Table 1. Legend: Details of 24 children with CT measurement M: Male, F: Female, U: Upper Mi: Middle, Lo: Lower,

HI: Head Injury, #: Fracture, Rt: Right, Lt: Left, Bil: Bilateral, Rad: Radius, Ipsi: Ipsilateral

No.	Age in Year / Sex	Side	Site	Type	Cause	Associated Injury	Fixation	Review Month	CT measured T&F	Total
1	5 M	Lt	U 1/3	Oblique	Fall	H.I.	Plate	33	F+0.5 T+0.2	+0.7
2	8 M	Rt	Mi 1/3	Comminuted	Fall	H.I.	Plate	12	F+0.1 T+0.2	+0.3
3	7.5 F	Lt	Mi 1/3	Transverse	RTA		Nail	18	F+0.9 T+0.1	+1.0
4	10 F	Rt	U 1/3	Transverse	RTA		Nail	18	F+0.9 T-0.2	+0.7
5	7 F	Rt	Mi 1/3	Comminuted	RTA		Plate	50	F+1.0 T+0.3	+1.3
6	15 M	Lt	Lo 1/3	Comminuted	RTA	H.I. Bil. Tibiae # Pelvis# Rad./Ulna #	Plate	36	F+0.1 T+0.5	+0.6
7	14 M	Rt	Mi 1/3	Transverse	RTA	Pelvis # Humerus #	Plate	49	F+0.9 T 0.0	+0.9
8	13 M	Rt	U 1/3	Spiral	RTA	Radius # Ipsi. Tibia #	Plate	19	F+0.8 T+0.2	+1.0
9	10 F	Lt	Mi 1/3	Oblique	RTA		Plate	52	F+1.0 T-0.1	+0.9
10	11 M	Rt	Mi 1/3	Comminuted	RTA		Plate	16	F+0.1 T-0.2	-0.1
11	10 M	Lt	Mi 1/3	Oblique	RTA	H.I. Clavicle #	Plate	12	F+0.6 T+0.4	+1.0
12	9 M	Lt	Mi 1/3	Transverse	RTA		Plate	24	F+1.2 T+0.6	+1.8
13	9 M	Lt	Mi 1/3	Transverse	RTA		Nail	60	F+0.5 T+0.1	+0.6
14	12 M	Lt	U 1/3	Spiral	Fall		Plate	20	F+0.7 T+0.2	+0.9
15	5 F	Lt	U 1/3	Oblique	RTA	H.I.	Plate	12	F+1.0 T+0.1	+1.1
16	8 M	Rt	Mi 1/3	Oblique	RTA		Plate	48	F-0.1 T-0.4	-0.5
17	11 M	Lt	Mi 1/3	Oblique	Fall		Plate	14	F+0.8 T+0.1	+0.9
18	14 M	Rt	Lo 1/3	Transverse	Fall	H.I. Radius # Ulna #	Plate	30	F+0.6 T+0.2	+0.8
19	12 M	Lt	Mi 1/3	Transverse	Fall		Plate	12	F-0.2 T-0.1	-0.3
20	5 M	Rt	Mi 1/3	Transverse	RTA		Nail	21	F+1.3 T 0.0	+1.3
21	5 M	Lt	U 1/3	Oblique	Fall		Plate	15	F+0.7 T-0.1	+0.6
22	14	Lt	U 1/3	Oblique	RTA	H.I.	Nail	20	F+0.2	0.0

	M								T-0.2	
23	6 F	Rt	Mi 1/3	Oblique	Fall	H.I.	Plate	13	F+0.4 T-0.2	+0.2
24	5 M	Lt	U 1/3	Comminuted	RTA	H.I.	Plate	15	F+1.0 T 0.0	+1.0

LEG LENGTH DISCREPANCY AFTER INTERNAL FIXATION OF FEMORAL SHAFT FRACTURES IN CHILDREN

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Objective:

To evaluate objectively the leg length discrepancy following internal fixation of femoral shaft fracture in children and its clinical significance.

Study Design:

Twenty four children who underwent open reduction and internal fixation of their femoral diaphysis fracture during an eight year period (1988-1996) were reviewed. Computer tomographic scanogram was used to measure the skeletal length of both femur and tiba on both sides. At least one year after fixation, the measurements were taken to evaluate leg length discrepancies and their clinical significance.

Results:

In 22 (91.7%) children the mean over growth of the operated femur was 0.7cm (Range 0.1-1.3cm). The mean increase in tibial length was 0.25cm on the same side in 13 (54.2%) children. In two children (8.3%) shortening of the operated femur was noted. These two children also had tibial shortening on the same side.

