

# Closed Reduction and Percutaneous Pinning Versus Open Reduction and Internal Fixation for Displaced Rockwood and Wilkins' Type C Thumb Metacarpal Base Fractures in Children

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## Research Article

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# Abstract

## Background

This retrospective study compared closed reduction and percutaneous pinning (CRPP) versus open reduction internal fixation (ORIF) methods in the treatment of severely displaced Rockwood and Wilkins' type C (RWC) thumb metacarpal base fractures in children.

## Methods

The article included 30 patients (14 boys, 16 girls; mean age 10.3 years; age range 6.2 to 14.0 years) with severely displaced RWC fractures. All patients were treated by CRPP and ORIF. The clinical results were assessed according to the criteria of modified Mayo scores. The mean follow-up period was 30.3 months (range 24.0–45.0 months). The level of significance was  $p < 0.05$ .

## Results

All fractures healed within 7 weeks postsurgery, regardless of the surgery method used, and differences between groups were observed in time to union. Recovery time after CRPP treatment averaged 4.2 weeks and was faster than that after ORIF, which averaged 4.7 weeks ( $P < 0.05$ ). The operative time for CRPP averaged 20 minutes, which was faster than that of ORIF ( $P < 0.05$ ). The overall minor complication rates were 6.3% for patients in the CRPP group and 21.4% for patients in the ORIF group ( $P > 0.05$ ). No major complications were observed in patients in the two groups. The clinical outcomes of CRPP were evaluated by modified Mayo scores: 15 patients had excellent outcomes, and one patient had a good outcome in the CRPP group. Twelve patients had excellent outcomes, and 2 patients had a good outcome in the ORIF group. ( $P > 0.05$ ). There were no refractures or incidences of nonunion, avascular necrosis (AVN), osteomyelitis, or premature physal closure.

## Conclusion

The CRPP and ORIF data of considerably displaced RWC fractures in children revealed approximately equal results for patient outcomes and rates of complications. We assert that CRPP is superior to ORIF as a treatment for RWC fractures because CRPP minimizes the operative time, precludes the need for an incision and enables faster fracture union; thus, it is our preferred treatment method.

## Background

Thumb metacarpal fractures in children are rare childhood injuries and represent 1 to 5% of hand fractures [1-3]. There are four types of thumb metacarpal base fractures in children, and type C Salter-Harris (S-H) type II physal fractures with medial angulation have been identified. Nondisplaced RWC

fractures and minimally angulated RWC fractures less than 30° of angulation disbalance are typically treated nonoperatively [4-6]. The treatment of severely displaced RWC thumb metacarpal base fractures is controversial. Some have advocated that if closed reduction is performed successfully and the result is stable, short-arm spica splint or cast immobilization is possible [4, 7-9]. Otherwise, unstable and irreducible RWC thumb metacarpal base fractures should be treated by open reduction and internal fixation [4, 10-12].

Surgical processes have been advocated for RWC fractures with a maximum angle of the fracture >30 degrees, a magnitude of displacement of the fracture >2/3 of the diameter of the growth plate, or a rotational deformity [6, 8, 9]. Both CRPP and OPIF approaches have been utilized at our institution. The purpose of this retrospective research was to compare the radiographic and clinical outcomes and complication rates of patients with RWC fractures treated by two methods. We hypothesized that these fractures could be successfully managed with CRPP with minimal processes, would not require an incision and would have low complication rates.

## Materials And Methods

After informed consent was obtained from all patients and patients' parents or guardians, this study was approved by the Institutional Ethical Review Board of Dalian Women and Children's Medical Group (approval number DLEY-KY-2021-08). This retrospective review of 32 patients with severely angulated RWC metacarpal base fractures was performed at a single level of 1 paediatric trauma centre from October 2011 to September 2017. Thirty patients were followed up for at least 24 months. Inclusion criteria included acute displaced RWC fractures with a maximum angle of the fracture >30°, a magnitude of displacement of the fracture >2/3 of the diameter of the growth plate, or a rotational deformity measured on either the anterior-posterior oblique radiograph or CT scan in a patient under 14.0 years of age who underwent surgical processes and Kirschner wires (K-wires) fixation by two senior surgeons. Patients were treated by CRPP and ORIF fixated with K-wires. The clinical records and radiographs of patients were retrospectively analysed by two other observers, and the records between the two groups were equal ( $p>0.05$ ). The results were assessed using a modified Mayo score [13] (Table 1). The demographic data and follow-up results are summarized in Table 2.

