■ CHILDREN'S ORTHOPAEDICS

Risk factors for the displacement of fractures of both bones of the forearm in children

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Forearm fractures in children have a tendency to displace in a cast leading to malunion with reduced functional and cosmetic results. In order to identify risk factors for displacement, a total of 247 conservatively treated fractures of the forearm in 246 children with a mean age of 7.3 years (SD 3.2; 0.9 to 14.9) were included in a prospective multicentre study. Multivariate logistic regression analyses were performed to assess risk factors for displacement of reduced or non-reduced fractures in the cast. Displacement occurred in 73 patients (29.6%), of which 65 (89.0%) were in above-elbow casts. The mean time between the injury and displacement was 22.7 days (0 to 59). The independent factors found to significantly increase the risk of displacement were a fracture of the non-dominant arm (p = 0.024), a complete fracture (p = 0.040), a fracture with translation of the ulna on lateral radiographs (p = 0.014) and shortening of the fracture (p = 0.019).

Fractures of both forearm bones in children have a strong tendency to displace even in an above-elbow cast. Severe fractures of the non-dominant arm are at highest risk for displacement. Radiographs at set times during treatment might identify early displacement, which should be treated before malunion occurs, especially in older children with less potential for remodelling.

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Displacement of fractures of both forearm bones in children treated in a cast has been described in between 7% and 91% of cases,[1-5] and can lead to malunion with reduced functional and cosmetic results.[6,7] Despite the high rate of displacement, there has not hitherto been an analysis of risk factors in large prospective studies.[3-5,8-11] We therefore performed a prospective multicentre study to identify the risk factors for displacement of reduced and unreduced fractures of both bones of the forearm in children when treated in a cast.

Patients and Methods

Between January 2006 and August 2010 a total of 247 children aged < 16 years with fractures of both bones of the forearm were included in a prospective study involving four hospitals (Fig. 1, Table I). The study had ethical approval and informed consent was obtained from all parents, and children aged > 12 years.

The criteria for reduction were based on previous studies (Table II).[1,12-20] Exclusion criteria were: torus fractures of both the radius and ulna; fractures sustained more than a week before presentation; severe open fractures (Gustilo II and III)[21]; and re-fractures. Exclusion criteria included those fixed with Kirschner (K-) wires or intramedullary nails, fractures without final radiographs, initially displaced fractures without reduction and reduced fractures with displacement on the first subsequent radiograph.

The study protocol distinguished different types of fractures. Distal metaphyseal fractures not requiring reduction were treated with a below- or above-elbow cast for four weeks,[22] whereas distal metaphyseal fractures needing reduction were treated with or without K-wires and an above-elbow cast for four weeks.[23] Diaphyseal fractures not requiring reduction and reduced stable diaphyseal fractures were treated for six weeks with an above-elbow cast or a combination of three weeks above and three weeks below. Unstable diaphyseal fractures were fixed with one or two intramedullary nails and three weeks in an above-elbow cast. The cast was applied in a standard way by a trained nurse in the emergency department or a surgeon in the operating room. Firstly, a stockinette and layer of wool were applied to protect the skin and bony prominences. Second, a well-fitted plaster slab was applied that covered approximately two-thirds of the circumference of the arm. Finally a bandage was wrapped around the arm.

