

Closed Reduction of Severely Angulated Rockwood and Wilkins' Type C Thumb Metacarpal Base Fractures in Children

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Research article

Keywords: Thumb Metacarpus, Fractures, Percutaneous Leverage, Children

Posted Date: January 11th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-36212/v2>

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Abstract

Background Management of severely angulated Rockwood and Wilkins' type C(RW-C) thumb metacarpal base fractures in children is challenging. We report experiences of percutaneous leverage reduction and dual antegrade crossing Kirschner (DACK) wire fixation in these fractures, aiming to assess the results using our reduction technique.

Methods From October 2011 to September 2015, A total of 17 patients with severely angulated RW-C thumb metacarpal base fractures were treated at our hospital. The injured arm, including the entire first ray, was immobilized with a thumb-spica cast for 4-6 weeks and evaluated radiologically and clinically. Percutaneous leverage reduction and DACK wire fixation were successfully performed for 17 patients. No patients were treated with open reduction. 16 patients were followed up for a mean of 32 months (range 24-41 months). The results were assessed using the modified Mayo score. The level of significance was set to be $p<0.05$.

Results There were 9 girls and 7 boys with ages ranging from 7.5 to 14.0 years and an average age of 10.8 years. Percutaneous leverage reduction and DACK wire fixation were successfully performed within an average total surgery time of 20 minutes (range 12-32 minutes). Bone union was achieved in all patients within a mean time of 4.2 weeks (range 4-6 weeks). The average angulation (preoperation: 50.5° (range 40.8°–67.0°) vs postoperation: 5° (range 0.0°–7.0°)) significantly changed from before to after surgery ($P<0.05$). The clinical results were evaluated by the modified Mayo score, and there were 15 patients with an excellent outcome and one patient with a good outcome. Cosmetic results were described as good and satisfactory by all patients. There were no refractures and no incidences of nonunion, growth arrest in the proximal epiphysis. Only one patient suffered from a superficial infection, which was resolved after the removal of the k-wires and the administration of oral antibiotics.

Conclusion Our percutaneous leverage technique with DACK wire fixation can be successfully used to treat these fractures. This technique is simple to learn and minimally invasive, and the results are satisfactory. It may be an appropriate choice for the treatment of irreducible RW-C fractures.

Background

Thumb metacarpal fractures account for 1% to 5% of hand fractures in children, with most occurring at the base [1,2,3]. There are four types of thumb metacarpal base fractures in children: type A, metaphyseal fractures; type B, Salter-Harris (S-H) type II physeal fractures with lateral angulation; type C, S-H type II physeal fractures with medial angulation; and type D, S-H type III fractures (paediatric Bennett fractures) [4,5,6]. Closed reduction is more difficult to perform for type C (RW-C) thumb metacarpal base fractures due to the mobility of the metacarpal base and swelling [4]. Some authors have advocated that if closed reduction is performed successfully and the result is stable, short-arm spica splint or cast immobilization is possible [4,7,8,9]. Otherwise, percutaneous pinning and open reduction and internal fixation are recommended for unstable and irreducible RW-C thumb metacarpal base fractures [4,10,11,12]. Several

techniques have been reported, including the Iselin technique and percutaneous K-wire fixation [4,5,6]. Percutaneous leverage reduction and fixation techniques for irreducible RW-C thumb metacarpal base fractures have not been mentioned before. This article is a retrospective study of our experience treating severely angulated RW-C thumb metacarpal base fractures using the percutaneous leverage technique and dual antegrade crossing Kirschner wire (DACK wire) fixation.