## Surgical Technique

In the supine position, the patient lay on the operating table with the affected arm abducted. After induction of general anaesthesia, skin preparation and draping of the injury arm were applied before reduction was attempted.

### CRPP

With a C-arm image intensifier, a leverage K-wire with a 1.5 mm diameter was percutaneously inserted radially into the bone fragment. The procedure was performed carefully so that the wire did not penetrate

too deeply past the dorsal cortex of the distal fragment. Once the K-wire crossed the fracture site, it was moved into position so that its tip could be moved towards the metaphysis to prevent injury to the physis, and supplementary pressure was placed on the dorsal and medial rims of the distal fragment for reduction. After fracture reduction was confirmed, especially as seen on the anteroposterior and lateral radiographs, anatomic reduction was maintained with dual antegrade crossing Kirschner (DACK) wires measuring 1.0 mm in diameter [14](Figure1,2).

## ORIF

A traditional radial approach to the elbow was performed following general anaesthesia. Care was taken to limit damage to the soft tissue and periosteum. After open reduction of the fracture, 3-4 retrograde crossing Kirschner (RCK) wires of 1.0 mm in diameter were used to fix the fracture. K-wires were required to pass through the epiphyseal fragment [4, 10, 11](Figure3,4).

After successful reduction and fixation, the external part of the wire was bent to an angle of 90°. After surgery, the injured arm was immobilized with a thumb-spica cast that included the entire first ray; the cast was worn for 4–7 weeks. When the wires and cast were removed at the outpatient clinic without anaesthesia, exercises of the injured thumb were encouraged to help the patient recover the full range of motion (FRM).

## Statistical analysis

SPSS v22 (IBM Corp., Armonk, NY, USA) was used for statistical analysis. For normally distributed data, the paired-samples *t* test was used. The Mann–Whitney U test for independent samples was used to evaluate nonnormally distributed data. The level of significance was set to  $p < 0.05$ .

## Results

Thirty patients met the inclusion/exclusion criteria and underwent surgical treatment. The average follow-up was 30.3 years (range 24.0 to 45.0 months). In the CRPP group, there were 7 males and 9 females (age range: from 7.5 to 14.0 years, mean age: 10.8 years), whereas in the ORIF group, there were 6 males and 8 females (age range: from 6.2 to 12.0 years, mean age: 9.6 years). There were no significant differences between the two groups in terms of demographic data or angulation of fracture distribution ( $p > 0.05$ ). Of the displaced thumb metacarpal fractures, 14 patients (average angulation 46.2°, range 35.0°–52.0°) were treated by ORIF (Fig. 2). These fractures were fixed with 3/4 retrograde crossing K-wires. Sixteen patients (average angulation 50.5°, range 40.8°–67.0°) were treated with CRPP (Fig. 3). Fewer k-wires were needed in patients who underwent CRPP ( $p < 0.05$ ). The operative time for CRPP averaged 20 minutes faster than that of ORIF ( $p < 0.05$ ). According to the criteria of the modified Mayo score, clinical outcomes in the group with CRPP were excellent in 15 patients, good in 1 patient; no patients had poor outcomes. Clinical outcomes in the ORIF group were excellent in 12 patients, good in 2 patients; no patients had poor outcomes. No statistically significant difference was found between CRPP and ORIF in the clinical results ( $p > 0.05$ ).

Regardless of treatment (CRPP or ORIF), all fractures healed within 7 weeks with a mean healing time of 4.4 weeks (range, 4.0 to 7.0 wks) (Figs. 1 and 2). There were significant differences in time to healing between groups (CRPP: 4.2 vs. ORIF: 4.7 wks;  $P=0.047$ ). The overall complication rate was 21.4% for patients in the ORIF group and 6.3% for patients in the CRPP group ( $P=0.498$ ). No major complications, including AVN, deep infection, premature physal closure and refracture, were observed in patients in the two groups. One minor complication was noted in patients in the CRPP group (1 pin site infection requiring oral antibiotics), whereas 3 minor complications were noted in patients in the ORIF group (3 pin site infections requiring oral antibiotics) (Table 2).

## Discussion

Surgical management of RWC thumb metacarpal base fractures with considerable angulation achieved good outcomes with 100% union rates regardless of whether patients were treated with CRPP or ORIF. Fortunately, most of the surgical complications were minor, with 6.3% observed in patients in the CRPP group and 21.4% in patients in the ORIF group, and no major complications were found.

