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ORIGINAL ARTICLE

The outcomes of displaced paediatric distal radius fractures treated with percutaneous Kirschner wire fixation: a review of 248 cases

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Abstract This study aimed to evaluate the effect of manipulation under anaesthesia (MUA) and Kirschner wire (K-wire) fixation of displaced, paediatric distal radius fractures on residual radiological angulation, displacement, and shortening, as well as functional outcomes, including complication rates. A retrospective review was conducted of all paediatric patients undergoing MUA and K-wire fixation for an extra-articular distal radius fracture over a period of 5 years. A total of 248 patients were included in the study with a mean age of 9.9 years (3–15). Mean follow-up was 6.6 weeks (4–156). There was a statistically significant increase in median dorsal angulation ($p < 0.0001$) between initial post-operative and follow-up radiographs at the time of K-wire removal. The number of K-wires used did not have a significant effect on dorsal angulation ($p = 0.9015$) at time of K-wire removal, nor did the use of an above or below elbow cast ($p = 0.3883$). Seventeen patients required a further general anaesthetic (5 revision operations, 12 removal of migrated K-wires). Eighty-seven percentage of (215 patients) of patients had normal function at follow-up post-K-wire removal. Angulation at time of K-wire removal of more than 15° was significantly associated with reduced functional outcome ($p = 0.0377$). A total of 41 patients (17 %) had complications associated with K-wire use. We conclude that though K-wire fixation is an effective technique, it does not prevent re-angulation of the fracture and is associated with a significant complication rate. Given the remodelling potential and tolerance to deformity in children, surgeons should give careful thought before utilising this technique for all displaced or angulated paediatric distal radius fractures. If used, 1 K-wire with immobilisation in a below elbow cast is sufficient in most cases.

Keywords Paediatric · Trauma · Distal radius · Kirschner wire · Upper limb

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Introduction

Distal radius fractures are the most common fractures sustained in childhood [1]. Treatments for displaced fractures include closed reduction and immobilisation in a plaster cast, with or without the insertion of percutaneous Kirschner wires (K-wires).

Controversy still exists regarding the most appropriate treatment for displaced fractures. Closed reduction and cast immobilisation has been associated with rates of redisplacement of 25–39 % [2, 3]. Previous studies have reported particular risk factors associated with a loss of reduction [3–8]. Jordan et al. [7] argued that if optimal reduction could be achieved, casting could be employed. There is a continued debate regarding the use of above versus below elbow casts, with recent studies finding no correlation between the type of cast and redisplacement [8–10].

The large remodelling potential of paediatric osseous anatomy may still allow displaced fractures to heal with minimal or no functional deficit [11, 12]. However, a malunited position leading to any functional deficit, even temporary, may be unacceptable to clinicians and parents.

The use of K-wires has been advocated as a method to avoid redisplacement of a reduced distal radius fracture [3, 7, 13]. K-wires have been shown to be significantly better at maintaining reduction when compared with

manipulation under anaesthesia (MUA) and casting alone in two randomised controlled trials (RCTs) [3, 13]. K-wires have also been shown to reduce the risk of redisplacement in those fractures with high initial translation and those with an imperfect reduction [5, 14].

Previous studies investigating the use of K-wires have used one or more wires through the radial styloid or Lister's tubercle [3, 7, 13, 15]. It is unknown whether the number of K-wires is associated with fracture redisplacement. Reported complications of K-wire fixation include pin-track infections, pin migration, and hypertrophic scars at a rate of 0–38 % [3, 7, 13, 15].

The reported radiological and clinical outcomes, as well as complications, of K-wire fixation have involved low patient numbers to date and may give an unreliable account of the true outcomes of those patients treated with K-wires.

With the common use of K-wires in this patient group, it is important to determine whether this form of fixation is a safe and effective technique. The aim of this study was to evaluate the effect of MUA and K-wire fixation on residual radiological angulation, displacement, and shortening, as well as functional outcomes, including complication rates.

