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ORIGINAL STUDY

Deformities in conservatively treated closed fractures of the shaft of the femur in children

Ravindra PUTTASWAMAIAH, Prakash CHANDRAN, Ramesh SEN, Sudha KATARIA, Shivender SINGH GILL

From the Post Graduate Institute of Medical Education and Research, Chandigarh, India

We present the outcome of non-operative management of fractures of the shaft of the femur in children. Thirty children with non-operatively managed unilateral fractures of the shaft of the femur were studied. The mean age was 6.5 years (range : 1.2 to 12). Axial, angular and rotational malunion were assessed clinically and radiologically by plain films and computed tomography (CT). All children had shortening of the fractured limb with a mean shortening of 1.8 cm (range : 0.5 to 3.5). A significant level of shortening was seen in children over 7 years. In the sagittal plane, all had anterior angulation ranging from 4° to 31° (mean : 17.8°) and in the coronal plane, lateral angulation (varus) was seen in 90% (27 patients) with a mean angle of 8.9°. Rotational malunion ranged from -43° to +43° (mean : 9.5°), 30% had rotational malunion of > 20° compared to the uninjured side ; 73% had internal rotation malunion and 27% had external rotation malunion.

We conclude that non-operative management of fractures of the shaft of the femur in children often results in malunion at the fracture, particularly in the older age group and in comminuted fractures. Perhaps a longer follow-up might have shown lower levels of malunion. Frequent monitoring of fracture position may reduce the occurrence of deformity. It may be appropriate to consider reduction and operative stabilisation of such fractures whenever necessary.

Keywords : femoral shaft fractures ; nonoperative management ; malunion ; children.

INTRODUCTION

Fracture of the shaft of the femur (*9, 25*) is one of the common long bone injuries in children. The management includes operative stabilisation by closed/open reduction or non-operative management by manipulation, traction and hip spica immobilisation. Operative treatment obtains early fracture stability with advantages of early mobilisation ; it also decreases the incidence of malunion (*7, 10, 15, 20*). The associated disadvantages include anaesthetic exposure, and need for second surgery to remove the implant ; the risk of infection is always present (*24*). The non-operative approach eliminates the above risks ; however control of fractured fragments

■ Ravindra Puttaswamaiah, MS, Clinical Fellow.
George Eliot Hospital, Nuneaton, Warwickshire, United Kingdom.
■ Prakash Chandran, MS, AFRCS, Specialist Registrar.
Scarborough General Hospital, Woodlands Drive, Scarborough, West Yorkshire, United Kingdom.
■ Ramesh Sen, MS, Associate Professor.
■ Shivender Singh Gill, MS, Additional Professor.
Department of Orthopaedics, PGIMER, Chandigarh, India.
■ Sudha Kataria, MD, Additional Professor.
Department of Radiology, PGIMER, Chandigarh, India.
Correspondence : Ravindra Puttaswamaiah, 15 Cresswell Close, Callands, Warrington WA5 9UA, United Kingdom. E-mail : pravindradr@yahoo.co.uk.

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is difficult and is often inadequate, this can lead to angular, axial and rotational malunion (*6, 17*). Malalignment if severe can alter limb length, alter the biomechanics and may lead to early osteoarthrosis of the adjacent joints (*12*). Growth and remodelling attempt to correct angular and axial deformities, while rotational deformities tend to persist. Younger children with greater growth potential may correct higher levels of malalignment ; however in older children the potential to correct with growth is limited. Increasingly surgeons are now opting for surgical intervention and stabilisation of fractures of the shaft of the femur (*8*) particularly in older children. We aimed to look at the outcome of fractures of the shaft of the femur when treated non-operatively in the paediatric age group.

