Overgrowth and correction of rotational deformity in 12 femoral shaft fractures in 3–6-year-old children treated with an external fixator

Ivo M Buchholz[1], Hugo W Bolhuis[2], Frederik H L Bröker[3], Jan Willem C Gratama[3], Ralph J B Sakkers[1] and Wim H Bouma[2]

Departments of [1]Orthopaedic Surgery, University Medical Center, Utrecht, The Netherlands, [2]Surgery Gelre Hospital, Apeldoorn, The Netherlands, [3]Radiology Gelre Hospital, Apeldoorn, The Netherlands. E-mail: buchholz@worldonline.nl
Submitted 01-01-30. Accepted 01-09-03

ABSTRACT – We treated 11 young children (3–6 years old) who had uncomplicated femoral shaft fractures primarily with an external fixator. 9 children were available for follow-up and were evaluated for the amount of overgrowth and rotational deformity. All underwent a clinical examination and an MRI after mean 21 (13–25) months. The mean overgrowth was 0.4 (-0.3—1.1) cm and the anteversion angle showed a mean increase of 12°, as compared to the contralateral femur.

In 5 children with an anteversion angle difference of 10° or more, a second MRI was done 4 years after the trauma. The mean anteversion angle difference of the femora in these 5 children had diminished from 15° on the first MRI to 7.4° on the second. 3 of the 5 children had a full correction of their rotational deformity. Growth did not correct the rotational deformity in the oldest child in this group.

■

There is more agreement about the correction of angular deformities (Karacharju et al. 1976, Murray et al. 1996) and overgrowth (Aitkin 1940, Edvardsen and Syversen 1976, Shapiro 1981, Hougaard 1989) after femoral shaft fractures in childhood in the literature than about correction of rotational deformities with conflicting reports (Parvinen et al. 1973, Verbeek et al. 1976, Verbeek 1979, Brouwer 1981, Hägglund et al. 1983, Davids 1994). Posttraumatic angular deformities usually correct themselves during further growth. The epiphyseal growth plates do most of the remodeling (75%) and only a small part of the correction (25%) takes place at the fracture site (Murray et al. 1996, Wallace and Hoffman 1992).

Overgrowth is frequently seen after a fracture. Hence, an overriding position of the fracture ends is usually accepted during treatment. To explain this overgrowth, Aitkin suggested that an increase in shortening of a fractured bone induces more callus formation, a longer period of periosteal hyperemia and epiphyseal stimulation. In a study of Corry and Nicol (1995), most overgrowth of the fractured femur was seen in the age group of 4–7 years. This finding has not been confirmed in other studies.

Rotational deformities are also common. A femoral rotational deformity of more than 10° is considered unphysiological (Brouwer 1981, Davids 1994). Although many animal studies have shown otherwise (Arkin and Katz 1956, Schneider 1963, Strong et al. 1992), it is widely believed by those in clinical practice that no corrective response of the epiphyseal growth plate will occur in posttraumatic rotational deformities (Parvinen et al. 1973, Verbeek et al. 1976, Benum et al. 1979). Most of these reports, however, concern all children (1–16 years), and discards the fact that remodeling is more likely to occur in children with a younger skeletal age (Gasco and de Pablos 1997). Correction of rotational deformity has occasionally been reported in younger subjects (Verbeek 1979).

We studied function, overgrowth, rotational deformities and treatment satisfaction in young children (3–6 years old) who were treated for a diaphyseal femoral shaft fracture with an external fixator (monotube, Howmedica) as first choice.

Table 1. Patient data

Patient	Sex	Side	Age at injury, months	AO class.	Length of follow-up, months I	II
1	F	L	42	A3	23	57
2	F	R	58	A3	24	57
3	M	L	35	A2	16	49
4	M	R	47	A1	23	57
5	F	L	43	A1	15	48
6	M	L	39	A1	13	
7	M	R	47	B1	23	
8	M	L	36	A1	25	
9	M	L+R	86	A1+A3	23	

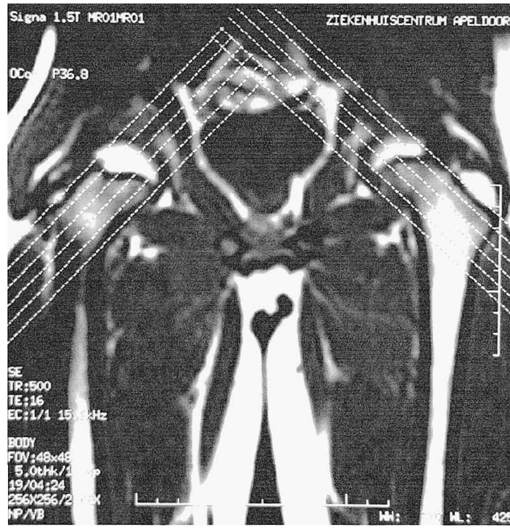

Figure 1. Coronal pelvic section showing the scan planes of the axial/sagittal sections (as seen in Figure 2).