Conclusion:

There were minimal skeletal overgrowths of the limb after open reduction and internal fixation of the femoral shaft fracture in children. The increase in length could be counter balanced by pre-existing shortening. Clinical decision of internal fixation of femoral shaft fracture in children should not be unduely influenced by the anticipated complication of leg length discrepancy.

INTRODUCTION:

Leg length discrepancy of an internally fixed fracture shaft of femur is a major concern for an orthopaedic surgeon. Although conservative treatment is an universally accepted form of treatment for the diaphysial fracture of femur in children, increasing number of children are undergoing operative fixation specially when there is associated head injury and polytrauma[1,2,3]. Beside these, other conditions e.g. neuromuscular disease, pathological lesions and socio-economic factors also influence decision for internal fixation. This has necessitated the need for assessing objectively the true nature of this complication and its clinical significance.

This paper presents the results of a study of leg length measurement of 24 children who underwent internal fixation for their femoral shaft fractures. Attempts have also been made to identify the possible causes which could contribute to the leg length discrepancy.

PATIENTS AND METHODS:

Twenty four children who underwent open reduction and internal fixation for their femoral diaphysial fracture during eight years period between 1988 to 1996 were studied. There were 18 boys and six girls (M:F=3:1) and their age range was from 5 years to 15 years with mean age of 9.4 years. Only closed diaphysial femoral fractures were included in the study. For descriptive purposes femoral shaft was divided to three equal segments of upper, middle and lower thirds. Seven (29.2%) children had fractures in the upper one third, 14 (58.3%) in the mid diaphysis and in remaining 3 (12.5%) it was the lower one third of femoral shaft. Distribution of fracture types was as follows: 9 short oblique, 2 spiral, 8 transverse and 5 comminuted.

The major cause of these fractures was road traffic accident 16 (66.7%), in the remaining 8 children the fracture was due to a fall. The left side was involved in 14 children compared to 10 on the right side. Two children (8.3%) had tibial fractures, one ipsilateral and the other bilateral. Ten children (41.7%) had significant head injury. Five (20.8%) children had upper limb fractures and polytrauma. The indications for internal fixation were head injury, loss of acceptable alignment and multiple fractures. Nineteen (79.2%) had open reduction and internal fixation by dynamic compression plate (DCP) and screws and in 5 (20.8%) the fractures were stabilized by intramedullary nails. None of these children had post fixation infection, non or mal-union nor had any complication during removal of metal works.

The minimum period of follow up was one year and maximum 5 years (12 months to 60 months) with mean follow up of 25.8 months. **All 24 children were regularly evaluated for fracture healing, range of movements of hips and knees, gait and posture. Parents were interviewed to obtain information regarding any abnormality they noticed. Metals were removed within one year of fixation. At least one year after internal fixation measurements of the lower limb skeleton were done by CT scanogram. Both femora were measured from the tip of the femoral head to the lowest point of**

the medial femoral condyle. Tibiae lengths were measured from the highest point of the medial tibial condyle to the mid point of the distal tibial plafond. The addition of these two bony length measurements was used to compare the overall leg length discrepancy (Fig 1). Both lower limbs were in the same position in extension and neutral rotation during measurements.

RESULTS:

In 22 children (91.7%) the internally fixed femur was longer than the contralateral side. The increase in length was from 0.1 cm to 1.3 cm (mean 0.7 cm). In 2 cases (8.3%) the femur was found to be shortened by 0.1 and 0.2 cm. It was interesting to note that in both these cases the ipsilateral tibiae were also found to be shorter by 0.4 and 0.1 cm respectively, contributing to the overall shortening of the whole leg length. This raises the possibility of pre-existing shortening of these lower limbs. In 13 children (54.2%), both affected femora and ipsilateral tibiae were lengthened. The lengthening of the tibia on the affected side ranged from 0.1cm to 0.6 cm (mean 0.25 cm). In four cases (16.7%) there were no differences between tibial length. However, in 7 cases (29.2%) the ipsilateral tibia was found to be shorter (0.1 to 0.4 cm; mean 0.18 cm). In two of these seven shortened tibiae, there were also shortening of the femur as mentioned earlier. In the remaining five cases, the lengthening of femur ranged from 0.1 to 1 cm. In fact in case no. 10 (Table 1), the measured tibial shortening on the fractured site was more than the femoral lengthening giving rise to overall leg length shortening.