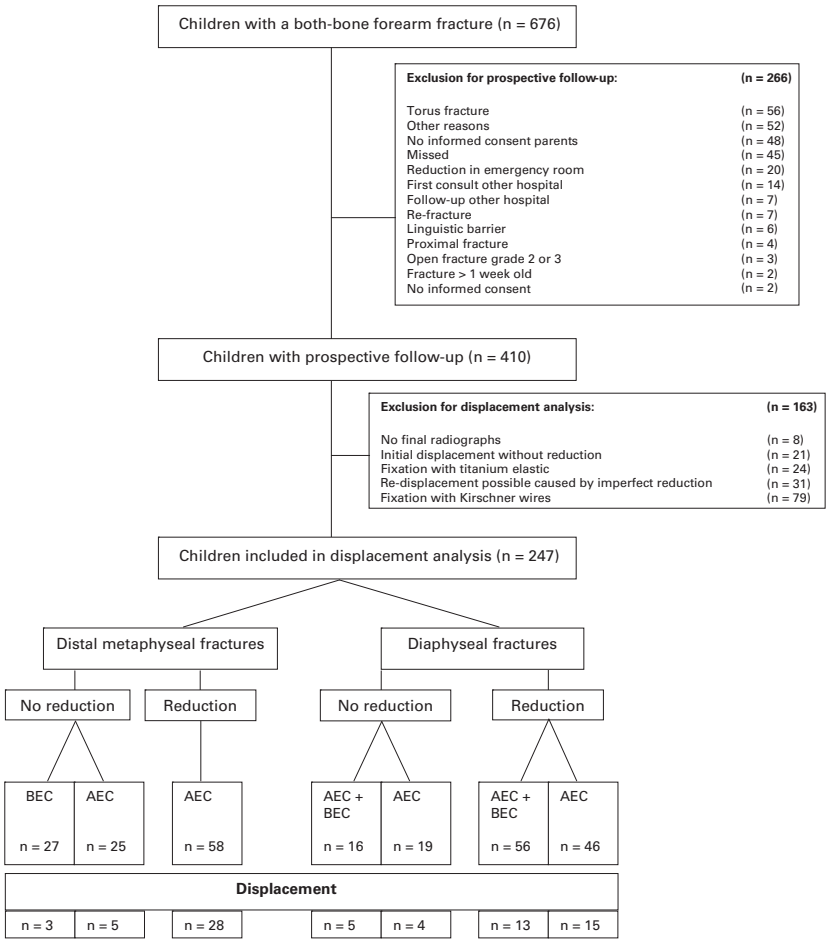

Fig. 1

Flowchart of enrolment in the study (B-/AEC, below-/above-elbow cast).

Radiographs were taken at presentation, after reduction and during treatment. An orthopaedic surgeon (JWC) who was not involved in primary treatment measured angulation, translation as a percentage of the width of radius/ulna rotation (yes/no) and shortening (yes/no) of all fractures. Rotation was detected by differences in the diameter of the diaphysis of radius and ulna on anteroposterior and lateral radiographs.[24]

A reduced or an unreduced fracture that showed progressive displacement (Fig. 2) during follow-up was defined as displaced if further reduction was needed according to the criteria for primary reduction (Table II).

In order to assess the inter-rater reproducibility of the radiological assessment, a trauma surgeon (LUB) who was not involved in treatment re-measured the angulation of the fracture in 45 children.

Statistical analysis. Our dependent variable was displacement of the fracture in the cast and we assessed whether this was related to any of the following factors: gender, hand dominance, location of the fracture (diaphysis *vs* distal metaphysis), type of fracture (greenstick or complete), primary displacement (angulation, translation, shortening, rotation), reduction of the fracture, location of reduction (emergency ward, operating room), type of cast (above- or below-elbow) and quality of cast (cast-index).[25] Fractures other than complete were defined as greenstick fractures. The choice of risk factors was based on previous studies.[3-5,8-11,26,27]

In order to assess which factors were related to displacement of the fracture in the cast, multivariate logistic regression analysis (enter method) was used to calculate odds ratios (ORs) including 95% confidence intervals (95% CI). In all analyses, a two-sided p-value of ≤ 0.05 was considered significant. Statistical analyses were performed with SPSS 17.0 (SPSS Inc., Chicago, Illinois).

Results

The fracture re-displaced in 73 children (29.6%). Re-displacement occurred more frequently in distal metaphyseal fractures compared with diaphyseal fractures (32.7%

Table I. Demographics

Characteristic	
Children (n)	247
Mean age (yrs) (SD; range)	7.3 (3.2; 0.9 to 14.9)
Male (n, %)	147 (*59.5*)
Fracture on dominant arm (n, %)	98 (*39.7*)
Right arm fractured	96 (*38.9*)
Location (n, %)	
Diaphysis	137 (*55.5*)
Metaphysis	110 (*44.5*)
Type of fracture (n, %)	
Both greenstick	111 (*44.9*)
Both complete	64 (*25.9*)
Greenstick (ulna) + complete (radius)	34 (*13.8*)
Complete (ulna) + greenstick (radius)	17 (*6.9*)
Torus (ulna) + greenstick (radius)	12 (*4.9*)
Greenstick (ulna) + torus (radius)	4 (*1.6*)
Torus (ulna) + complete (radius)	4 (*1.6*)
Complete (ulna) + torus (radius)	1 (*0.4*)

Table II. Criteria for reduction of the fracture of radius and/or ulna based on anteroposterior and/or lateral radiographs

Type of deformity	Age (yrs)	Deformity
Angulation	< 10	> 15°
	10 to 16	> 10°
Translation	< 16	> half of bone diameter
Rotation	< 16	> 0

Fig. 2

Lateral radiographs showing a both-bone forearm fracture (left) which was properly reduced (centre) but showed re-displacement after four weeks (right). This fracture demonstrates all risk factors: complete fracture in non-dominant arm with shortening and translation of the ulna on the lateral radiograph.

(36 of 110) *vs* 27.0% (37 of 137)). The mean time between the injury and displacement was 22.7 days (SD 13.5; 0 to 59), and 65 re-displacements (89.0%) were in an above-elbow cast (Fig. 2).

The factors that were significantly and independently associated with redisplacement were hand dominance and three factors associated with the severity of the fracture, namely complete fractures, translation of the ulna on lateral radiographs and shortening (Table III, Fig. 2).

