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Prebending of a Titanium Elastic Intramedullary Nail in the Treatment of Distal Radius Fractures in Children

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The aims of this study were to introduce a method to treat distal radius diaphyseal metaphyseal junction fractures by prebending an elastic intramedullary nail and to evaluate the factors influencing fracture apposition. Fifty-two consecutive patients (4 to 15 years old) with a distal radius diaphyseal metaphyseal junction fracture were included. The nail was inserted and advanced into the proximal radial fragment as normal. After bending the nail distally about 90° at the site predetermined to lie at the distal segment, the elastic intramedullary nail was advanced until the prebent part completely entered the marrow cavity. The fracture angular deformity was fully corrected in anterior-posterior and lateral views. The apposition rate was 90% to 100% in lateral view, >50% in anterior-posterior view. The operation time was 16.73 ± 6.253 minutes. The average time of fracture healing was 5 months (range, 4–7 months). During 12 to 19 months of follow-up, firm fracture healing and good remodeling were observed, and there was no impaired forearm rotation function or secondary fracture. Our study showed the treatment of distal radius diaphyseal metaphyseal junction fractures by prebent intramedullary nail could make up for the deficiency of Kirschner wires and steel plates and keep the fracture stable. Fracture type and the anatomical features of the distal radius were associated with fracture apposition.

Key words: Distal metaphysealdiaphyseal fractures of radius in children – Titanium flexible nails – Prebending

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Distal radius fracture is one of the most common fractures in children,[1] the incidence of which has sustainaned growth.[1,2] To date, closed reduction in combination with plaster immobilization is still the first choice of treatment. However, the rate of fracture displacement is 4% to 39%.[3–6] Because forearm rotation is impaired by angular and rotational deformity, surgery treatment should be employed for those children with unstable or aborted closed reduction.

On the basis of the AO Foundation's The AO Pediatric Comprehensive Classification of Long Bone Fractures,[7] the metaphysis area is marked by a rectangle containing the diameter of the growth plate of the distal radius and ulna. We make another small square the side of which has the same length as the widest part of the distal radial epiphysis. The segment of radius between these two squares is defined as the distal radius diaphyseal metaphyseal junction (Fig. 1, the green area).

Steel plates and Kirschner wires are some of the tools that could be used in the surgical treatment of the distal radius diaphyseal metaphyseal junction fracture (DRDMJF). However, steel plates may sometimes result in severe injury, broken internal fixation, infection, bone nonunion, and secondary operation, although they could bring complete anatomical reduction. And crossed Kirschner wires fixed with an acute angle or entry point are very close to the fracture line because of the gradual narrowing of the marrow cavity in this area. De Gheldere[8] suggested that this would lead to unstable fracture reduction, bone inclination and rotation, and even fracture displacement. Moreover, repeated insertion of Kirschner wires could possibly cause iatrogenic fracture and bring additional difficulty in internal fixation.[9] The incidence of complications by Kirschner wires is 38% in the treatment of distal radius fracture.[6]

The treatment of forearm fracture by elastic intramedullary nail has been accepted and widely used in clinics at present. The advantages, including minimal invasion, greater stability, and less complication, have been described in many reports.[10–14] However, there is no report about its application in the distal radius fracture. The reason is mainly that the elasticity of the intramedullary nail will push the proximal end of the fracture to the opposite side and result in angular deformity and inaccurate reduction. In the current study, we made attempts to improve this method by bending the distal part of the elastic intramedullary nail before pushing it into the marrow cavity, which could make the intramedullary nail maintain its linear state as it passes the fracture line.

Fig. 1 The segment of radius between these 2 squares is defined as the distal radius diaphyseal metaphyseal junction (the area bounded by the two squares on the right [gray]).

Materials and Methods

Between Jan 2009 and May 2011, 52 children (4–15 years old) with DRDMJF (angulation >15° after closed reduction, crispation >1 cm, and rotation >45°) were collected for the present study, including 42 males and 10 females. The chart review showed that all fractures were closed, and 28 fractures were on the left side, 24 fractures were on the right side; 34 fractures were complete radius fractures (65.4%), including 16 oblique fractures (30.8%). In addition, 36 radius fractures were combined with an ulnar fracture on the same side (69.2%). The time window is 1 to 9 days from injury to surgery treatment. The percentage of fracture distal segment length to radius total length ranged from 13% to 3%.