Surgical treatment and stabilization of RWC thumb metacarpal base fractures displaced with angulation  $>30^\circ$  have been advocated in an attempt to maximize thumb and joint function. To date, some published manuscripts addressing surgical intervention for RWC fractures have focused on techniques utilizing open and closed approaches. Overall, these researchers have shown good outcomes in 80.2–95.0% of patients; however, postoperative complications remain one of the major challenges with between 30.5% and 8.2% of patients experiencing complications [4, 6-12]. In treating 16 patients with RWC fractures angulated  $>30^\circ$  using CRPP, we achieved excellent results in 15/16 patients with no reports of major complications. We expanded the indications of CRPP to widely displaced and rotated fractures averaging  $48.5^\circ$  of angulation and obtained excellent results with no major complications in all patients whose fractures were successfully reduced.

At our institution with 2 senior paediatric orthopaedic surgeons, different treatment processes exist regarding the management of RWC fractures. Some favour ORIF because it allows direct reduction of the fracture and removal of the interposed tissue, whereas others favour CRPP when anatomic reduction can be confirmed because it is less invasive and potentially minimizes complications. Our data show that although no major differences in the clinical findings exist, CRPP has the outstanding advantages of shorter surgery time and no required incision. We theorize that although every attempt was made to minimize iatrogenic damage at the time of operation, additional damage to soft tissue, including vessels and tendons, may occur, increasing the likelihood of major complications. This iatrogenic risk minimization may be another of the primary benefits of CRPP over ORIF.

Internal fixations are necessary to treat these fractures. Jehanno et al. [6] reported on a nonoperative treatment for RW-C fractures, in which early secondary displacement occurred in 2 out of 4 patients. K-wires can pass through the physis without damaging it. Wiggins preferred transfixing a K-wire across the epiphyseal growth plate, which has never been reported to cause epiphysiodesis [15]. Antegrade K-wires

have the advantage of easy fixation and reduce the possibility of skin infection and K-wire loosening; in addition, fewer K-wires are needed for this approach than for retrograde approaches. The CRPP surgery time averaged 20 minutes faster than that of ORIF ( $P < 0.05$ ). Brüske et al. [16] have shown that intraarticular K-wires may aggravate articular surface lesions and cause posttraumatic arthritis. Thus, the Iselin method was proposed.

Niekerk et al. [17] and Greeven et al. [18] reported complications, including slight and severe complications treated by the Iselin technique, in 33.3–50.0% of patients. We did not observe any severe complications, except pin tract infection in 13.3% of patients. In our series of 30 patients, crossing K-wires fixation could reduce the possibility of secondary movement, similar to the Iselin method.

The main limitation of this study was that it is a retrospective study with a small sample size. Another limitation in this study was the short-term results evaluated when comparing these two types of surgical progress. Additional studies with larger sample sizes and longer follow-up periods are needed.

## **Conclusion**

In conclusion, both ORIF and CRPP procedures of RWC fractures angulating  $>30^\circ$  with yield good outcomes with high union rates and fewer complications than other methods. CRPP has more advantages than ORIF, including shorter surgery times, less k wire needed and avoidance of an open incision. For these reasons, CRPP is our preferred technique for these RWC fractures.

## **Abbreviations**

CRPP:closed reduction and percutaneous pinning;ORIF:open reduction internal fixation;RWC:Rockwood and Wilkins' type C;S-H:Salter-Harris;K-wires:Kirschner wires;DACK:dual antegrade crossing Kirschner;RCK:retrograde crossing Kirschner;FRM:the full range of motion;AVN:avascular necrosis

## **Declarations**

### **Conflict of interest**

The authors declare that they have no conflict of interest.

### **Ethics approval and consent to participate**

This retrospective study was approved by the Institutional Ethical Review Board of Dalian Women and Children's Medical Group, 154 Zhongshan Road, Dalian 116012, China (approval number DLEY-KY-2021-08).All methods were performed in accordance with the relevant guidelines and regulations.All the participants gave their informed consent.

### **Consent for publication**

Written informed consent was obtained from all guardians for anonymized data analysis and publication.

### **Authors' contributions**

FQ and FJ collected patient material, designed and drafted the manuscript. LC and FJ advised on the main subject and worked on the manuscript, FQ and LC was the main statistician. FQ, LC and FJ edited manuscript and presented the concept of the study. All authors read and approved the final manuscript.