Methods

Patients

This study was approved by the Institutional Ethical Review Board of Dalian Children's Hospital (approval number 20003). Written informed consent was obtained from all guardians for anonymized data analysis and publication. A total of 17 patients with severely angulated RW-C thumb metacarpal base fractures were treated at our hospital from October 2011 to September 2015. A total of 16 patients were followed up for a mean of 32 months (range 24-41 months). All cases were classified as severely angulated RW-C fractures. There were 9 girls and 7 boys, with an average age of 10.8 years (range 7.5 to 14.0 years). A total of 10 patients had fractures on the right side, and 6 patients had fractures on the left side. All surgeries were performed by the senior surgeon, and the average surgery time was 20 minutes (range 12-32 minutes). The injured arm, including the entire first ray, was immobilized with a thumb-spica cast for 4-6 weeks and evaluated radiologically and clinically.

Surgical Procedures

General anaesthesia was induced in all patients. First, with the guidance of the C-arm image intensifier, a leverage K-wire with a 1.5 mm diameter was percutaneously inserted into the bone fragment from the displacement direction of the fractured thumb metacarpal base fragment (Figs. 1, 2). 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, and supplementary pressure was placed on the volar rim of the distal fragment for reduction. Then, reduction was confirmed with an image intensifier (Fig. 3a, 3b). Anatomic reduction was maintained with DACK wires measuring 1.0 mm in diameter (Fig. 3c). After successful reduction and fixation, the external part of the nail was bent to an angle of 90°. The injured arm, including the entire first ray, was immobilized with a thumb-spica cast for 4-6 weeks; when the wires and cast were removed at the outpatient department, continuous passive motion (CPM) was encouraged.

Postoperative evaluation

The first clinical review was conducted two weeks after surgery. Then, the cases were assessed radiographically for fixation and bone union at 4 weeks, 6 weeks, 8 weeks and 6 months postoperatively and every 6 months thereafter. When calluses formed, the cast and K-wires were removed without

anaesthesia, and active exercise was encouraged to recover the full range of motion (ROM) of the thumb. The average follow-up duration was 30 months (range 12-41 months). The results were assessed using the modified Mayo score [13] (Table 1) (Fig. 4).

Statistical analysis

SPSS v22(IBM Corp., Armonk, NY, USA) was used for statistical analysis. For the nonnormally distributed data, the Mann-Whitney U test for independent samples was conducted. For the normally distributed data, the paired-samples *t* test was used to assess the differences between the preoperative and postoperative results. The level of significance was set to be $p<0.05$.

Results

There were 9 girls and 7 boys, with ages ranging from 7.5 to 14.0 years and an average age of 10.8 years. Percutaneous leverage reduction and DACK wire fixation were successfully performed within an average total surgery time of 20 minutes (range 12-32 minutes). Bone union was achieved in all patients within a mean time of 4.2 weeks (range 4-6 weeks). The average angulation (preoperation: 50.5° (range 40.8° - 67.0°) vs postoperation: 5° (range 0.0° - 7.0°)) significantly changed from before to after surgery ($P<0.05$). Only one patient suffered from a superficial infection, which was resolved after the removal of the k-wires and the administration of oral antibiotics. The clinical outcomes were evaluated by the modified Mayo score, and there were 15 patients with an excellent outcome and one patient with a good outcome. There were no cases of deep infection, secondary displacement, malunion, or growth arrest in the proximal physis (at least 2 years follow-up). All 16 patients recovered full mobility of the first ray with respect to that on the contralateral side.

Discussion

Obviously displaced RW-C thumb metacarpal base fractures are rare in children and still challenging for paediatric orthopaedic clinicians to manage. Closed reduction is difficult to perform for severely angulated and displaced RW-C fractures. According to some authors, RW-C fractures with fewer than 30 degrees of angulation disbalance can be treated by closed reduction and splinting. Ruptures of the medial periosteum make the fracture unstable, and immobilization with the first ray yields unreliable results [6]. Some researchers have recommended that aggressive procedures are performed in children when the maximum angle of fracture is > 30 degrees, the magnitude of displacement of the fracture is $> 2/3$ of the diameter of growth plate, or a rotational deformity is present [6,8,9]. All 17 cases exhibited these operative indications. Thus, the indications of acceptability of imperfect reduction exist for two reasons. First, the first ray is constituted by a series of joints that can compensate for small extra-articular displacements without causing severe disability. Second, such displacements can be corrected by remodelling the growth plate [14,15]. However, this spontaneous correction requires two years [5]. We

must remember that the growth plate closes at an average age of 14.5 years in girls and 16.5 years in boys when considering the indications for the treatment of these fractures [6,15].

