Arch Orthop Trauma Surg (2014) 134:1699–1707
DOI 10.1007/s00402-014-2091-8

TRAUMA SURGERY

Think twice before re-manipulating distal metaphyseal forearm fractures in children

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Received: 1 June 2014 / Published online: 7 October 2014

Abstract

Background Treatment of displaced paediatric distal forearm fractures is not always successful. Re-occurrence of angular deformity is a frequent complication. No consensus exists when to perform secondary manipulations. The purpose of this study was to analyse the long-term outcome of re-angulated paediatric forearm fractures to determine if re-manipulations can be avoided.

Methods Children who underwent closed reduction for distal forearm fractures and presented with re-angulation at follow-up were included in this retrospective cohort study. We compared those that were re-manipulated to those managed conservatively. Re-angulation was defined as ≥15° of angulation on either the AP or lateral view. Children were reviewed after 1–8 years post injury. Outcome measures were residual angulation on radiographs, active range of motion, grip strength, Visual Analogue Scales (satisfaction, cosmetics and pain) and the ABILHANDS-kids questionnaire.

Results Sixty-six children (mean age of 9.6 years) were included. Twenty-four fractures were re-manipulated and 42 fractures had been left to heal in angulated position. At time of re-angulation, children <12 years in the conservative group had similar angulations to those re-manipulated. Children ≥12 years in the re-manipulation group had significantly greater angulations than children in the conservative group. At final follow-up, after a mean of 4.0 years, near anatomical alignment was seen on radiographs in all patients. Functional outcome was predominantly excellent. There was no significant difference in functional, subjective or radiological outcomes between treatment groups.

Conclusion Re-manipulation of distal forearm fractures in children <12 years did not improve outcomes, deeming re-manipulations unnecessary. Children ≥12 years in the conservative group achieved satisfactory outcomes despite re-angulations exceeding current guidelines. Based on observed remodelling, we now accept up to 30° angulation in children <9 years; 25° angulation in children aged 9–<12; 20° angulation in children ≥12 years, when re-angulation occurs. We conclude that clinicians should be more reluctant to perform re-manipulations.

Keywords Distal forearm · Fracture · Paediatrics · Remodelling

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Introduction

Distal forearm fractures are the most common injuries seen in paediatric traumatology, accounting for 40 % of all fractures in children [1]. Severely angulated forearm fractures are generally reduced under general anaesthesia or sedation and stabilised in a cast. Reduction is not always successful and re-displacement during the first few weeks after reduction is a frequent complication [2]. Rates of re-displacement have been reported to be between 7 and 91 % [3]. A previous study revealed a re-displacement rate of

21.3 % at our institute [4]. In case of re-displacement, especially re-angulation, the clinician is often confronted with a treatment dilemma: whether to perform a re-manipulation or to accept re-displacement and trust on correction by growth [3]. This study focuses on the angular deformity of re-displacements and excludes the cases with solely a transitional or rotational aspect.

Earlier, Wilkins and O'Brien had suggested that dorsal angular deformities up to 30°–35° will remodel adequately in children still having at least 5 growing years left [5]. More recently, it has been suggested that in children below 9 years, up to 20° of dorsal angulation or 15° of radial angulation will yield a good result. With increasing age, the degree of tolerable angulation decreases, recommending to accept up to 10°–15° in children aged 9–13 years and up to 5°–10° in children aged 13–15 [6]. Controversy exists about the degree of angulation tolerable [7].

A recent trend toward increasingly more operative management has been observed, despite the fact that, to our knowledge, there have been no long-term outcomes studies showing superior results following operative treatment [8–11]. Some authors even recommend the routine use of K-wires in cases where anatomical reduction cannot be achieved [12–15]. This zero-tolerance approach does not give the well-known spontaneous correction of angulation, seen after fractures of long bones in children, an opportunity to take place [16, 17].

The long-term outcome of a re-displaced fracture has not yet been clarified [18]. Little attention has been paid to the outcome after re-manipulations [19]. Reports on clinical and radiological long-term results are altogether rare [20]. Due to the lack of consensus about the data on acceptable degrees of angulation, we developed a study with long-term follow-up. The purpose was to find whether re-manipulation of re-angulated fractures in children leads to an improved long-term outcome. We hypothesised that re-manipulations are often unnecessary.

