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Clinical results of phalangeal neck fractures in children aged 3 years or younger: a case series of *37 patients*

Yang Liu[1†], Hang Chen[2†], Yunlan Xu[1] and Bingqiang Han[1*]

Abstract

Background Phalangeal neck fractures (PNFs) are predominantly observed in the pediatric population. This study aims to investigate surgical outcomes and complications of *PNF* in children less than 3 years of age.

Methods Clinical data of children diagnosed *with* PNF treated in our hospital from January 2012 to December 2022 were retrospectively reviewed. At final follow-up, the outcome was evaluated by a modified Al-Qattan's grading system.

Results There were 37 patients as our study population, including 22 male and 15 female patients with a mean age of 26.7 ± 2.1 months. *Patients were followed up for a mean of 20 months.* There were 27 PNFs with Type II fractures and ten patients were confirmed as Type III before treatment, respectively. Eight children had concurrent *injuries*, four of them accompanied by soft tissue injury and four of them accompanied by open *fractures*. Four cases occurred loss of reduction without further surgical correction. There was a significant difference *in* loss of reduction between PNFs of the thumbs and PNFs of other fingers ($P < 0.05$). According to the modified Al-Qattan's grading system, 33 patients (89.2%) had good to excellent results and 4 patients had fair to poor results.

Conclusion Most PNFs in children less than 3 years old obtained satisfied results. We have recommended that single and longitudinal K-wire be used to fix PNFs. An additional oblique candlestick may be utilized to prevent loss of reduction if the thumb affected, and stability was questionable following reduction.

Level of evidence III.

Keywords Phalangeal neck fracture, Children, Complication, Replacement, Surgery

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Phalangeal neck fracture (PNF) was usually seen in children [1, 2] but rarely seen in adults [3]. It accounted for 13% of finger fractures in children [4]. The most common mechanism of injury is trapping the finger in a closing door, which delivers a transverse crush injury to the digit, with or without soft tissue injury. Al-Qattan's classification system was critical for clinical decision-making as it stratifies PNFs based on displacement and stability, directly influencing treatment pathways [5, 6]. Most children with Al-Qattan Type 1 (nondisplaced) closed PNFs were well treated using closed reduction and cast or splint immobilization. Surgical intervention was recommended for displaced and unstable fractures for both Al- Qattan Type II (displaced with bone-to-bone contact at the fracture site) and Al-Qattan Type III (displaced with no bone-to-bone contact) (Fig. 1). Kirschner-wires were the most performed fixation procedure [7, 8].

PNF present unique clinical challenges in the pediatric population due to ongoing skeletal immaturity. The incomplete ossification of the phalangeal head in children complicated both diagnosis and management. There are few studies in the literature focusing on the clinical outcomes of management of PNF in children in early childhood. Al- Qattan, et al. were the first to retrospectively reviewed the outcome of seven "troublesome" versus nine "non-troublesome" PNFs in this age group in 2016 [9]. They indicated most of patients, with non-troublesome fractures, obtained a satisfactory outcome. In contrast, all seven children with troublesome fractures had an unsatisfactory outcome and the difference was highly significant. However, this was a comparative study with a small number of cases that did not truly reflect clinical characteristics and surgical outcomes in young children with PNFs. As we known, there was no literature reporting the outcome of PNFs in children younger than 3 years old. The purpose of our current study is to evaluate the clinical outcomes and complications after surgical treatment of PNFs in children less than 3 years of age.

Patients and methods

Clinical data of children diagnosed with PNF treated in our hospital from January 2012 to December 2022 were retrospectively reviewed. All patients underwent surgical intervention by three senior orthopaedic surgeons under general anaesthesia. Inclusion criteria were PNFs treated with closed/or open reduction and internal fixation (CRIF/ORIF) in children less than 36 months old. Patients with the following conditions were excluded: (1) pathological fracture; (2) multiple fractures of the hand; (3) aged more than 3 years old (4) follow-up time of fewer than 12 months.