In 12 (50%) children the whole leg lengthening was found to be around 1 cm (0.9 cm or more), of these, 10 sustained femoral fracture due to high velocity road traffic accident. These fractures were located at the upper two thirds of the femur. All ten children with head injury also had femoral lengthening. All five femoral fractures fixed by intramedullary nails healed with lengthening of the femur (0.2 to 1.3 cm mean 0.76). Total lower limb lengthening of these cases was (0 to 1.3 cm, mean 0.72cm).

The age, sex, side, site, type, cause and method of fixation of fracture along with the (CT) measurement of femur and tibia of these children are shown in Table 1.

DISCUSSION:

Growth of a long bone is influenced by trauma such as fracture[4] and various experimental studies have demonstrated the role of periosteum. Initially, overgrowth was thought to be due to hyperaemia near the cartilage growth plate due to opening up of the perforating metaphysial vessles when the nutrient vessles were disrupted at the fracture site. However, Brookes (1957)[5] in experimental studies noted only minimal overgrowth of the bone after ligation of the nutrient artery and obliteration of the medullary canal. On the other hand Crilly (1972)[6] produced significant overgrowth of a long bone after transverse osteotomy and transverse division of periosteum or damage of adjacent muscles (with or without nutrient artery

destruction). Longitudinal incision of periosteum had no such effect on bone growth. This was reconfirmed in animal studies by Ali and Dickson (1993)[7].

In femoral shaft fractures in children, particularly after high velocity injuries, there is considerable disruption of the periosteum. Adjacent muscles and nutrient vessels are also affected. Overgrowth of bone is well expected after such trauma. Internal fixation of these fractures by plate and screws or nail adds to these injuries. In most cases plating is similar to the longitutinal split or disruption of the periosteum. Internal fixation, therefore, is expected to contribute to the lengthening of long bone; but the question is how much this adds to the overgrowth expected by primary trauma and what is its clinical significance?

Kregor et al[2] reported average overgrowth by 0.9cm in 26 months follow-up in 12 cases of femoral shaft fracture fixed by plate. On the other hand, Ziv et al[8] used either retrograde Rush nail or Kuntschner Nail, and Heinrich et al[9] fixed pediatric diaphysial femur fractures with flexible intramedullary (Ender) nail without reporting any significant leg length discrepancy. As for the measurement of skeletal length, Several authors[10,11,12,13,14] concluded that computer tomography is more accurate than orthoroentgenography for the measurement of leg length differences. **Tachdjian[15] concluded that CT scanogram measurement of leg length discrepancy is the method of choice due four reasons: it is accurate, it visualizes the entire lower limbs and pelvis, it is easy to store and the measurement of the bone is made on the console and you do not have to measure radiograph by which observer error is also reduced. In addition radiation involved is also significantly lower than the standard method of orthoroentgenography[11,12,13].**

In this series, CT scanogram was used to measure skeletal length of both lower limbs to identify leg length discrepancy. The average increase in length of the affected femur was 0.7cm which was similar to other published series. In addition to the femoral lengthening, we also observed smaller increase in ipsilateral tibial length (mean 0.25cm) in thirteen children. However, in seven cases, the ipsilateral tibiae were found to be shorter (mean 0.18cm) than the contralateral side. In two of these cases, there were also femoral shortening on the same side and in another two, the tibial shortening had either negative (Case 10 Table 1) or no effect (Case 22) on the total leg length**. Minor differences (0.5-1.5cm) of limb length between right and left side are very common[16]. Discrepancy of few millimeters to 2cm are observed in about 2/3 of US army recruits. Shortening of the right lower limb is more frequent than the left[17].** Therefore, the observed discrepancy could be due to pre-existing leg length differences. Without the knowledge of pre-trauma measurement this is impossible to confirm.

Increase in leg length by around 1cm (0.9 cm or more) was found mostly in fractures sustained by high velocity road traffic accidents associated with significant head injury where fractures were fixed by plates and screws or nails. None of the children in this series had any complication of infection, non-union or mal-union. No children nor their parents complained about gait or posture problem except in 2, there were few degrees limitation of terminal flexion of their knees at one year follow up.

Conclusion:

This is a relatively small series to draw major conclusion but we observed that end to end approximation of fracture femur by internal fixation not only produces femoral lengthening but also smaller amount of tibial lengthening too.

High velocity trauma associated with head injury and internal fixation of the femur can contribute to further increase in length. In few cases, increase in the length of the whole leg may be counter-balanced by pre-existing shortening of the femur and tibia.

Finally, overall leg length increase following internal fixation of femoral shaft fracture is usually smaller than conventionally believed and in most of the cases should not negatively influence the need for internal fixation.

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Figure 1. Computer Tomography Scanogram for Measurement of the Length of Femur and Tibia.