Materials and methods

This retrospective cohort study was performed at a level 1 trauma institute. Ethics approval was obtained from the local medical ethics committee. A medical records search was performed to identify all children admitted with a distal forearm fracture between January 2005 and June 2012. Included in the study were: children who were ≤15 years old at the time of injury, who sustained a fracture of the distal third of the radius (with or without associated ulna fracture) which required closed reduction and subsequently presented with re-angulation at the initial follow-up. Re-angulation was defined as the progression of fracture angulation to greater than 15° on the lateral or posterior-anterior (PA) radiograph. Excluded were: non-displaced fractures; fractures that maintained satisfactory alignment after primary closed reduction; fractures initially treated by internal fixation; intra-articular fractures (Salter Harris); fractures treated by open reduction and open fractures. All included children were managed with an above-elbow cast according to the institute's clinical management protocol.

Eligible patients were invited to revisit the orthopaedic outpatients' clinic for long-term functional and radiographic assessment. Patients unable to attend were interviewed via telephone for subjective outcome. Informed consent was obtained from children's parents/guardians. All children voluntarily agreed to take part.

Patients were divided into two groups. The re-manipulation group consisted of patients, who underwent secondary closed reduction after re-angulation had occurred. The conservative group consisted of patients where re-angulations were accepted with the expectation that spontaneous correction by remodelling would occur. These patients were managed by casting alone and did not undergo a secondary closed reduction.

We classified our participants' angulated fractures into three categories of fracture types: (A) incomplete fractures, (B) Complete fractures with bone contact and (C) Complete fractures with 100 % displacement. Presence of an associated ulna fracture was noted. We also investigated when re-angulation occurred, when re-manipulation was performed and what the total duration of treatment was in both treatment groups. Total duration of treatment was defined as time of injury until removal of cast.

One observer (first author) analysed radiographs by measuring the degree and direction of angulation at the site of the fracture, using standard techniques [21]. Fracture angulation was analysed at the time of trauma, re-angulation, post re-manipulation and final follow-up. The decision whether or not to re-manipulate was made at the time re-angulation was noticed. A method described by Ries et al. was used to determine the true angular deformity, which combines the findings of the PA and lateral radiograph [22, 23]. The maximum degree of angulation may occur in a plane other than the PA or lateral and the degree of true angulation can therefore be underestimated. True angulation was calculated with the formula given by Bär et al. [23]. Therefore, instead of presenting re-angulation as two findings (angular deformities on PA and lateral), radiographic results are presented as only one calculated finding. True angulation is demonstrated in Fig. 1.

As remodelling potential decreases with increasing age [24, 25], radiographic results on angular deformity are subdivided into the following age categories: children <9 years old, children aged 9–<12 years and children aged ≥12 years.

