Acta Orthop. Belg., 2011, **77**, 21-26

ORIGINAL STUDY

Angulated greenstick fractures of the distal forearm in children : Closed reduction by pronation or supination

Alexander VAN TONGEL, Pieter ACKERMAN, Koen LIEKENS, Bart BERGHS

From AZ St Jan Hospital, Brugge, Belgium

The purpose of this study was to evaluate a reduction method that is based on the theory of Evans to reduce angulated greenstick fractures of the distal forearm with a rotation manoeuvre, to evaluate an immobilisation technique and to evaluate a brief survey on surgeon practice for treatment of these fractures. A retrospective study was performed on 21 patients. Fractures were reduced with a pronation or supination manoeuvre depending on the angulation of the fracture and were immobilised in pronation or supination. A good reduction was achieved in all patients. Six weeks after manipulation a loss of reduction was seen in 6 out of 21 patients, but with a re-angulation of less than 15°. There was no significant difference between fractures immobilized in pronation or in supination. There was no need for re-manipulation. At the 2008 Osteosynthesis and Trauma Care Foundation (OTC) meeting, a brief informal survey was performed concerning the reduction method and the use of K-wires after reduction. No surgeons indicated they would perform only a rotation manoeuvre.

Keywords : distal forearm fracture ; children ; reduction ; pronation ; supination.

INTRODUCTION

The most common fractures in children are fractures of the distal radius and ulna with greenstick fractures as the most common fracture type (*3,11-12*). The majority have satisfactory outcomes, but poor results do occur. If malunion occurs, it can compromise pronation-supination (*2*). The amount of angulation considered acceptable is still not completely clear. Greater angulation has been shown to be acceptable in younger patients, but an actual threshold is difficult to establish (*5,9*).

As Evans emphasized, greenstick forearm fractures have a rotatory component to their malalignment (*4*). The more common apex volar fractures represent a supination deformity, whereas the less common apex dorsal fractures are malrotated in pronation. Correction of malrotation is necessary to achieve anatomic alignment ; however more recently, there has been a simplification of this theory (*3,10,13*). The objective of the current study is

■ Alexander Van Tongel, MD, Orthopaedic Surgeon.
■ Pieter Ackerman, MD, Orthopaedic Surgeon.
■ Koen Liekens, MD, Resident in Orthopaedic Surgery.
Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital, De Pintelaan 185, B-9000 Gent, Belgium.
■ Bart Berghs, MD, Orthopaedic Surgeon.
Department of Orthopaedic Surgery and Traumatology AZ St Jan Hospital, Ruddershove 10, B-8000 Brugge, Belgium.
Correspondence : Alexander Van Tongel, Department of Orthopaedic Surgery and Traumatology, Ghent University Hospital, De Pintelaan 185, 9000 Gent, Belgium.
E-mail : alexander_vantongel@hotmail.com

No benefits or funds were received in support of this study

to evaluate the reduction method proposed by Evans and to evaluate an immobilisation technique in pronation or supination. A brief survey on surgeon practice for treatment of greenstick fractures, conducted at the Osteosynthesis and Trauma Care foundation (OTC) congress in 2008, is also reported.

MATERIALS AND METHODS

This retrospective study included all children (5-14 years old) seen at our hospital between January 2005 and December 2008 with a closed greenstick fracture of the distal third of the forearm that required reduction. Our cut-off line for closed reduction was 15° of volar or dorsal angulation on the lateral radiograph. Reduction was performed under general anaesthesia in the operating room or under local anaesthesia. The method of reduction was always a rotation maneuvre, depending upon the direction of the angulation of the fracture on the lateral radiograph. With volar angulation, reduction was accomplished by pronating the forearm without bringing the wrist into hyperflexion. With dorsal angulation, the hand of the child was forced in supination. We did not bring the wrist into hyperextension. After this maneuvre, the reduction was checked radiographically. Five degrees of residual angulation was deemed acceptable. Afterwards, the patients were put in an upper-arm cast for three weeks. Patients with pre-operative volar angulation were immobilized with the forearm in pronation and those with pre-operative dorsal angulation were immobilized with the forearm in supination. After three weeks, all patients received a lower-arm cast for an additional three weeks.

Clinical data (including demographics, side of injury) were recorded from the patients' charts. Radiographs, taken at the time of initial injury, after reduction, and after six weeks post-reduction, were evaluated. The radiographs were analyzed to determine the amount of volar or dorsal angulation and radial or ulnar angulation. For further analysis, patients were divided into two groups, according to the volar or dorsal angulation of their fracture pre-operatively ('volar group' or 'dorsal group', respectively). Analysis was conducted to investigate if there were statistically significant differences in frequency of displacement between the two groups using Fisher's Exact Test and/or if a pattern in fracture type could be identified.