PATIENTS AND METHODS

Children in the age group of 1-12 years, who sustained a unilateral fracture of the shaft of the femur and were managed non-operatively at the Postgraduate Institute of Medical Education and Research, Chandigarh, India, formed the study group. Patients with a bilateral fracture of the shaft of the femur, open fractures, pathological fractures, patients with congenital anomalies like developmental dysplasia of the hip, Perthes disease, neuromuscular disorder like cerebral palsy, myelomeningocoele, and patients with re-fracture were excluded from the study. Thirty patients fulfilled our criteria and were included in the study. Case notes were studied to record events of injury, time of presentation, treatment method, duration of immobilisation, time to clinical fracture union and any complications. Initial anteroposterior and lateral radiographs were studied to determine the fracture anatomy, level of fracture, grade of comminution, and displacement. All patients were treated by immediate closed reduction and hip spica immobilisation including the pelvis, the whole of the injured limb down to the toes and the uninjured limb down to the knee. An initial overriding of a maximum of 10 mm, medial and anterior angulations of less than 10° and lateral angulation up to 5° were considered acceptable. Posterior angulation and malrotation were not accepted. All patients had check radiographs at 1 week following spica application. The average duration for which the spica was applied was $8^{1}/_{2}$ weeks.

At a mean follow-up of 1.5 years (1 to 2.5 years) following clinical fracture union, all patients were assessed clinically and radiologically for malunion. Clinically comparative limb lengths were used to determine axial malunion. The limb length was measured from the anterior superior iliac spine to the medial malleous (*5, 11, 13, 30*). Comparative range of hip movements on either side was used to determine the rotational malunion. Radiological assessment was done by full length femur radiographs which included hip and knee, and computerised tomography. Radiographs were used to measure the angular malunion by measuring the angle between the axis of the main fractured fragments. Computed tomography (CT) scans were used to measure the rotational malalignment (*14*) which involved measuring the femoral torsion on the uninjured side and comparing it with the femoral torsion on the fractured side.

The child was placed supine on the CT table. An appropriate CT section was obtained at the level of the symphysis pubis, which included the neck and greater trochanter on both sides to look for the neck axis. Another CT section was obtained just above the upper pole of the patella. If required, additional sections were taken till the neck axis and the condylar axis were adequately seen (*6, 14*). The depiction was made with a wide window width of 400 and a level of +200 to +300 to eliminate soft tissues and to provide outline of the bone only. A line was drawn along the axis of femoral neck. Tangents were drawn to the anterior and posterior ends of the condyles. A median line between these two lines was defined as the transcondylar axis (*21*). Femoral torsion was measured as the angle between the axis of the femoral neck and the transcondylar axis (*14*). The angles measured on both sides were noted. In each case the difference in the angle on two sides was measured.

Each type of malunion was analysed with respect to age, sex, type of fracture (transverse, oblique or spiral), comminution according to Winquest's classification and the level of the fracture (proximal, middle and distal). The results were statistically analysed to look for significance of association with any of the factors.

All 30 children were available for analysis ; 14 were females. The mean age was 6.5 years (range : 1.5 to 12). Ten children were 1 to 4 years old, 7 were 5-7 years and 13 were in the age group of 8-12 years. Sixty three percent of the fractures occurred due to a road traffic accident and the remaining were due to a fall from a height. Seventeen percent (5 patients) of the fractures involved the upper third of the femur, 80% (24 patients) involved the middle third of the femur and 1 patient had a fracture of the lower third of the femur. The fracture line was transverse in 53%, oblique in 40% and spiral in the remaining cases. Sixty seven percent had no com-

Table I. — Angulation in relation to age, type of fracture and comminution

	Number of cases	Angulation in degrees			
		Sagittal plane		Coronal plane	
Age Group		Mean	SD	Mean	SD
0-4 years	11	17.64	± 7.32	7.18	± 5.21
5-7 years	7	18.86	± 6.91	10.57	±2.14
> 7 years	12	17.33	± 6.41	9.42	± 5.36
Type of Fracture					
Transverse	16	19.13	± 6.84	8.31	± 5.22
Oblique	12	16.75	± 6.49	9.92	± 4.91
Spiral	2	13.5	± 6.36	7	± 5.6
Grade of Comminution					
Group A (Grade 1&2)	24	17.92	± 6.26	8.46	± 4.75
Group B (Grade 3&4)	6	17.33	± 8.75	10.5	± 5.12

SD = Standard Deviation.

minution, 23% had Winquest grade 1 and 2 comminution and 10 % had Winquest grade 3 comminution.