The following data were collected: age, gender, affected finger (thumb, index finger, middle finger, ring finger or little finger), fracture location (middle phalanx or proximal phalanx), classification (based on the Al- Qattan classification [5], concurrent soft tissue injury, adjacent interphalangeal joint fixation/ without fixation, and number of K-wires.

Intraoperative kirschner wire (K-wire) fixation followed a stepwise algorithm

Reduction: Closed reduction under direct visualization for Type II fractures; mini-open approach for Type III.

Fixation: Dual 0.8-mm or 1.0-mm K-wires were inserted (antegrade or retrograde), bent, cut, and then buried or not based on the individual habits of each

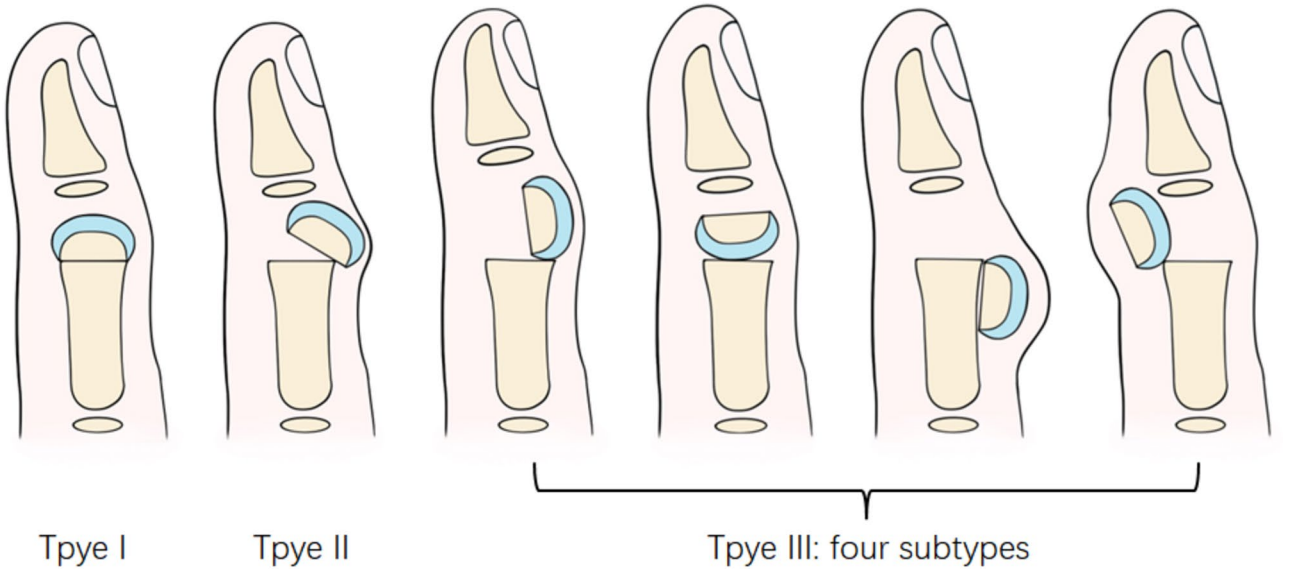

Fig. 1 Classification of phalangeal neck fracture. Cited by Al-Qattan MM. Phalangeal neck fractures in children. Classification and outcome in 66 cases. J Hand Surg Eur. 2001, 26: 112–21

surgeon and the intraoperative situation. Postoperative Validation: Immediate post-op radiographs were reviewed by an independent radiologist to confirm technical adherence. A full cast was applied for the patients, with hand, forearm and upper arm were fixed for at least 4 weeks. The patients with open injury were hospitalized for 3 days with the application of antibiotics. The other patients were discharged after 6 h of post aesthesia monitoring. All patients were routinely seen at post-operative weeks four, eight, and sixteen. Anteroposterior and lateral radio graphs of phalanx and the function of interphalangeal joint were collected at each visitation.

