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Pediatric distal both-bone forearm fractures treated with percutaneous pinning with or without ulna fixation: a retrospective cohort study from two centres

Biao Wang[1], Jiale Guo[2], Zhenwei Li[1], Zejuan Ji[1], Fangna Liu[1], Keming Sun[1*] and Wei Feng[2*]

Abstract

Purpose This study investigated the clinical and functional outcomes of children with distal both-bone forearm fractures treated by fixation of the radius only compared to fixation of both the radius and ulna.

Methods A total of 71 patients from two centres with distal both-bone forearm fractures (30 in the ulna-yes group, 41 in the ulna-no group) who underwent closed reduction and percutaneous pinning treatment were retrospectively analysed. Operation duration, number of fluoroscopic exposures, loss of reduction rate and angulation based on radiographic assessment were compared between the two groups. Evaluation of wrist function including Gartland-Werley Score and Mayo Wrist Score were compared at the last follow-up.

Results Ulna angulation upon bone healing on the posteroanterior and the lateral plane of ulna-no group (6.11 ± 1.56°; 6.51 ± 1.69°) was significantly greater than that of ulna-yes group (4.49 ± 1.30°; 5.05 ± 2.18°) ($p < 0.05$). No significant difference was found in the loss of reduction rate between ulna-yes group (6.67%, 2/30) and the ulna-no group (4.88%, 2/41) ($p > 0.05$). At last follow-up, no significant difference was found between the Gartland-Werley Scores of the ulna-yes group (1.83 ± 3.25, range: 0–16) and ulna-no group (1.85 ± 2.72, range: 0-11.5) ($p > 0.05$). No significant difference was found between the Mayo Wrist Scores of the ulna-yes group (92.60 ± 6.20) and ulna-no group (92.15 ± 7.58) ($p > 0.05$).

Conclusions For distal both-bone forearm fractures in children, fixation of only the radius appears to be a viable method with equivalent clinical outcomes compared to fixation of both the radius and ulna.

Keywords Radius, Ulnar, Fracture, Fixation, Percutaneous pinning, Children

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Introduction

Distal forearm fractures are among the most common fractures encountered in pediatric populations and frequently involve both the ulna and radius [1–5]. Most of these fractures can be treated conservatively with good clinical outcomes due to the considerable remodeling potential of the distal part of the ulna and radius in children [5; 6]. However, for severely displaced fractures, operation may be necessary to restore anatomic alignment and maximize wrist motion [7–9]. Closed reduction and percutaneous pinning is the most common treatment method [7; 8]. In clinical practice, it is relatively easy to fix fractures of the distal radius, whereas fixation of distal ulnar fractures is very challenging due to its small diameter and triangular prism-like shape. For distal ulnar fractures that are slightly further from the epiphysis, elastic stable intramedullary nail fixation can be used, which requires a second surgery for removal [10]. Despite the controversy, recent studies suggest that untreated ulnar styloid fractures and ulnar styloid nonunions in adults do not affect patient outcomes in distal radius fractures treated with open reduction and internal fixation (ORIF) of the radius alone [11–19].

The question remains whether surgical fixation of the ulna for both-bone forearm fractures in children is necessary. Current research in this area is scarce. Thus, in this retrospective study, we evaluated the clinical and functional outcomes of surgically fixing the radius only compared to fixing both the radius and ulna in children with distal both-bone forearm fractures.

Methods

Participants

Data from 71 pediatric patients with distal radius and distal ulnar fractures (DRUF) between September 2017 to September 2022 were collected from two hospital databases. Patients were divided into an ulna-yes group ($n=30$) that received fixation of both the radius and ulna and an ulna-no group ($n=41$) consisting of patients who received fixation of the radius only.

The inclusion criteria consisted of patients with unilateral closed displaced DRUF between the ages of 3–10 years old, received closed reduction and percutaneous pinning, and a follow-up period up to at least one year. Distal was defined the square area covered by the epiphyseal plate of the ulna towards the direction of the bone shaft. Displaced was defined as angle of fracture greater than 25 degrees, with complete fracture and a full bone width displacement. The exclusion criteria consisted of patients with epiphyseal fractures, with closed physes, pathological fractures, open fractures, combined fractures, diseases affecting target wrist joint rehabilitation, compartment syndrome, severe neurovascular insufficiency, and lack of follow-up information.