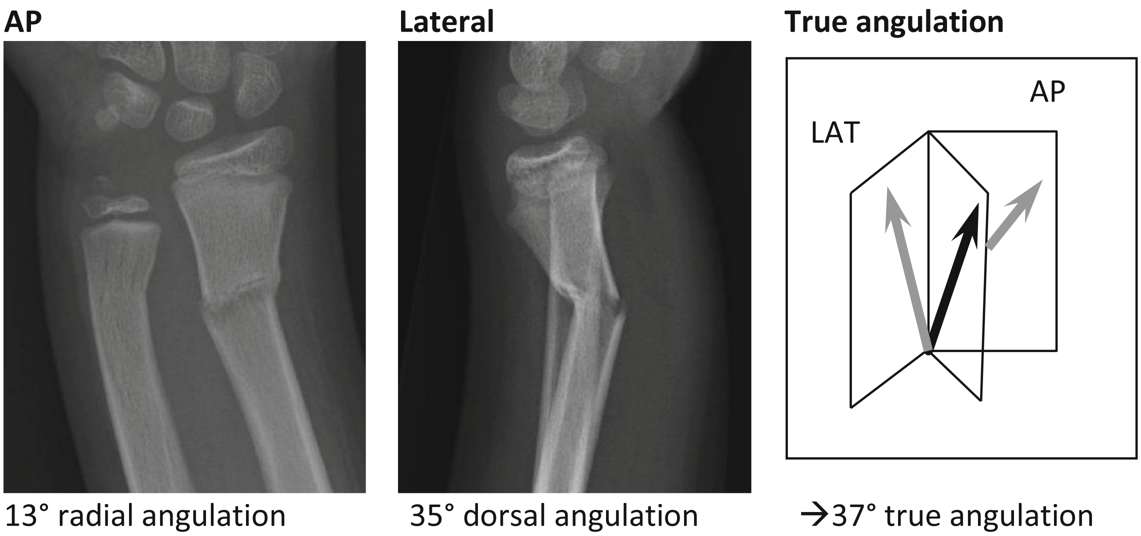

Fig. 1 True angulation

To assess functional outcome, range of motion was measured using a goniometer and grip strength was measured using a JAMAR hydraulic hand dynamometer (Lafayette Instrument Company, Lafayette, IN, USA). To assess the subjective outcome, patient satisfaction regarding wrist function, cosmetic appearance and pain was documented using Visual Analogue Scales (VAS). The ABILHANDS-kids questionnaire was used to assess hand function in daily activities [26, 27]. Overall outcome was graded according to the criteria of Price et al. [8, 28]. A result was considered excellent if there were no complaints with strenuous physical activity and/or a loss of ≤10° of forearm rotation. A result was considered good if there were only mild complaints with strenuous physical activity and/or a loss of 11–30° forearm rotation. Fair results consisted of mild subjective complaints during daily activities and/or a 31–90° loss of forearm rotation. All other results were considered poor.

Statistical methods

Results are presented as means (±standard deviation). Chi-square test was used for analysis of patient demographics. Student's *t* tests for independent samples, with equal variances not assumed, were performed to analyse differences in outcomes between groups. Fishers' exact test was used to compare overall outcome. One-way analysis of variance (ANOVA) was performed to study the effect of age, after subdividing patients into age categories: <9 years, 9–<12 years and ≥12 years. Remodelling capacity (re-angulation minus final residual angulation) was compared between age categories. Also, the effect of an associated ulna fracture was investigated.

Fracture angulation was re-measured in twenty cases by an independent trauma surgeon to confirm reproducibility of radiological assessment of fracture angulations (intra-class correlation). Statistical analyses were performed with Statistical Package for Social Sciences (SPSS) version 20.0 (SPSS Inc., Chicago, IL, USA). *P* values <0.05 were considered statistically significant.

Results

Our search identified 917 children with a forearm fracture who underwent closed reduction. Re-angulation (≥15°) occurred in 126 patients (=14 %), hereby meeting the inclusion criteria for enrolment (Fig. 2). Re-manipulation was performed in 35 children (=28 % of 126), of whom 12 received additional internal fixation with K-wires. We included 66 children with a mean age of 9.6 years (±2.9) at the time of fracture. Table 1 shows the patient demographics, treatment chronology and fracture characteristics of the study population. We reviewed the functional, radiological and subjective outcome of 39 patients clinically and the subjective outcome of an additional 27 patients via telephone. There was a mean follow-up of 4.0 years; 4.8 years in the re-manipulation group, 3.6 years in the conservative group. There was no significant difference between the groups in terms of age, gender and side or dominance of the injured extremity. Re-angulation occurred after a mean of 15 (±9) days post injury. Re-manipulation was performed after a mean of 11 (±4) days post injury. A significant difference in total duration of treatment was found in favour of the conservative group with a mean of 17 days shorter total treatment duration.