RESULTS

All children had shortening of the fractured limb with a mean shortening of 1.8 cm (range : 0.5 to 3.5) ; 0.5 to 1 cm shortening was seen in 40% (12 children), 1 to 2 cm shortening was seen in 17% (5 children) and more than 2 cm shortening was seen in 43% (13 children). A statistically significant higher level of shortening was seen in children above 7 years ($p < 0.05$) and in those with Winquest grade 2 and 3 comminution ($p < 0.01$). A mean shortening of 2.83 cm with a standard deviation of 0.6 was seen among Winquest 2 and 3 comminution, while a mean shortening of 1.54 cm and standard deviation of 0.84 was seen in Winquest 0 and 1 comminution. The amount of shortening did not show significant correlation with the level of fracture.

In the sagittal plane all patients had anterior angulation ranging from 4° to 31° (mean 17.8°). Nine had angulation of > 20°. In the coronal plane lateral angulation (varus) was seen in 90% (27 patients) with a mean angle of 8.9° (range : 0° to 20°). One patient had medial angulation of 3°. No correlation could be established when comparing the degree of angulation with age, sex, level and type of fracture (table I).

In the uninjured femur the mean femoral torsion was 18.8° anteversion (range : from 3° retroversion to 46° anteversion). Except one, all had anteversion of the femur, the anteversion was 0-20° in 17 patients, 21-40° in 11 patients, and more than 40° in 1 patient. There was no significant difference between the normal male and female femoral anteversion angles, with a mean value of 19.4° for females and 18.8° for males. The mean anteversion of a normal femur was 14.6° in 0-4 year-old children, 26.6° in 5-7 year-old and 18.1° in 7-12 years.

On the fractured side the mean anteversion was 27.7°. The difference in torsion between the normal and the affected femur ranged from 43° anteversion to 43° retroversion, the mean difference was 8.9° anteversion, 73% (22 patients) had internal rotational malunion and 27% (8 patients) had external rotational malunion (table II). In the internal rotational malunion group 60% (18 patients) had malunion ranging from 0° to 20° and 13% (4 patients) had malunion of 21° to 43° of internal rotation. In the external rotational malunion group, 23% (7 patients) had malunion in 0° to 20° and 1 patient had 43° of external rotational malunion. There was no statistically significant correlation between groups in relation to age, sex, type of fracture or level of comminution (table III).

Fractures of the proximal third of the femur had a mean rotational malunion of 26.2°, middle third fractures had 27.5° and one patient had a fracture

Table II. — Magnitude of torsional difference between the injured and the uninjured side

Torsion difference	Increased in	Decreased in	Total
0°-10°	7	5	12
11°-20°	8	1	9
> 20°	7	2	9
Total	22	8	30

Table III. — Difference (in degrees) in torsional alignment between the injured and the uninjured side

	Number of patients	Difference in torsion	
		Mean	SD
Type of Fracture			
Transverse	16	10.75	± 18.44
Oblique	12	7	± 20.52
Spiral	2	5.5	±16.26
Grade of Comminution			
0 and 1	24	10.5	± 17.24
2and 3	6	2.5	± 24.37
Level of Fracture			
Proximal 1/3	5	0.8	± 14.39
Middle 1/3	24	9.17	± 18.41
Distal 1/3	1	43	

SD = Standard Deviation.

of the distal third of the femur which malunited in 43° external rotation ; no statistically significant correlation could be established between the groups.

Torsional difference was found to be highest with transverse fractures (mean 10.75°) followed by oblique fractures (mean : 7°) and spiral fractures (mean : 5.5°). Less comminuted fractures had higher torsional difference (mean : 10.5°) than the more comminuted fractures (mean : 2.5°), but the difference was not statistically significant.