Surgical technique

The patient was situated in a supine position and administered general anesthesia. Aside from the affected limb, the patient's body was covered with lead protection for X-ray imaging. The affected limb was routinely disinfected and sterile towels were placed. Under the guidance of the C-arm X-ray machine, fracture reduction was performed manually according to the degree of displacement. The surgical assistant stabilized the proximal forearm while the surgeon gently rotated the forearm forward and simultaneously pulled the forearm towards the distal end. The surgeon used the thumbs and index fingers of both hands to pinch the dorsal and ventral sides of the distal end of the fracture, and the index fingers were used to press against the ventral side of the fracture's proximal end. The fracture was first compressed laterally in a non-traction state to correct the lateral displacement. Following, excessive dorsiflexion of the wrist joint to 90 degrees was performed to increase deformity, and the assistant provided counter-traction while the surgeon pressed the distal end of the fracture with the thumbs of both hands. When there was a rubbing sensation at the fracture site and it was confirmed that the length of the limb had been restored, the surgeon immediately reversed direction to align the fracture end, gradually returning it to a horizontal position after reversing it to an angle of approximately 5 degrees. If reduction is difficult, a vascular clamp or a 3.0 mm Kirschner wire can be used to assist in reduction. Fracture reduction was confirmed satisfactory under the C-arm X-ray machine. Two Kirschner wires (K-wires) with a diameter of 1.5 mm were percutaneously inserted along the styloid process or lateral side of the radius for fixation (Fig. 1A-F). If ulnar fixation was conducted (Fig. 2A-F), one Kirschner wire with a diameter of 1.5 mm was percutaneously inserted along the lateral side of the ulna for fixation. After confirming pin and wire configurations fluoroscopically, K-wires were unburied and the region was covered with iodoform gauze. Postoperation, a plaster cast was applied for immobilization.

Postoperative care and followup

Intravenous prophylactic cephalosporin was routinely administered 1 h before operation and once postoperatively. Follow-up appointments with clinical and radiographic evaluation were scheduled regularly at 1, 2, and 4 weeks after surgery until bone union was confirmed. If the callus bridging the fracture gap was confirmed in radiography, the cast and K-wires were removed in the outpatient clinic. Range-of-motion exercises were then initiated. The patients were required to go to the outpatient clinic for follow-up at three month and at one year after the operation.

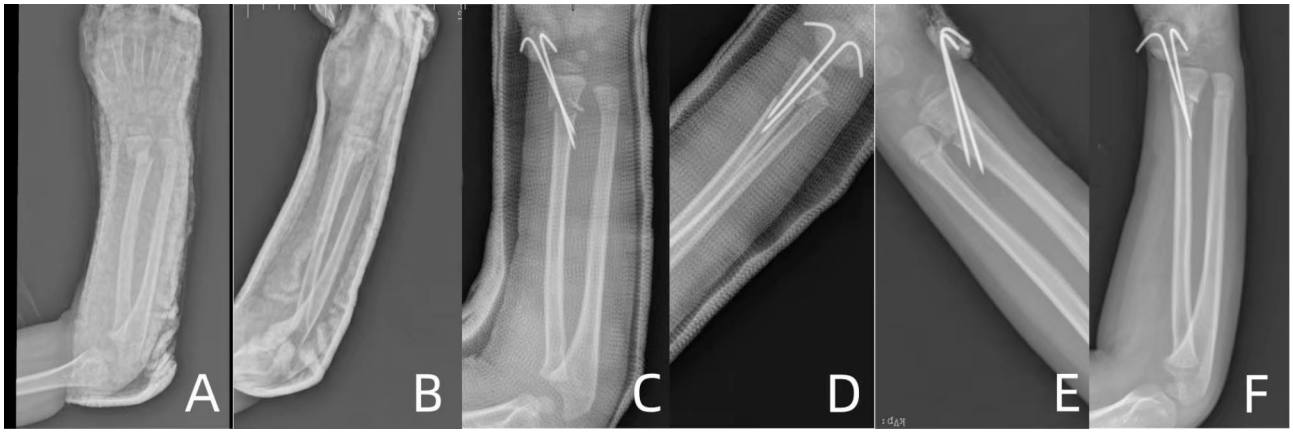

Fig. 1 Radiographs of a 4 year and 5-month-old boy with fractures of the left distal radius and ulna. He was treated with closed reduction and percutaneous pinning (radius fixation only) followed by immobilization with a cast. **A**-**B**: Pre-operative radiographs; **C**-**D**: Radiographs on the first day after surgery; **E**-**F**: Radiography showed good fracture healing 4 weeks after surgery and the K-wire was removed

