Original Clinical Article

JOURNAL OF CHILDREN'S ORTHOPAEDICS

Redisplacement of paediatric distal radius fractures: what is the problem?

Diogo M.C. Constantino
Luis Machado
Marcos Carvalho
João Cabral
Pedro Sá Cardoso
Inês Balacó
Tah Pu Ling
Cristina Alves

Abstract

Purpose Distal radius fractures represent one of the most common fractures in children. Our purpose is to analyze risk factors for redisplacement in children with distal radius fractures treated by means of closed reduction and plaster cast immobilization.

Methods Retrospective study, including children under the age of 17 years, who underwent closed manipulation and cast immobilization for a distal third radius fracture, between 2012 and 2015. Preoperative radiographs were reviewed for initial translation, angulation and shortening, distance of the fracture from the physis, degree of fracture obliquity and the presence of an ulna fracture. Postoperative radiographs were analyzed for translation, angulation and shortening, as well as the quality of closed reduction. Cast index, gap index and three-point index, were measured on the postoperative radiographs. Redisplacement and re-intervention during follow-up were registered.

Results A total of 26 patients were included in this study. Comparison between post-reduction and immediate post-cast removal radiographs did not show any statistically significant difference between translation or shortening. Coronal ($p = 0.002$) and sagittal ($p = 0.002$) angulation showed a statistically significant difference, but both median values remained below cut-off values for redisplacement. Redisplacement was observed in four patients. Only one patient underwent remanipulation. All four had full remodelling and proper radiological alignment at final follow-up. Quality of reduction was found to be a statistically significant risk factor for redisplacement ($p = 0.013$).

Conclusion Closed reduction and cast immobilization under general anaesthesia yields good results in the treatment of distal forearm fractures in paediatric patients. Quality of reduction was the only risk factor that we found to be predictive of redisplacement.

Level of Evidence: Level III – Retrospective comparative study

Department of Pediatric Orthopaedics, Hospital Pediátrico de Coimbra, Coimbra, Portugal

Correspondence should be sent to Dr Cristina Alves, Department of Pediatric Orthopaedics – Hospital Pediátrico de Coimbra, Av Afonso Romão, 3000-602 Coimbra, Portugal.
Email: cristina.alves@me.com

Cite this article: Constantino DMC, Machado L, Carvalho M, Cabral J, Sá Cardoso P, Balacó I, Ling TP, Alves C. Redisplacement of paediatric distal radius fractures: what is the problem? *J Child Orthop* 2021;15:532-539. DOI: 10.1302/1863-2548.15.210111

Keywords: distal radius fracture; loss of reduction; redisplacement; risk factors

Introduction

Forearm fractures represent one of the most common fractures in children,[1-3] with the distal radius being the most common fracture site, accounting for 20% to 30% of these fractures.[1,4] In total, 81% occur in children who are older than five years, with a peak incidence of distal forearm fractures occurring between ages 12 and 14 years in boys and ten to 12 years in girls. The usual mechanism of injury is a direct fall in or around the house.[1]

Historically, most of these fractures in children have been treated by closed reduction and immobilization in a cast,[1,5,6] with 85% of these patients achieving satisfactory results.[1,7] Redisplacement is the most commonly reported complication; in general, up to one-third of cases will have late redisplacement.[1,4,7] Parameters for appropriate alignment are controversial. In general, 20° to 25° of flexion-extension angulation and 10° of radial-ulnar deviation may remodel with growth in younger patients.[4] Malrotation will not remodel.[4]

Risk factors for redisplacement can be broadly divided into two groups: fracture-related (initial displacement, location of the fracture, distance from the physis, obliquity of the fracture and associated ulna fracture)[1,4,7]; and treatment-related factors (quality of reduction, quality of immobilization and type of anaesthesia).[1,4,7,8]

Recent information has challenged traditional trends of fracture care, with some reports indicating an increased routine use of percutaneous pin fixation for the initial treatment of high-risk-of-displacement fractures[1,6-8] However, other reports suggest that anatomical reduction is not necessary in many cases.[9,10]

The aim of our study is to analyze the risk factors for redisplacement in children with displaced distal radius fractures treated by means of closed reduction and plaster cast immobilization.

Materials and methods

We have performed a retrospective study, including all children under the age of 17 years, who underwent closed manipulation and cast immobilization for a bicortical distal third radius fracture in a Paediatric Tertiary Hospital, between 1 January 2012 and 31 December 2015. Articular, physeal or undisplaced fractures were excluded. Open fractures were also excluded. We excluded patients with follow-up less than four weeks. Demographic data was collected on all patients.