Patients and methods

During 1992–1995, we treated 11 children (7 boys) for an uncomplicated femoral shaft fracture with the monotube (Howmedica) (Table 1). The mean age at the time of fracture was 49 (35–68) months. 1 child had a fracture of both legs. No other injuries were present. 4 children had been involved in a car accident, the other 7 had fallen. According to the AO classification (Müller et al. 1990), 6 children had an A1 fracture, 3 children an A3 fracture, and the remaining 3 children an A2, B1 and B2 fracture. All fractures were located in the middle 1/3 of the femur shaft. 8 children were operated on within 24 hours. 3 children had Bryant traction and were operated on after a few days.

The fracture was reduced under general anesthesia. Overriding of the fracture ends was not accepted and the fracture ends were aligned. A maximum angulation of 10° was accepted. Rotation was checked by assessing the forward position of both patellae.

After reducing the fracture, the external fixator was placed with 2 screws proximal and 2 screws distal from the fracture. The screws were placed at least 2 cm away from the epiphysis. After the operation, the patients were allowed to bear weight as much as possible. The average hospital stay was 8 (4–11) days.

The treatment with the external fixator was well accepted by all 11 patients and their parents. Pin-care caused no problems because of good instructions. 2 children were treated with antibiotics for superficial pin-tract infections.

The external fixator was removed after consolidation at 39 (30–51) days. The children were then further mobilized without any protection. None of them had a refracture.

2 patients were lost to follow-up because they moved out of the region. 9 children were available for follow-up examination 21 (3–25) months after the fracture. They answered a questionnaire and underwent a physical examination and an MRI. We determined leg length and anteversion angles of both femora. For the MRI examination, they were placed supine with "feet first", and the legs fixed. No sedation was needed, only earphones with music. After a scout view was taken with a coronal section (Figure 1) of the femoral head, oblique axial T1-weighted Spin Echo sections were made parallel through the femoral neck to visualize the true femoral neck axis. In addition, axial slices were taken through the centers of the femoral condyles, without changing the patient's position. The angle (α) was formed by the line through the femoral neck axis and the horizontal plane (Figure 2) and angle (β) between the posterior tangent of the femoral condyles and the horizontal reference (Figure 3). Femoral anteversion was calculated by subtracting the β-angle from the α-angle. The leg-length measurements were obtained from the coronal sections by drawing a line from the top of the femoral head to the most distal part of the medial femoral condyle.

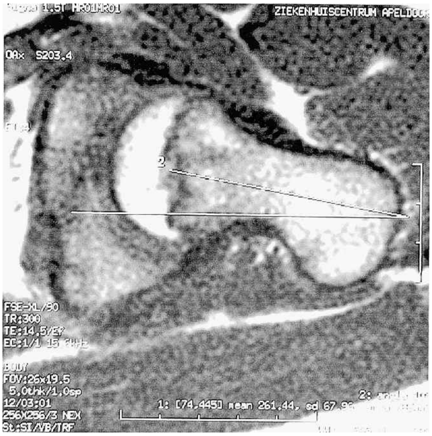

Figure 2. MRI measurement of the alpha angle of the left femoral neck (10°).

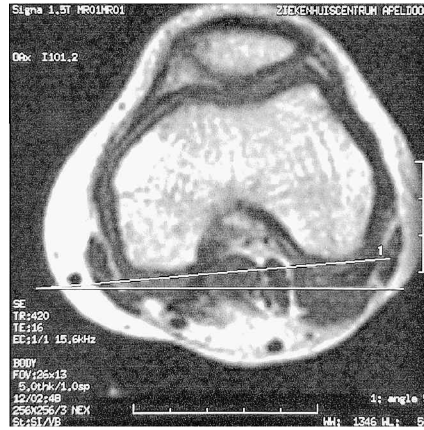

Figure 3. MRI measurement of the beta angle of the left femoral condyles (5°). The true anteversion angle is 15°.

When we found a rotation difference between the femora that exceeded 10°, and the anteversion angle of the fractured femur was outside the normal range (5 children), a second MRI was done 4–5 years after the trauma.