Fig. 2 A 5 year and 2-month-old boy suffered fractures of the right distal radius and ulna. The displacement was still obvious after manual reduction, so surgical treatment was conducted. He was treated with closed reduction and percutaneous pinning (radius and ulna both fixed) followed by immobilization with a cast. **A**-**B**: Pre-operative radiographs; **C**-**D**: Radiographs on the first day after surgery; **E**-**F**: Radiography showed good fracture healing 4 weeks after surgery and the K-wire was removed

Data collection and outcome indicators

Data collected from the patients consisted of sex, age, side of injury, time interval from injury to operation, operation duration, intra-operative fluoroscopy times, perioperative complications, and results of functional rehabilitation. Complications recorded consisted of infections, neurological deficits, growth arrest, malunions, and nonunions. The angulation and displacement of the fracture were measured on posteroanterior (PA) and lateral radiographs with a goniometer at 4 different time points: immediately postoperation, and 1, 2, and 4 weeks after surgery. The angulation was measured by drawing a line perpendicular to the epiphyseal plate and a second line along the long axis of the radius and ulna, proximal to the fracture site (the second line extended only along a part of the radius and ulna near the fracture site). The angulation was defined as the angle between these two lines. Loss of reduction (redisplacement) was defined as follows: >5 degrees change of angulation on PA radiographs or >10 degrees change of angulation on lateral radiograph, with a full bone width displacement.

Measurements for functional scores included:

(1) Gartland-Werley score [20] was used to assess functional outcome at the last follow-up, which included subjective (activity limitation, pain, dysfunction, etc.) and objective (range of motion, neuromuscular evaluation, grip strength, etc.) evaluation. Scores between 0 and 2 points was considered to be excellent, 3–8 points was good, 9–14 points was fair, and ≥15 points was poor.
(2) Mayo Wrist Score [1] was used to evaluate wrist joint function at the last follow-up, which included pain (25 points), satisfaction (25 points), range of motion (ROM) (25 points), and grip strength (25 points). Higher scores out of 100 indicated better

wrist function, which was categorized into excellent (90–100), good (80–89), fair (65–79), and poor (<65) outcomes.

Statistical analysis

Normal or lognormal distribution of the data was assessed based on the D'Agostino and Pearson test. Continuous variables were expressed as mean±standard deviation (range). The Student's *t*-test or Mann-Whitney U test was used to compare numerical data depending on if the data was parametric or nonparametric, respectively, and the chi-square test or Fisher's exact test was used to compared categorical data. Statistical analysis was conducted using GraphPad Prism 9.

Results

Patient characteristics

Patient demographics and perioperative parameters are shown in Table 1. The ulna-yes group consisted of 19 males and 11 females with a mean age of 5.27±1.75 years old (range: 3–10 years old), 14 fractures were on the left side and 16 on the right side, and mean time interval from injury to operation was 17.63±8.17 h (range: 6–69 h). The ulna-no group consisted of 26 males and 15 females with a mean age of 4.90±1.49 years old (range: 3–9 years old), 19 fractures were on left side and 22 on the right side, and mean time interval from injury to operation of 18.27±10.95 h (range: 6–71 h). There were no significant differences in the mean gender and age between the two groups ($P>0.05$).

Perioperative parameters

All patients underwent closed reduction and internal fixation with K-wire. The mean duration of surgery (53.33±12.18 min, range: 40–105 min) for the ulna-yes group was significantly higher ($p<0.0001$) compared to the ulna-no group (36.27±9.25 min, range: 25–85 min). The mean number of fluoroscopies for the ulna-yes group (26.30±3.22 times, range: 18–45 times) was significantly higher ($p<0.0001$) compared to the ulna-no group (15.78±5.00 times, range: 10–39 times). There was no significant difference in fracture angulation between the two groups after initial treatment (Table 2).

Postoperative complications occurred in one case. One child in the ulna-no group developed superficial infection, which healed successfully after dressing change and oral antibiotics. There were no other complications and no incidences of nerve injury, malunion, nonunion or growth arrest in the two groups.