Patients and methods

After local research and audit committee approval, a retrospective review was conducted of all paediatric patients (aged <16 years) undergoing MUA and K-wire fixation of dorsally angulated, closed, extra-articular distal radius fractures over a 5-year period (2008–2012). Patients with epiphyseal injuries or with closed physes were excluded from this study. A total of 248 patients were included in this study, 196 males (79 %) and 52 females (21 %), with a mean age of 9.9 years (range 3–15 years). Baseline demographics, operative records, radiological images, and follow-up details were reviewed. All operations were performed by orthopaedic consultants or by trainees under consultant supervision. Procedures were performed using fluoroscopic guidance, and intra-operative images (AP and Lateral) were saved (termed immediate post-operative radiographs). The number and position of K-wires and the use of an above or below elbow cast were determined by the consultant in charge of the operation and were recorded in the patient's case notes. Previous literature has defined redisplacement requiring a repeat procedure as residual angulation and displacement of >20° and >50 %, respectively [5, 6]. Therefore, acceptable post-operative reduction was defined as <20° dorsal angulation, <50 % displacement, and <5 mm shortening.

The routine follow-up protocol for these patients was follow-up at 1 week with check radiographs and then at approximately 4 weeks post-operatively for check radiographs and K-wire removal. Patients were discharged at this point unless further follow-up was warranted.

Pre-operative, immediate post-operative, and follow-up AP and lateral radiographs at the time of K-wire removal were independently reviewed by two orthopaedic trainees (DR and FS), who were blinded to the clinical outcome of the patients. AP radiographs were assessed for radial shortening in millimetres. Lateral radiographs were assessed for dorsal angulation (°) and percentage displacement (Fig. 1).

Electronic clinic letters were reviewed to calculate the time of plaster and K-wire removal and any complications encountered. Patient function at follow-up post-K-wire removal was categorised into normal, mildly reduced, moderately reduced, or severely reduced. Mildly reduced function was defined <10° restriction in forearm rotation compared with the contralateral side, with spontaneous resolution. Moderately reduced function was defined as >10° restriction in forearm rotation compared with the contralateral side and resolved with physiotherapy. Severely reduced function was defined >30° restriction that did not resolve with physiotherapy and required further investigation and treatment. Mean length of follow-up was 6.6 weeks (4 to 156).

Statistics

Descriptive statistics were reported as the median and interquartile range. Data were first assessed using the D'Agostino and Pearson omnibus normality test. Immediate post-operative radiological measures and those taken at the time of K-wire removal were found to be nonparametric and hence compared using Wilcoxon's matched pairs signed rank test. The effect of the number of K-wires and different types of casting on radiological measures were analysed using the Mann–Whitney U test. Statistical significance was defined as a p value <0.05. Effect of angulation at time of K-wire removal on function was analysed using contingency table analysis and Fisher's Exact test. All statistical analyses were performed by author JR, using GraphPad Prism version 6.0a (GraphPad Software Inc., USA).

Results

The most common mechanism of injury was a fall (242 patients—97.6 %). Four patients suffered a direct blow to the forearm, and 2 patients were involved in polytrauma. A total of 205 patients had associated ulna fractures.

Mean pre-operative radial shortening was 7.5 mm (0–22 mm), displacement 77.6 % (0–100 %), and dorsal angulation 23.9° (0°–60°). Mean immediate post-operative

