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ORIGINAL STUDY

Percutaneous Kirschner-wire fixation for displaced distal forearm fractures in children

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A prospective study was conducted to evaluate the efficacy of percutaneous Kirschner-wire fixation for the management of high-risk distal forearm fractures in children. Thirty two children (22 boys & 10 girls) with displaced fractures of the distal third of the radius with or without ulnar fractures were managed by closed reduction and percutaneous Kirschner-wire fixation. Their average age was 10.1 years (4-16 years). The fracture was open (Grade 1) in two cases (6.3%). Antegrade intramedullary Kirschner-wire fixation was done for distal radial fractures in 71.9% of cases. Patients were evaluated clinically and radiologically after an average duration of follow-up of 28.6 months. Patients with residual angulation more than 15°, limitation of forearm or wrist movement more than 20°, persistent pain or clinical deformity were considered to have unsatisfactory results. Satisfactory results were obtained in 87.5% of all cases. The residual radioulnar and dorsovolar angulations were significantly related to the decrease in forearm rotation and the unsatisfactory results. High-risk distal forearm fractures in children should be treated by primary percutaneous Kirschner-wire fixation supplemented by cast immobilisation.

Keywords : percutaneous ; K-wire fixation ; distal forearm fractures ; children.

INTRODUCTION

Distal forearm fractures are among the commonest skeletal injuries in childhood (*3,19*). Closed reduction and cast immobilisation has been the mainstay of treatment supported by studies which have demonstrated remodeling of mal-union in children (*8,11*). This has sometimes led to the acceptance of poor reduction and loss of reduction (*5*). However, more recent studies have shown poor end-results in 15% to 29% of cases, particularly with regard to limitation of forearm rotation (*4,12*). Loss of rotation has been correlated with angular deformity and residual mal-alignment at the time of removal of the plaster (*16,18*). By contrast, Hogstrom *et al* (*10*) and Nilsson and Orbant (*13*) have shown that loss of rotation is not related to residual angulation and may persist despite apparently full remodeling of the fracture.

Several studies have concentrated on the amount of residual angulation which is allowable and the

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potential for remodeling. Hughston (*11*) recommended that fractures in patients over 14 years of age should be treated as for adults but, that in children under 10 years of age with distal third fractures, 30° to 40° of angulation was acceptable. Daruwalla (*4*) suggested that no more than 10° of angulation should be allowed in children over the age of ten. Fuller and McCullough (*7*) reported that up to 20° of angulation in distal third fractures would be accepted in patients under 14 years. Generally speaking, the younger the child, the more distal the fracture and the smaller the angulation, the better the result (*8,12*).

Translation of the fracture is the most important risk factor for poor outcome. Proctor *et al* (*15*) identified two factors which increase the chance of re-displacement of forearm fractures in children : the presence of complete displacement and failure to achieve a perfect reduction. Mani *et al* (*12*) have shown a predicted failure rate of 60% if the radial fracture is displaced by more than half the diameter of the radius and 68% after complete displacement. These authors advised the addition of percutaneous Kirschner wires for cases with high risk of re-displacement.

The purpose of the current study is to evaluate the efficacy and value of percutaneous Kirschner-wire fixation for treating severely displaced distal forearm fractures in children.

PATIENTS & METHODS

Between January 2006 and December 2008, 32 children with displaced fractures of the distal third of the radius, with or without distal ulnar fractures, were admitted to King Saud Hospital, Unayzah, Kingdom of Saudi Arabia, and managed by closed reduction and percutaneous Kirschner-wire (K-wire) fixation. Fracture dislocation, distal radial epiphyseal injuries, and pathological factures were excluded. The thirty two cases included in the current study were 22 male and 10 female patients. Their ages ranged from 4 to 16 years (average 10.1). The left forearm was involved in 21 cases (65.6%) ; in two of them, the left side was dominant. All the remaining eleven right forearms (34.4%) were dominant. The mechanism of trauma was a fall during playing in 14 cases (43.8%), a motor wheel accident in 10 (31.3%), a fall from a height in 7 (21.9%), and a motor car accident in 1 (3.1%). The fracture was open (Grade 1 puncture from within) in only two cases. In three cases, the fracture was associated with other injuries.

The initial radiographs were assessed to determine the site of the fracture, whether involving the distal 1/6 or between 1/6 and 1/3 of the total length of the radius, the amount of translation and angulation, and the presence of a distal ulnar fracture. The degree of translation of the radius and ulna at the fracture sites was categorized as follow : grade I, no translation ; grade II, translation < half the diameter of the bone ; grade III, translation > half the diameter of the bone ; grade IV, complete translation with no end-to-end contact (*12*).