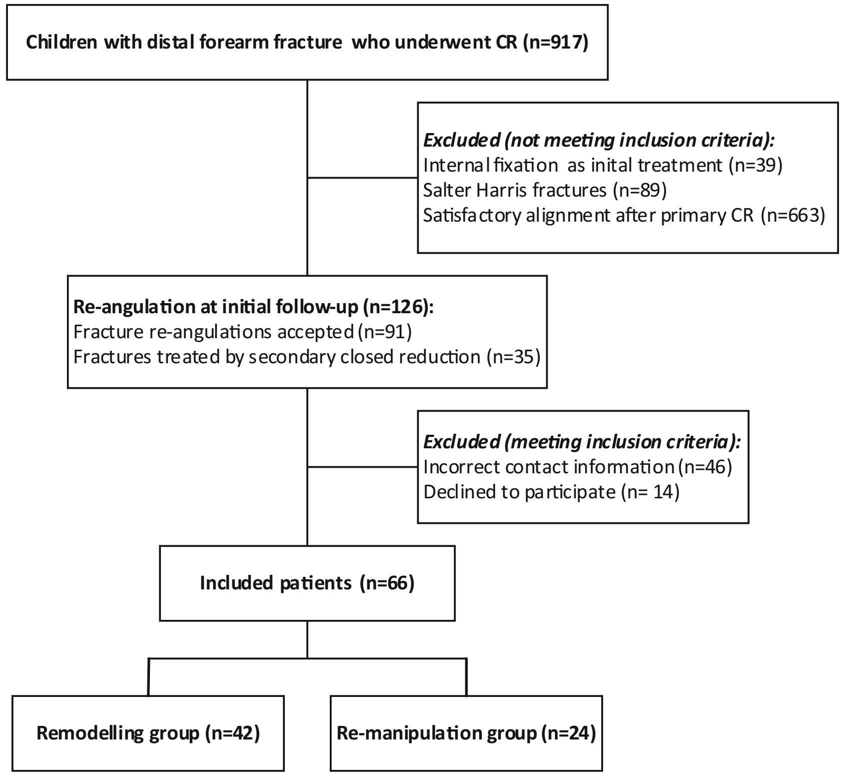

Fig. 2 Flowchart of enrolment

Table 1 Patient demographics/fracture baseline characteristics of the study population

	Total	Re-manipulation	Conservative
Number of children	66	24	42
Clinically reviewed	39	16	23
Subjectively reviewed	27	8	19
Gender (% male)	56	54	57
Age at trauma in years (mean ± SD)	9.6 (±2.9)	9.8 (±2.7)	9.3 (±3.1)
Days until re-angulation	15 (±9)	11 (±4)*	17 (±11)*
Total days of treatment	46 (±15)	57 (±19)*	40 (±7)*
Final follow-up (in years)	4.0 (±1.7)	4.8 (±1.6)*	3.6 (±1.7)*
Fracture characteristics: Both bone forearm fracture			
A. Incomplete fracture (%)	9.1	0	14.3
B. Complete with contact (%)	56.1	62.5	52.4
C. Complete, 100 % displaced (%)	34.8	37.5	33.3
Associated ulna fracture (%)	53	38	62
Dominant arm fractured (%)	48	44	50

* Significant difference ($P \leq 0.0504$)

Comparison of radiological results between the two treatment groups are presented in Table 2. At time of injury fracture angulations were similar between the two groups. When re-angulation occurred (±15 days post injury), in the age category of <12 years there was no significant difference in angulation between fractures of the two treatment groups. In the age category of children ≥12 years, the re-manipulation group had significantly greater re-angulations than the conservative group. Re-manipulation was initially successful in all cases, but fractures healed with a mean residual angulation of 12° due to secondary re-angulation. This was significantly less than seen in children <12 years in the conservative group. No significant difference in angulation was seen between groups in children ≥12 years post re-manipulation. At final follow-up, near anatomical alignment was achieved in all patients and no significant difference was found in degree of angulation.

In terms of functional outcome, there were no significant differences between the two groups at final follow-up, likewise when subdivided by age. Limitations in functional outcome were minimal and are presented in Table 3. Following the criteria of Price [28], there were 18 excellent, 4 good and 1 fair outcome in the conservative group and 12 excellent, 3 good and 1 poor outcomes in the re-manipulation group. The patient with a poor outcome in the re-