To evaluate surgeons' practice, all attending orthopaedic surgeons at the 2008 OTC meeting were invited to take part in a brief informal survey via a questionnaire. Lateral radiographs of an angulated greenstick fracture (Fig. 1) were shown and two questions were asked (Table I). For both questions, participants were only allowed to select one response. The aim of the survey was to gain a very general understanding of the differences in opinion with respect to this issue.

Fig. 1. — Lateral radiographs of an angulated greenstick fracture.

RESULTS

Twenty-one angulated oblique greenstick distal radius fractures in children (with a minimum angulation of 15° on lateral view) were evaluated retrospectively (Table II). Mean age of the children was 113 months (SD 33.17 ; range 65 to 168). Nine fractures were on the left side and twelve on the right. There were ten girls and eleven boys. Fifteen

Table I. — Survey

Question 1 : Would you and how would you reduce this fracture ?
1. no reduction
2. hyperflexion
3. hyperflexion with supination
4. hyperflexion with pronation
5. hyperflexion after hyperextension (Charnley-manoeuvre)
6. pronation
7. supination
Question 2 : Would you use a K-wire to stabilize the fracture ?
1. no K-wire
2. K-wire

patients also had a fracture of the ulna (71%). The mean absolute angulation in lateral view was 23.6° (SD 8.7 ; range 15° to 42°). General anaesthesia was used in 15 patients, local anaesthesia in 6. On radiographs taken immediately post-operatively, eighteen patients displayed a neutral position in lateral view and three had 5° of angulation. A second closed reduction was not necessary in any case.

Callus formation was observed on the radiographs taken six-weeks post-reduction in all patients. Fifteen patients had no change in angulation in lateral view from immediately post- to 6 weeks post-reduction. Five patients showed a loss of 10° of angulation and one showed a loss of 15°. There was no significant difference in age between those patients with and without a loss of reduction after six weeks ($p = 0.536$). Furthermore, there was no significant difference in pre-operative angulation between those patients with and without loss of reduction, with a mean of 22.4° (SD 8.4) and 26.7° (SD 9.6), respectively ($p = 0.32$). The patient with a

Table II. — Patient demographics, injury details and pre-op and postop radiological results

	Gender	left/ right	Age (months)	ulna fracture*	volar/ dorsal angulation on lateral view	angulation** lateral view pre-op	AP view	angulation AP view pre-op	angulation** lateral view postop 1 d	angulation AP view postop 1d	angulation** lateral view postop 6 weeks	angulation AP view postop 6 weeks
1	male	Left	116	+	volar	-18°	r	-6	0	0	0	0
2	male	Right	81	-	dorsal	19°	n	0	0	0	0	0
3	female	Right	75	+	dorsal	31°	u	20	0	0	15	10
4	female	Right	65	+	dorsal	18°	n	0	0	0	0	0
5	female	Left	144	+	dorsal	29°	u	23	0	0	0	0
6	male	Right	168	+	dorsal	42°	u	20	0	0	0	0
7	male	Right	72	-	dorsal	15°	n	0	0	0	0	0
8	female	Left	144	+	dorsal	38°	n	0	0	0	0	0
9	male	Left	144	+	dorsal	39°	n	0	0	0	10	0
10	male	Left	136	+	dorsal	16°	u	20	0	0	10	0
11	male	Right	144	+	volar	-26°	r	-5	0	0	10	0
12	female	Right	100	+	volar	-20°	n	0	0	0	0	0
13	male	Left	72	+	dorsal	33°	u	15	0	10	10	10
14	male	Right	139	-	dorsal	21°	n	0	0	0	0	0
15	male	Right	133	+	volar	-15°	n	0	0	0	0	0
16	male	Left	124	-	volar	-20°	r	-10	0	0	0	0
17	female	Right	65	+	dorsal	15°	n	0	0	0	10	0
18	female	Left	119	+	volar	-15°	r	-10	-5	-5	5	0
19	female	Right	109	-	dorsal	28°	u	15	5	0	5	5
20	female	Left	152	-	volar	-15°	n	0	-5	0	5	-5
21	female	Right	78	+	dorsal	23°	n	0	0	0	0	0

* ulna fracture : + = ulna fracture, - = no ulna fracture.

** angulation : < 0° = volar angulation, > 0° = dorsal angulation.

r = radial ; u = ulnar ; n = neutral.

loss of reduction of 15° had a pre-operative dorsal angulation of 31°. Follow-up of this patient showed a neutral position one year after trauma.

There were fourteen patients in the volar group (66%) and seven in the dorsal group (33%). In the volar group the mean pre-operative angulation was 26.2° (SD 9.4, range 15-42). Six of these fourteen showed radial angulation on AP-view. There were no patients with ulnar angulation of the radius in this group. In the dorsal group the mean angulation was 18.4° (SD 4.0, range 20 to 15). The radius fracture showed ulnar angulation in three out of seven patients (based on pre-operative AP view). No patients had radial angulated fractures in this group.