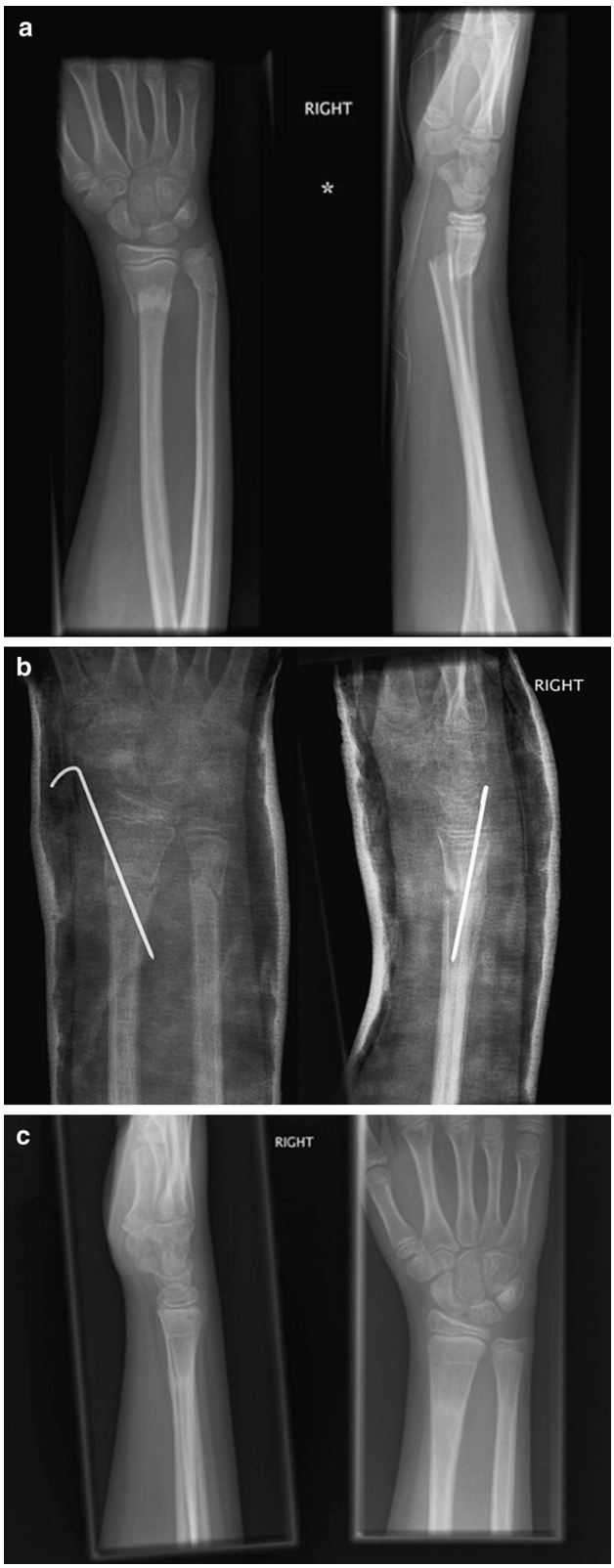

Fig. 1 AP and lateral radiographs of initial injury (**a**), operative fixation (**b**), and post-consolidation (**c**) of a right-sided distal radius fracture, treated with 1 K-wire

radial shortening was 0.4 mm (0–5 mm), displacement 6.4 % (0–34 %), and dorsal angulation 4.1° (0°–20°). Mean time to K-wire removal was 4.1 weeks (3–6 weeks) and plaster removal 4.4 weeks (3–7 weeks).

A total of 162 patients (65.3 %) were treated with 1 K-wire, 82 (33.1 %) with 2 K-wires, and 4 (1.6 %) with 3 K-wires. A total of patients (55.2 %) were treated in an above elbow cast.

Radiological outcome

A total of 195 patients (80 %) had radiographs taken at the time of K-wire removal (Fig. 1). There was no significant change in displacement or radial shortening when comparing immediate post-operative and these follow-up radiographs. However, there was a significant increase in dorsal angulation at this follow-up (Table 1).

The number of K-wires (one versus greater than one wire) used did not have a significant affect on dorsal angulation ($p = 0.9015$) at time of K-wire removal. The use of an above or below elbow cast also did not have a significant effect on this dorsal angulation ($p = 0.3883$).

