Clinical Report

Fixation of distal radial epiphyseal fracture: Comparison of K-wire and prebent intramedullary nail

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Abstract

Objective: To compare the use of crossed K-wire and prebent intramedullary nail techniques for the fixation of distal radius metaphyseal fracture in children.

Methods: Intraoperative and follow-up data for children with distal radius metaphyseal fracture, treated using crossed K-wire or prebent intramedullary nail fixation, were retrospectively analysed. Patient groups were matched for age, sex and clinical parameters (fracture location, affected side, fracture type).

Results: Patients treated using prebent intramedullary nail fixation \((n = 52)\) had significantly shorter surgery duration, fewer intraoperative X-radiographs, and lower prevalence of postoperative redisplacement and malalignment deformity than those treated using crossed K-wire fixation \((n = 52)\). Both techniques resulted in similar postoperative complications and recovery of forearm rotation.

Conclusions: Prebent intramedullary nail fixation has a better functional outcome than crossed K-wire fixation in the treatment of distal radial epiphyseal fracture in children.

Keywords

Distal radius fracture, children, titanium flexible nails, pre-bent, K-wire fixation

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Introduction

Distal radius fracture is a common injury in children, with an incidence of 372 per 100 000.\(^1\) Closed reduction followed by cast immobilization is the first-choice treatment, but redisplacement occurs in 4–39% of cases.\(^2,3\) There is also a risk of fracture malalignment (rotation and angulation deformities), resulting in limited forearm rotation. Thus, surgical immobilization...
should be considered for children with unstable or failed closed reduction.

Surgical immobilization techniques include compression plates,\textsuperscript{4,5} percutaneous Kirschner wires (K-wires),\textsuperscript{6} and intramedullary devices.\textsuperscript{7,8} Compression plates offer excellent anatomic reduction and early resumption of physical activities,\textsuperscript{4,8,9} but require large incisions and cannot be used in children aged <8 years.\textsuperscript{5} In addition, the small diameter of the radius in children necessitates the use of small-sized plates, which require special care after placement.\textsuperscript{10} Metaphyseal fractures of the distal radius in children are therefore immobilized using K-wires (including intrafocal [Kapandji] and intramedullary pinning).\textsuperscript{11–13}

Clinical experience gained in our hospital suggests that fractures in a specific area of the distal radius (Figure 1, green area\textsuperscript{14}) are especially difficult to immobilize by crossed K-wire fixation, and the rate of redisplacement is high even after successful initial fixation. An alternative technique is the use of prebent intramedullary nails, which retain the advantages of intramedullary nail fixation, including minimal invasiveness and simple surgery. Studies have indicated no difference in outcome between K-wires and elastic stable intramedullary nails (ESIN),\textsuperscript{15} but the outcomes of K-wires and prebent intramedullary nails have yet to be compared. The aim of the present study, therefore, was to analyse retrospectively the outcomes of prebent intramedullary nail or traditional crossed K-wire fixation for the treatment of distal radial metaphyseal fracture in children.

**Patients and methods**

**Study population**

This retrospective study included patients aged <16 years with distal radial metaphyseal fractures, treated at the Department of Orthopaedic Surgery, Shanghai Children’s Medical Centre, Shanghai Jiaotong University School of Medicine, Shanghai, China, between January 2009 and December 2010. Inclusion criteria were: (i) for patients with remaining growth potential ≥2 years: angulation >15°, rotation >45°, shortening >1 cm;\textsuperscript{16,17} (ii) for patients aged <8 years: angulation >20°. Data including sex, age, fracture side, complete fracture, oblique fracture, absence/presence of combined ulnar fracture, location of fracture (length of the distal fragment/total radial length),

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**Figure 1.** Schematic illustration of the fracture area investigated in the present study (anteroposterior view, according to the Pediatric Comprehensive Classification of Long Bone Fractures;\textsuperscript{14} the black (larger) square at the distal end of the forearm has a side length equal to the diameter of the ulna-radius complex (at the epiphyseal lines); the red (smaller) square has a side length equal to the diameter of the radius at its epiphyseal line; a fracture in the radial section (green area) between the two squares is difficult to stabilize using traditional crossed K-wire fixation. The colour version of this figure is available at: http://imr.sagepub.com.
duration of surgery and number of intraoperative X-ray images were extracted from patients’ medical records.