To minimize the influence of subjective factors and enhance the objectivity of evaluation outcomes, the evaluators were blinded to the identities of the subjects, thereby preventing personal preferences or biases from affecting the assessment results. All radiographic measures were performed by two senior pediatric musculoskeletal radiologists using PACS software and digital images. Radiographs were measured for displacement and angulation in both the coronal and sagittal planes. At the final follow-up, the outcome was evaluated by a modified Al- Qattan's grading system [5]. Both Middle phalanxes of 2–5 finger and proximal phalanxes of all fingers could be classified by Al-Qattan classification. The outcome was considered satisfactory in patients with excellent and good grades, and it was considered unsatisfactory with fair and poor grades.

Continuous data were presented as mean ± standard deviation, and categorical data were presented as frequencies. A comparison was performed using Student's t test or Pearson/ Fisher's exact test when appropriate. $P < 0.05$ was considered statistically significant. Informed consent was obtained from all participants involved in the study. Additionally, institutional review board approval was acquired under the reference number SCMCIRB-K2025001-1.

Results

Between January 2012 and December 2022, we identified 463 potential patients based on ICD-9 codes. Of these, 162 patients had their CRIF/ ORIF performed at our centre. Of these 162, 43 patients met the initial criteria of PNF in children less than 3 years of age. Four patients were excluded for multiple fractures in the affected hands, and two patients had less than 12 months' follow-up. These left 37 patients as our study population (Fig. 2).

The most common injury mechanism in this age group in our cases series was crush injury in a door This study included 22 males and 15 females with a mean age of 26.7 ± 5.3 months (range, 11–35 m). The most frequently fractured finger the thumb ($n = 18$), followed by the index finger ($n = 7$), the ring finger ($n = 6$), the litter finger ($n = 3$), and the middle finger ($n = 3$). Twenty-two fractures involved the proximal phalanx (including thumb fractures), and fifteen involved the middle phalanx. The right side was affected in twenty patents, the left side in seventeen patients. There were 27 PNFs with Type II fractures and ten patients were diagnosed with Type III fractures before treatment, respectively. One patient of them was initially confirmed as PNF with Type I fracture of the left thumb and underwent cast immobilization immediately in the emergency department. However, radiographs at follow-up a week later showed a Type II fracture on the lateral view (Fig. 3). Eight children had concurrent injury, four of them with accompanying soft tissue injury and four of them with an accompanying open fracture. Basic information of all patients was listed in Table 1.

All patients received emergent reduction with 1.0–1.2 mm K-wires fixation after admission. The mean time from injury to operation was 10 h (range, 4–26 h). Thirteen cases were fixated by crossed K-wires and twenty-four cases fixated by a single K-wire. Cast immobilization was used for four to six weeks, and internal fixation was removed at four to six months postoperatively. Patients were followed up for a mean of 20 months (range, 12–40 months).

Three cases experienced the loss of reduction during the X-ray images at follow-up, and all of them located on thumbs. One was a 22 -months -old boy, crushed by a door, diagnosed with PNF of the right thumb (Type II). He underwent debridement and antegrade crossed K-wires fixation because of concurrent soft tissue and nail injury. Displacement was again noted at the five-week follow up. We removed the pins and founded residual 128°dorsal angulation in the sagittal plane and radial deviation 30° in the coronal plane at six-weeks follow-up. The patient's family refused to further revision at that time. Surprisingly, the boy maintained the satisfied remodelling at 30 months' follow- up, with a stable interphalangeal joint and excellent function, without dorsal angulation in the sagittal plane or no significant radial deviation in the coronal plane (Fig. 4). The second patient had loss of reduction diagnosed after removal of cast immobilization at the five-week follow-up, fixated by cross K-wires. We removed the pins and founded residual 110°dorsal angulation in the sagittal plane and radial deviation 20° in the coronal plane at six-week follow-up. The patient's family also refused to further revision at that time. Encouragingly, the boy maintained the good remodelling at 8 months' follow- up (Fig. 5). The third patient also had re-displacement after removal of cast immobilization at the four-week follow-up, fixated by a single K-wire. There was a significant difference of loss of reduction between PNFs of the thumbs and PNFs of other fingers (4/18 Versus 0/17, $P < 0.05$).