Functional outcome

All 248 patients returned for clinical review. Of these, 215 patients (87 %) had normal function at follow-up post-K-wire removal. A total of 25 patients (10 %) had mildly reduced function, and five patients (2 %) had moderately

Table 1 Radiological measurements

Fracture characteristics	Immediate post-op	Follow-up at time of K-wire removal	*p* value
Mean radial shortening (mm)	0.4	0.8	0.2442
Median (IQ range)	0 (0–0)	0 (0–0)	
Mean displacement (%)	6.4	9.5	0.3689
Median (IQ range)	1 (0–13)	0 (0–13)	
Mean dorsal angulation (°)	4.1	6.7	<0.0001*
Median (IQ range)	3 (0–6)	5 (1–12)	

All measurements correspond to radial shortening on the AP and displacement and dorsal angulation on the lateral film

* Statistically significant ($p < 0.05$)

Fig. 2 AP and lateral radiographs of initial injury (**a**) and operative fixation (**b**). Radiographs taken at time of clinical union and wire removal (**c**) show displacement of fracture with dorsal angulation. Radiographs taken at radiographic consolidation (**d**), 3 months post-injury, show dorsal angulation of 20°. This patient had moderately reduced function that resolved after physiotherapy 5 months post-injury

reduced function. Three patients (1 %) had severely reduced function. One patient was investigated and discharged 3 years post-injury. Two patients are still under follow-up, both more than 1 year post-injury and are awaiting investigations (CT/MRI) and further management. All patients with functional limitation were under 12 years of age (range 6–12 years).

In the 195 patients with follow-up radiographs at the time of K-wire removal, there was no significant difference in functional outcome (normal versus reduced) if angulation at K-wire removal was more than 10° versus less than 10° ($p = 0.3167$). However, an angulation of more than 15° was significantly associated with a reduced functional outcome ($p = 0.0377$) when compared with angulation of less than 15° (Fig. 2). The relative risk of 'not normal' function from angulation >15° was 2.895 (95 % CI 1.194–7.020).

Table 2 Complications associated with K-wire use

Complication	Number of patients
K-wire migration further into bone: general anaesthetic required for removal	12 (5 %)
Wound overgranulation requiring treatment	12 (5 %)
Wound infection requiring antibiotics	7 (3 %)
Redisplacement of fracture requiring revision surgery	5 (2 %)
K-wire migration outwards	3 (1 %)
Ulnar nerve neuropraxia	2 (1 %)

Complications

A total of 41 patients (17 %) had complications associated with K-wire use as can be seen from Table 2. There were no cases of deep infection.

Seventeen patients (6.9 %) needed a further general anaesthetic (GA) procedure: four patients underwent remanipulation and K-wire fixation for significant redisplacement, angulation, or migration of the wires; one patient underwent plate fixation for redisplacement; twelve patients warranted a GA for removal of K-wires that could not be removed in the clinic due to proximal migration of the wire below the skin.

Discussion

The aim of this study was to establish the radiological and clinical outcomes following MUA and K-wire fixation of displaced paediatric distal radius fractures. To our knowledge, this study is the largest series to date detailing these outcomes. It has shown that, overall, K-wire fixation is associated with favourable radiological and functional outcomes, after satisfactory fracture reduction. However, K-wires do not completely prevent loss of reduction of fractures in terms of dorsal angulation. Though this increased angulation was found to be statistically significant, it was not clinically important. There is, however, a significant complication rate associated with the use of K-wires, primarily due to wound complications and problematic wire removal.

The management of paediatric distal radius fractures is controversial. The need for optimal reduction to allow normal patient function post-injury has recently been questioned. Crawford et al. [12] treated 51 children with cast application and gentle moulding to correct the angulation only, with no formal reduction, hence requiring no sedation or anaesthesia. All cases united with full function at 1 year, and they found this to be 9 times cheaper than MUA and K-wire fixation.

In other studies, the use of closed reduction and cast immobilisation alone in paediatric distal radius fractures has been associated with high rates of redisplacement which result in remanipulation under anaesthesia [7, 8]. Recent studies have demonstrated pre-operative risk factors associated with redisplacement such as completely displaced fractures, radial shortening, >11° angulation, and an intact ulna [4–6]. Initial reduction has also been found to be essential in preventing redisplacement. Jordan and Westacott [7] found that unless optimal reduction (defined as <10 % residual translation and <5° of angulation) was obtained, there was a significant risk of redisplacement [7]. In addition, three-point moulding of the plaster cast has been shown to have a significant effect on preventing displacement [2].