Preoperative radiographs were reviewed for initial translation, angulation and shortening. Initial translation was graded according to the system proposed by Mani et al.[11]: grade I has no loss of contact, grade II has < 50% loss of contact, grade III has > 50% loss of contact and grade IV has no contact. The distance of the fracture from the physis, degree of fracture obliquity and the presence of an ulna fracture were also recorded. The degree of obliquity was analyzed based on the maximum fracture-line angle in either the coronal or the sagittal plane. Post-operative radiographs were analyzed to quantify translation, angulation and shortening, as well as the quality of closed reduction: 'anatomic' reduction was defined as virtually no displacement or angulation; 'good' reduction as < 2 mm of displacement and < 10° of angulation; and 'fair' reduction as > 2 mm of displacement or > 10° of angulation. Cast index, gap index and three-point index, calculated according to Alemdaroğ lu et al[7] were also measured on the postoperative radiographs. Radiographic measurements are displayed in Figure 1. Redisplacement during follow-up was defined as > 15º of coronal angulation, > 20º of sagittal angulation – or 30° if patient was less than ten years old, or > 50% translation.

Descriptive statistics are given as the median, maximum and minimum for continuous variables and as percentage for categorical variables. Continuous variables were compared using the Mann-Whitney U-test and ***t***-test, while categorical outcomes were compared using Fisher's exact test. Statistical significance level was set for $p < 0.05$.

Results

During the study period, 143 patients with forearm fractures were identified. Only 26 patients fulfilled all criteria determined for this study (Fig. 2). Collected data from our study group is presented in Table 1. In all, 21 (80.8%) were male and five (19.2%) were female. Median age was 9.5 years old (5 to 15). Initial radiographs showed that six patients (23.07%) had a grade II translation, eight patients (30.77%) had a grade III translation and 12 patients (45.15%) had a grade IV translation. Median initial coronal plane translation was 36.88% (0% to 62.1%) and sagittal was 89.8% (40.9% to 100%). Median coronal plane angulation was 11.56° (0° to 24.2°) and sagittal was 14.4° (1° to 48.5°). Median coronal plane shortening was 7.85 mm (0 to 15) and sagittal was 8.75 mm (0 to 25.4). A concomitant ulnar fracture was present in 19 (73.7%) patients. Median distance from fracture to physis was 14.4 mm (4.6 to 31.8). Median fracture obliquity was 11.2° (0.7 to 23.4). All patients were treated with closed reduction and short arm plaster cast immobilization under general anaesthesia, except one patient who was treated under analgesia with morphine. The wrist was immobilized in neutral or slight ulnar deviation and in a maximum of 30° of flexion. In the postoperative radiographs, reduction was considered 'anatomic' in 11 patients, 'good' in 12 patients and 'reasonable' in three patients. Median coronal plane translation was 6.64% (0% to 30%) and sagittal 0% (0% to 100%). Median coronal plane angulation was 0° (0° to 15.2°) and sagittal 0.2° (0° to 18.3°). Median coronal plane shortening was 0 mm (0 to 4.4) and sagittal 0 mm (0 to 9.5). Median cast-index was 0.72 (0.57 to 0.89), median gap-index was 0.23 (0.13 to 0.39) and median three-point index was 1.48 (0.85 to 4).

Median immobilization period was 35 days (20 to 54) and median follow-up was 40 days (28 to 360). Final radiographs showed median coronal plane translation of 6.5% (0% to 37.4%) and sagittal of 0% (0% to 40.5%). Median coronal plane angulation was 6° (0° to 34°) and sagittal was 8.75° (0° to 32.2°). Median coronal plane shortening was 0 mm (0 to 8.9) and sagittal was 0 mm (0 to 5.4).

To evaluate the maintenance of the alignment during follow-up, we compared post-reduction and immediate post-cast removal radiographs and did not find any statistically significant difference when considering coronal ($p = 0.502$) and sagittal ($p = 0.609$) planes translation or coronal ($p = 0.086$) and sagittal ($p = 0.208$) planes shortening. However, coronal angulation ($p = 0.002$) and sagittal angulation ($p = 0.002$) showed a statistically significant difference, with a median final coronal plane angulation of 6° and a median final sagittal plane angulation of 8.75°, at median 35 days (20 to 54) follow-up, although both remained below the cut-off values for redisplacement (Table 2).

