



The effect of proximal tibial fractures on the limb axis in children

Sawas NENOPOULOS, Aristides VRETTAKOS, Nikolaos CHAFTIKIS, Theodoros BESLIKAS, Dimitrios DADOUKIS

From the Aristotle's University of Thessaloniki, Thessaloniki, Greece

Between 1985 and 2002 we treated 38 children with 39 fractures of the proximal tibia. Fractures affecting the proximal tibial physis were excluded from this study. Mean age at the time of injury was 7.1 years (range : 2.5 to 14). Conservative treatment was followed in 34 cases and four patients underwent surgery. We examined 31 children with 32 fractures followed up for an average of 4.8 years (range : 16 months to 15 years).

Twenty eight (90.3%) patients developed post-traumatic tibia valga. Deformities were observed at an average 5.3 months after injury. All the cases with fractures of the medial cortex developed valgus angulation. The mean valgus angular deformity was 5.5°. There was also an average of 5.31 mm limb lengthening in 27 patients. Eleven patients with an angulation >5° were reevaluated at an average of 7.4 years from the initial injury. Partial remodelling was observed in 6 patients (54.5%) and total remodelling in 3 (25%).

We recommend that children with proximal metaphyseal tibial fractures should be initially treated conservatively and followed up during skeletal development, because valgus deformity tends to remodel with age.

Keywords : fractures of the proximal tibia ; children ; limb axis.

INTRODUCTION

Proximal tibial fractures in children are relatively rare : 5-6/1 00000 per year including proximal tibial epiphysis fractures (22). They deserve special

attention for a number of reasons. Rang (17) considers them among the worst fractures of childhood because they carry the potential of vascular complications and suggest that one must be aware that, in rare cases, these “innocent little cracks” may cause Volkmann’s ischaemia. Infrequently, they are misdiagnosed and it is subsequently not always easy to differentiate a hypertrophic callus from a malignant tumour or osteomyelitis, which may lead to unnecessary diagnostic biopsy. In addition, fractures near the growth plate level may be confused with collateral ligament injuries. Such fractures often result in leg length discrepancy and axial deformity of the limb. Although several reasons have been advocated to explain the residual valgus deformity of the tibia, clinical and experimental studies show that this is still controversial.

■ Sawas Nenopoulos, MD, PhD, Associate Professor of Orthopaedics.

■ Aristides Vrettakos, MD, Consultant Orthopaedic Surgeon.

■ Nikolaos Chaftikis, MD, Orthopaedic Surgeon.

■ Theodoros Beslikas, MD, PhD, Assistant Professor of Orthopaedics.

■ Dimitrios Dadoukis, MD, Orthopaedic Resident.

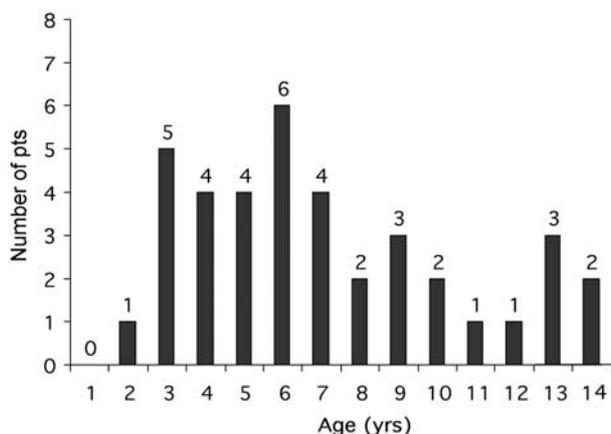
Paediatric Orthopaedics Unit, 2nd Orthopaedic Department, Aristotle's University of Thessaloniki, Thessaloniki, Greece.

Correspondence : Sawas Nenopoulos, K. Mitrousi 1, Thessaloniki, 54646, Thessaloniki, Greece.

E-mail : savanen@med.auth.gr.

© 2007, Acta Orthopædica Belgica.