In such cases where redisplacement is a high risk, K-wire fixation has been recommended as a method to prevent this [3, 7, 13]. Two RCTs have previously found no patients treated with a K-wire required a second procedure due to fracture displacement [3, 13]. Jordan and Westacott also had no patients remanipulated out of the 17 patients treated with K-wires [7]. These studies have low numbers of patients (between 16 and 35) when compared with our series. Our results showed a 2 % redisplacement rate requiring further surgery. We have shown that K-wires do not completely prevent re-angulation of the fracture. K-wires are not, therefore, a guaranteed method to hold reduction. This also confirms that K-wires should not be used to prevent a mal-reduced fracture from further loss of reduction, as has previously been suggested, as angulation can still increase with K-wires in situ [14].

Previous studies have compared the functional status after MUA versus K-wire fixation [13, 15], but these studies too have had small sample sizes. Our study showed that 87 % of patients had normal function at follow-up post-K-wire removal, which demonstrates that though K-wire fixation is associated with good outcomes, 13 % of patients did suffer from a functional deficit for some period of time, but this may be expected after any fracture treated with a period of immobilisation.

The results showed that fractures with more than 15° angulation were associated with poorer functional outcomes, showing the importance of adequate reduction, independent of the use of percutaneous fixation. It also demonstrates the tolerance of paediatric patients to a reasonable amount of deformity given their remodelling potential. Hove and Brudnik [11] have previously suggested that even greater than 15° of angulation at union completely remodelled and had normal function at follow-up.

Our results show that the number of K-wires does not affect re-angulation. This should be considered when one takes into account the wound complications associated with K-wires.

Complication rates associated with K-wire use are highly variable. Miller et al. [3] reported 6 out of 16 patients (38 %) experienced complications such as pin-site infection (13 %) and pin migration (13 %). In a series of 157 patients, Choi et al. [15] found pin-site infection occurred in 8 patients (5.7 %) and neuropraxia in 2 (1.4 %). Our results showed an overall complication rate of 17 %. Pin-site infections (3 %) and over-granulation (5 %) were problems encountered at a lower rate than previous studies and resolved with oral or topical substances [3, 15]. However, a common complication that has not been previously discussed was the 5 % of patients requiring a repeat general anaesthesia for removal of K-wires that had migrated proximally and deep to the skin, resulting in an inability to remove these in clinic. These patients were subjected to repeat surgery with the attendant risks and resource implications.

Our study agreed with previous research that has found no difference in fracture redisplacement when using above or below elbow casts [8–10]. It is known that below elbow casts result in fewer missed school days and less interruption in daily activities, and therefore, their use should be encouraged [10].

This study does have its limitations. There is an incomplete radiographic follow-up, and so redisplacement could not be calculated for all patients. However, one can assume that a patient who had a clinically healed fracture with normal function most likely would not warrant a repeat X-ray and would be unlikely to have a significant radiographic deformity of the distal radius. Being a retrospective review, the data gathered were limited to what was presented in the case notes. However, we found all patients had sufficient detail written to judge function and complications. Finally, functional outcomes were defined as degrees of restriction of movement as set by the authors, rather than formal, validated measures, which do introduce bias. However, to the authors' knowledge, commonly used outcome scores such as the patient-rated wrist evaluation score and the Gartland and Werley score have not been validated for use in the paediatric population [16, 17].

This study is the largest series of paediatric distal radius fractures treated with K-wire fixation reported in the literature. It has shown that this fixation provides a reliable method of treating these injuries and is, overall, associated with good functional outcomes. However, K-wires do not completely prevent re-angulation of the fracture and are associated with a significant complication rate. Given the remodelling potential and tolerance of deformity in children, it would prudent that surgeons give careful thought before utilising this technique for all displaced or angulated paediatric distal radius fractures. If percutaneous fixation is to be used, a single K-wire is sufficient in most cases with immobilisation in a below elbow cast.

Conflict of interest None.

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