Redisplacement was observed in four patients (15.4%) during follow-up. One had been initially treated with reduction under analgesia. Two days later he underwent remanipulation and cast immobilization under general anaesthesia. The other patients had no further procedure

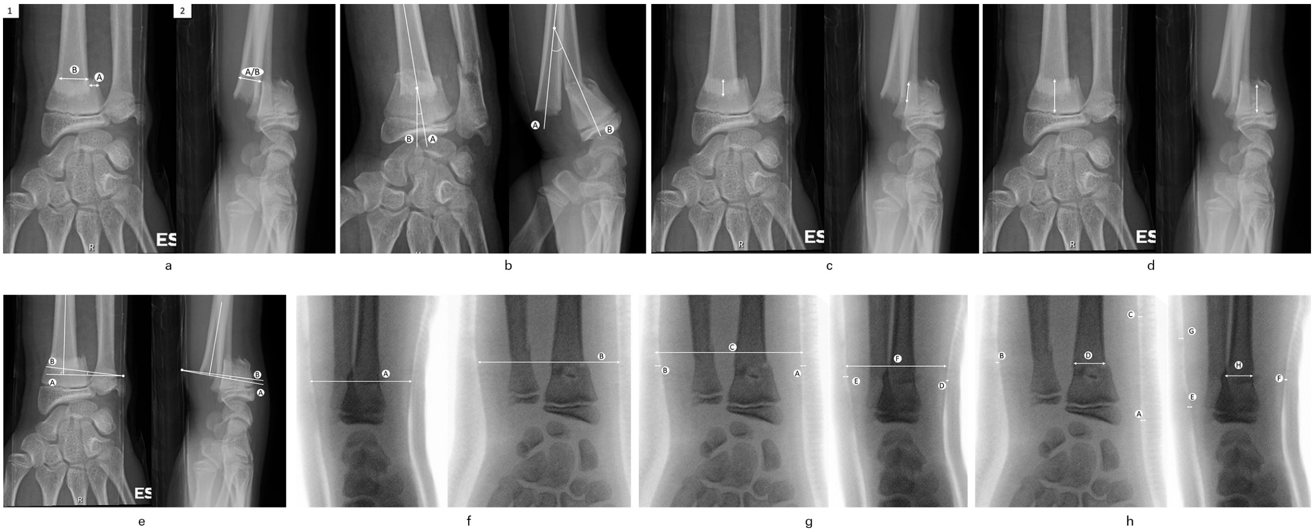

Fig. 1 Preoperative and immediate postoperative measurements: a) coronal and sagittal plane translation: 1) displacement (A), as a percentage of total cortical diameter (B), 2) 100% displacement, A and B are the same length; b) coronal and sagittal plane angulation: angle between radial dyaphisis axis (A) and distal radius fragment axis (B); c) coronal and sagittal plane shortening; d) distance from physis; e) degree of fracture obliquity: angle between a line perpendicular to the radial dyaphisis axis (A) and proximal fracture line (B); f) cast index: inner diameter of cast on lateral radiograph at fracture site (A) / Inner diameter of cast on anteroposterior radiograph at fracture site (B). Cut off < 0.7; g) gap index: [(Radial gap (fracture site) (A) + ulnar gap (fracture site) (B)) / inner diameter of cast in AP (C)] + [(Dorsal gap (fracture site) (D) + volar gap (fracture site) (E)) / inner diameter of cast in lateral plane (F)]. Cut off < 0.15; h) 3-point index: [(Distal radial gap (A) + ulnar gap (fracture site) (B) + proximal radial gap (C)) / Transverse distance of cortical contact on AP (D)] + [(Distal dorsal gap (E) + volar gap (fracture site) (F) + proximal dorsal gap (G)) / Transverse distance of cortical contact on lateral plane (H)]. Cut off < 0.8.

after redisplacement, option justified due to diagnosis more than two weeks after initial injury and presumed remodelling potential. At median 310 days (126 to 360) follow-up these patients had full remodelling and proper radiological alignment. These cases are described in Table 3. Case 4 is depicted in Figure 3.

Different risk factors for redisplacement are compared between the redisplaced and undisplaced groups in Table 4.

Quality of reduction was found to be a statistically significant risk factor for redisplacement (p = 0.013). Another relevant finding is that all patients in the redisplacement group had an initial displacement of > 50%, Grade III or IV. However, grade of initial displacement did not reach statistical significance as a risk factor for redisplacement (p = 0.161). Although higher values were found in the redisplacement group for degree of fracture obliquity, gap index and three-point index, the difference was not statistically significant (Table 4).

Discussion

Distal radius fractures are common in children; 143 were reviewed in our database for a three-year period but only 26 fulfilled the inclusion criteria for this study. All fractures were managed initially with closed reduction and short arm plaster cast immobilization. In most of our patients, reduction and immobilization was successful in maintaining alignment throughout the follow-up period. Only coronal and sagittal angulation significantly changed between postoperative and final radiographs, although median final values were both well below cut-off values for redisplacement. Only four fractures out of 26 (15.4%) had redisplacement. No patients developed carpal tunnel syndrome during the immobilization period, with a maximum of 30° wrist flexion. Gelberman et al[12] describe 40° of flexion as the position at which the risk of median neuropathy drastically increases.