The patients underwent general anesthesia in the supine position. The forearms were placed on a C-arm X-ray. Titanium elastic intramedullary nails (SynthesTM, Synthes Biomaterials, Swiss) with 2.0-, 2.5-, and 3.0-mm diameters were employed on the basis of two thirds the diameter of the least-narrow part of marrow cavity.

X-ray images of the lateral position and anterior-posterior position before operation are shown in Fig. 2A. After creating the entrance site (dorsal site of radius) just 0.5 to 1.0 cm proximal to the epiphysis line of the radius, the intramedullary nail was inserted and advanced through the fracture line until the tip reached the middle-upper segment of the radius (Fig. 2B). The nails were bent distally by about 90° at the site close to the entry, and the elastic intramedullary nail was advanced until the prebent part completely entered the marrow cavity (Fig. 2C). In its final position, the apex of the bend was located at the distal fragment, and the nail became straight in the cavity, keeping the two fragments in satisfactory alignment (Fig. 2D). The fracture angular deformity was corrected completely, and the apposition rate >50% was obtained under C-arm X-

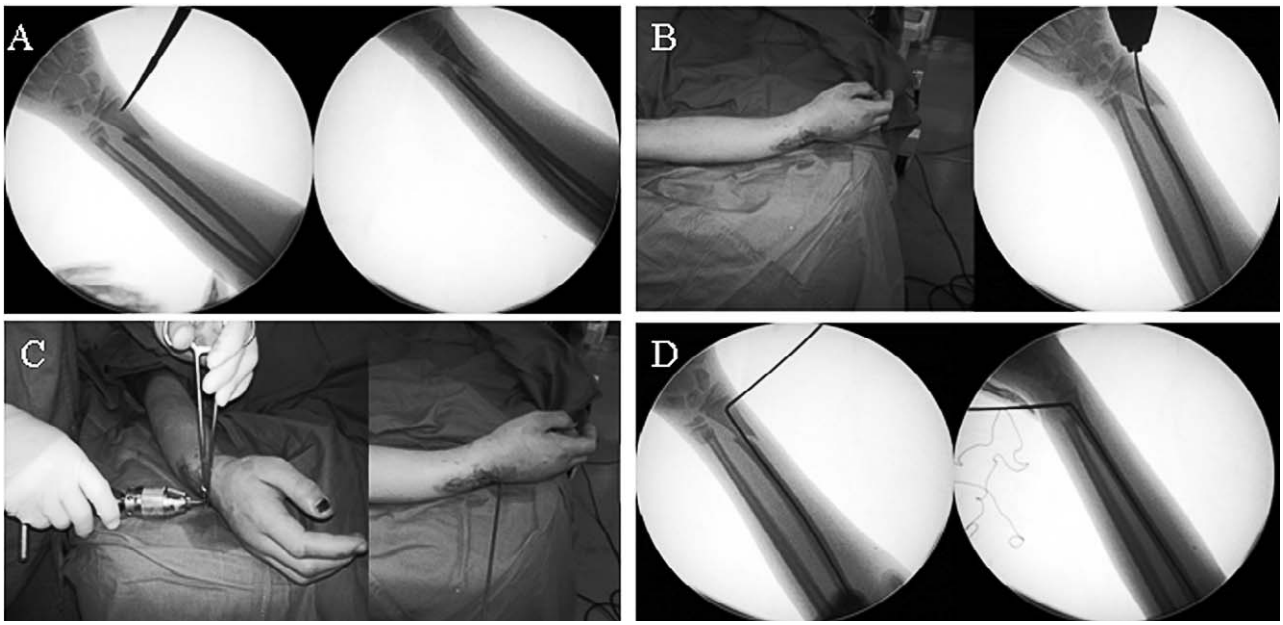

Fig. 2 The surgery procedure and X-ray image. The lateral view and anterior-posterior view before operation (A). After creating the entrance site just 0.5 to 1.0 cm proximal to the epiphysis line of the radius, the intramedullary nail was inserted and advanced to pass through the fracture line until the tip reaced the middle-upper segment of the radius (B). The nail was bent distally by about 90° at the site very close to the entry; the elastic intramedullary nail was advanced until the prebent part completely entered the marrow cavity (C). In its final position, the apex of the bend was located at the distal fragment so that the nail became straight in the cavity, keeping the 2 fragments in satisfactory alignment (D).

ray, then plaster cast fixation in a functional position was employed for 3 to 4 weeks.

