ACTA
ORTHOPAEDICA
et
TRAUMATOLOGICA
TURCICA

Acta Orthop Traumatol Turc 2010;44(2):117-123
doi:10.3944/AOTT.2010.2133

Selective Kirschner wiring for displaced distal radial fractures in children

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Objectives: This study was designed to evaluate our departmental policy of plaster immobilization and selective Kirschner (K) wiring for the management of displaced distal radius fractures in children.

Methods: On a retrospective basis, we evaluated a consecutive series of 112 childhood displaced distal radius fractures (108 patients; 77 boys, 31 girls; mean age 10.5±2.6 years; range 5 to 16 years) presenting with clinical deformity during a two-year period. There were 97 incompletely displaced (86.6%), and 15 completely displaced (13.4%) fractures. All the fractures were managed with manipulation under general anesthesia and plaster immobilization. Additionally, K-wire fixation was performed following manipulation in seven (46.7%) of the completely displaced fractures. The mean follow-up period was 1.1 years (range 10 weeks to 2 years).

Results: The mean angulation of fractures prior to manipulation was 21.5±10.1°, it decreased to 2.4±4.8° following manipulation. Remanipulation was required in 11 fractures (9.8%) based on clinical and radiographic findings of redisplacement. Of these, eight fractures (8.3%) were incompletely displaced, and three fractures (20%) were completely displaced. All completely displaced fractures that required remanipulation had been additionally treated with K-wire fixation. Fractures requiring further treatment had a mean angulation of 17.1±5.8° prior to remanipulation, and a mean residual angulation of 4.7±6.0° at final radiographic assessment. A perfect fracture reduction was achieved in all the patients with a Salter-Harris II injury (n=22), and none of these patients required remanipulation. However, the quality of initial reduction was not associated with the development of redisplacement. There was no significant difference between isolated distal radius fractures (n=58) and combined radius and ulna fractures (n=32) with respect to remanipulation rate and final angulation ($p>0.05$). Final radiographs showed a significantly greater angulation in fractures which were initially completely displaced in comparison with those that were incompletely displaced (8.2±7.1° *vs*. 4.2±5.7°; $p=0.024$), but this was not of clinical significance. None of the patients had radial shortening and no K-wire related complications were encountered.

Conclusion: Our data suggest that there should be other factors involved in the development of redisplacement and the need for remanipulation other than the degree of fracture displacement and the quality of initial reduction. Selective K-wire fixation in displaced fractures does not seem to decrease redisplacement and remanipulation rates.

Key words: Bone nails; child; fracture fixation/instrumentation; fractures, closed/therapy; manipulation, orthopedic; radius fractures/therapy; ulna fractures.

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Submitted: October 23, 2009 **Accepted:** December 7, 2009

Fractures of the distal radius are common in childhood, and usually heal quickly with no residual problems.[1,2] Unlike adult fractures, some residual angulation is acceptable when the fracture has united, due to the remodeling potential in this age group. However, there are conflicting opinions on the range of acceptable residual angulation that would not result in loss of function.

Hughston[3] suggested that, under the age of 10 years, angulations in a range of 30° to 40° were acceptable. Fuller and McCullough[4] suggested that angulations up to 20° might be acceptable under the age of 14 years.[4] On the other hand, Friberg[5,6] noted that, in residual angulations exceeding 20°, the fracture might not remodel. In skeletally immature patients with open physes, fractures with dorsovolar and radioulnar angulations of less than 15° and less than 1 cm of shortening healed within an average of six weeks, and completely remodeled within an average of 7.5 months.[7] Over the age of 10 years, angulations greater than 10° interfered with adequate remodeling with growth.[8]

Greater residual angular deformities are acceptable in younger children and in fractures closer to the growth plate due to their greater remodeling potential.[9] Although volarly displaced fractures have less remodeling capacity than dorsally displaced fractures, Zimmermann et al.[10] found no difference in the remodeling capacity of fractures.