Of the 37 patients with complete follow-up, 33 (89.2%) had excellent or good results and 4 (10.8%) had fair

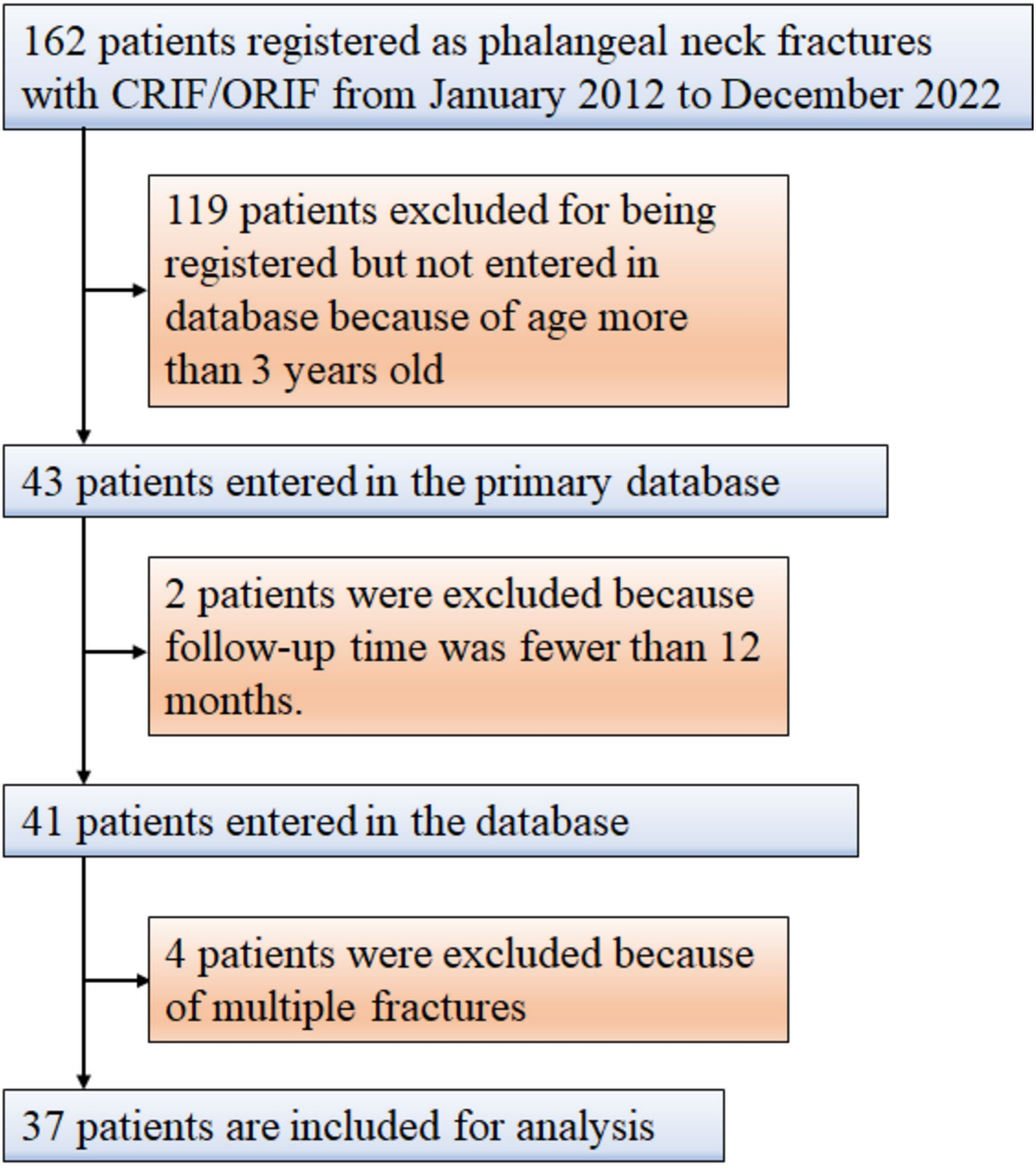

Fig. 2 Flowchart of patients' selection

or poor results. Two patients with Type III PNFs had a fair result secondary to a proximal interphalangeal joint flexion contracture, one with a final range of motion of 30° to 90° and the other with range of motion of 20° to 80°. Another two patients with open fractures had poor results secondary to a proximal interphalangeal joint flexion contracture with a final range of motion of 30° to 70° and 20° to 70°, respectively. The incidence of reduction loss did not differ significantly between fracture types (Type II vs. III), injury patterns (open vs. closed), or fixation methods (single vs. crossed K-wires), with all comparisons showing $P > 0.05$.

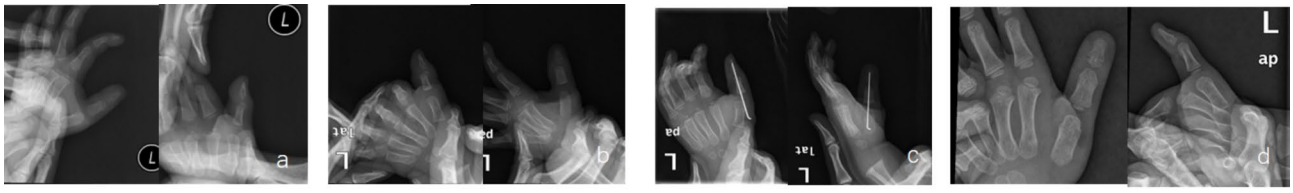

Fig. 3 **a**. 25-month-old boy was initially confirmed as PNF with Type I fracture of the left thumb and underwent cast immobilization immediately in the emergency department. **b** however, radiographs at follow-up a week later showed a Type II fracture on the lateral view. **c**. closed reduction and a single k-wire fixation. **d**. satisfied radiologic outcome and function at 18 months after operation

Table 1 Characteristics and outcomes of all patients treated for phalangeal neck fractur (*N* = 37)

Variable	Value
Age, yrs ± SD	26.7 ± 5.3
Sex, *n*(Male/Female)	22/15
Side, *n* (Left/ Right)	17/20
Location, *n* (T/I/M/R/L)	18/7/ 3/6/3