Some studies have reported that severely displaced RW-C fractures might require open reduction to remove any portions of interposed periosteum that prevent reduction. Open reduction is indicated for irreducible RW-C fractures [4,12]. However, Jehanno et al reported that open reduction is not difficult due to interposition of tendons or of the periosteum [6]. The mobility of the metacarpal base and swelling make closed reduction difficult. Comminution, soft tissue interposition, or transperiosteal “buttonholing” may further complicate reduction [4,10]. Manual closed reduction of RW-C fractures requires axial traction on the thumb, and pressure is placed on the base of the distal fragment [17]. Both the second metacarpal and thenar impact manual closed reduction. In theory, these are the true reasons that closed reduction fails. When closed reduction is performed unsuccessfully, open reduction is also required [4]. The leverage technique that we described in this study showed a minimally invasive and reliable choice to avoid open reduction.

In general, manual reduction and leverage treatment for paediatric fractures, including S-H type II fractures of the distal radius, radial neck fractures, supracondylar fractures, and Bennett fractures, are successful and yield good results, and satisfactory results have been reported [18-21]. We performed leverage reduction to anatomically reduce these fractures. The number of leverage manual reduction attempts can be reduced to fewer than 3, while injury to the physis caused by the tip of the leverage k-wire can be avoided. For at least 2 years follow-up, there were no cases of premature physis closure, bone bridge formation or epiphyseal ischemic necrosis in our study.

There are many pin configuration options, including pinning across the reduced carpometacarpal (CMC) joint, the Iselin technique, the modified Iselin technique, and direct fixation across the fracture [6,12,22,23,24]. Some authors have shown that intraarticular k-wires may aggravate articular surface lesions and cause posttraumatic arthritis. Thus, the Iselin method was proposed [25]. Some researchers have determined the incidence of secondary displacement because of the faulty Iselin technical approach and a decrease in the quality of reduction [17]. Wiggins preferred the technique of transfixing a k-wire across the epiphyseal growth plate, which has never been reported to cause epiphysiodesis [26]. Hastings also demonstrated that thumb base fracture fixation with longitudinal K-wire fixation yields good results [22]. We prefer DACK wire fixation, which has been proven to be a good technique in previous studies. Bone union was achieved in all 16 patients within a mean time of 4.2 (range 4~6 weeks). A total of 15 patients had an excellent outcome, and one had a good outcome, without secondary displacement of the fracture or tendinous adhesion. In our experience, the advantages of DACK wire fixation include the easy selection of the needle puncturing point and stable transfixion of K-wires across the epiphyseal growth plate, which yields higher stability than does the Iselin technique.

In our research, most of the leverage procedures were performed within 0.30 min with 1-3 leverage attempts. A longer duration of the leverage procedure is associated with more radiation exposure (RE). The risk of RE needs to be understood and minimized in paediatric trauma theatres, as RE is associated

with malignant diseases [27]. Ultrasonography (US) has also been used for intraoperative monitoring for the treatment of radial neck fractures in children to reduce the dose of RE [28]. US could be a useful alternative to X-ray in the future for this kind of fracture during intraoperative intensification.