There were twenty cases with Grade IV translation of the distal radial fracture, seven had Grade III and five had Grade II. Three of the five patients with Grade II translation presented late after being managed conservatively by closed reduction and plaster cast immobilisation (delayed failure). The remaining two patients presented initially with angulation greater than 15°. Surgical treatment was indicated in cases with a considerable translation (Grade III & Grade IV), angulation greater than 15° in any direction in children less than 10 years of age or greater than 10° in children over the age of ten, and in patients with irreducible fracture (immediate failure) or re-displaced fracture (delayed failure).

Operative Technique

The procedure was performed under general anaesthesia and image intensifier control. An arm tourniquet was applied but inflated only when antegrade intramedullary K-wire fixation was planned. Satisfactory reduction was defined as at least 75% of bony apposition across the fracture site and angulation of less than 15° in patients under ten years of age or 10° over this age. Rotational mal-alignment was corrected and assessed before fixation by checking the width and shape of bone fragments and after fixation by detecting any limitation in the range of forearm rotation. Grossly displaced distal ulnar fractures (G III & G IV) were also reduced and percutaneous K-wire fixation was done to add more stability of fixation. No fixation was attempted for distal ulnar epiphyseal injury or minimally displaced fractures.

In cases managed by retrograde K-wire fixation, a (1.2-1.8 mm) K-wire was inserted from the radial styloid through the metaphyseal part of the distal fragment in a more proximal fracture (between the 1/6 and 1/3 of the total length of the radius). If the fracture was more distal (1/6 or less of radius), it was possible to insert the K-wire through the distal radial epiphysis. After crossing the

fracture, the tip of the K-wire was directed into the opposite cortex of the radius. For the more proximal fractures, the K-wire was passed up the medulla for at least 4 cm beyond the fracture site. An extra-wire was inserted from the dorsoulnar aspect, if the surgeon judged that fixation was insecure with the first wire (fig 1).

For ante-grade K-wire fixation, a small longitudinal stab incision (1.5-2 cm) was made at the mid-lateral border of the radius. The brachioradialis tendon together with the underlying superficial radial nerve were retracted volarly and tendons of the extensor carpi radialis longus and brevis dorsally to expose the insertion of pronator teres. After minimal retraction of the pronator tendon insertion, a hole was made, the size of which was less than half the diameter of bone. At first the drill bit was directed perpendicular to the bone then obliquely to provide a smooth passage for insertion of K-wires without endangering the bone. A drill sleeve was used to protect the soft tissue and to control the drill bit over the bone.

In cases in which two K-wires were used for ante-grade intramedullary (IM) fixation, the sum of their width should be less than the size of the medulla to facilitate their gliding and prevent jamming. For young patients with a narrow medulla, one K-wire was used ante-grade and augmented with another retro-grade

Fig. 1. — a. A 15-year-old boy presented with a Grade IV displaced distal radial fracture with an angulated distal ulnar fracture ; b. he was treated with closed reduction and percutaneous retrograde K-wire fixation for the radius, two K-wires were used from radial styloid as the first one was not holding well, so another one was inserted and kept there ; c. satisfactory end results.

Fig. 2. — a. This 13-year-old boy presented with Grade IV displaced fractures of the distal third of both bones of the left forearm ; b. he was managed with antegrade intramedullary K-wire fixation of radius and ulna ; c. satisfactory end result ; d. good range of forearm and wrist movement.

K-wire. The K-wires were pre-bent and inserted over a T-handle with their tips directed radially. Once the tips of the wires reached the fracture, the distal fragment was manipulated to obtain an acceptable reduction. Then one K-wire was rotated 180° and pushed toward the ulnar side of the distal fragment. The other K-wire was directed to the radial styloid guided with the C-arm through anteroposterior (AP) and lateral images (fig 2). In cases in which the fracture was unstable and had the tendency for radial drift, the lateral K-wire was used to help and maintain the reduction by pushing it into the radial styloid then rotating it to keep the distal fragment in the

reduced position. Fixation of an ulnar fracture was done by the antegrade technique in most cases using one K-wire inserted percutaneously. In each technique of fixation K-wires were buried under the skin.

An above-elbow plaster cast with the forearm and wrist in neutral position was applied for an average duration of 5.4 weeks (range 4-10) during which the child was encouraged to move fingers fully. After removal of the cast, patients were asked to strengthen the wrist grip and to move the forearm, and elbow. K-wires were removed under anaesthesia after an average time interval of 9.9 weeks (range 8-21).