Table I. — Graph showing the numbers and ages of patients.
Mean age at the time of injury was 7.1 years



The purpose of our research was to study the potential disturbance of tibial and fibular growth, the aetiology of valgus deformity and its relationship to the fracture pattern (complete, incomplete, medial cortex fractures, stress fractures). We also tried to determine after which time interval following initial injury the axial deformity occurs and to evaluate the potential for spontaneous improvement (remodelling) during skeletal development. Finally, we examined the effects of this type of injury on the tibial and fibular growth plate.

PATIENTS AND METHODS

Over a period of 18 years (from 1985 to 2002) we treated 38 children with 39 fractures of the proximal tibia (one child had bilateral fracture). There were 21 boys and 17 girls, aged from 2.5-14 years (average : 7.1 yrs, table I). The right leg was injured in 17 cases and the left in 22. Seventeen children had sustained a road traffic accident, thirteen were injured during participation in sports and six had a fall. In two cases a blow with a heavy object on the leg caused the injury. In 14 cases there was also a fibular fracture.

As far as the fracture type is concerned (table II), there were 14 undisplaced fractures of the proximal tibia, 13 metaphyseal fractures with a medial gap (involving only the medial cortex), 9 cases of complete displaced fractures, and 3 cases of stress fractures (fig 1a-d). The fracture was open in two cases. The first patient was a 5-year-old boy with a type I (Gustilo and

Anderson) displaced fracture who had been injured in a road traffic accident. The second was a 3-year-old boy with a type III C comminuted fracture with extended soft tissue damage and disruption of the popliteal artery. The boys' leg was crushed by the wheel of a car.

Thirty five fractures were treated conservatively. The initial treatment consisted of closed reduction after sedation or general anaesthesia if the displacement was severe, and immobilisation in a long leg cast for 4-8 weeks (depending on the child's age), followed by gradual weight bearing and rehabilitation.

Four fractures were treated surgically :

The patient who sustained the open type IIIC comminuted fracture with severe soft tissue damage and disruption of the popliteal artery underwent immediate amputation.

A 14-year-old patient with complete fracture of both the proximal tibia and fibula underwent open reduction and internal fixation with 3 screws. Intraoperatively we had to remove parts of the periosteum from the fracture site to achieve optimal reduction (fig 2a-c).

A patient with a stress fracture underwent a diagnostic biopsy.

The patient with a type I open fracture was treated with irrigation, surgical debridement and primary closure of the wound. After satisfactory reduction, a long leg cast was applied. Antibiotic prophylaxis was administered and the patient had no signs of infection during follow-up.

Thirty one patients (32 fractures) were available for follow-up (11 undisplaced fractures of the proximal tibia, 13 metaphyseal fractures involving only the medial cortex, 6 cases of complete displaced fractures and 2 cases of stress fractures). The patient who underwent amputation and six other patients were lost to follow-up. Patients were re-examined at 1, 2 and 6 weeks and 3, 6, 12 and 24 months.

Children were examined clinically and radiologically with plain radiographs of the femur and tibia (anteroposterior and lateral). Radiographic measurement involved the femoral - tibial angle of the affected side in comparison with the normal limb, and measurement of the limb length. Angulation was calculated on the AP radiograph by determining the angle between a line perpendicular to the upper epiphyseal plate and the axis of the tibial shaft below the fracture site, according to Visser and Veldhuizen (26) (fig 7). We used the Student-t test for statistical analysis of our data. Differences were regarded as being statistically significant with a p value < 0.05.