The distal segment length and the radius total length were collected before the procedure. Follow-up was conducted for all subjects for 12 to 19 months, then angulation and apposition degree in anterior-posterior and lateral X-ray films were evaluated. In addition, the function of the forearm was evaluated using the Demerit-Point System of Gartland and Werley.[24]

The data were expressed as mean ± SD. The χ^2 test was used to evaluate numeric data, and the *t*-test was used to evaluate ages in different groups. $P < 0.01$ was regarded as statistically significant.

Results

Fifty-two patients were subjected to closed reduction and fixation with a prebent titanium elastic intramedullary nail under general anesthesia. The operation time was 16.73 ± 6.253 minutes (range, 10–30 minutes). During operation there were 22.31 ± 11.309 X-ray images (range, 10–50 images). Three patients had taken the Kirschner wire as the first choice of fixation method, with an operation time of over 60 minutes and over 100 X-ray images. Finally, they obtained satisfactory results after replacement of the Kirschner wire with a prebent elastic intramedullary nail. We found that once the prebent part was fully inserted into the marrow cavity, the fracture angular deformity was corrected in anterior-posterior and lateral X-ray films immediately. The apposition rate was 90% to 100% in lateral view; in the anterior-posterior view, the apposition rate in all cases was >50%, with the apposition rate being >75% in 24 of those cases (Table 1). Of these, the apposition rate of 2 patients declined slightly 10 days after operation, but then kept stable under follow-up. Good callus growth was observed in the X-ray films at 1 month after operation. The average time of fracture healing was 5 months (range, 4–7

Table 1 Basic postoperation data

	Anterior-posterior X-ray films	Lateral X-ray films
Angulation	All patients less than 5°	All patients less than 5°
Apposition	24 patients more than 75% 28 patients 50% to 75%	All patients more than 90%

Table 2 Forearm function evaluated by Demerit-Point System of Gartland and Werley

Category	Points	No. of cases
Residual deformity (range, 0 to 3 points)		
Prominent ulnar styloid process	1	0
Residual dorsal tilt	2	0
Radial deviation of hand	2, 3	0
Subjective evaluation (range, 0 to 6 points)		
Excellent: no pain, disability, or limitation of motion	0	50 cases
Good: occasional pain, slight limitation of motion, and no disability	2	2 cases
Fair: occasional pain, some limitation of motion, feeling of weakness in wrist, no particular disability if careful, and activities slightly restricted	4	0
Objective evaluation[a] (range, 0 to 5 points)		
Loss of dorsiflexion	5	0
Loss of ulnar deviation	3	0
Loss of supination	2	0
Loss of palmar flexion	1	0
Loss of radial deviation	1	0
Loss of circum duction	1	0
Pain in distal radio-ulnar joint	1	0
Grip strength 60% or less than on opposite side	1	0
Loss of pronation	2	0
Complications (range, 0 to 5 points)		
Arthritic changes		
Slight	1	0
Slight, with pain	3	0
Moderate	2	0
Moderate, with pain	4	0
Severe	3	0
Severe, with pain	5	0
Nerve complications (median)	1 to 3	0
Poor function of fingers due to cast	1 or 2	0
Final result (ranges of points)		
Excellent	0 to 2	52 cases
Good	3 to 8	0
Fair	9 to 20	0
Poor	$\geq$21	0

[a]The objective evaluation is based on the following ranges of motion being the minimum for normal function: dorsiflexion, 45°; palmar flexion, 30°; radial deviation, 15°; ulnar deviation, 15°; pronation, 5°; and supination, 50°.

months) based on the evaluation of fracture line disappearances. When healing was confirmed, the nail was removed. Under 12- to 19-month follow-up, firm fracture healing and good remodeling were observed, and there was no impaired forearm rotation function or secondary fracture. There were no other complications except for irritant of nail end in 4 patients. We evaluated the forearm function by the Demerit-Point System of Gartland and Werley after the nails were removed. All 52 patients had excellent final results. Only 2 patients suffered from occasional pain (Table 2).

Figure 3 shows the results of one 13-year-old right-hand–dominant male. He accidentally fell while playing football with his classmates and suffered a displaced DRDMJF combined with a distal ulnar fracture (Fig. 3A and 3B). The radius was treated with the described technique 8 hours after the injury, while the ulnar was treated with a normal elastic intramedullary nail. The intramedullary nails were removed at 5 months after surgery, and the patient got full range of motion of his right forearm (Fig. 3C and 3D).