Complication rates of distal radius fractures in the literature vary from 6% to 80%.[11] Many distal radius fractures are managed by manipulation under anesthesia and application of a cast. Factors that predispose the fracture to redisplacement include complete displacement at initial presentation and failure to achieve complete reduction.[12,13] Additionally, redisplacement may be less likely when managed by more experienced surgeons, perhaps due to an improved ability to understand the fracture mechanism,[14] achievement of an anatomical reduction, and application of a cast with better three-point fixation.[15]

Because of the significant risk for redisplacement of completely displaced fractures even if a perfect reduction is achieved, some authors advocate immediate Kirschner (K) wire stabilization as a safe, effective method of stabilizing severely displaced fractures to avoid the need for remanipulation.[12,13,16-20] Disadvantages include the risk for pin-track infections,[21] nerve injury, and the need for a further procedure to remove the wires. Remanipulation of redisplaced fractures has also been shown to be a safe, reliable option in the management of these fractures.[20] However, there is still a lack of knowledge on normal anatomical values and generally accepted measurement criteria do not exist to predict fractures that are unlikely to benefit from repeat manipulations.[14]

Our departmental policy was designed to eliminate the risk for redisplacement and avoid subsequent manipulations. We evaluated the effects of the departmental policy of selective K-wiring for the management of displaced childhood distal radius fractures presenting with clinical deformity.

Patients and methods

A retrospective analysis of case notes and radiographs was undertaken, of children who had sustained a distal radius fracture that required manipulation during a two-year period. The study was approved by our local ethics committee. All the procedures (manipulation, remanipulation, K-wiring) described in the study were performed after signed informed consent had been obtained from the parent(s) of the child in whom the injury had occurred.

The unit policy of management of distal radius fractures in children is based on three categories: *(i)* below-elbow cast immobilization in undisplaced fractures; *(ii)* above-elbow cast in stable (incompletely) displaced fractures following manipulation under anesthesia (Fig. 1); *(iii)* percutaneous K-wire fixation and below-elbow cast for unstable (completely) displaced fractures following manipulation under anesthesia. In this study, we included only patients with displaced fractures. The data from 112 fractures of 108 patients up to the age of 16 years were analyzed. Patients having open fractures, multiple fractures, or any other associated injuries were excluded from the study.

Patient details included age, sex, side of injury, mechanism of injury, details of the management of the fracture, and complications. Review of the radiographs was performed by two independent clinicians, and also by each observer twice with one week interval, to identify the site of injury, the initial displacement of the fracture, the position of the fracture following manipulation and remanipulation if undertaken, and the final position of the fracture. The angulation at the fracture site was identified by measuring