In the volar group, lateral and AP radiographs taken immediately after reduction showed a neutral position of the radius in 13 patients. However, on lateral view, there was one patient with 5° residual dorsal angulation of the radius fracture and on AP view, there was another patient with 10° ulnar displacement of the radius fracture. In the dorsal group, there was a neutral position on lateral view in five patients and 5° of residual dorsal angulation in two patients. On AP view, six patients showed a neutral position and one showed 5° radial displacement of the radius fracture. No angulation was seen on lateral view for this patient.

Six weeks after closed reduction, there was no displacement on lateral view in nine cases in the volar group. In the remaining five patients, four showed 10° of volar angulation and one had an angulation of 15°. In two of these cases there was also displacement to the ulnar side on AP view. In the dorsal group, there was no displacement seen on lateral view in six cases and one patient had 10° of dorsal angulation. There was no displacement on AP view in this group. There was no statistically significant difference between the volar group and dorsal group with respect to rate of displacement (p-value 0.3371).

To gain a general idea of surgeons' opinions in this area, the two questions survey was distributed to 70 orthopaedic surgeons, of whom 40 responded (57.1%). All respondents stated they would reduce the fracture by applying hyperflexion, but only 6 out of 40 (15%) would also perform a pronation maneuvre. No surgeons indicated they would perform only a rotation maneuvre. Twenty-three surgeons (57.5%) would break the intact cortex by hyperextension, thereby converting a greenstick fracture into a complete fracture and then reduce it with a flexion maneuvre. Five out of 40 (12.5%) surgeons indicated they would add a K-wire.

DISCUSSION

Most displaced and malaligned greenstick fractures of the radius should be reduced closed. The areas of controversy in the literature for these fractures are the degree of acceptable deformity, whether the intact cortex should be fractured, and the position and type of immobilization. As Evans emphasized in 1951, greenstick forearm fractures have a rotatory component to their malalignment (*4*). He described that the main force acting on the limb is a vertical compression, but that some lateral or rotatory element is to be expected in its momentum, to which the forearm will respond by pronation or supination. Pronation and flexion are closely allied, both mechanically and developmentally, and a fracture occurring while the forearm is pronating is likely to develop a forward deviation of the distal fragment, with backward angulation at the fracture site. Supination and extension are similarly related, and supination fractures will, if they angulate, angulate forwards. Evans describes that the apex volar fractures, representing a supination deformity, are more common whereas the apex dorsal fractures, malrotated in pronation, are less common (*4*). This is confirmed by our study were 66% of the patients showed an apex volar fracture and 33% and an apex dorsal fracture. The rotatory component was also confirmed by the fact that volar angulated fractures could have radial, but never ulnar angulation, and that dorsal angulated fractures could have ulnar but never radial angulation.

Correction of the malrotation is necessary to achieve anatomic alignment. Evans described that the reduction of a greenstick fracture with angular deformity by full pronation or supination, according to whether the angulation is forwards (supination type) or backwards (pronation type), is surprisingly easy (*4*). This theory has been simplified in studies

over the years. Davis and Green stated that 'As Evans showed, distal third greenstick fractures are easily reduced by maximum pronation of the forearm'. In their conclusion they wrote 'Greenstick fractures should be reduced by manipulating them into the correct proper plane of rotation ; *i.e.*, maximum pronation for distal third fractures' (*3*). Similarly, Rang emphasized that forearm fractures can have a rotatory component to their malalignment. But, in contrast to the proposed treatment in midshaft radius and ulna fracture, he does not take this into account when describing the treatment of distal forearm greenstick fractures. Instead, he advocates to use a flexion type mold in an apex volar fracture and an extension type mold in a fracture with apex dorsal angulation (*10*). Charnley described in his book 'The closed treatment of common fractures' that the angulated fracture has to be straightened and that manipulation often results in the fracture becoming complete. In contrast to this theory, he proposed to perform a rotation maneuvre in late dorsal angulated fractures after initital perfect reduction (*2*). Our study showed that the original reduction method described by Evans is very efficient and we propose to perform this maneuvre in the first attempt.