Figure 4 shows the data of one patient whose apposition rate declined slightly after operation, but then remained stable during follow-up. Figure 4A and 4B shows the lateral view and anterior-posterior view before operation and just after operation, respectively. Then, 1 month (Fig. 4C) and 6 months (Fig. 4D) after operation, images were obtained at the lateral position.

Regarding the anterior-posterior view, 24 patients with 75% to 100% apposition rate and 28 patients with 50% to 74% apposition rate were divided into 2 groups that we named *good group* and *fair group*. The preoperation data were analyzed, and the results showed that radius complete fracture, radius oblique fracture, and radius fracture combined with ulnar fracture were the factors that were associated with the apposition (Table 3).

Discussion

Careful evaluation and control of the nail is always very important in all the stages of managing these mataphyseal diaphyseal fractures. In this study, we find that the application of pre-bending the elastic intramedullary nail in the treatment of DRDMJF not only prevented the injury of epiphysis, repeated operation by Kirschner, and large-scale peeling by steel plate, but also obtained a satisfactory alignment. We also found that bending the nail about 90° was more stable for fixation and would tend to lessen migration.

In 52 patients with DRDMJF subjected to prebent elastic intramedullary nail treatment, no postoperative angular deformity was seen. The lateral shift of fracture coronal in 28 cases was not corrected completely; the apposition rate was 50% to 75% (including the shift after operation in 2 cases). However, after 12 to 19 months of follow-up, we found that residual displacement of the fracture site in the coronal plane did not influence the prognosis.

Fig. 3 The X-ray images of one 13-year-old right-hand–dominant male preoperation and postoperation. The lateral view (A) and anterior-posterior view (B) before operation. For 5 months after operation, the X-ray images were obtained at the lateral (C) and A-P positions (D).

Although complete anatomical reduction was not obtained, the forearm rotation function was not impaired, because of the benefit of the stronger remodeling ability of the distal radius than of the bone shaft in children if the angular deformity is completely corrected. Some reports have suggested that the impaired forearm rotation function mainly results from the angular deformity.[15–20] Additionally, the slightly impaired forearm rotation should not influence daily life and sports.[15,17,21] Thus, it is not necessary to perform open reduction to achieve anatomic alignment for minor loss of motion.[14,15,22]

Next, we analyzed the factors that influence the fracture reduction in the coronal plane and the present study. Our data showed that complete reduction was not achieved in the fracture types, including radius complete fracture, radius oblique fracture, and radius fracture combined with ulnar fracture. Some reports also revealed that these types of fractures are the factors related to fracture displacement after closed reduction.[23] It was probably due to severe violence, the peeling of large-area periosteum, the periosteum intercalation, and the fracture instability. As a kind of incompletely stable structure, intramedullary nail is difficult to manage to complete anatomical reduction.

Another factor influencing the fracture reduction in the coronal plane may be the anatomical features of the distal radius. The cavity of the distal radius, the oblate ellipsoid, is special so that the nail seems slim compared to the transverse diameter, although it has filled the anteroposterior diameter of the cavity. Therefore, the correction of the coronal lateral shift by the nail is limited.

The treatment of DRDMJF by prebent elastic intramedullary nail could make up for the deficiency of Kirschner wire and steel plate in fixation and could obtain a satisfactory alignment in simple mode. We now use this method as the first choice to treat this type of fracture and, sometimes, as the remedial measure after the failure of Kirschner wire fixation.

Although function of the radius was recovered completely in 52 patients in the present study, whether the residual displacement in the coronal plane will influence the appearance and functions in a larger sample remains unknown. Thus, the improvement of the stability of the elastic nail and the coronal apposition rate still play an essential role in the prevention of displacement of fracture end, the reduction of fracture remodeling, the acceleration of fracture healing, and the recover of forearm functions. Therefore, it is necessary to evaluate the fracture types carefully, choose the nail with suitable diameter, and improve the surgical technique to rule out the factors influencing reduction. In addition, the fixation of Kirschner wire has been less likely to be employed in our center since the prebent intramedullay nail was used to treat the DRDMJF; therefore, we do not have enough perfect-paired data to compare the effect of the 2 methods for the time being. In addition, no obvious, serious complications were found in this study, which suggests that elastic nails are able to be used for child bone fractures. This study could be seen as exploratory.