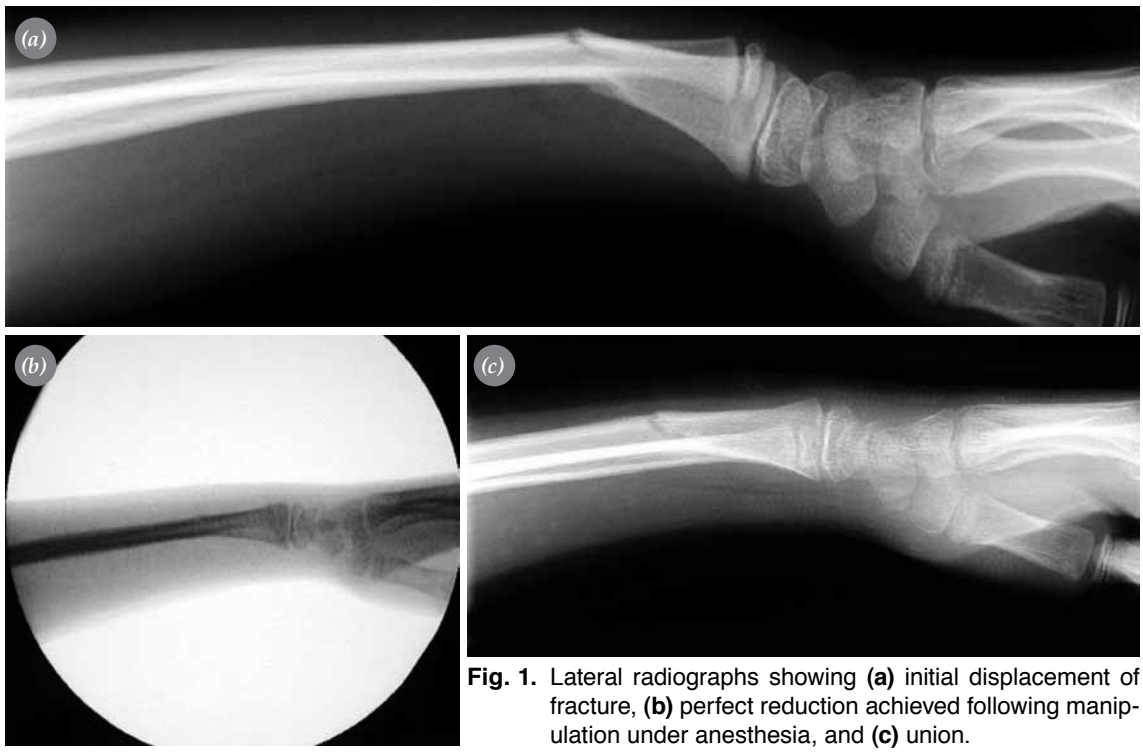

Fig. 1. Lateral radiographs showing **(a)** initial displacement of fracture, **(b)** perfect reduction achieved following manipulation under anesthesia, and **(c)** union.

the angle subtended by the intersection of two lines parallel to the axis of the shaft of the radius on either side of the fracture, using a hand-held goniometer. Radiographs of the contralateral wrist were not routinely obtained unless it was clinically warranted. The means of the two radiographic raters were used.

Operative technique

Manipulation was performed under general anesthesia and with tourniquet control, with the patient in the supine position on a radiolucent arm table, by maintaining traction and countertraction and correcting the components of the deformity. Following manipulation under anesthesia, an above-elbow cast was applied in stable displaced fractures, whereas percutaneous K-wire fixation and a below-elbow cast were used in unstable displaced fractures. Two stab incisions were made just distal to the distal radius at the selected entry sites for the insertion of two K-wires. A mosquito artery clamp was used to spread the tissues away from the line of K-wire incision. After the fracture had been reduced, two 1.6-mm K-wires were inserted at slow speed in a crossed and distal-to-proximal fashion to maintain fracture reduction. One wire was inserted from the tip of the radial styloid, and the other from Lister's tubercle. The first one was advanced in a radial-to-ulnar direction, and the other in a dorsal-to-volar direction, purchasing the opposite cortex. The fracture reduction was checked perioperatively using the image intensifier, and a below-elbow cast was applied.

Statistical analysis

The data were analyzed using the SPSS (version 10.0) software program. Descriptive statistics were derived including the mean and standard deviation. Correlations between data were analyzed using the Pearson chi-square test. Cohen's kappa was calculated to analyze intraobserver and interobserver variability. Kappa values from 0.40 to 0.59, 0.60 to 0.79, and 0.80 to 1.0 were considered to show moderate, substantial, and outstanding intraobserver and interobserver agreement, respectively. Cohen's kappa coefficients showed good interobserver reliability and intraobserver reproducibility (kappa=0.66 for both).