Radiographic outcomes showed no significant difference in redisplacement when comparing the radius alignment immediately post-operation and upon bone healing in the ulna-yes (PA: 0.67°±1.16°, lateral: 0.79°±1.58°) and ulna-no group (PA: 0.79°±1.50°, lateral: 0.62°±1.11°) ($p>0.05$). The ulna angulation at bone healing on the PA and the lateral plane of the ulna-no group (6.11±1.56°; 6.51±1.69°) was significantly greater than that of the ulna-yes group (4.49±1.30°; 5.05±2.18°) ($p<0.05$). Two cases (6.67%) experienced fracture loss of reduction in the ulna-yes group, and two cases (4.88%) experienced fracture loss of reduction in the ulna-no group. There was no significant difference in loss of reduction rate between the two groups ($p>0.05$).

Functional outcomes

Functional outcomes are displayed in Table 2. At the last follow-up, according to the Gartland-Werley wrist score, the ulna-yes group had 25 excellent, 3 good, 1 fair and 1 poor outcome whereas the ulna-no group had 34 excellent, 4 good and 3 fair outcomes. There was no significant difference ($p=0.6857$) between the

Table 1 Patient characteristics and perioperative parameters

	Ulna-yes group ($n=30$)	Ulna-no group ($n=41$)	*p*-value
Age (years)	5.27±1.75	4.90±1.49	0.3299*
Sex (male: female)	19:11	25:16	0.8398#
Side of fracture (left: right)	14:16	19:22	0.9783#
Time to surgery (hours)	17.63±8.17	18.27±10.95	0.7898*
Operation duration (min)	53.33±12.18	36.27±9.25	<0.0001**
Fluoroscopies (times)	26.30±3.22	15.78±5.00	<0.0001**
Time to union (weeks)	4.73±0.64	4.66±0.66	0.6364**
Follow-up (month)	28.77±8.78	29.44±8.71	0.7499*
Complications			
Superficial infection	0	1	1.000##
Loss of reduction	2	2	1.000##
Neurological deficits	0	0	-
Growth arrest	0	0	-
Nonunion	0	0	-

*Student's *t*-test; **Mann-Whitney U test; #chi-square test; ##Fisher's exact test

Table 2 Radiographic and functional results

		Ulna-yes group (*n* = 30)	Ulna-no group (*n* = 41)	*p*-value
Radiographic outcomes				
Immediately post-operation (°)	Radius - PA	2.90 ± 1.59	2.98 ± 1.64	0.8435*
	Radius-lateral	3.80 ± 1.17	4.02 ± 1.38	0.3113**
	Ulna - PA	3.82 ± 1.10	4.15 ± 1.19	0.2712**
	Ulna - lateral	4.37 ± 1.06	4.57 ± 1.44	0.5241*
Bone healing (°)	Radius - PA	3.58 ± 1.16	3.77 ± 2.42	0.7567**
	Radius-lateral	4.59 ± 1.88	4.64 ± 1.64	0.6322**
	Ulna - PA	4.49 ± 1.30	6.11 ± 1.56	< 0.0001*
	Ulna - lateral	5.05 ± 2.18	6.51 ± 1.69	< 0.0001**
Redisplacement (°)	Radius - PA	0.67 ± 1.16	0.79 ± 1.50	0.4840**
	Radius-lateral	0.79 ± 1.58	0.62 ± 1.11	0.9284**
	Ulna - PA	0.68 ± 0.91	1.95 ± 1.67	0.0001**
	Ulna - lateral	0.68 ± 2.26	1.94 ± 2.31	0.0005**
Functional outcomes				
	Gartland-Werley score	1.83 ± 3.25	1.85 ± 2.72	0.6857**
	Mayo Wrist Score	92.60 ± 6.20	92.15 ± 7.58	0.9186**

*Student's *t*-test; **Mann-Whitney U test; Abbreviations: posteroanterior, PA

mean Gartland-Werley wrist scores in the ulna-yes group (1.83±3.25, range: 0–16) and the ulna-no group (1.85±2.72, range: 0-11.5). Based on Mayo Wrist Score, the ulna-yes group had 25 excellent, 3 good and 2 fair outcomes whereas the ulna-no group had 35 excellent, 3 good and 3 fair outcomes. There was no significant difference between the mean Mayo Wrist Scores in the ulna-yes group (92.60±6.20, range:75–100) and the ulna-no group (92.15±7.58, range:70–100).

Discussion

Although most distal forearm fractures in children are treated conservatively and the mainstay treatment is manual reduction and immobilization with a cast [5; 6], multiple authors have recommended reduction and internal fixation of severely displaced fractures [7–9]. However, insufficient work has been conducted in investigating the surgical fixation management of distal ulnar fractures in cases of both-bone forearm fractures.