Previous work has shown higher values of redisplacement; between 22% and 33%.[1,3-5,7,8] However, rate of re-intervention is much lower; 4.7% as described by Mazzini et al,[1] 7% by Voto et al,[3] 8% by Alemdaroğlu et al[7]. In our study, only one of four patients with redisplacement was re-operated, corresponding to 3.8% of all patients. This might suggest a higher displacement threshold for secondary intervention than after initial injury. It has been reported that most of these fractures heal well despite failed or lost reductions and shortening up to 10 mm and angulations up to 35° in the sagittal plane can be expected to remodel.[10] In our study, all patients with redisplacement and no further intervention had fully remodelled at the final follow-up.

Method of stabilization is highly debated, either in primary or redisplacement setting. Both manipulation and immobilization with or without percutaneous pin-

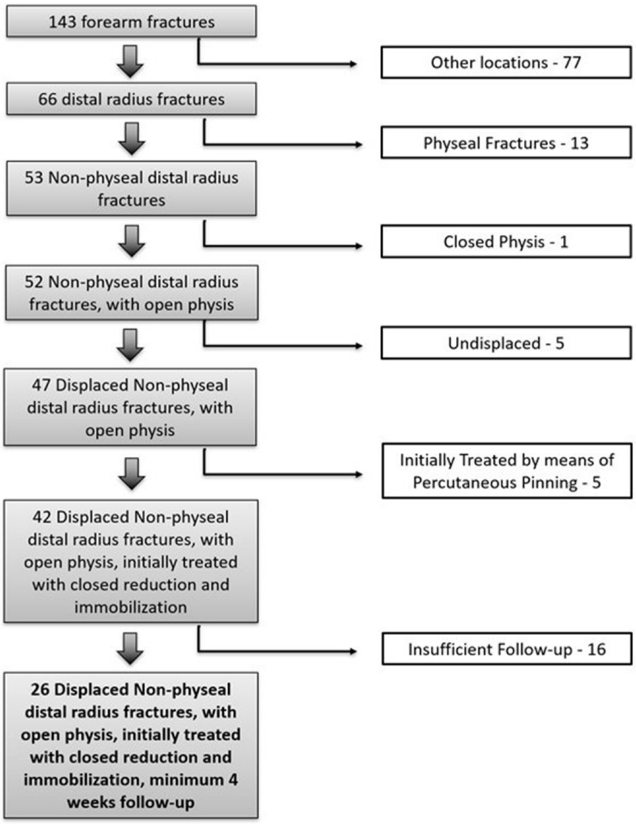

Fig. 2 Fluxogram followed to include ***versus*** exclude patients in this study.

Table 1 Descriptive statistics of 26 displaced non-physeal radius fractures, with open physis, initially treated with closed reduction and immobilization, with minimum four weeks follow-up.

Variable	Value
Median age, yrs (range)	9.65 (5 to 15)
Sex, male (%)	21 (80.8)
Grade of initial displacement, n (%)	
II	6 (23.07)
III	8 (30.77)
IV	12 (45.15)
Median initial coronal plane translation, % (range)	36.88 (0 to 62.1)
Median initial sagittal plane translation, % (range)	89.8 (40.9 to 100)
Median initial coronal plane angulation (range)	11.56° (0° to 24.2°)
Median initial sagittal plane angulation (range)	14.4° (1° to 48.5°)
Median initial coronal plane shortening (range)	7.85 mm (0 to 15)
Median initial sagittal plane shortening (range)	8.75 mm (0 to 25.4)
Associated ulna fracture, n (%)	19 (73.7)
Distance from physis, mm (range)	14.4 (4.6 to 31.8)
Degree of obliquity	11.2° (0.7° to 23.4°)
Quality of reduction, n (%)	
A	11 (42.3)
G	12 (46.15)
F	3 (11.5)
Cast index (cut off < 0.7)	0.72 (0.57 to 0.89)
Gap index (cut off < 0.15)	0.23 (0.13 to 0.39)
Three-point index (cut off < 0.8)	1.48 (0.85 to 4)

A, anatomic; G, good; F, fair

ning are valid options, with no clear criteria for choosing one over the other. Immobilization without any manipulation has proven to be effective for treating overriding fractures – 100% translation and some degree of shortening, with low grade angulation – particularly in younger children, highlighting the importance of remodelling.[9,10]

Material used for immobilization is also open to debate, particularly between plaster of Paris and synthetic materials. A prospective randomized clinical trial by Inglis et al[13] with a total of 199 patients compared rate of complications between plaster of Paris and synthetic casts. Patient satisfaction was higher and cast-care-related issues were less frequent with the synthetic casting. However, cast indexes were higher in the synthetic group, but this did not translate into a statistically significant difference in loss of reduction rates between the two groups. It is noteworthy that strictly long-arm casts were used in this study, as opposed to short-arm casts in our study.[13] In light of our experience, plaster of Paris is preferred due to its superior malleability leading to improved cast-indexes and lower risk of fracture displacement.