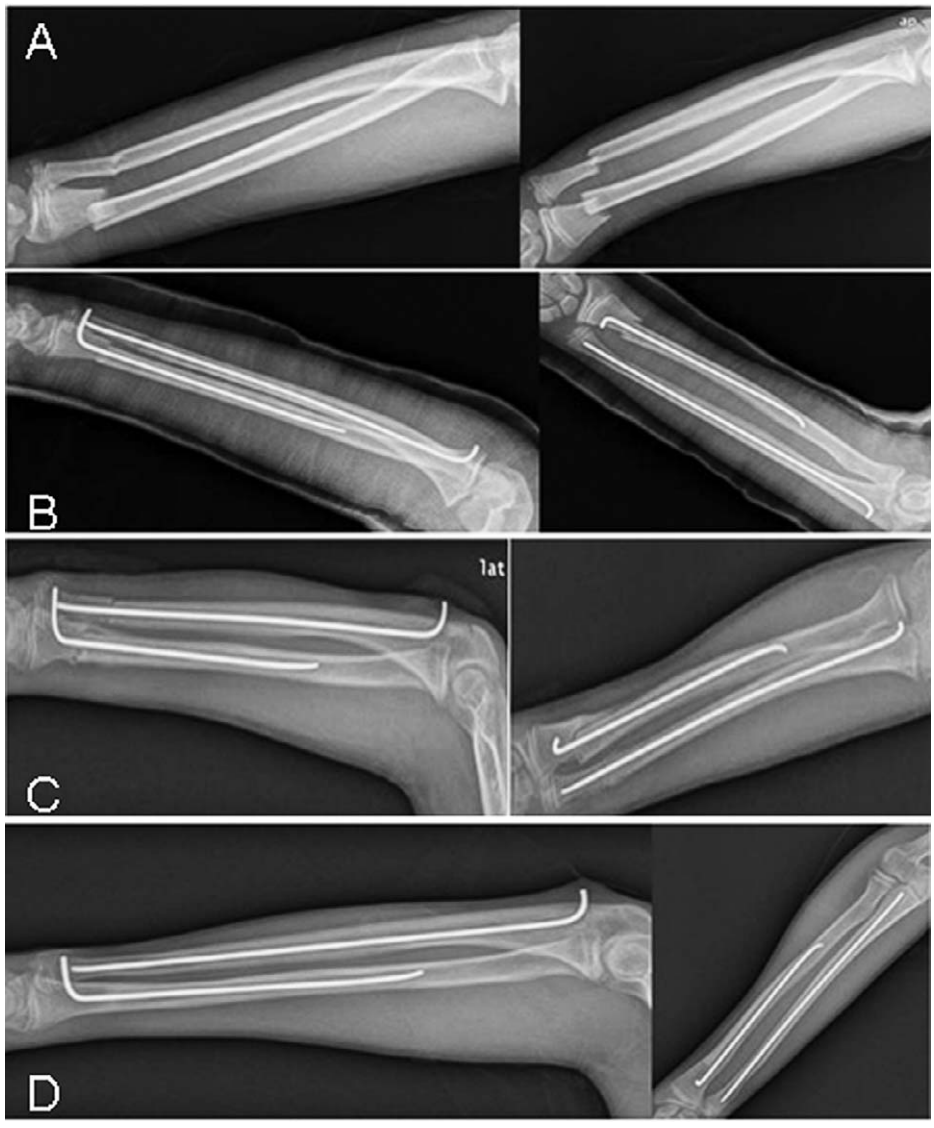

Fig. 4 The X-ray images of one patient whose apposition rate declined slightly after operation, but then remained stable during follow-up. The lateral view and anterior-posterior view before operation (A) and just after operation (B). For 1 month (C) and 6 months (D) after operation, the X-ray images were obtained at the lateral position.

Table 3 Factors related to prognosis

	Good (75%–100%) (n = 24)	Fair (50%–74%) (n = 28)	*P* value	OR (95% CI)
Radius complete fracture	10	24	0.001	4.083 (1.551–10.753)
Radius oblique fracture	0	16	0.000	2.333 (1.521–3.579)
Male	20	22	0.736	0.778 (0.248–2.436)
Left side	12	16	0.781	1.167 (0.650–2.096)
Combine ulnar fracture	12	24	0.007	3.500 (1.298–9.434)
Age, y	10.00 ± 3.07	9.57 ± 3.90	0.665	

CI, confidence interval; OR, odds ratio.

In conclusion, our data showed that the application of prebent elastic intramedullary nail is a good method to treat DRDMJF, with a satisfactory alignment, stable fixation, and less migration.

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