the 14 patients experienced hardware irritation or movement obstruction during elbow flexion or extension. Although all patients required a second operation to remove the hollow screw, the use of the hollow screw resulted in a smaller incision and less surgical trauma than those observed in the TBW or TBS group. Further, postoperative hardware irritation and persistent joint pain were negligible, and the second operation was a minimally invasive surgery. Compared with TBW or TBS removal, Herbert screw removal is associated with a shorter operative time, less intraoperative bleeding, smaller surgical incisions, and less damage to the blood supply around the epiphysis of the olecranon. During our later follow-ups, we observed fewer scars in patients who underwent Herbert screw fixation than in those who underwent TBW or TBS removal.

Table 1 Patients’ characteristics

| Number | Age (year) | Surgery duration (min) | Number of intraoperative fluoroscopy procedures | QuickDASH score |
|--------|-----------|------------------------|-----------------------------------------------|----------------|
| 14     | 11.36     | 31.7                   | 36.5                                          | 1.58           |

Data are presented as means

QuickDASH short version of the Disabilities of the Arm, Shoulder, and Hand outcome questionnaire

Table 2 Comparison of clinical outcomes between the fractured and non-fractured arms

|                     | Fractured arm | Non-fractured arm | t    | p    |
|---------------------|---------------|-------------------|------|------|
| Elbow flexion (°)   | 143.93 ± 1.38 | 145.16 ± 2.21     | 1.589| 0.136|
| Elbow extension (°) | 1.80 ± 0.89   | 1.17 ± 0.60       | 2.080| 0.058|
| Forearm pronation (°)| 84.14 ± 1.28  | 85.10 ± 1.73      | 1.445| 0.172|
| Forearm supination (°)| 85.71 ± 3.26  | 88.02 ± 2.22      | 2.138| 0.052|
| Maximum length of the ulna (cm) | 22.89 ± 2.80 | 22.91 ± 1.51 | 0.017| 0.987|
Good reduction and stable fixation are critical for the recovery of olecranon fractures. Because these fractures involve the ulnar articular surface, it is required that the fracture gap during surgery be less than 2 mm. In Herbert screw fixation, the screws are pressurized by the head and tail thread difference and the number of screw-in threads to reduce the fracture gap and achieve a better reduction. Although it has been shown that 39%–55% of compression is lost during the first 12 h after fixation, good initial compression remains important [17].

The triceps tendon, which is attached to the olecranon, will pull the olecranon back after fracture reduction. It has been reported that there is no difference in the reoperation and complication rates between TBW and screw fixation in adult olecranon fracture [18]. However, it should be noted that in patients with OI type I, there is a risk of loose internal fixation, which can be attributed to an inadequate adhesion of the implant to the osteoporotic bone in these patients [12]. In the present study, we found no significant contraindications for the use of Herbert screws in patients aged 10–14 years. None of the patients developed osteoarthritis during the short-term follow-up. Furthermore, the QuickDASH score for the elbow was inspiring. Compared with TBW and TBS, Herbert screw fixation is a reasonable treatment option for olecranon fractures that can significantly reduce the incidence of persistent joint pain, implant migration, and particularly, foreign body irritation. Furthermore, the QuickDASH score for the elbow was inspiring.

In our study, the elbow joint was straightened and flexed after the Herbert screws were implanted to assess the stability of the implant to the osteoporotic bone in these patients [12]. In their study on the outcomes of intramedullary nail fixation through the olecranon apophysis in skeletally immature forearm fractures, Rabinovich et al. found no significant ulnar length disruption or functional limitations [20]. During the follow-up, we found that none of the patients had unequal limb length, although six patients had premature epiphyseal closure. Therefore, it can be said that growth arrest caused by the insertion of hollow screws is very rare and insignificant, particularly considering that primary ossification centers of the olecranon had emerged in our patients.

There are several limitations to our study that relate to its retrospective design. First, this was a single-institution study, and the treatment outcome depended on a single surgeon. Hence, this study has low representativeness. Second, our sample size was small, and the follow-up period was short. Therefore, we could not determine the impact of Herbert screws on the epiphyses. However, we will continue to follow up these patients, and relevant data will be collected and analyzed.

Conclusions

In the present study, we found no significant contraindications for the use of Herbert screws in patients aged 10–14 years. None of the patients developed osteoarthritis during the short-term follow-up. Furthermore, the QuickDASH score for the elbow was inspiring. Compared with TBW and TBS, Herbert screw fixation is a reasonable treatment option for olecranon fractures that can significantly reduce the incidence of persistent joint pain, implant migration, and particularly, foreign body irritation. Furthermore, the QuickDASH score for the elbow was inspiring.

Author Contributions  LY contributed to study conception and data collection, and performed the surgeries. WKL performed follow-up assessments and drafted the manuscript. SD and LYK performed the radiologic analysis and literature review. WZ contributed to data collection. LAW supervised the study and are guarantors for the accuracy of the study data. All the authors have read and approved the submitted manuscript.

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Availability of Data and Materials  The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.
Declarations

Conflict of Interest The authors declare that they have no conflicts of interests.

Ethical Standard Statement This article does not contain any studies with human or animal subjects performed by the any of the authors.

Ethical Approval and Consent to Participate This study was approved by the Medical Ethics Committee of Qilu Hospital of Shandong University (approval number KYLL-2020008-165). All study procedures were in line with the tenets of the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed Consent All subjects gave their written informed consent to participate in this investigation.

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