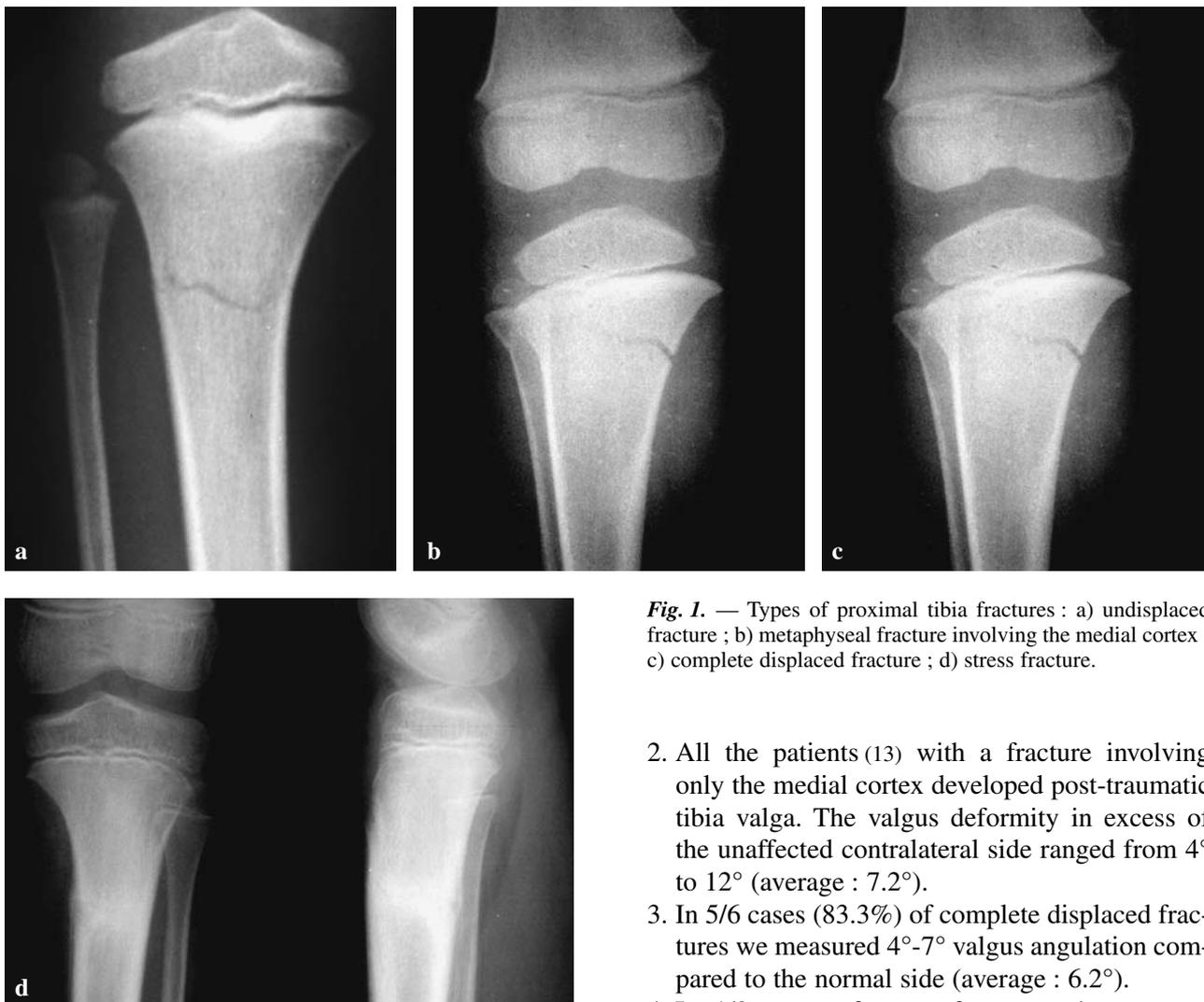


Fig. 1. — Types of proximal tibia fractures : a) undisplaced fracture ; b) metaphyseal fracture involving the medial cortex ; c) complete displaced fracture ; d) stress fracture.

RESULTS

Clinical examination revealed normal range of motion in hip, knee and ankle joint in all children. In 3/32 cases there was limitation of knee extension compared with the normal side and in one child tibia recurvatum was observed (fig 3a, b). We had no vascular complications and no instance of delayed fracture union.

The limb axis measurements in the various fracture types were as follows :

1. In 9/11 cases (81.8%) of undisplaced fractures there was an increase in valgus angulation ranging from 1° to 9° (average : 3.3°).

2. All the patients (13) with a fracture involving only the medial cortex developed post-traumatic tibia valga. The valgus deformity in excess of the unaffected contralateral side ranged from 4° to 12° (average : 7.2°).
3. In 5/6 cases (83.3%) of complete displaced fractures we measured 4°-7° valgus angulation compared to the normal side (average : 6.2°).
4. In 1/2 cases of stress fractures, there was a 2° valgus deformity. This patient had a further stress fracture of the proximal tibia during follow-up. The other patient had no angular deformity.