Control subjects treated with crossed K-wire fixation were identified from the hospital database and matched for age, sex, and clinical parameters (fracture location, affected side, fracture type).

The study was approved by the research ethics committee of Shanghai Children’s Medical Centre, Shanghai, China, and the requirement for informed consent was waived.

**Surgical technique**

Intramedullary nail fixation was performed as follows. Under X-radiography guidance, a titanium alloy elastic stable intramedullary nail (Synthes™, Solothurn, Switzerland) was inserted from the dorsal aspect of the radius (0.5–1.0 cm distal from the epiphyseal line; Figure 2A). The nail was advanced to penetrate the fracture plane and reach the middle-upper segment of the radius (Figure 2B). The nail was then bent at a site close to the entry point (Figure 2C), and further advanced until the angled section was inside the medullary canal (Figure 2D). The nail position was adjusted. The radius was checked under X-radiography imaging in both anteroposterior and lateral directions, to ensure satisfactory alignment (>50%) and complete correction of distal angulations. The nail was cut and the protruding end was left under the soft tissues.

Crossed K-wire fixation was performed as follows. Under C-arm monitoring, the fracture was manually reduced until satisfactory alignment was achieved. A pair of K-wires was inserted in a crossed manner to fix the fracture.

After fixation, all patients underwent cast immobilization for 4 weeks. K-wires were removed shortly after cast removal; intramedullary nails were removed 4–6 months after surgery.

**Follow-up**

Patients were followed-up for a minimum of 12 months. Distal fragment length/total radial length, radial angulation, radial alignment (visualised via anteroposterior and lateral X-radiographs), range of forearm rotation, fracture displacement and postoperative complications were recorded. Information was retrieved from X-radiographs using Picture Archiving & Communication System (PACS; version 2.0, DJ HealthUnion, Shanghai, China).

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Figure 2. X-radiographs showing bent intramedullary nail fixation of a distal radial fracture. (A) A titanium alloy elastic stable intramedullary nail is inserted from the dorsal aspect of the radius (0.5–1.0 cm distal to the epiphyseal line). (B) The nail is advanced to penetrate the fracture plane and reach the middle/upper segment of the radius, bent close to the entry site (C), and further advanced until the angled section is inside the medullary canal (D).
Statistical analyses

Data were presented as mean±SD (range), median (range) or n (%). Between-group comparisons were made using \( \chi^2 \)-test (categorical data) or Student’s \( t \)-test (continuous data). Statistical analyses were performed using SPSS® version 11.5 (SPSS Inc, Chicago, IL, USA) for Windows®. \( P \)-values < 0.05 were considered statistically significant.

Results

The study included 52 patients in each study group: demographic and clinical data are given in Table 1. There were no significant between-group differences in any demographic or fracture parameter. The duration of surgery was significantly shorter, and the number of intraoperative X-radiographs was significantly lower, in the patient group than in the control group (\( P < 0.01 \) for each comparison; Table 1).

Clinical follow-up data are given in Table 2. There were no significant between-group differences in median time to healing, distal fragment length/total radial length, postoperative angulation (anteroposterior and lateral), lateral alignment, postoperative complications, or loss of forearm rotation. The prevalence of fracture displacement and that of poor anteroposterior alignment (50–75%) was significantly lower in the patient group than in the control group (\( P < 0.01 \) for each comparison; Table 2).

Preoperative, postoperative, and follow-up X-radiographs of a 12-year-old male treated using crossed K-wire fixation are shown in Figure 3. Those of a 14-year-old male treated using intramedullary nail fixation are shown in Figure 4.