Position, *n* (PP/MP)	22/18
Concurrent soft tissue injury, *n*	8
Fracture type, *n* (Type II/III)	27/10
No. Pin used, *n* (1/2)	24/13
Loss of reduction, *n*	4
Final results, *n* (satisfactory / unsatisfactory)	33/4

PP: Proximal phalanx; MP: Middle phalanx;

Location (T/I/M/R/L): Thumb/Index finger/ Middle finger /Ring finger/ Little finger

Discussion

PNFs are relatively common in children and these fractures with Type II or Type III require prompt reduction and fixation [5, 10–12]. There can be to poor functional results if not reduced and stabilized [2, 13, 14]. However, in young children, the condyles of the phalanges are not fully ossified, and the distal fragment is mainly composed of cartilage; and its shape resembles a cap that it also been called "cartilaginous cap fracture" [1].

Dua K et al. [15] reviewed 1061 lateral finger radiographs (without thumb) and indicated that phalangeal condyles ossify in an eccentric manner and the volar phalangeal line will intersect the phalangeal condyle more dorsally with increasing age; this could serve as a reference tool for assessing phalangeal neck fracture alignment during the surgery. However, the author also indicated that the significance of the volar phalangeal line was not useful reference for children under 3 years of age. Because of the non-visualization of the eccentric phalangeal condyle, the volar phalangeal line is not able to indicate the fracture alignment. Furthermore, it was difficult for surgeons to judge satisfactory reduction in