Several studies recommend Kirschner-wire fixation over cast immobilization alone in the primary setting, even with satisfactory closed reduction.[8,14] A positive aspect of percutaneous pinning is its low rate of reoperation,[15] making it particularly attractive for fractures that are considered to be at a high risk for redisplacement.[1,14,16] However, it has a higher incidence of complications, namely infections,[4,15] and no difference in clinical outcomes has been reported between techniques.[4,14,15] Cost of treatment is also significantly different – in our institution, total hospital cost for closed reduction and plaster casting under general anaesthesia is €176.17, while closed reduction and pinning under general anaesthesia is €1476.80. However, these costs are fully supported by our national healthcare system and the type of treatment performed does not affect the surgical team income. In our study, even high-risk fractures were treated with closed reduction and cast immobilization with a low rate of re-intervention, which supports this type of treatment if performed properly.

All patients underwent closed reduction and cast immobilization under general anaesthesia, except for one patient who underwent initial closed reduction under morphine analgesia. This patient suffered redisplacement two days after initial treatment and was the only one in our study to undergo remanipulation and casting under anaesthesia. This points towards more favourable outcomes with initial manipulation under anaesthesia, which is our recommendation, in line with previous studies that report conscious sedation as a risk factor for redisplacement.[8]

Table 2 Alignment preservation. Wilcoxon Signed Rank test was used. Parameters that showed a statistically significant difference are in bold ($p < 0.05$).

	Postoperative (range)	Final (range)	p-value
Median coronal plane translation (%)	*6.64* (*0* to *30*)	*6.5* (*0* to *37.4*)	0.502
Median sagittal plane translation (%)	*0* (*0* to *100*)	*0* (*0* to *40.5*)	0.609
Median coronal plane angulation	**0° (0° to 15.2°)**	**6° (0° to 34°)**	**0.002**
Median sagittal plane angulation	**0.2° (0° to 18.3°)**	**8.75° (0° to 32.2°)**	**0.002**
Median coronal plane shortening (mm)	0 (0 to 4.4)	0 (0 to 8.9)	0.086
Median sagittal plane shortening (mm)	0 (0 to 9.5)	0 (0 to 5.4)	0.208

Table 3 Cases of redisplaced fracture

	Case 1	Case 2	Case 3	Case 4
Age, (yrs)	9	13	12	12
Sex	Female	Male	Male	Male
Initial displacement	Grade III	Grade III	Grade III	Grade IV
Initial sagittal angulation	13.5°	6.1°	1°	36.5°
Initial coronal angulation	24.5°	12°	8.9°	10°
Associated ulna fracture	Yes	Yes	No	Yes
Distance from physis, mm	8.5	27.6	18.1	16.7
Degree of obliquity	10.5°	17.3°	23.4°	0.7°
Quality of reduction	Fair	Fair	Anatomic	Anatomic
Cast index	0.75	0.87	0.57	0.62
Gap index	0.37	0.22	0.23	0.15
Three-point index	4	2.17	1.07	1.375
Follow-up, days	270	360	350	126
Re-intervention	Remanipulation under anaesthesia	No further procedure. Fully remodelled at final follow-up	No further procedure. Fully remodelled at final follow-up	No further procedure. Fully remodelled at final follow-up

Fig. 3 Case 4 of fracture redisplacement: a) preoperative radiograph; b) postoperative radiograph; c) redisplacement at 30 days of follow-up; d) remodelling at 126 days of follow-up.

When managing redisplacement, several studies present different approaches without clear criteria for decision. Voto et al[3] recommended remanipulation as an effective method. Alemdaroğlu et al [7] had six patients undergoing remanipulation, and only one of those required wiring. Another study had two patients undergo remanipulation without pinning, seven underwent closed reduction with percutaneous pinning, and two had an open reduction

Table 4 Risk factor comparison between undisplaced and redisplaced groups. Continuous variables were compared using the Mann-Whitney U-test, while categorical outcomes were compared using Fisher's exact test. Risk factors found to be statistically significant are in bold ($p < 0.05$).