Results

Characteristics of the patients and fractures are shown in Table 1. The mean age at the time of fracture was 10.5±2.6 years (range 5 to 16 years) and age was not a factor to influence remanipulation rate or final angulation ($p>0.05$). There were 97 incompletely displaced (86.6%), and 15 completely displaced (13.4%)

Table 1
Characteristics of 108 patients and 112 fractures

	n	%
Gender		
Male	77	71.3
Female	31	28.7
Side of injury		
Left	62	55.4
Right	50	44.6
Mechanism of injury		
Fall (unspecified)	61	54.5
Fall from bicycle	11	9.8
Fall from play equipment	18	16.1
Rollerblades/roller skates	6	5.4
Football	11	9.8
Road traffic accident	4	3.6
Assault	1	0.9
Types of fractures		
Salter-Harris II	22	19.6
Radius only	58	51.8
Radius and ulna	32	28.6
Incompletely displaced	97	86.6
Completely displaced	15	13.4

fractures. The mean follow-up period was 1.1 years (range 10 weeks to 2 years).

The mean initial angulation of fractures prior to manipulation was 21.5±10.1°, it decreased to 2.4±4.8° following manipulation. A perfect fracture reduction was achieved in 50 fractures (44.6%) (Fig. 1).

Remanipulation rates related to the type of fractures, and degree of initial displacement and reduction achieved are shown in Table 2. Remanipulation was required in 11 fractures (9.8%) following both clinical and radiographic assessment showing redisplacement of the fracture. Of these, eight fractures (8.3%) were incompletely displaced, and three fractures (20%) were completely displaced. Remanipulation rates did not differ significantly between incompletely and completely displaced fractures ($p>0.05$). Fractures deemed to require further treatment had a mean angulation of 17.1±5.8° prior to remanipulation, and a mean residual angulation of 4.7±6.0° at final radiographic assessment.

A perfect fracture reduction was achieved in all the patients who sustained a Salter-Harris II injury, and none of these patients required remanipulation. However, the quality of initial reduction was not associated with the development of redisplacement. There was no significant difference between isolated distal radius fractures and combined radius and ulna fractures with respect to remanipulation rate and final angulation ($p>0.05$). Two patients had a final angulation above 20°: one patient (age 7 years) with an isolated distal radius fracture, and the other (age 11 years) with a completely displaced fracture of the distal radius and ulna. In the former, the initial angulation was 10° and gradually increased following an incomplete reduction and application of an above-elbow cast, resulting in a final angulation of 22° and clinical deformity. The latter underwent manipulation and stabilization with a single K-wire. However, technical errors during insertion of the K-wire resulted in redisplacement of the fracture and a final angulation of 22°.

Following reduction, K-wire stabilization was performed in seven (46.7%) of the completely displaced fractures. Remanipulation was required in three fractures (42.9%) undergoing K-wire fixation, and in none of the remaining eight fractures conservatively managed despite complete displacement. The higher remanipulation rate in patients undergoing K-wire fixation was attributed to the intrinsic instability of the initial fracture.

Review of the final radiographs showed significantly increased angulation in fractures which were initially completely displaced in comparison with those that were incompletely displaced (8.2±7.1° *vs.* 4.2±5.7°; $p=0.024$), although this was not clinically significant.

Table 2
Remanipulation rates related to the type of fractures, and degree of initial displacement and reduction achieved

		Remanipulation	
	Total	n	%
Types of fractures			
Salter-Harris II	22	–	
Radius only	58	7	12.1
Radius and ulna	32	4	12.5
Perfect reduction	50		
Incompletely displaced	41	3	7.3
Completely displaced	9	2	22.2
Imperfect reduction	62		
Incompletely displaced	56	5	8.9
Completely displaced	6	1	16.7

Remodeling process may take up to 6 to 12 months or even longer in forearm bones. Therefore, the residual angulation in this study was evaluated irrespective of the remodeling time.

There were some deviations from our departmental policy in terms of the use of elbow casting and K-wire fixation in that 95 fractures (84.8%) were managed with an above-elbow cast, 10 fractures (8.9%) were managed with a below-elbow cast, and seven fractures (6.3%) were treated with both K-wire and below-elbow stabilization. The frequent change of juniors and their ignorance of the departmental policy were thought to be responsible for this altered management of completely displaced fractures (with and without K-wire fixation).