Our results show that the following key points should be understood when performing the procedures: (1) According to the preoperative imaging and C-arm image intensifier data, the plane with the largest displacement and angulation of fractures should be chosen as the leverage plane to achieve anatomical reduction and reduce the number of leverage attempts. (2) The abductor pollicis longus tendon and the first metacarpal epiphysis should be considered the puncturing points for the wires to reduce tendinous adhesion. (3) DACK wire fixation is more reliable. (4) When leveraging, the tip of the K-wire should be moved towards the metaphysis to prevent injury to the physis. (5) In contrast to other metacarpals, the thumb metacarpal is visible on both AP and lateral X-rays, and the angulation and displacement can more reliably be assessed.

The main limitation of this study is that it is a retrospective cohort study with a small sample size and without a control group. We cannot confirm that our technique is superior to others. However, our technique yielded satisfactory outcomes with few complaints. Additional studies with large sample sizes are needed.

Conclusions

Our percutaneous leverage technique with DACK wire fixation can be successfully used to treat these fractures. This technique is simple to learn and minimally invasive, and the results are satisfactory. It may be an appropriate choice for the treatment of irreducible RW-C fractures.

Abbreviations

RW-C, Rockwood and Wilkins' type C

DACK-wires, dual antegrade crossing Kirschner wires

S-H, Salter-Harris

CPM, Continuous passive motion

CMC, carpometacarpal

3DCT, three-dimensional computerized tomography

US, Ultrasonography

RE, radiation exposure

ROM, rang of movement

IP, interphalangeal

MCP, metacarpophalangeal

Declarations

Ethics approval and consent to participate

This retrospective study was approved by the Institutional Ethical Review Board of Dalian Children's Hospital, 154 Zhongshan Road, Dalian 116012, China (approval number 20003). Informed consent was waived due to the retrospective nature of this study.

Consent for publication

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

Availability of data and materials

All data generated and/or analyzed during the current study are available in this published article. Data required that are not in the article are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

None.

Authors' contributions

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

Acknowledgements

Not applicable.

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Table

Table 1. Modified Mayo Score*

Category	Points	Examination Findings
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 †IP, MCP, saddle joint‡	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 §	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 §	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	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".

Figures

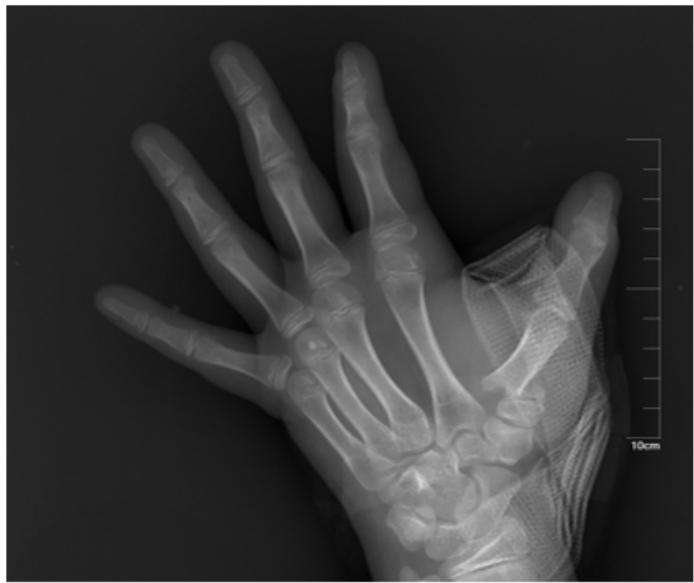
A**B**

Figure 1

Typical thumb metacarpal base RW-C fracture of 10.5 years old boy. a AP X-Ray of left thumb preoperative. b lateral X-Ray of left thumb preoperative.