Table 2 Data on radiological outcomes

Degree of mean true angulation (±SD)	n (=66)	Trauma	At time of re-angulation	Post re-manipulation	Final follow-up (n = 39)
Children <9 years					
Re-manipulation	8	26° ± 13°	31° ± 9°	12° ± 7°	3° ± 2° (n = 7)
Conservative	21	31° ± 11°	25° ± 6°	×	1° ± 2° (n = 13)
P value	–	0.36	0.12	0.00[a]	0.51
Children 9–12 years					
Re-manipulation	10	28° ± 9°	26° ± 7°	12° ± 6°	1° ± 2° (n = 7)
Conservative	12	33° ± 15°	21° ± 5°	×	3° ± 3° (n = 5)
P value	–	0.24	0.12	0.00[a]	0.37
Children ≥12 years					
Re-manipulation	5	28° ± 20°	25° ± 6°	15° ± 9°	2° ± 2° (n = 2)
Conservative	9	26° ± 10°	19° ± 3°	×	6° ± 4° (n = 5)
Significance	–	0.85	0.04	0.45[a]	0.14
Total					
Re-manipulation	24	27° ± 13°	27° ± 8°	12° ± 7°	2° ± 2°
Conservative	42	31° ± 12°	23° ± 6°	×	3° ± 3°
Significance	–	0.27	0.01	0.00[a]	0.21

[a] Compared to angulation of conservative group at time of re-angulation

Table 3 Data on limitation of range of motion, grip strength and VAS scores

	Re-manipulation group (n = 16)	Conservative group (n = 23)
Loss of pro-supination	4° (±5°)	6° (±6°)
Loss of radial–ulnar deviation	5° (±7°)	5° (±7°)
Loss of wrist flexion/extension	2° (±4°)	2° (±6°)
Grip strength (in kg)	3 (±6)	1 (±3)
VAS satisfaction[a]	8.8 (±2.0)	9.2 (±1.3)
VAS cosmetic appearance[a]	9.4 (±1.1)	9.0 (±1.6)
VAS pain[a]	0.8 (±1.4)	1.2 (±1.4)

Limitation is in comparison to the contralateral arm. There are no statistically significant differences between the groups

[a] VAS scores (in cm) ranging from 0 to 10 cm (with 0 being the best and 10 the worst)

manipulation group had a progressive loss of strength of >50 %, which caused moderate to severe complaints during daily activities. The fracture of this child was re-manipulated and fixated with K-wires. The patient with a fair outcome in the conservative group had ulnar-sided wrist pain due to positive ulnar variance requiring ulna shortening osteotomy at skeletal maturity. Both children with inferior outcomes were above 12 years of age. All others had a near full to full range of motion and grip strength and all had returned to normal activities without restrictions. Overall outcome was not significantly different between treatment groups ($P = 0.81$).

Patients' subjective assessment of pain, function and cosmetics (VAS) are presented in Table 3 and demonstrated no significant difference between groups. The ABILHANDS-kids questionnaire ($n = 66$) revealed a score of 40.8 (±3.0) in the re-manipulation group and a score of 41.0 (±1.9) in the conservative group (maximal score: 42). Patients subjectively reviewed had no significant differences in patient demographics or fracture angulations when compared to those clinically reviewed. Associated ulna fractures did not influence outcomes significantly.

The inter-reproducibility of the radiological assessment of the degree of true angulation showed an intra-class correlation range of 0.88–0.98.

Discussion

The purpose of this study was to analyse the effect of manipulating re-angulations of initially reduced paediatric distal forearm fractures on the long-term outcome. We hypothesised that re-manipulations are often unnecessary. At final follow-up, near anatomical alignment was achieved in all patients and no significant difference was found in residual angulation between the treatment groups, despite the fact that the conservative group had greater residual angulation than the re-manipulation group. At final follow-up both groups performed just as well in terms of functional and subjective outcomes. Figure 3 demonstrates the power of remodelling over time.

One of the factors affecting the decision whether or not to re-manipulate is evidently the degree of angulation. Our study revealed that children <12 years old did not differ significantly in degree of fracture re-angulation initially, when the decision whether or not to re-manipulate was