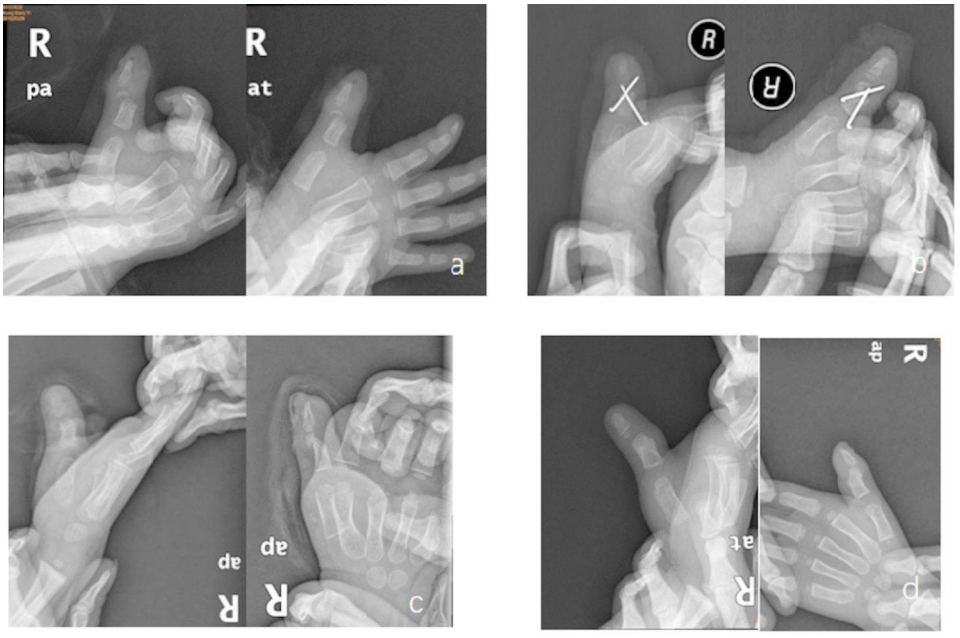

Fig. 4 **(a)** One was a 22-months -old boy, crushed by a door, diagnosed with PNF of the right thumb (Type II). He underwent debridement and antegrade crossed K-wires fixation because of concurrent soft tissue and nail injury. **(b)** Displacement was noted during the five-week follow-up. **(c)** We removed the pins and found residual 128°dorsal angulation in the sagittal plane and radial deviation 30° in the coronal plane at six-week follow-up. **(d)** Encouragingly, the boy maintained the fair remodeling at 4 months' follow- up