Clinical assessment showed that patients with internal rotational malunion had increased internal rotation at the hip joint and a corresponding decreased external rotation and those with external rotation malunion had increased external rotation with corresponding decreased internal rotation at the hip joint. Observation of the gait showed all children were walking comfortably with no limp ; one child tended to externally rotate the foot when asked to walk on a straight line.

DISCUSSION

During growth and remodelling, partial or complete correction in the deformity can occur, but while angular and axial malunion tends to correct, rotational deformity persists. The extent to which the correction can occur depends on the growth potential of the child, and hence in very young children higher levels of malunion are likely to get corrected (*28*).

Clinkscales *et al* (*7*) concluded that limb length discrepancy is a major complication of non-operative treatment of fractures of the shaft of the femur in children. Jamaludin (*17*) recorded an average shortening of 15 mm at the time of fracture union following early spica immobilisation for fracture of the shaft of the femur in children. We had similar observations with limb length discrepancy of more than 2 cm, seen in 43% of our patients. A significant proportion of our patients also had angular malunion, which is in contrary to the findings by Infante *et al* (*16*) who observed no significant angular deformity with early hip spica application in children.

The mean torsion of the uninjured femur in our study was 18.8° anteversion, comparable to the observations by Moulton *et al* (*23*) who measured torsion directly from dried femora and found femoral torsion to vary from 0°-36° with a mean 15.38° anteversion. Berman *et al* (*4*) in normal volunteers using CT scan found the anteversion angle to vary between 11° to 32° and Lausten *et al* (*18*) showed variation from -30° to +36°.

The difference in torsion between the normal and the fractured femur is reported to be -25° to +27° by Benum *et al* (*4*), -20° to +17° by Hagglund *et al* (*12*), and up to 26° by Brouwer *et al* (*5*). Abnormal anteversion was defined as a difference in angle of > 10°. Hagglund *et al* (*12*) reported a mean of 9.6° in 25.45% of children, but the anteversion difference reduced to a mean of 5.6° at subsequent follow-up. In our study the variation in torsion difference was found to range from -43° to +43° (mean 9.5°). More than 10° difference in rotation was seen in 66.7% and more than 20° was seen in 30%. We observed higher rates of rotational malunion probably due to improved accuracy in

Table IV. — Details of patient characteristics

Case	Age (years)	Sex	Level of Fracture	Type of Fracture	Comminution	Torsion in normal Femur (Degrees)	Torsion in fractured Femur (Degrees)	Difference in rotation (Degrees)	Axial difference (Cm)
1.	3.5	M	Lower 2/3	T	1	3	38	35	1.0
2.	7	M	Lower 2/3	T	1	13	46	33	2.5
3.	5	M	Lower 2/3	T	1	36	-7	-43	1.5
4.	11	M	Lower 2/3	O	1	16	37	21	3.0
5.	4	M	Lower 2/3	S	1	9	26	17	1.0
6.	5	M	Upper 1/3	T	1	45	46	1	1.0
7.	9	F	Lower 2/3	O	2	-3	40	43	3.5
8.	12	M	Upper 1/3	O	2	12	-7	-19	2.5
9.	9	M	Lower 2/3	O	2	37	14	-23	3.0
10.	1.5	F	Lower 2/3	T	1	15	26	11	1.0
11.	3	M	Lower 2/3	T	1	8	17	9	0.5
12.	3	F	Lower 2/3	T	1	15	18	3	0.5
13.	11	F	Lower 2/3	T	1	27	50	23	2.5
14.	9	M	Lower 2/3	T	1	20	39	19	0.5
15.	6	F	Lower 2/3	O	1	28	21	-7	2.5
16.	2	F	Lower 2/3	O	1	8	43	35	1.0
17.	9	F	Lower 2/3	O	1	26	18	-8	1.5
18.	3.5	F	Lower 2/3	T	1	24	32	8	1.0
19.	8	F	Lower 2/3	O	2	15	29	14	2.0
20.	5	F	Lower 2/3	T	1	29	24	-5	2.0
21.	11	F	Lower 2/3	T	1	24	28	4	2.5
22.	8	M	Lower 2/3	O	2	18	24	6	2.5
23.	4	M	Upper 1/3	O	1	10	24	14	0.5
24.	9	M	Lower 2/3	S	2	24	18	-6	3.5
25.	10	F	Lower 2/3	T	1	14	30	16	2.5
26.	6.5	M	Upper 1/3	O	1	25	40	15	2.5
27.	5.5	M	Lower 2/3	T	1	0	30	30	2.0
28.	3.5	M	Upper 1/3	O	1	35	28	-7	0.5
29.	3	F	Lower 2/3	T	1	19	29	10	1.0
30.	8	F	Lower 2/3	T	1	12	30	18	2.5