Results

At follow-up, all children had normal motion of the hip and knee joints. Leg-length differences were –0.3–1.1 cm in the 8 children with 1 femur fractured. Only 1 child had shortening of the injured leg. In 4 children, the overgrowth exceeded 0.5 cm. The mean overgrowth was 0.37 cm (SD 0.5). The boy who had both femora fractured had a leg-length difference of 1.2 cm (Table 2).

Table 2. MRI measurements

Patient	Leg length Δ I mm	AV-angle Δ I	Leg-length Δ II mm	AV-angle Δ II
1	11	19	0	3
2	9	17	5	19
3	0	20	5	12
4	3	10	5	0
5	–3	10	–5	3
6	0	–1		
7	5	10		
8	1	9		
9	12	13		

Δ = difference between injured and non-injured leg

The mean anteversion angle of the femoral neck was 20 (8–34)° in the uninjured leg. Anteversion on the fractured side ranged between 17° and 47°. In 1 case, the anteversion-angle decreased by 1° and in 7 children, it increased, as compared to the unfractured leg. The mean increase in anteversion was 11.8° (SD 6.8°). The boy with a fracture on both sides had an anteversion angle of 9° on one side and 22° on the other.

In the 5 children who underwent a second MRI, the mean difference in leg length was 0.2 (–0.5–0.5) cm. The mean leg-length difference in this subgroup was 0.4 cm at the time of the first MRI.

The mean difference between the anteversion angle of the treated femur and the contralateral femur at the time of the second MRI was 7.4 (0–19)° (Table 2), as compared to a mean difference of 15° on the first MRI. In 3 children, the difference in anteversion angle between both femurs had nearly disappeared. 1 child showed no correction. The mean difference between the first and second MRI anteversion angle measurements was 7.8 (-2–16)°, p = 0.06 two-tailed paired sample t-test.

Discussion

As regards the use of the external fixator we had the same good results as several others (Aronson and Tursky 1992, Canale and Tolo 1995, De Sanctis et al. 1996). Bony overgrowth after femoral shaft fractures is well documented, especially in unoperated children (Aitkin 1940, Edvardsen and Syversen 1976, Shapiro 1981, Hougaard 1989, Corry and Nicol 1995) and is reported to be ± 1 cm. Tolo (1983) thought that the overgrowth might even increase in a patient with an anatomical reduction fixed with an external fixator because of the added stimulus of pins both proximal and distal to the fracture site. However, in our patients, anatomical reduction and fixation with the monotube undoubtedly reduced overgrowth, the mean overgrowth of the fractured femur being 0.37 cm. This finding resembles those of Aronson and Tursky (1992) and De Sanctis et al. (1996) who also used the external fixator as primary choice of treatment for uncomplicated femoral shaft fractures. According to Aronson and Tursky (1992), overgrowth after "non-anatomical" reduction may be secondary to the loss of the tension-band effect of the periosteum. He thought that an anatomic reduction of this tension band would keep overgrowth to a minimum. Aitkin (1940) thought that an anatomical reduction should cause less callus formation than a fracture healed in an overriding position, and therefore a shortened period of stimulation of the epiphyseal growth plate and remodeling. Weight bearing is also thought to have an effect. According to the Hueter-Volkmann law and the experiments of Arkin and Katz (1956) and others (Schneider 1963, Karacharju et al. 1976, Ryoppy and Karacharju 1978, Murray et al. 1996), higher pressure parallel to the axis of epiphyseal growth inhibits the growth rate while lower pressure accelerates the growth. Early weight bearing in the children of this study may therefore have reduced the growth rate of the femur as compared to children who had Bryant traction and no weight bearing for at least 6 weeks.

The difference in the anteversion angle with a mean of 12° at first follow-up confirms that one of the difficulties with the use of external fixation is the control of rotation (Canale and Tolo 1995). The distal fragment was often internally rotated.

The second MRI in our study showed a full correction of the rotational deformity in 3 of 5 children. The possibility of correction of rotational deformity is controversial, especially as regards the differences in outcome in animal (Arkin and Katz 1956, Schneider 1963, Moreland 1980, Strong et al. 1992) and clinical studies (Parvinen et al. 1973, Verbeek et al. 1976, Benum et al. 1979). In animal experiments, very young animals were used, while most reports on the correction of rotational deformities in children are based on the age group 1–16 years. In their review article, Gasco and de Pablo (1997) mentioned that remodeling is usually more complete in younger children. Verbeek (1979) reported correction of rotational deformity in a subgroup of children who were less than 5 years old at the time of the injury, which is similar to our findings. This potential for correction might be incorporated in the natural development of the proximal femur that reduces the anteversion angle from 40° after birth to about 10° at the end of growth (Reynolds and Herzer 1959).