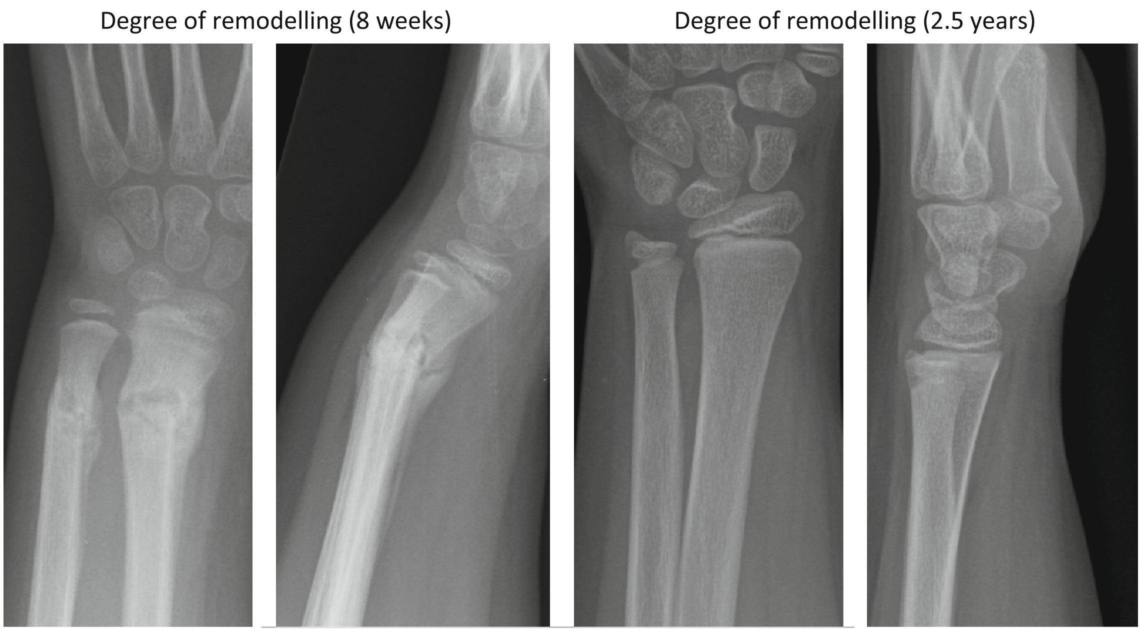

Fig. 3 Example of remodelling in radiological follow-up

made. However they still received different types of treatment (one being more invasive). This clearly indicates that when opting for re-manipulation, not only the severity of angulation, but also surgeons' preferences and parents' opinions are taken into account in the decision-making process whether to manipulate or not.

At final follow-up, our study did not demonstrate superior radiological, functional or subjective outcomes in the re-manipulation group. Therefore, re-manipulations in children <12 years would seem unnecessary, as fracture re-angulations did not vary significantly within this age category. In children ≥12 years, re-angulations were more severe in the re-manipulation group. This reveals that especially in the older children, severity of angulation plays an important part in the decision whether or not to perform secondary manipulation. As expected and in accordance with the literature, the capacity for remodelling at the fracture site was greater in the younger children than in the older children [29]. However, the degree of secondary angulation seen in the conservative group did exceed the amount considered tolerable and nevertheless, satisfactory results were still achieved. This deems guidelines too strict.

Only a few randomised controlled trials have compared functional outcomes following closed reduction and cast immobilisation versus percutaneous pin fixation of angulated distal radius or both-bone forearm fracture in children thus far [3, 30, 31]. Two RCTs found no significant difference in functional outcome after a mean period of approximately 3 months [30, 31] and one randomised controlled trial showed a significantly lower rate of loss of pronation/supination after percutaneous pin fixation of forearm fractures at 6 months follow-up [3], whereas our study shows predominantly excellent functional outcomes after a mean period of 4.0 years. This highlights that remodelling takes place over a long period of time and functional outcome can be restored in due time. Thereby, Zimmerman et al. [20] also found that in children <10 years, large dislocations at the time of fracture healing do not influence the 10-year functional outcome and that repeated reduction of fractures produced significantly poorer results in the long term. Furthermore, Price et al. [28] studied the outcome of angulated paediatric forearm fractures after a mean follow-up of 5.8 years and found 32 excellent, 4 good, 3 fair and 0 poor outcomes. Using the same grading system, we found similar results in overall outcome of fractures left to correct by remodelling.

Our findings suggest that the criteria of published guidelines recommending when to manipulate paediatric forearms fractures are too strict. This is supported by other studies: despite protocols suggesting to re-manipulate all fractures that fail to maintain these reduction parameters, only 51 % of these children received secondary manipulation, found in two impartial studies [3, 18] and a recent study by Asadollahi et al. [32] concludes that only a small number of fractures that lose reduction require a second intervention. Reasons for clinicians to avoid (re-)manipulations of children's fractures are mainly based on risks associated with anaesthesia [33–37]. Moreover, the treating surgeon may expect correction of the malunion by growth, may be reluctant to burden the child again and prolong the period of casting, or may find it difficult to accept failure of the initial treatment. In our study, a delay of 17 days in total duration of treatment was seen in the re-manipulation group, causing extra discomfort and interference with daily activities without accomplishing superior outcomes.