The only known study related to the comparison of fixation versus no fixation treatment of distal ulna fracture associated with distal radius fractures treated with percutaneous pinning was conducted by Hakan et al. (2020) [21]. In this retrospective study, 18 ulnas were fixed with K-wires and 16 ulnas were treated conservatively, and all radius fractures in both groups were fixed with K-wires. There were no significant differences in the functional and radiological results, including the Mayo Wrist Score (MWS) and ROM limitations (pronation/supination) between the two groups. Based on the results of the study, the authors believed that radius-only fixation for fractures of both distal forearm bones in children can be recommended as an alternative treatment method and merits further investigation.

Fixation of distal metaphyseal ulnar fractures in children can be very difficult and requires proficient surgical techniques. The diameter is narrow and its cross-section has a triangular prism-shape, covered by 270 degrees of cartilage. When the fracture is slightly further from the epiphyseal plate, it becomes more difficult to place the wire. In situations where K-wire placement is difficult, orthopaedists are often forced to choose intramedullary fixation with K-wires passing through the epiphysis. Multiple wire insertion during fixation may cause epiphyseal damage and development of the bone bridges. In addition, repeated fluoroscopy also increases radiation exposure for the child. Although we did not find bone bridging or obvious epiphyseal damage in the postoperative follow-up of our patients, occurrence of this complication was still a plausible risk given that the distal ulna epiphysis bears 81% of the growth potential of the ulna [2], and its epiphyseal plate diameter is only equivalent to the width of several K-wires.

The results of our study showed that peri-operative complications, loss of reduction rate, and functional outcomes were not significantly different in patients treated with ulna fixation compared to patients treated without ulna fixation. We did not find a benefit to the surgical fixation of the ulna. Satisfactory clinical outcomes were achieved in both groups with a low rate of complication. Not surprisingly, there was a significant difference in operation duration and number of intra-operative fluoroscopies between the two groups where operation duration and the number of fluoroscopies were longer and more in the ulna-yes group compared to the ulna-no group. It should be noted that among the patients in the ulna-no group, there were some patients where we initially attempted ulna fixation and eventually failed. If we

chose not to fix the ulna from the start for these patients, the mean operation duration for patients in the ulna-no group would be even shorter and there would be fewer instances of X-ray imaging.

One major concern in choosing not to fix the ulna fracture in distal both-bone forearm fractures is the risk of loss of reduction after operation. In this study, among the 41 cases of patients in the ulna-no group, two patients experienced fracture redisplacement, both occurring within one week after surgery. For these two patients, since the displacement angle was less than 15 degrees, we did not perform manual reduction but opted for observation. Postoperative follow-up showed good healing of the fracture, and no abnormalities were observed in forearm rotation and wrist joint function.

We found that there were significant differences between children and adults in terms of distal both-bone forearm fractures. Fractures at the ulnar styloid process are very common in adults, accounting for over 60% of cases [11; 12; 14; 15], whereas in children, ulna fractures rarely occur at the styloid process; instead, they mostly occur at the metaphyseal region, which is slightly further from the epiphyseal plate (Fig. 3). Among the 71 cases of distal ulna fractures in our study, not a single case involved styloid process fractures. Metaphyseal fractures with a slightly distant location from the epiphyseal plate implies that there is less impact on the stability of the triangular fibrocartilage complex, which possibly provides theoretical support for not choosing K-wire fixation for pediatric distal ulna fractures.

A limitation of this study included the relatively short follow-up period of some these patients, which prevented us from evaluating the damage to the epiphysis caused by pins. Furthermore, this was a retrospective study. Lastly, although this did not affect the conclusions of our study, there were some patients in the ulna-no group where we initially attempted ulna fixation, but eventually failed.

Conclusion

In conclusion, for distal both-bone forearm fractures in children, we did not find a benefit to surgical fixation of the ulna. Fixation of the radius only appears to be a viable method with equivalent clinical results compared to patients that underwent fixation of both the radius and ulna.