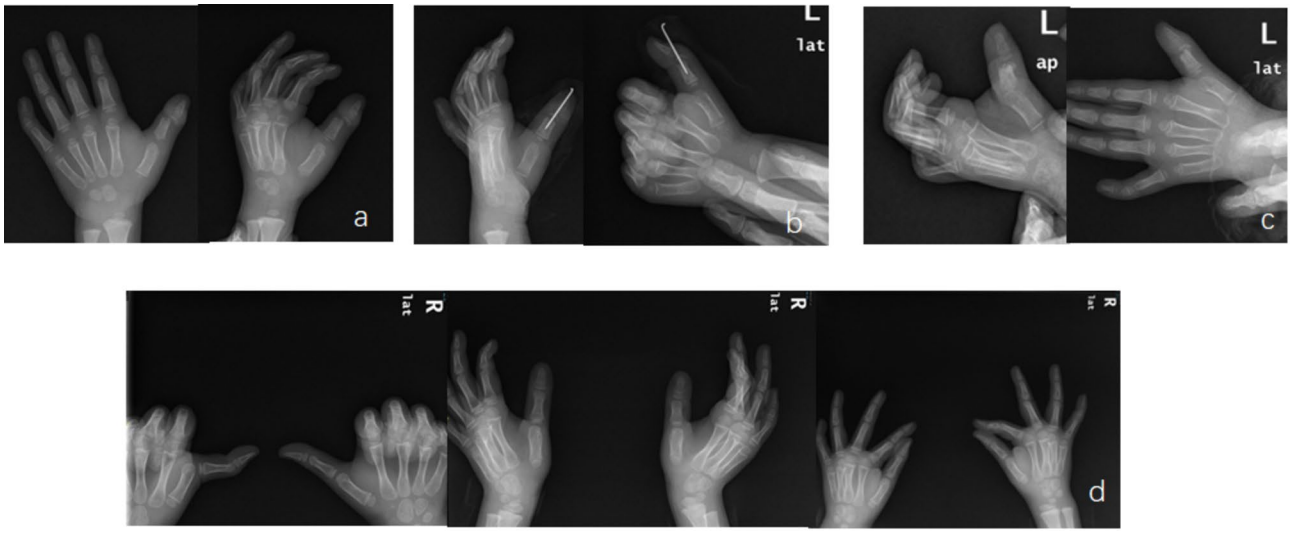

Fig. 5 **(a)** One was a 29-months -old boy, crushed by a door, diagnosed with PNF of the left thumb (Type II). He underwent debridement and antegrade crossed K-wires fixation. **(b)** Displacement was noted during the five-week follow-up. **(c)** We removed the pins and founded residual 110°dorsal angulation in the sagittal plane and radial deviation 20° in the coronal plane at six-week follow-up. **(d)** Surprisingly, the boy maintained the good remodeling at 8 months' follow- up

operative room under the supervision of fluoroscopy. Al- Qattan [16] proposed that incomplete ossification of condyles in this younger age group is a risk factor for non-union of PNF of the thumb. We deduced that the surgical outcomes were uncertain in children aged 3 years or younger.

Additionally, Al-Qattan and his colleagues [7] firstly pointed out that there can be "troublesome" digits with some specific poor prognostic factors: concurrent vascular compromise of the fractured digit, open/ partial amputation injuries, comminution of the fractured phalangeal head, concurrent epiphyseal or juxta-epiphyseal fractures distal to the fractured phalangeal head, and all Type III fractures in children less than 2 years of age. Those poor prognostic factors were confirmed by other authors before [17, 18]. In our study, all cases were selected PNF in children less than 3 years old. Most of them had excellent or good results benefitted from the hate rate of the Type II fractures and the low rate of cases with serious concurrent *soft tissue* injuries. According to this study, people with soft tissue injuries or severe fractures typically had the worst prognosis, indicating that soft tissue disorders are related to prognosis.

Loss of reduction was described in Al-Qattan's study in 2001 [5]. Only one patient had a type II fracture of the thumb; this patient was treated elsewhere with closed reduction and K-wire fixation for a period of 3 weeks. Premature removal of the K-wire resulted in fracture redisplacement. The result in this patient was considered poor, as she presented with non-union two years later. In our study, four children experienced loss of reduction of the thumb, and they were founded at the one to four weeks follow-up without premature removal of the K-wires. There was a significant difference of loss of reduction between PNFs of the thumbs and PNFs of other fingers ($P < 0.05$). The re-displacement occurred in cases either they were fixed by a single K-wire or crossed K-wires. The thumb accounted for 18 of the 37 phalange neck fracture cases in this study. The incidence rate was high, and complications were more likely to occur as a result. The possible cause of re-displacement was inferred as follows: (1) Both the three cases with loss of reduction had concurrent soft tissue injury, which implied that the children were crushed by high- energy injury, with the possibility of comminated fracture of the phalangeal head. However, it was difficult to identify because of absence a clear lateral X-ray images preoperatively; (2) Passing the K-wires multiple times through the bone; (3) Overemphasis on crossed pins fixation. It may increase the frequency of passing the K-wires with resultant injury of phalangeal head; (4) Cast immobilization was unstable for the affected thumbs because of slight movement of the interphalangeal joints.

Sadek AF et al. [19] recommended using joint-sparing K-wire fixation with two wires for displaced proximal phalangeal neck fractures. The aim of joint sparing techniques is to avoid trans-articular K-wire fixation, which carries a high risk of complications, including joint stiffness, avascular necrosis and iatrogenic phalangeal head comminution. However, the techniques of joint sparing Kirschner-wire fixation are more suitable for both adolescents and adults. We recommended that displaced PNF in children less than 3 years old could be treated by a single k-wire, with adjacent interphalangeal joint fixation.