Limitations

Our study had some limitations. In our study, all included children were managed with an above-elbow cast according to our institute's former clinical management protocol. Recent literature [38–44] provides insights that below-elbow casting (BEC) is not inferior to above-elbow casting (AEC) and should be considered first-choice for conservative treatment. A recent meta-analysis by Hendrickx et al. updated by Bekerom et al. in 2012 including 5 randomised controlled trials comparing AEC versus BEC for the treatment of distal third forearm fractures in children had the following results: BEC had significantly fewer loss of reduction [OR 0.44 (0.24–0.82)]; there was no significant difference in the number of performed re-manipulations [OR 0.64 (0.34–1.20)]; there was no significant difference in plaster-related complications [OR 0.60 (0.42–1.12)] and children treated with BEC missed less school days and encountered less difficulties in daily living. In the interim, our protocol has been updated and we have implemented the use of below-elbow casting to treat metaphyseal distal radius or both-bone forearm fractures.

Due to the retrospective nature of this research, recruitment rates were modest. Geographic dispersion of the study population meant that 27 out of 66 children were unable to revisit clinics. Patients who could not revisit clinics did not significantly differ from those who were clinically reviewed in terms demographics, baseline fracture angulations and long-term subjective outcomes. Patients clinically reviewed thus represent a good sample of the homogenous total group of participants. Franklin et al. [10] suggested that the ideal study to aid in evidence-based decision-making for paediatric distal forearm fractures would be a randomised controlled trial comparing cast immobilisation and closed reduction versus operative management, in children aged older than 8 years with distal metaphyseal forearm fractures with angulation $\geq$20°, subdivided for fracture classification, with a minimum of 5 years of follow-up, studying the final functional outcome, defined as pronation and supination at final presentation. In our opinion, the treatment option of below-elbow cast immobilisation without closed reduction in children up to 12 years of age should be included in this ideal RCT.

The mean age for ossification of the physis differs between boys and girls (14.5 and 12.9 years, respectively) [45] which suggests a divergence in remodelling capacity especially in the oldest group. We did not detect a gender difference in remodelling capacity within this group, though statistical power might not have been strong enough. Numbers of males and females were however, homogenous within all 3 groups, which balanced potential differences.

A difference in length of follow-up between the two groups was seen. Mean follow-up was 4.8 years in the re-manipulation group compared to 3.6 years in the conservative group. Yet, this reinforces our hypothesis, because the shorter follow-up period disadvantaged the conservative group in its remodelling potential.

Lastly, the clinical applicability of "true angulation" requires further investigation.

Conclusion

As a result of our findings, when re-angulation occurs at our institute, we now accept up to 30° true angulation in children <9 years; up to 25° true angulation in children aged 9–<12; 20° true angulation in children $\geq$12 years. We based these recommendations on our observed range of angulations within 1 SD from the mean of each age category which lead to predominantly excellent outcomes. If these recommendations would have been implemented beforehand, only three patients in the conservative group and nine patients in the re-manipulation group would have been re-manipulated. This would decrease the amount of re-manipulations performed by 50 % without, to our beliefs, compromising outcomes. Our results provide yet another piece of evidence to justify this non-invasive management approach preferred by many clinicians.

We conclude that re-manipulation of re-angulated paediatric distal forearm fractures in children <12 years does not provide an improved 4-year outcome as compared to conservative management. Children $\geq$12 years also demonstrated to exceed the expected remodelling capacity and achieved satisfactory outcomes. Therefore, we recommend to accept up to 30° true angulation in children <9 years; up to 25° true angulation in children aged 9–<12; 20° true angulation in children $\geq$12 years. We believe that the clinician's reluctance to perform re-manipulations can be justified and suggest thinking twice before re-manipulating children's forearm fractures in clinical practise.

Conflict of interest None.

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