Index to master sheet :
Type of fracture : T = Transverse ; O = Oblique ; S = Spiral
Comminution : 1 = No or minimal comminution (Type 0 & 1 Winquest Hensen classifications) ; 2 = Significant comminution (Type 2 & 3 Winquest Hensen classifications).

measurement of femoral torsion using CT scan. The difference in the treatment modality, and the time of assessment of the deformity may also have an influence on the outcome. Hagglund *et al* (*12*) used bilateral Bryant traction in patients younger than five years and upper tibial pin traction in those older than five years, they followed up for 10 years. Benum *et al* (*3*) used unilateral vertical adhesion traction for patients younger than three years and tibial or femoral K wire traction on an oblique frame for those above three years and followed up for 5-13 years. Our follow-up was between 1 to 2.5 years ; perhaps a longer follow-up may show lower levels of malunion.

Significant reduction in external rotation and increase in internal rotation at the hip was seen in cases with internal rotation malunion by Benum *et al* (3), which is similar to our observation. An abnormal increase in medial rotation of 10° to 15° was seen by Sagi *et al* (*29*) in about 10% of their patients though they do not mention the anteversion difference.

Bulut *et al* (*6*) assessed 28 children with femoral shaft fractures, treated with early spica cast and evaluated with computed tomography (CT) : 93% had rotational deformities, 14% had rotational deformity of more than 10° and were corrected with a gypsotomy at the level of the fracture. They concluded that a rotational deformity, which is an important complication in conservative treatment of the femoral shaft fractures in children, can be determined exactly with CT and corrections on the spica cast can be made with gypsotomy. Although CT scan accurately measures rotational alignment, regular follow-up of fractures of the shaft of the femur in children with CT scan may not be practically available to all. Al Habdan (*1*) observed that a rotational malalignment of up to 20° gets corrected during growth. Moses *et al* (*22*) concluded that significant shortening is associated with more than 2 cm overlap of the fracture ends at the time of cast fitting. They have recorded an average compensatory overgrowth of 7 mm of the injured femur. They also found that angular deformity was not a significant problem. Ballah *et al* (*2*) concluded that shortening of up to 2 cm and angulation of 20° can get corrected by spontaneous remodelling and their study group had 63% shortening at the time of fracture union.

The above observations may allow us to accept less than accurate reduction and alignment during early management of shaft fracture of the femur in children. Further follow-up of patients in our study group can show the extent to which the correction in linear, angular and rotational malalignment can occur with remodelling.

Studies demonstrate that operative stabilisation of fractures of the shaft of the femur in children decreases the incidence of malunion and subsequent deformity (*7, 10*). In a multicentric study using titanium elastic nails, Flynn *et al* (*8*) found no child lost rotational alignment in the post operative period. Other similar studies show better control of rotation with use of titanium elastic nail (*15, 19*) and perhaps subsequently less rotational and angular deformity.

We conclude that non-operative management of fractures of the shaft of the femur in children often results in malunion at the fracture. Frequent monitoring of fracture position may reduce the occurrence of deformity. Perhaps a longer follow-up may show lower levels of malunion. It may be appropriate to consider reduction and operative stabilisation of such fractures, particularly in the presence of comminution and in the older age group.

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