	Undisplaced group	Redisplaced group	p-value
Median age, yrs (range)	9 (5 to 15)	12 (9 to 13)	-
Sex, male (%)	18 (81.8)	3 (75)	-
Grade of initial displacement, n (%)			0.161
II	6 (27.3)	0 (0)	
III	5 (22.7)	3 (75)	
IV	11 (50)	1 (25)	
Median initial coronal plane translation, % (range)	26.3 (0 to 100)	26.4 (0 to 46.8)	0.452
Median initial sagittal plane translation, % (range)	100 (39.4 to 100)	57.7 (50 to 100)	0.286
Median initial coronal plane angulation (range)	11.5° (0° to 31.3°)	11° (8.9° to 24.2°)	0.656
Median initial sagittal plane angulation (range)	15.6° (2° to 48.5°)	9.8° (1° to 36.5°)	0.477
Median initial coronal plane shortening, mm (range)	7.95 (0 to 15)	9.2 (7.5 to 11.1)	0.471
Median initial sagittal plane shortening, mm (range)	9.85 (0 to 25.4)	11.6 (8.2 to 14.5)	0.627
Associated ulna fracture, %	72.7	75	0.713
Distance from physis, mm (range)	18.9 (4.6 to 31.8)	17.4 (8.5 to 27.6)	0.656
Degree of obliquity (range)	10° (0° to 22.6°)	13.9° (0.7° to 23.4°)	0.429
Quality of reduction, n (%)			**0.013**
A	**9 (*40.9*)**	**2 (*50*)**	
G	**12 (*54.5*)**	**0 (*0*)**	
F	**1 (*4.5*)**	**2 (*50*)**	
Cast index, cut off < 0.7 (range)	0.7 (0.13 to 0.89)	0.7 (0.57 to 0.87)	0.918
Gap index, cut off < 0.15 (range)	0.19 (0.05 to 0.39)	0.223 (0.15 to 0.37)	0.324
Three-point index, cut off < 0.8 (range)	1.59 (0.47 to 3.45)	1.77 (1.07 to 4)	0.703

A, anatomic; G, good; F, fair

and internal fixation.[6] In another study percutaneous pinning was used for all patients that required manipulation after redisplacement.[8] Manipulation under anaesthesia and immobilization was successful in our case.

Risk factors for redisplacement can be broadly divided into two groups: fracture-related and treatment-related. We present some of the most significant risk factors according to different studies in Table 5.

Considering fracture-related risk factors for redisplacement, a high-grade initial displacement – over 50% in any plane – was found in 100% of patients who later redisplaced. In patients with no redisplacement, 72.7% had high grade initial displacement. This points to a trend of high-grade initial displacement being a risk factor for redisplacement, although this did not reach statistical significance in our study. Initial displacement has been identified as the most important factor leading to redisplacement.[4-8,16] Severe injury to the periosteum and the surrounding soft tissues has been proposed as the causative mechanism. The lack of a periosteal hinge may affect stability, and severe soft-tissue injury causes initial swelling which after subsiding results in a loose cast.[8] Several studies showed that this factor was significant even in the occurrence of a satisfactory reduction.[5,8,14]

Obliquity of the fracture line was the second most important risk factor for redisplacement, according to Alemdaroğlu et al, [7] with higher obliquity corresponding to higher risk of redisplacement. In our study, fracture obliquity was also higher in the redisplacement group, although not statistically significant ($p = 0.429$).

The role of an associated ulnar fracture is controversial. Some studies indicate it as a risk factor for redisplacement,[4,7,8,16] others suggest that isolated distal radial fractures are more prone to redisplacement,[6,17] and a third finding is that it doesn't affect the rate of redisplacement.[5,7,14] In our study both groups had similar percentage of associated ulna fracture ($p = 0.713$).

Initial angulation and shortening have also been shown to be risk factors for redisplacement.[6] In our study initial angulation and shortening were not found to be significantly different in both groups.

Distance from physis was lower in the redisplacement group, but this difference was not statistically significant. It was not found to be a relevant risk factor for redisplacement in several studies.[2,5,7] In one study by Jordan et al[16] it was found to be a risk factor for redisplacement, but statistically significant only when considering patients with acceptable reduction.

Quality of initial reduction and adequate casting technique are commonly debated factors relating to proper conservative treatment.

When considering quality of initial reduction, the subgroup with no redisplacement had an 'anatomic' reduction in 40.9% of the patients, 'good' reduction in 54.5% of the patients and a 'fair' reduction in only 4.5% of the patients. Patients with redisplacement had an 'anatomic' reduction in 50% of the cases, no cases of 'good' reduction and 'fair' reduction in 50% of cases. The sub-groups with no redisplacement and redisplacement were significantly different regarding quality of initial reduction ($p = 0.013$).