All patients were evaluated clinically and radiologically after an average duration of follow-up of 28.6 months (range 6-37 months). Clinical evaluation included assessment of any limitation of wrist, forearm, or elbow movements compared to the sound limb, presence of clinical deformity, and persistent pain. AP and lateral radiographs were evaluated for healing and any residual angulation. Patients with unsatisfactory results showed loss of forearm rotation > 20°, loss of wrist movement > 20°, persistent pain or clinical deformity, or residual angulation $\geq 15°$ in any direction. Statistical analysis was performed using SPSS for Windows (version 8.0). Pearson Chi-square test, independent samples t-test, and one way ANOVA test were used to define relations between clinical and radiological end results. Statistical significance was set at $p < 0.05$.

RESULTS

The age distribution of the current series was bimodal with peaks at 6 and 14 years. Fifteen patients (46.9%) were less than 10 years of age and seventeen (53.1%) were more than 10 years of age. The male to female ratio was 2.2 to 1. The left forearm was more frequently involved than the right side (table I). The distal 1/6 of the radius was fractured in the majority of cases (80%). A concomitant fracture of the distal ulna was present in 28 cases (87.5%), 20 of them had a severely displaced fracture (G III in 8 cases & G IV in 12 cases) (table II).

Most of the operations were done on the day of admission, and the average hospital stay was two days. The average duration of operation was 32 minutes (range 15 to 40 minutes). The longer duration was attributed to the presence of an ulnar fracture that needed fixation, and the small approach used for ante-grade fixation of the radius. No cases required open reduction. Fixation of the distal radial fracture with or without fixation of an ulnar fracture was performed by an antegrade IM K-wire in 71.9% of cases, a retrograde K-wire in 21.9%, and mixed ante & retrograde K-wires in 6.2%. All fractures united after an average period of 7.5 weeks (6-10 weeks). Superficial pin-tract infection was encountered in 3 cases (9.4%), which healed after early removal of K-wires. There were no cases of deep infection, nerve injury, vascular complications, tendon rupture, or premature physeal closure.

Satisfactory results were obtained in 87.5% of cases. Of the four cases which developed unsatis-

Table I. — Analysis of patients

Data	Grade of translation of radial fracture			Total
	GII	GIII	GIV	
	No. (%)	No. (%)	No. (%)	No. (%)
Age in years				
≤ 10 years	2 (13.3%)	2 (13.3%)	11 (73.3%)	15 (46.9%)
> 10 years	3 (17.7%)	5 (29.4%)	9 (52.9%)	17 (53.1%)
Sex				
Male	5 (22.7%)	5 (22.7%)	12 (54.6%)	22 (68.7%)
Female	–	2 (20%)	8 (80%)	10 (31.3%)
Side				
Right	3 (27.3%)	3 (27.3%)	5 (45.5%)	11 (34.4%)
Left	2 (9.5%)	4 (19.1%)	15 (71.4%)	21 (65.6%)
Total	5 (15.6%)	7 (21.9%)	20 (62.5%)	32 (100%)

Table II. — Analysis of the fracture pattern

Pattern of fracture	Grade of translation of radial fracture			Total
	GII	GIII	GIV	
	No. (%)	No. (%)	No. (%)	No. (%)
Site				
Distal 1/6	3 (13%)	2 (8.7%)	18 (78.3%)	23 (71.9%)
Between 1/6 and 1/3	2 (22.2%)	5 (55.6%)	2 (22.2%)	9 (28.1%)
Dorsovolar angulation				
Dorsal	4 (14.4%)	5 (19.2%)	17 (65.4%)	26 (81.3%)
Volar	1 (16.7%)	2 (33.3%)	3 (50%)	6 (18.7%)
Radioulnar angulation				
Radial	2 (10%)	4 (20%)	14 (70%)	20 (62.5%)
Ulnar	–	1 (50%)	1 (50%)	2 (6.3%)
Neutral	3 (30%)	2 (20%)	5 (50%)	10 (31.2%)
Ulnar involvement				
No fracture	3 (75%)	1 (25%)	–	4 (12.5%)
Greenstick	–	–	1 (100%)	1 (3.1%)
Complete fracture	1 (4%)	5 (20%)	19 (76%)	25 (78.1%)
Epiphyseal injury	1 (50%)	1 (50%)	–	2 (6.3%)
Total	5 (15.6%)	7 (21.9%)	20 (62.5%)	32 (100%)

factory results, two had residual dorsal angulation of the distal radial fragment of 17° and 19° with limited forearm supination of 22° and 24° respectively. Pain was insignificant in these two cases and resolved spontaneously. The first case was 14 years of age, presented late after a trial of conservative treatment with dorsal tilt of 29° and radial tilt of 10° that improved to 17° and 4° after remanipulation and ante-grade IM K-wire fixation. The 2nd child was 12 years of age, sustained a fall down trauma 5 weeks after surgery and developed dorsal tilt of 25° and radial tilt of 7° that decreased to 19° and 0° after manipulation and plaster cast immobilisation for 3 weeks more. The remaining two cases with unsatisfactory results had pain with limited wrist flexion of 22° and 25°. One of them was 6 years of age and showed improvement of pain with time. Pain was attributed to irritation of extensor tendons of the wrist. All cases showed full range of motion of the elbow joint.