Discussion

Intramedullary nail fixation required considerably shorter surgery and fewer intraoperative X-radiographs than K-wire fixation, in the present study. Low-dose ionizing radiation exposure may be related to future cancer risk, particularly in children and infants,\(^{18}\) and intramedullary nail fixation may reduce intraoperative radiation exposure.

Clinical experience gained in our hospital suggests that the location of distal forearm

Table 1. Demographic and clinical characteristics of children with distal radial metaphyseal fracture included in a study to compare intramedullary nail fixation and crossed K-wire fixation.

| Characteristic                        | Intramedullary nail fixation group | K-wire fixation group | Statistical significance\(^a\) |
|--------------------------------------|------------------------------------|-----------------------|------------------------------|
| Age, years                           | \( n = 52 \)                       | \( n = 52 \)          |                              |
|                                      | 9.77 ± 3.51 (4–15)                | 9.43 ± 2.97 (4–15)    | NS                           |
| Sex, male/female                     | 42/10                              | 42/10                 | NS                           |
| Fracture side, left/right            | 28/24                              | 28/24                 | NS                           |
| Complete radial fracture             | 34 (65.4)                          | 34 (65.4)             | NS                           |
| Oblique radial fracture              | 16 (30.8)                          | 16 (30.8)             | NS                           |
| Combined ulnar fracture              | 36 (69.2)                          | 36 (69.2)             | NS                           |
| Duration of surgery, min             | 16.73 ± 6.25 (10–30)               | 45.32 ± 4.37 (20–75)  | \( P < 0.01 \)               |
| Images taken during surgery          | 22 ± 11 (10–50)                    | 60 ± 9 (30–100)       | \( P < 0.01 \)               |

Data presented as mean±SD (range) or \( n \) (%).

\(^{a}\)\( \chi^2 \)-test (categorical data) or Student’s \( t \)-test (continuous data).

NS, not statistically significant (\( P \geq 0.05 \)).
Table 2. Clinical follow-up data for children with distal radial metaphyseal fracture treated using intramedullary nail fixation or crossed K-wire fixation.

| Parameter                                | Intramedullary nail fixation group n = 52 | K-wire fixation group n = 52 | Statistical significance\(^a\) |
|------------------------------------------|------------------------------------------|----------------------------|---------------------------------|
| Time to union, months                    | 5 (3–7)                                 | 5 (3–7)                   | NS                              |
| Follow-up period, months                 | 15 (12–19)                              | 16 (12–24)                | NS                              |
| Distal fragment length/total radial length, % | 21.21 \pm 6.81 (13–33)                  | 20.17 \pm 8.67 (12–31)    | NS                              |
| Anteroposterior angulation, °             | <5                                       | <5                        | NS                              |
| Lateral angulation, °                     | <5                                       | <5                        | NS                              |
| Anteroposterior alignment, %             |                                          |                           | \(P < 0.01\)                    |
| 50–74                                     | 28                                       | 0                         |                                 |
| 75–100                                    | 24                                       | 52                        |                                 |
| Lateral alignment, %                     | >75                                      | >75                       | NS                              |
| Fracture displacement                     | 2 (3.8)                                  | 5 (9.6)                   | \(P < 0.01\)                    |
| Postoperative complications               | 3 (5.8)\(^b\)                           | 5 (9.6)\(^c\)             | NS                              |
| Loss of forearm rotation                  | 0                                        | 0                         | NS                              |

Data presented as median (range), mean \pm SD (range) or n (%).

\(^a\) \(\chi^2\)-test (categorical data) or Student’s t-test (continuous data).

\(^b\) Pin site irritation.

\(^c\) Wire tract infection.

NS, not statistically significant (\(P \geq 0.05\)).