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None

### **Availability of data and materials**

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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## Tables

<b>Table1.ModifiedMayoScore*</b>		
<b>Category</b>	<b>Points</b>	<b>Examination Findings</b>
Pain	25	No pain
	20	Pain only with weather change
	15	Moderate pain on exertion
	15	Slight pain with activities of daily living
	5	Moderate pain with activities of daily living
	0	Pain at rest
Satisfaction	25	Very satisfied
	20	Moderately satisfied
	10	Unsatisfied but fit for work
	0	Unsatisfied and unfit for work
ROM † <sup>‡</sup> IP, MCP, saddle joint <sup>§</sup>	25	100% of the uninjured thumb
	15	75-99% of the uninjured thumb
	10	50-74% of the uninjured thumb
	5	25-49% of the uninjured thumb
	0	0-24% of the uninjured thumb
Pulp-to-palm distance <sup>‡</sup>	25	100% of the uninjured thumb
	15	75-99% of the uninjured thumb
	10	50-74% of the uninjured thumb
	5	25-49% of the uninjured thumb
	0	0-24% of the uninjured thumb
Power measurement <sup>§</sup>	25	100% of the uninjured thumb
	15	75-99% of the uninjured thumb
	10	50-74% of the uninjured thumb
	5	25-49% of the uninjured thumb
	0	0-24% of the uninjured thumb
Sensibility <sup>  </sup>	25	Normal sensibility

	20	Diminished light touch
	15	Diminished protective sensation
	10	Loss of protective sensation
	5	Deep sensation of pressure
	0	Without sensation
Final score(points)	135-150	Excellent
	120-134	Good
	97-119	Fair
	<97	Poor
*Reference: Parvizi D, Haas FM. Division of Plastic, Aesthetic and Reconstructive Surgery, Department of Surgery, Medical University Hospital of Graz, Austria.		
†Rang of movement (sum of IP, MCP, and saddle joint).		
‡Defined as the distance of the thumb pulp to the metacarpophalangeal furrow of the fifth digit in centimeter.		
§Sum of adduction and pinch grip.		
By Semmes-Weinstein monofilaments.		
A score of 97 points or better was considered to be a “satisfactory result”.		

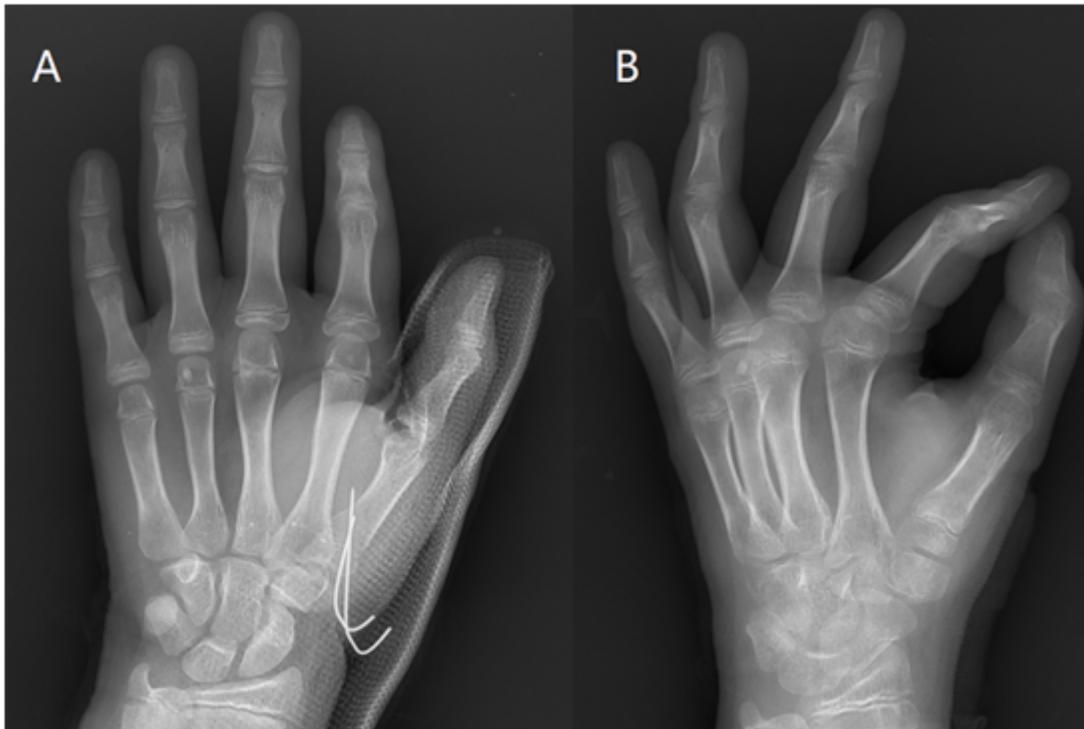
<b>Table 2. The demographic characteristics, evaluation results and complications of the patients and fractures</b>			
	<b>CRPP [n=16]</b>	<b>ORIF [n=14]</b>	<b>p-value</b>
Age			0.166
Mean age (years)	10.8	9.6	
Sex, n (%)			0.984
Female	7	6	
Male	9	8	
Surgery time (min)	20	32	0.000
Complications	1/16	3/14	0.498
Amount of K-wire	2	3.7	0.000
Removal of K-wires (weeks)	4.2	4.7	0.047
Mean Angulation (°)			
Preoperation	50.5°	46.2°	0.101
Postoperation	5.0°	4.6°	0.448
The modified Mayo score			0.728
Excellent	15	12	
Good	1	2	
Fair			
poor			
Statistically significance was set to be p<0.05			