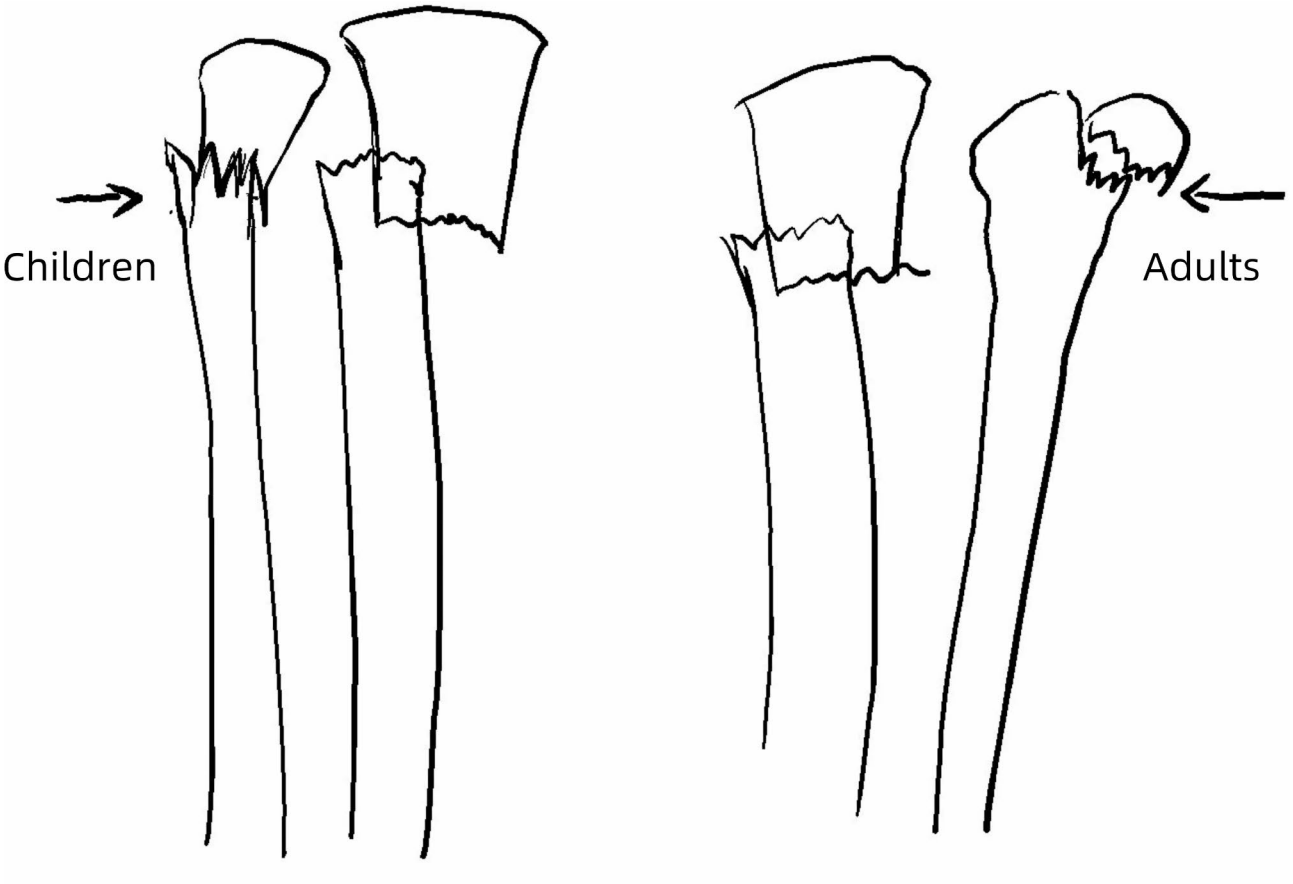

Fig. 3 Distal ulnar fractures in adults mostly occur in the styloid process, whereas distal ulnar fractures in children mostly occur in the metaphysis, which is slightly further away from the epiphysis

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Author contributions
BW and JG contributed to writing—original draft; BW, JG and ZL contributed to investigation; all authors contributed to formal analysis; BW, JG, FL, and ZJ contributed to resources; KS and WF contributed to conceptualization; all authors contributed to writing—review and editing. All authors read and approved the final manuscript.

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Data availability
The datasets used and/or analyzed for the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Review Committee of Children's Hospital Affiliated to Zhengzhou University (No. 2023-K-141, 2023.11.8, Children's Hospital Affiliated to Zhengzhou University), and the Ethics Review Committee of Beijing Children's Hospital (No. 2023-E-173, 2023.11.25, Beijing Children's Hospital). Consent to participate was waived by the Ethics Review Committee of Children's Hospital Affiliated to Zhengzhou University and the Ethics Review Committee of Beijing Children's Hospital as this was a retrospective study and no identifiable information was included in the data.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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