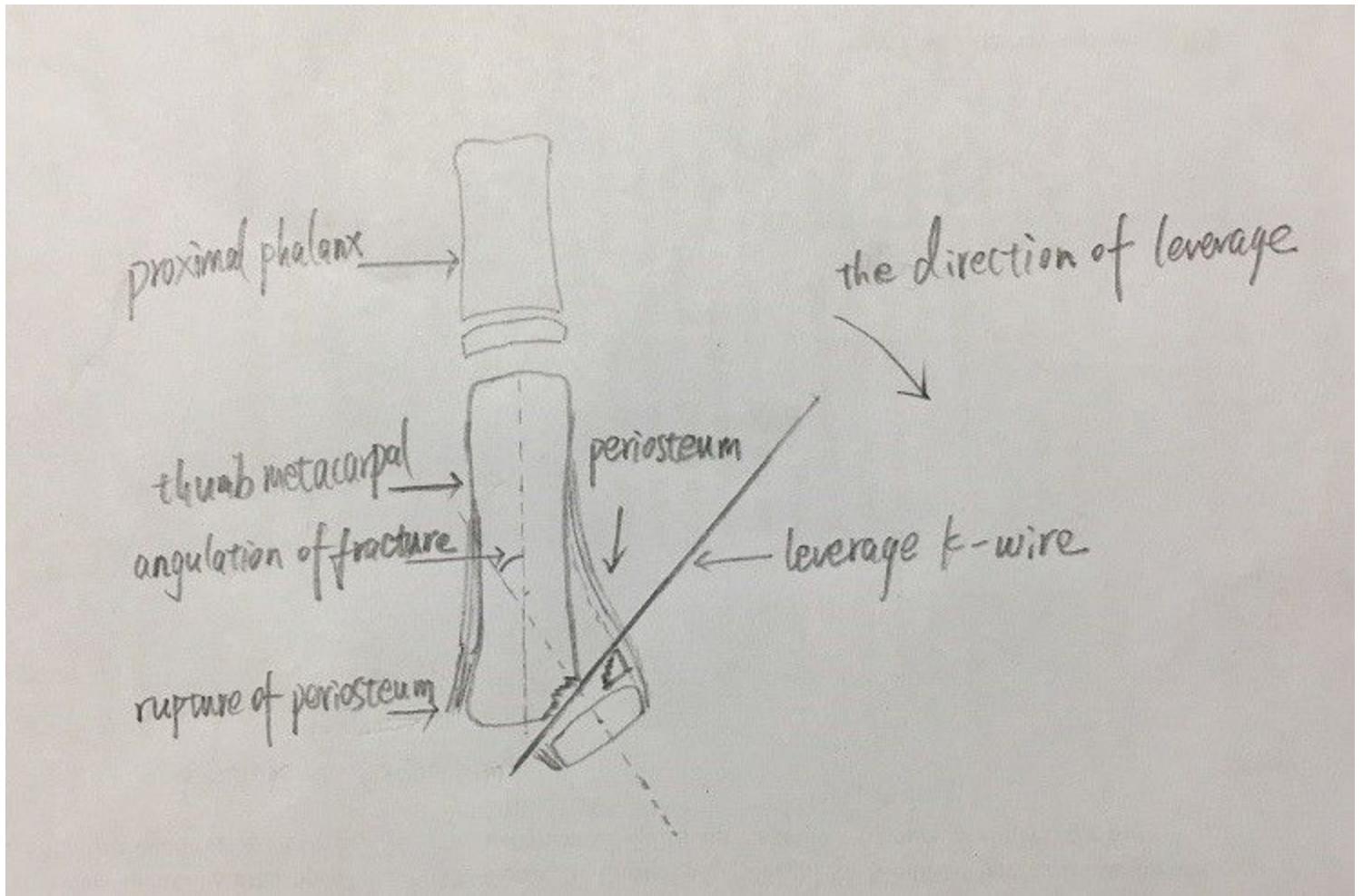


Figure 2

Diagram of percutaneous leverage of RW-C fracture of left hand.



Figure 3

Typical thumb metacarpal base RW-C fracture of 10.5 years old boy. a leverage reduction of the fracture.
b aspect of leverage reduction. c C-arm result after pinning.

A

B



Figure 4

Typical thumb metacarpal base RW-C fracture of 10.5 years old boy. 8 weeks follow-up X ray.