Discussion

We found that 29.6% of fractures of both bones of the forearm in children treated in a cast displaced, the risk of which was increased in more severe fractures of the non-dominant arm. Earlier authors reported displacement of between 7% and 91% of fractures in the distal metaphysis[1-5,28-31] and between 7% and 27% of fractures in the diaphysis,[5,15,27,32-35] compared with 33% and 27% respectively in our study. Our relatively high percentage of displacement can be explained by the inclusion of only both-bone fractures, which are more unstable than single-bone fractures.[4,27,36]

Whereas an earlier study reported hand dominance as a risk factor for displacement,[27] others found similar numbers in dominant and non-dominant arms.[3] Our results suggest that fractures in the non-dominant arm are at increased risk for displacement, which might be explained by less stability of the fracture by less developed muscles in the non-dominant forearm.

As with earlier reports[3-5,8,9,27] the severity of the fracture in our study seemed highly predictive of displacement. Complete fractures significantly increased the risk for displacement, a finding supported by some studies[3,4,8,9,27] but not others.[5,11] Whereas translation of the ulna on lateral radiographs has been reported as a risk factor for displacement,[32] shortening has not. Complete fractures with translation and shortening seem to be more unstable than angulated greenstick fractures with intact periosteum on one side. Angulation of the fracture did not appear to be a risk factor for displacement in this or previous studies.[3,11] Also, location in the diaphysis or metaphysis had no significant influence on displacement, a finding supported by Monga et al[27] but not Younger et al.[25]

Although several studies considered displacement to be related to an above- or below-elbow cast,[3,10,26,27] this was not supported by our results. Also, several studies[5,8,10,11,25,32] reported quality of the cast as a risk factor, while others found no such correlation.[9,27] The cast index was not considered as a risk factor in our study.[25,32]

Our study has several limitations. Because it is impossible to differentiate between imperfectly reduced and redisplaced fractures, we excluded children with reduced fractures that showed displacement at the first available radiographs after the reduction. Similarly, we could not analyse imperfect reduction as a risk factor for displacement. Furthermore, we measured the cast index in non-circumferential casts whereas this measurement is only validated for circumferential casts.[25,32] Nevertheless, we assumed that the cast index is also important in non-circumferential casts because it indicates how well the cast is moulded to the contour of the forearm. This is supported

Table III. Factors associated with displacement of the fracture with multivariate logistic regression analysis. Only significant odds ratios are provided (CI, confidence interval); AP, anteroposterior; lat, lateral

Factors	Rate of displacement (%)	Odds ratio (95% CI)	p-value
Gender			0.561
Male (n = 147)	*29.9* (n = 44)		
Female (n = 100)	*29.0* (n = 29)		
Dominant arm fractured			0.024
No (n = 149)	*31.5* (n = 47)*	0.46 (0.23 to 0.89)	
Yes (n = 98)	*24.5* (n = 24)*		
Fracture location			0.751
Metaphyseal (n = 110)	*32.7* (n = 36)		
Diaphyseal (n = 137)	*27.0* (n = 37)		
Type of fracture			0.040
Complete (n = 120)	*45.0* (n = 54)	3.34 (1.63 to 6.86)	
Greenstick (n = 127)	*15.0* (n = 19)		
Primary displacement†			
Angulation AP radius			0.760
Angulation lat radius			0.126
Angulation AP ulna			0.779
Angulation lat ulna			0.261
Translation AP radius			0.189
Translation lat radius			0.915
Translation AP ulna			0.952
Translation lat ulna		0.98 (0.96 to 0.99)	0.014
Shortening of radius and/or ulna			0.019
No (n = 199)	*21.6* (n = 43)		
Yes (n = 48)	*62.5* (n = 30)	5.67 (2.27 to 14.17)	
Rotation of radius and/or ulna			0.065
No (n = 232)	*27.2* (n = 63)		
Yes (n = 15)	*66.7* (n = 10)		
Reduced fracture			0.452
No (n = 87)	*19.5* (n = 17)		
Yes (n = 160)	*35.0* (n = 56)		
Location of reduction			0.445
Emergency ward (n = 28)	*28.6* (n = 8)		
Operation room (n = 129)	*36.4* (n = 47)		
Type of cast			0.085
Above-elbow (n = 188)	*34.6* (n = 65)		
Below-elbow (n = 59)	*13.6* (n = 8)		
Cast index†			0.597

* excluding two in whom this information was unknown

† no dichotomous outcomes

by a study in which there were similar rates of displacement in circumferential and non-circumferential casts.[3]

In summary, reduced and unreduced fractures of both bones of the forearm in children displaced frequently, even if treated with an above-elbow cast. The most severe fractures in the non-dominant arm had the highest risk for displacement. Radiographs at set times during treatment might identify early displacement, which should be treated before malunion occurs, especially in older children with less potential for remodelling.

Supplementary material

A further opinion by Simon Thomas is available with the electronic version of this article on our website at www.boneandjoint.org.uk/site/education/further_op

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