Figure 3. X-radiographs from a 12-year-old male with a left-arm distal radial fracture treated by crossed K-wire fixation. (A) Anterior–posterior and (B) lateral views before fixation. (C) Anterior–posterior view 5 months after surgery.
fractures determines their response to different fixation techniques. Distal radial metaphyseal fractures (Figure 1, green area) are difficult to manage by K-wire fixation because of the geometry of this area. In this region, the intramedullary canal narrows gradually and K-wires are therefore usually placed at an acute angle or inserted near the fracture plane. This K-wire configuration may lead to postfixation instability, bone fragment movement (rotation or inclination), and redisplacement. Soft tissue coverage and the narrow diameter of the metaphyseal region of the ulna–radius complex further complicate crossed K-wire fixation. Repeated K-wire insertions are frequently required to ensure satisfactory stability, increasing the risk of iatrogenic fracture. K-wire fixation maintains the distal fragment position after reduction and therefore requires expert skills during manual reduction. As a result, this fixation

Figure 4. X-radiographs from a 14-year-old male with a left-arm distal radial fracture treated by intramedullary nail fixation. Anterior–posterior view (A) before, (B) immediately after, and (C) 6 months after fixation. Lateral view (D) before, (E) immediately after, and (F) 6 months after fixation.
technique requires a long duration of surgery and many intraoperative X-ray images.

It is difficult to maintain fracture stability after K-wire fixation, and redisplacement can occur. K-wire fixation is effective for epiphyseal fractures but may not be successfully applied when managing metaphyseal fractures of the ulna and radius. The risk of redisplacement after K-wire fixation of fractures at the metaphysis or epiphysis–metaphysis junction has been reported. In order to prevent redisplacement, we applied strict cast fixation to patients following K-wire fixation in the present study. As a result, the few cases of redisplacement that occurred were within the acceptable range and required no additional treatment.

Other fixation techniques have been applied for distal forearm metaphyseal fractures. Elastic stable intramedullary nailing has been widely accepted as an effective treatment for forearm fractures, but the application of this technique to distal radial metaphyseal fractures has not been studied. This is because, in standard elastic stable intramedullary nailing practice, the entry point is close to the fracture plane and the elasticity of the nail would push the proximal fragment toward the contralateral side, thereby potentially leading to angulation and malalignment. In the present study, we modified this technique by prebending (i.e. de-elasticizing) the nail end postinsertion. This modification, combined with selection of an appropriate nail diameter, achieved satisfactory fixation without angulation deformity. In this modified technique it is unnecessary to restore the normal anatomy accurately (provided that a good alignment is achieved), as residual angulation can be corrected by the subsequent intramedullary nailing. This modified technique requires simple procedures, short surgery, and a small number of intraoperative X-ray images. This technique could not effectively maintain the fracture at the original position attained by closed reduction, however, and is therefore ineffective in correcting postfixation malalignment. Limitations in forearm rotation are primarily due to uncorrected angulation, not malalignment, and slightly limited forearm rotation does not considerably affect normal activities or participation in sport.

Our modified intramedullary nail technique has biomechanical advantages over crossed K-wire fixation. The stiff nature of K-wires means that even slight postoperative displacement may create secondary damage to the cortex, potentially leading to fixation loosening and failure. Although intramedullary nails are less effective at resisting bending and torsion than K-wires, they are more flexible and do not create tearing damage under moderate displacement. Both techniques require additional external fixation, but K-wires require more rigid external fixation, because of the risk of postoperative displacement and fixation failure in noncompliant patients.

The techniques used in the present study had similar complications, which generally had excellent outcomes. Common complications after fixation include incision infection, fixation device displacement, neural injury, fracture redisplacement, malunion, and delayed bone union. One disadvantage of intramedullary nails is that their removal requires surgery, whereas K-wires can usually be removed during outpatient visits.

The present study has several limitations. First, the sample size was small. Secondly, we did not compare intramedullary nail fixation with other techniques such as intrafocal pinning and intramedullary pinning. Thirdly, although the number of X-ray images was recorded, we could not determine the actual radiation dose.

In conclusion, prebent intramedullary nail fixation has a better functional outcome than crossed K-wire fixation in the
treatment of distal radial epiphyseal fracture in children.

Declaration of the conflicting interest
The authors declare that there are no conflicts of interest.

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