We could not find significant relations between age, sex, side or mechanism of trauma and the end results ; however, 93.3% of patients less than 10 years of age had satisfactory results. Majority of fractures involved the distal 1/6 of radial length (95.7%) ; this was associated with satisfactory results ($p = 0.026$). No significant correlations could be detected between the grade of radial fracture translation or the presence of ulnar fracture and its extent of displacement and the end results. This may be explained by the small number of patients.

Most of patients (91.3%) managed by antegrade IM K-wire fixation of radial fractures with or without fixation of ulnar fractures obtained satisfactory results. The mean residual radioulnar and dorsovolar angulations were significantly smaller in patients with satisfactory results than in patients with unsatisfactory results ($p = 0.023$ and 0.001 respectively). Earlier removal of K-wires was significantly associated with satisfactory results ($p = 0.01$). The mean time to remove the cast was shorter (5.3 weeks) in patients with satisfactory results than in those with unsatisfactory results (6.3 weeks), but this relation was not significant ($p = 0.25$). The more neutral the final radioulnar angulation, the better was the range of forearm rotation ($p = 0.01$). Also, the increase in residual dorsovolar angulation was significantly associated with a decrease in range of forearm rotation as compared to the contralateral side ($p = 0.01$).

DISCUSSION

Conservative treatment for displaced distal forearm fractures in children is possible, but reduction must be perfect and the cast must be well moulded. The most important risk factors for re-displacement and poor outcome of distal radial fracture were children older than 10 years with fracture translation more than half the diameter of the bone at the fracture site or angulation more than 20°, failure to achieve a perfect reduction, repeated reduction maneuvers, and the presence of additional fracture of the ulna (*19*).

Percutaneous Kirschner wires are widely used for treating children's fractures such as supracondylar fracture of the humerus and shaft fractures of the foream bones (*1,9*) ; however, their use in high-risk distal radial fractures in children has not been popularized. Several previous studies recommended the use of percutaneous K-wire directly for stabilization of high-risk fracture and reserved open reduction and K-wire fixation if closed reduction failed and for open fractures (*12,15*).

The current study was a chance to present a novel technique for stabilization of such fractures by antegrade intramedullary K-wire. This technique is easy to the surgeon, tolerable to the patient and avoids many complications of retrograde K-wire fixation such as irritation or impalement of extensor tendons, skin irritation, pin tract infection, and the less common partial premature physeal closure. For cases managed by retrograde K-wire fixation we did not see any case of premature physeal closure. Although rare, this complication has been reported sporadically (*2*).

Noonan and Price (*14*) reported that successful outcomes are based on restoration of adequate pronation and supination and to a lesser degree, acceptable cosmesis. All cases in our study were operated and immobilized with the forearm in neutral or slight supination position. This will help to keep the interosseous membrane stretched and space most wide, regaining maximum range of motion after cast removal. Fatti *et al* (*6*) noted that limitation of forearm rotation has usually been associated with immobilization of the forearm in full pronation, however, the cause of the interosseous membrane scarring is still unknown.

The present study indicates that residual dorsal angulation and radial deviation of the distal fragment were significantly associated with a decrease in the range of forearm rotation and unsatisfactory end results. Roberts (*16*) found that residual radial deviation of the distal fragment was more closely related to the loss of forearm rotation than was dorsal angulation. He explained this by the narrowing of the interosseous space which did not occur with dorsal angulation.

CONCLUSIONS

For distal radius fractures in children with a high risk of re-displacement after closed reduction, primary percutaneous K-wire fixation should be the preferred procedure. Despite the limited number of cases, antegrade intramedullary K-wire fixation was found to be a safe, easy and effective technique for reduction and stabilization of distal forearm fractures in children. Grossly displaced and unstable distal ulnar fractures require reduction and fixation to add more stability. Immobilization of the forearm in neutral position or in slight supination, early mobilization, and early removal of the K-wires are advised to obtain better functional results.

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