Although most paediatric PNFs were situated distant from the epiphysis, more recently, several authors have demonstrated complete re-modelling of malunited fractures with sagittal deformity [20–23]. Cornwall et al. [21] reported a displaced fracture of the neck of the proximal phalanx in a 5-year-old boy that remodelled, resulting in excellent proximal interphalangeal joint motion. He was the first to suggest some conditions that must be met before taking the conservative approach with malunited phalangeal neck fractures in children. These conditions included: (1) no rotational or coronal malalignment exists, with malalignment in the sagittal plane only; (2) congruent adjacent joint, (3) bony union of the fracture is achieved, (4) significant growth potential exists, (5) patience by the family to allow remodelling to occur. Furthermore, Matzon and Cornwall [24] reported on a large series of 61 Type-II displaced phalangeal neck fractures. All cases which met the above remodelling criteria were treated closed reduction, even for delayed cases.

Al-Qattan [25] also agreed with the criteria of Cornwell and Waters regarding the issue of "watch and wait for remodelling". However, they noted that mild malalignment in the coronal plane also was remodelled. We had observed the same phenomenon in children less than 3 years of age in our study (Fig. 4). It was unclear that the maximal degree of angulation in the sagittal plane / coronal plane according to the age of patients, which needed to study further.

Despite the observation of remodelling, we also noted proximal interphalangeal joint flexion contracture in the displaced cases. In our displaced cases, the fracture bone fragments were pressed posteriorly by the distal phalanx. The relative shortening of flexion muscle tendon and volar joint capsule would be the predisposition of flexion contracture. A fixation of inter phalangeal joint at extension may prevent the fracture fragments from displacement and following flexion contracture. Matzon et al. [22] also reported that 2 patients developed flexion contracture after reduction and pin fixation and noted that the flexion contractures likely due to soft tissue contracture. Given that the pin fixation may lead to the tethering of the extensor hood and shortening of volar plate, the fixation of adjacent interphalangeal joint with maximally extended was suggested, which may stabilize fractures.

The strengths of this study included the larger cohort of patients under three years of age with PNFs than in previous studies. We also reported four cases of loss of reduction as possible complication after surgical intervention and we have suggested possible causes for the loss of reduction. Also, we have recommended that a single and longitudinal K-wire be used to fixate PNFs of the thumb. An additional oblique candlestick may be utilized to prevent loss of reduction if the thumb effected, and stability was questionable following reduction.

However, our study is limited by its retrospective design and the number of patients because of the extremely low incidence of PNF in children less than 3 years of age. The *P*-values in our results should be interpreted with caution, given the small number of fair or poor outcomes. We could not analyse the risk factors for poor prognosis in patients with PNFs. A multicenter prospective study with a larger sample size is required for the subsequent investigation because this one is a single-center retrospective study with a small sample size and unavoidably biased results.

Conclusion

Most PNFs in children less than 3 years of age obtained satisfactory results. We recommended the use of a single K-wire fixation in young children with PNFs. An additional oblique candlestick may be utilized to prevent loss of reduction if the thumb affected, and stability was questionable following reduction.

Abbreviations

PNF Phalangeal neck fractures
CRIF Closed reduction and internal fixation
ORIF Open reduction and internal fixation

Acknowledgements

Not applied.
Declaration of conflicting interests: The authors declare that they have no conflicting interest.

Author contributions

Y Liu was a major contributor in writing the manuscript, who collected the patients' data. H Chen and YL Xu analyzed and interpreted the patients' data. BQ Han designed the study. All authors read and approved of the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Compliance with Helsinki declaration and Ethics approval by ethics committee of Shanghai Children Medical Center (SCMCIRB-K2025001-1). Informed consent was obtained from a parent or guardian for participants under 16 years old.

Competing interests

The authors declare no competing interests.

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