Table 5 Significant risk factors for redisplacement according to author

Author	Journal	Year	Study	Significant risk factors for redisplacement
Voto et al[3]	*J Pediatric Orthopaedics*	1990	90 children with displaced forearm fracture	Inappropriate casting
Mani et al[11]	*J Bone Joint Surg*	1993	94 children with displaced distal radius fracture	Initial translation
Proctor et al[5]	*J Bone Joint Surg*	1993	68 children with displaced distal radius fracture	Initial translation; inappropriate reduction
Chess et al[18]	*J Pediatric Orthopaedics*	1994	761 children with distal one-third forearm fracture	Cast index > 0.7
Gibbons et al[17]	*J Pediatric Orthopaedics*	1994	23 children with displaced distal radius fracture	No ulna fracture
Haddad and Williams[2]	*Injury*	1995	86 children with distal one-third forearm fracture	Inappropriate reduction
Zamzam and Khoshhal[8]	*J Bone Joint Surg*	2005	183 children with displaced distal radius fracture	Initial translation; reduction under sedation; associated ulna fracture
Malviya et al[19]	*J Pediatric Orthopaedics B*	2007	100 children with displaced distal radius fracture	Gap index > 0.15
Alemdaroğlu et al[7]	*J Bone Joint Surg*	2008	75 children with displaced distal radius fracture	Initial translation; degree of obliquity; three-point index > 0.8
Sankar et al[6]	*J Children's Orthopaedics*	2011	76 children with displaced isolated distal radius fracture	Initial coronal angulation; post-reduction coronal translation
Jordan et al[16]	*European Journal of Orthopaedic Surgery and Traumatology*	2015	107 children with displaced distal radius fracture	Initial translation; inappropriate reduction; associated ulna fracture

Success of initial reduction has been described widely in the literature as an independent risk factor for redisplacement.[2,4,5,16] In a study by Jordan et al,[16] a redisplacement rate of 27% dropped to 10% when considering only the cases where an optimal reduction was achieved, defined as < 10% residual translation and < 5° of angulation in any plane. According to Alemdaroğlu et al,[7] a 'fair' initial reduction, defined as > 2 mm of displacement or > 10° of angulation (identical to our definition), was found to be a risk factor for redisplacement with an odds ratio of 5.176.[7] In our study, 66.7% of patients with a 'fair' reduction ended up with redisplacement.

Sankar et al[6] studied several different aspects of reduction quality, concluding that post-reduction translation in the coronal and sagittal planes and angulation in the coronal plane were all statistically significant factors for redisplacement.

Proctor et al[5] studied the combined effects of initial displacement and perfect reduction: if incompletely displaced fractures are perfectly reduced there is a 5% chance of redisplacement, but there is a 43% chance if reduction is poor. For completely displaced fractures the equivalent figures are 20% and 73%.

Probability of redisplacement has also been linked to adequate casting technique, namely cast moulding and cast looseness.[3,5]

In our study, no difference was found between redisplaced and non-redisplaced groups regarding cast index – its median was 0.7 in both groups with $p = 0.918$. Regarding gap index and three-point index, median was higher than the cut-off value in both groups. However, both were higher, but not significantly different, in the redisplaced group – 0.223 compared with 0.19 in the gap index and 1.77 compared with 1.59 in the three-point index.

Chess et al[18] proposed the cast index in a study with 558 cases, in which cast index values averaged 0.72 and the change in angulation was > 5° in 90% of cases. Re-angulation was related to poor cast moulding, reflected by a high cast index ($p < 0.01$). Other studies have supported these findings.[1,4,7]

Malviya et al[19] compared the gap index and the cast index in a study with 20 cases and 80 controls. A significant difference ($p < 0.001$) was observed in these two indices of both groups. The gap index was more sensitive than the cast index in predicting failure. Other studies have supported these findings,[7] while others, like our own, have failed to demonstrate a statistically significant association between either of the indices and the risk of redisplacement.[16]

Most recent studies consider that the three-point index is the most valuable treatment-related radiographic measurement for predicting re-displacement.[1,4,7] This superiority might be attributed to the fact that it assesses both three-point fixation – a basic principle for achieving stability in a cast – and quality of reduction – particularly fragment translation – in its calculation.[7]

Our study has some limitations, namely is retrospective in nature, the relatively short follow-up and the reduced number of patients included. However, we believe that this study brings important data to the existing literature.

Conclusion

Our findings support that treatment of displaced distal forearm fractures by means of closed reduction and cast immobilization under general anaesthesia yields good results, with low rates of redisplacement or re-intervention. While angulation in both planes increased significantly during follow-up, translation and shortening did not. Remanipulation under anaesthesia was successful when re-intervention was needed. Quality of reduction was the only risk factor that we found to be predictive of redisplacement. Although failure to demonstrate an association between other variables and redisplacement may be secondary to insufficient patient numbers, the ability of the data to clearly demonstrate a significant link between redisplacement and quality of reduction suggests that this is the most important factor.

Received 02 June 2021, accepted after revision 27 August 2021

COMPLIANCE WITH ETHICAL STANDARDS

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

OA LICENCE TEXT

This article is distributed under the terms of the Creative Commons Attribution-Non Commercial 4.0 International (CC BY-NC 4.0) licence (https://creativecommons.org/licenses/by-nc/4.0/) which permits non-commercial use, reproduction and distribution of the work without further permission provided the original work is attributed.