We did not observe any pin site infections or pull-out of the wire. None of the patients had radial shortening. One patient sustained a refracture following a fall five months after the initial treatment, and this was managed by manipulation under general anesthesia and application of an above-elbow cast.

Discussion

In the present study, K-wire stabilization of fractures was used selectively for displaced fractures. There was no significant difference between the remanipulation rates of incompletely and completely displaced fractures. Choi et al.[16] showed that K-wire fixation of high-risk distal radius fractures reduced their predicted failure rate from 60% to 14%, with no incidence of physeal closure or deep infection.

In a prospective, randomized study, Miller et al.[22] compared cast immobilization alone versus percutaneous pin fixation following closed reduction of distal radial metaphyseal fractures in 34 children older than 10 years and having a dorsal angulation of greater than 30°. Thirty-nine percent of patients treated with casting had loss of reduction requiring remanipulation, but none lost reduction in the pin fixation group.

In another prospective, randomized controlled trial, it was found that the use of K-wire stabilization of distal radius fractures resulted in significantly better maintenance of reduction and fewer follow-up radiographs were required.[20] These findings suggest that K-wire stabilization of completely displaced fractures be seriously considered.[13,18-20,23] Gambhir et al.[24] recommended that a minimum of two K-wires with a back slab would be necessary to provide rotational stability in the management of completely displaced metaphyseal fractures of the distal radius in children.

The present study reflects the management of distal radius fractures in children within a single unit using a protocol of selective K-wire stabilization, with a high rate of follow-up. Despite its retrospective design,

Fig. 2. Lateral radiographs showing **(a)** initial displacement of fracture, **(b)** perfect reduction achieved following manipulation under anesthesia, **(c)** redisplacement of fracture, and **(d)** remanipulation and Kirschner wiring of fracture.

it demonstrates the value of a standardized protocol implemented by a large group of surgeons for the management of this injury. Only a small number of patients sustained a completely displaced fracture and, therefore, it was not possible to determine exactly the role of K-wire fixation on final outcome. There is still a need for further investigation of the management of these injuries with prospective randomized trials, particularly to clarify the best use of K-wire stabilization.

Findings of a recent meta-analysis confirm that percutaneous K-wire fixation prevents redisplacement; however, the effects on long term outcomes, including wrist function, are not well-established.[25] Although K-wires may prevent redisplacement of a fracture, we emphasise the need for a good surgical technique to achieve a stable fixation. We did not observe any of the potentially serious complications described in the literature, such as pin site infections or pull-out of the K-wires.[18,21]

Voto et al.[17] reported that 7% of pediatric forearm fractures required further treatment for redisplacement, and following remanipulation, all patients had a functionally satisfactory result, with no complications. Remanipulation provides a safe and effective means to obtain and maintain reduction, and is an alternative option in the management of redisplaced distal radius fractures.[17]

Previous studies have shown that a high rate of fracture redisplacement occurs following manipulation under anesthesia, necessitating further manipulation under anesthesia[22] or a second procedure,[20] and concomitant K-wire stabilization has been advocated for such fractures (Fig. 2).[12]

Given the high turnover of patients and involvement of many short-term junior staff in day-to-day immediate management of these fractures, it is probably not surprising that the exact mechanism of injury was not recorded in 61 fractures. Instead, a generic cause of injury, i.e., fall on the outstretched hand, was written for most of these patients. Insufficient documentation may also result from loss of information during transfer of a patient from one consultant to another after admission. This, we believe, gives a snapshot of real-life management of skeletal trauma in a busy tertiary referral unit with a catchment population of 1.5 million.

The policy of K-wiring for completely displaced fractures appears to be safe. However, its effectiveness could be questioned based on the results of the present study. Larger randomized controlled trials are warranted to confirm the long-term efficacy of K-wiring in completely displaced distal radius fractures including functions. We also insist on the need for good surgical technique to achieve a stable fixation.

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