No funds have been received to support this study.

Aitkin A P. Overgrowth of the femoral shaft following fracture in children. Am J Surg 1940; 49: 147-8.

Arkin A M, Katz J F. The effects of pressure on epiphyseal growth. J Bone Joint Surg (Am) 1956; 38: 1059-76.

Aronson J, Tursky E A. External fixation of femur fractures. J Pediatr Orthop 1992; 12: 157-63.

Benum P, Ertresvag K, Hoiseth K. Torsional deformities after traction treatment of femoral fractures in children. Acta Orthop Scand 1979; 50: 87-91.

Brouwer K J. Torsional deformities after fractures of the femoral shaft in childhood. Acta Orthop Scand (Suppl 195) 1981.

Canale S T, Tolo V T. Fractures of the femur in children. J Bone Joint Surg (Am) 1995; 77: 294-315.

Corry I S, Nicol R O. Limb length after fracture of the femoral shaft in children. J Pediatr Orthop 1995; 15: 217-9.

Davids J R. Rotational deformity and remodeling after fracture of the femur in children. Clin Orthop 1994; 302: 27-35.

De Sanctis N, Gambardella A, Pempinello C, Mallano P, Della Corte S. The use of external fixators in femur fractures in children. J Pediatr Orthop 1996; 16: 613-20.

Edvardsen P, Syversen S M. Overgrowth of the femur after fracture of the shaft in childhood. J Bone Joint Surg (Br) 1976; 58: 339-42.

Gasco J, de Pablos J. Bone remodeling in malunited fractures in children. Is it reliable? J Pediatr Orthop 1997; 6: 126-32.

Guenther K P, Tomczak R, Kessler S, Pfeiffer T, Puhl W. Measurement of femoral anteversion by magnetic resonance imaging: evaluation of a new technique in children and adolescents. Eur J Radiol 1995; 21: 47-52.

Hougaard K. Femoral shaft fractures in children: a prospective study of the overgrowth phenomenon. Injury 1989; 20; 170-2.

Hägglund G, Hansson L I, Norman O. Correction by growth of rotational deformity after femoral fracture in children. Acta Orthop Scand 1983; 54: 858-61.

Karacharju E O, Ryoppy S A, Makinen R J. Remodeling by asymmetric epiphyseal growth. J Bone Joint Surg (Br) 1976; 58: 122-6.

Moreland M S. Morphological effects of torsion applied to growing bone. J Bone Joint Surg (Br) 1980; 62: 230-7.

Müller M E, Nazarin S, Koch P, Schatzker J. The comprehensive classification of fractures of long bones. Springer Verlag, Berlin 1990.

Murray D W, Wilson-MacDonald J, Morscher E, Rahn B A, Käslin M. Bone growth and remodelling after fracture. J Bone Joint Surg (Br) 1996; 78: 42-50.

Parvinen T, Viljanto J, Paananen M, Vilkki P. Torsional deformity after femoral fracture in children. Ann Chir Gynaecol Fenn 1973; 62: 25-9.

Reynolds T G, Herzer F E. Anteversion of the femoral neck. Clin Orthop 1959; 14: 80-8.

Ryoppy S, Karacharju E O. Alteration of epiphyseal growth by an experimentally produce angular deformity. Acta Orthop Scand 1978; 45: 490-8.

Schneider M. The effect of growth on femoral torsion. J Bone Joint Surg (Am) 1963; 45: 1439-49.

Shapiro F. Fractures of the femoral shaft in children. Acta Orthop Scan 1981; 52: 649-55.

Strong M, Wong-Chung J, Babikian G, Brody A. Rotational remodeling of malrotated femoral fractures: a model in the rabbit. J Pediatr Orthop 1992; 12: 173-6.

Tolo V T. External skeletal fixation in children’s fractures. J Pediatr Orthop 1983; 3: 435-42.

Verbeek H O F. Does rotation deformity following femur shaft fracture correct during growth? Reconstr Surg Traumat 1979; 17: 75-81.

Verbeek H O F, Bender J, Sawidis K. Rotational deformities after fractures of the femoral shaft in childhood. Injury 1976; 8: 43-8.

Wallace M E, Hoffman E B. Remodelling of angular deformity after femoral shaft fractures in children. J Bone Joint Surg (Br) 1992; 74: 765-9.