ETHICAL STATEMENT

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Was not required – this study includes completely anonymized radiographs and no individual identifying information.

ICMJE CONFLICT OF INTEREST STATEMENT

All authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTIONS

DC: Data acquisition, Data analysis, Data interpretation, Drafting, Critical revision.
LM: Study design, Data acquisition, Data analysis, Data interpretation, Drafting, Critical revision.
MC: Drafting, Critical revision.
JC: Drafting, Critical revision.
PSC: Drafting, Critical revision.
IB: Drafting, Critical revision.
TP-L: Drafting, Critical revision.
CA: Study design, Data acquisition, Data analysis, Data interpretation, Drafting, Critical revision.

REFERENCES

1. **Pretell Mazzini J, Rodriguez Martin J.** Paediatric forearm and distal radius fractures: risk factors and re-displacement—role of casting indices. *Int Orthop* 2010;34:407-412.

2. **Haddad FS, Williams RL.** Forearm fractures in children: avoiding redisplacement. *Injury* 1995;26:691-692.

3. **Voto SJ, Weiner DS, Leighley B.** Redisplacement after closed reduction of forearm fractures in children. *J Pediatr Orthop* 1990;10:79-84.

4. **Bae DS.** Pediatric distal radius and forearm fractures. *J Hand Surg Am* 2008;33:1911-1923.

5. **Proctor MT, Moore DJ, Paterson JM.** Redisplacement after manipulation of distal radial fractures in children. *J Bone Joint Surg [Br]* 1993;75-B:453-454.

6. **Sankar WN, Beck NA, Brewer JM, Baldwin KD, Pretell JA.** Isolated distal radial metaphyseal fractures with an intact ulna: risk factors for loss of reduction. *J Child Orthop* 2011;5:459-464.

7. **Alemdaroğlu KB, Ilter S, Çimen O, et al.** Risk factors in redisplacement of distal radial fractures in children. *J Bone Joint Surg [Am]* 2008;90-A:1224-1230.

8. **Zamzam MM, Khoshhal KI.** Displaced fracture of the distal radius in children. *J Bone Joint Surg [Br]* 2005;87-B:841-843.

9. **Crawford SN, Lee LSK, Izuka BH.** Closed treatment of overriding distal radial fractures without reduction in children. *J Bone Joint Surg [Am]* 2012;94-A:246-252.

10. **Laaksonen T, Puhakka J, Stenroos A, et al.** Cast immobilization in bayonet position versus reduction and pin fixation of overriding distal metaphyseal radius fractures in children under ten years of age: a case control study. *J Child Orthop* 2021;15:63-69.

11. **Mani G V.,** Hui PW, Cheng JCY. Translation of the radius as a predictor of outcome in distal radial fractures of children. *J Bone Joint Surg [Br]* 1993;75-B:808-811.

12. **Gelberman RH, Szabo RM, Mortensen WW.** Carpal tunnel pressures and wrist position in patients with colies' fractures.*J Trauma Inj Infect Crit Care* 1984;24:747-749.

13. **Inglis M, McClelland B, Sutherland LM, Cundy PJ.** Synthetic versus plaster of Paris casts in the treatment of fractures of the forearm in children: a randomised trial of clinical outcomes and patient, satisfaction. *J Bone Joint Surg [Br]* 2013;95 B:1285-1289.

14. **McLauchlan GJ, Cowan B, Annan IH, Robb JE.** Management of completely displaced metaphyseal fractures of the distal radius in children. A prospective, randomised controlled trial. *J Bone Joint Surg [Br]* 2002;84-B:413-417.

15. **Rai P, Haque A, Abraham A.** A systematic review of displaced paediatric distal radius fracture management: plaster cast versus Kirschner wiring. *J Clin Orthop Trauma* 2020;11:275-280.

16. **Jordan RW, Westacott D, Srinivas K, Shyamalan G.** Predicting redisplacement after manipulation of paediatric distal radius fractures: the importance of cast moulding. *Eur J Orthop Surg Traumatol* 2015;25:841-845.

17. **Gibbons CL, Woods DA, Pailthorpe C, Carr AJ, Worlock P.** The management of isolated distal radius fractures in children. *J Pediatr Orthop* 1994;14:207-210.

18. **Chess DG, Hyndman JC, Leahey JL, Brown DC, Sinclair AM.** Short arm plaster cast for distal pediatric forearm fractures. *J Pediatr Orthop* 1994;14:211-213.

19. **Malviya A, Tsintzas D, Mahawar K, Bache CE, Glithero PR.** Gap index: a good predictor of failure of plaster cast in distal third radius fractures. *J Pediatr Orthop B* 2007;16:48-52.