Another important topic in the treatment of greenstick fractures of the radius is the immobilisation technique. In the same article of 1951 Evans proposed to hold the position by immobilising the limb in an above-elbow plaster in full pronation or supination according to the type of fracture one is dealing with (*4*). In contrast to Evans however, most articles fail to describe the rotation component in the immobilisation technique. Zamzam *et al* described a retrospective study of 183 children with displaced fractures of the distal radius. One hundred and eight had an initial incomplete displacement. The reduction method was not described, but they indicated immobilising the fractures in an above-elbow cast in a position of stability which avoided extreme pronation or wrist flexion (*13*). Gupta *et al* described a study about immobilisation in pronated, neutral and supinated position for dorsally angulated solitary metaphyseal greenstick fractures in the distal radius in 60 patients. Twenty-nine patients needed a reduction. They did not describe the reduction method. When the wrist was immobilized in pronation, the degree of re-angulation was greater in the reduced than in the unreduced group of patients. If the wrist was immobilized in the neutral position or in supination, there was no difference in the degree of angular displacement between reduced and unreduced cases (*7*). Bohm *et al* compared above and below- elbow cast types with respect to the amount of residual angulation of the fracture while in the cast. The below - elbow casts were found to maintain the alignment of distal forearm fractures in children as well as above – elbow casts. This study only described the cast type, but not the method of reduction and position of the forearm in the above – elbow cast (supination or pronation) (*1*). Two more recent studies also seem to support the fact that below – elbow cast treatment was comparable to above – elbow immobilization (*8,11*). However, also in these articles the rotation maneuvre was not used (*11*) or not described (*8*).

We treated our patients with an above-elbow cast because theoretically an above - elbow cast prevents flexion and extension of the elbow as well as forearm rotation, which minimizes the risk of angulation or displacement.

Limitations of the current study are the retrospective design and the small sample size. There is no control group of children with angulated greenstick fractures who did not have a closed reduction. There is only a short-term radiographic follow-up and there is no clinical comparison with the radiographic results.

The results of our survey show that the reduction method described by Evans is not commonly used in the treatment of this type of fractures. Another important finding is the tendency among many surgeons (57.5%) to break the intact cortex and thereby convert a greenstick fracture into a complete fracture. To our knowledge this is the first study that evaluated the Evans reduction technique. In our study, radiographs immediately following reduction in pronation or supination showed a complete reduction in 18 of 21 patients. Three patients had a residual angulation of 5 degrees. This angulation is acceptable in children with more than two years of residual growth (*6*).

CONCLUSION

This study supports the theory of Evans that the most important maneuvre in angulated greenstick fractures is rotation. The most common dorsally angulated greenstick fracture can be reduced by pronating and those volarly displaced can be reduced by supinating. There is no need for complete breaking of the cortex or the use of K-wires in patients with angulated greenstick fractures. The survey demonstrated that this maneuvre is not commonly used by orthopaedic surgeons.

REFERENCES

1. **Bohm ER, V. Bubbar V, Yong Hing K, Dzus A.** Above and below-the-elbow plaster casts for distal forearm fractures in children. A randomized controlled trial. *J Bone Joint Surg Am* 2006 ; 88-A : 1-8.
2. **Charnley J.** *The Closed Treatment Of Common Fractures*. 4th ed. Cambridge University Press, Cambridge, 1999, pp 123-124.
3. **Davis DR, Green DP.** Forearm fractures in children : pitfalls and complications. *Clin Orthop Relat Res* 1976 ; 120 : 172-183.
4. **Evans EM.** Fractures of the radius and ulna. *J Bone Joint Surg* 1951 ; 33-B : 548-561.
5. **Friberg KS.** Remodelling after distal forearm fractures in children. I. The effect of residual angulation on the spatial orientation of the epiphyseal plates. *Acta Orthop Scand* 1979 ; 50 : 537-546.
6. **Fuller DJ, McCullough CJ.** Malunited fractures of the forearm in children. *J Bone Joint Surg* 1982 ; 64-B : 364-367.
7. **Gupta RP, Danielsson LG.** Dorsally angulated solitary metaphyseal greenstick fractures in the distal radius : results after immobilization in pronated, neutral, and supinated position. *J Pediatr Orthop* 1990 ; 10 : 90-92.
8. **Paneru S, Rijal R, Shrestha B *et al.*** Randomized controlled trial comparing above- and below-elbow plaster casts for distal forearm fractures in children. *J Children's Orthop* 2010 ; 4 : 233-237
9. **Randsborg PH, Sivertsen EA.** Distal radius fractures in children : substantial difference in stability between buckle and greenstick fractures. *Acta Orthop* 2009 ; 80 : 585-589.
10. **Rang M, Stearns P, Chambers H.** *Children's Fractures*. 3rd edn. JB Lippincott, Philadelphia, 2005, pp 138-143
11. **Webb GR, Galpin RD, Armstrong DG.** Comparison of short and long arm plaster casts for displaced fractures in the distal third of the forearm in children. *J Bone Joint Surg* 2006 ; 88-A : 9-17.
12. **Worlock P, Stower M.** Fracture patterns in Nottingham children. *J Pediatr Orthop* 1986 ; 6 : 656-660.
13. **Zamzam MM, Khoshhal KI.** Displaced fracture of the distal radius in children : factors responsible for redisplacement after closed reduction. *J Bone Joint Surg* 2005 ; 87-B : 841-843.