## Figures



**Figure 1**

Typical thumb metacarpal base RW-C fracture of 10.5yearsold boy. A AP X-Ray of left thumb preoperative. B leverage reduction of the fracture. Caspect of leverage reduction.



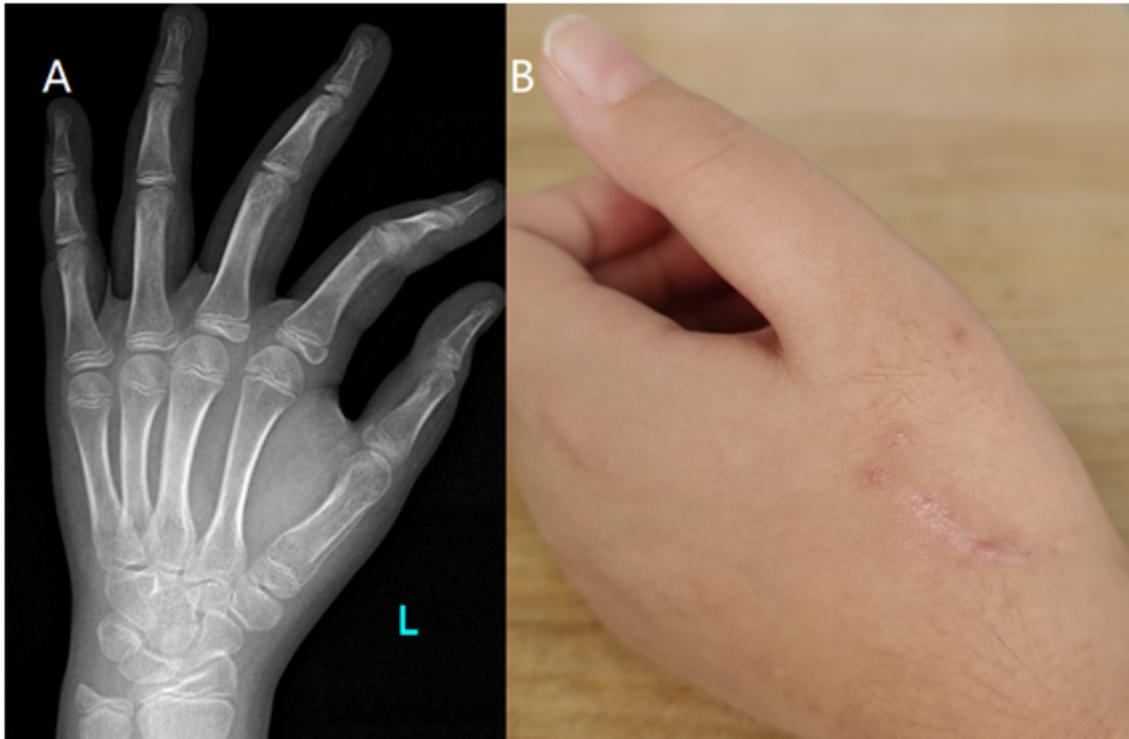
**Figure 2**

A result after CRPP. B 8weeksfollow-upXray after CRPP.



**Figure 3**

Typical thumb metacarpal base RW-C fracture of 9.3 yearsold boy. A AP X-Ray of left thumb preoperative. B result after ORIF.



**Figure 4**

A 12 weeksfollow-upXray after ORIF. B aspect of ORIF.