Valgus deformity was observed in 28/31 patients (90.3%). The mean valgus deformity measured 5.5°.

The average time interval between the injury and the onset of valgus angulation was 5.3 months. The maximum valgus angulation was observed at an average of 16.5 months after injury. In the case of a 5-year-old boy with medial cortex fracture, valgus deformity was observed in the third month after injury, after plaster cast removal (fig 4a, b). Six months after injury no remarkable difference was



Fig. 2. — a) A 14-year-old boy with a displaced proximal tibia fracture treated initially with a long leg cast ; reduction was lost after subsidence of initial swelling ; b) he underwent open reduction and internal fixation with 3 screws ; c) comparative radiographs (frontal view) three years after injury, showing complete restoration without any limb axis deformity.

noted (fig 4c). Fourteen years later almost complete remodelling was noted (fig 4d).

A four-year-old girl, who sustained a fracture of the medial cortex of the proximal tibia after a fall from a height (3.5 m), was initially treated conservatively with a long leg cast. After three months, the radiographs showed valgus deformity which continued to increase during follow-up. At its maximum it measured 9° . A varus osteotomy of the upper tibia was performed thirteen months later. Unfortunately, there was recurrence of the valgus deformity.

We also noted that in 27/32 (84.3%) cases there was over lengthening of the tibia compared with the fibula, ranging from 1 to 18 mm (average : 5.3 mm).

In two cases of stress fracture there was shortening of the tibia. One of these patients sustained a new stress fracture of the proximal tibia a few months after the first fracture had healed.

Sixteen patients (51.6%) had persisting valgus angulation $> 5^\circ$ after an average follow-up of 2.3 years. We wished to reevaluate these patients with moderate deformity, so we decided to call them back for an additional clinical and radiological assessment. Eleven patients responded positively and were re-examined after an average time period of 7.4 years (4.5 to 15) from the initial injury. Partial remodelling of 2° - 3° was observed in 6 (54.5%) and total remodelling in 3 (25%) (fig 5a, c).



Fig. 3. — a) Complete displaced proximal tibia fracture in a girl aged 12 years, in frontal and lateral views, b) genu recurvatum of the right leg was observed in comparative lateral views, 3 years later after conservative treatment.

DISCUSSION

Proximal tibial fractures in children often lead to leg length discrepancy and axial deformity of the limb. In paediatric trauma literature several theories have been put forward with respect to the causes of axial deformity following fractures of the proximal tibia in children. Cosen (4) and Blount (2) believed that axial deformity is due to asymmetrical stimulation of the upper tibial growth plate. Experimental studies concerning proximal tibia fractures in rabbits showed obvious clinical and radiological asymmetry of the tibial growth plates but light microscopy failed to reveal histological asymmetry of the physis (1).

Lehner and Dubas (14) believed that the growing callus distracts the fracture gap and leads to tibial angulation. Taylor (24) believed that tibial valgus deformity is related with a delay in development of the tibia in comparison to the fibula and suggests combined tibial and fibular osteotomy. Pollen (16) in 1973 mentioned that early weight bearing causes deformity before the formation of a rigid callus. This concept was supported by Salter

and Best (21) who described an increase in valgus angulation by an average of 4° on weight bearing radiographs.

The theory of soft tissue interposition preventing accurate reduction was supported by many authors. Jackson and Cozen (8) proposed that cartilaginous callus in the fracture gap causes wedging of the proximal tibia. Weber (27) found that part of the pes anserinus and periosteal flaps were interposed between the fracture surfaces and disturbed the healing process, causing a valgus deformity, and tethering of the iliotibial band contributed to this. Coates (3) reported two cases of medial collateral ligament interposition at the fracture site.

Jordan *et al* (9) suggested that increased vascular response to the fracture resulting in asymmetric stimulation of the proximal tibial growth plate is the basic reason for the valgus deformity. Houghton and Rooker (7) in 1978 and Dimitriou *et al* (5) in 1987 made experimental efforts to simulate an incomplete proximal tibial fracture by incision of the periosteum at the level of the pes anserinus and the result was a valgus deformity. Ogden (15) believes that the normal pattern of a more extensive

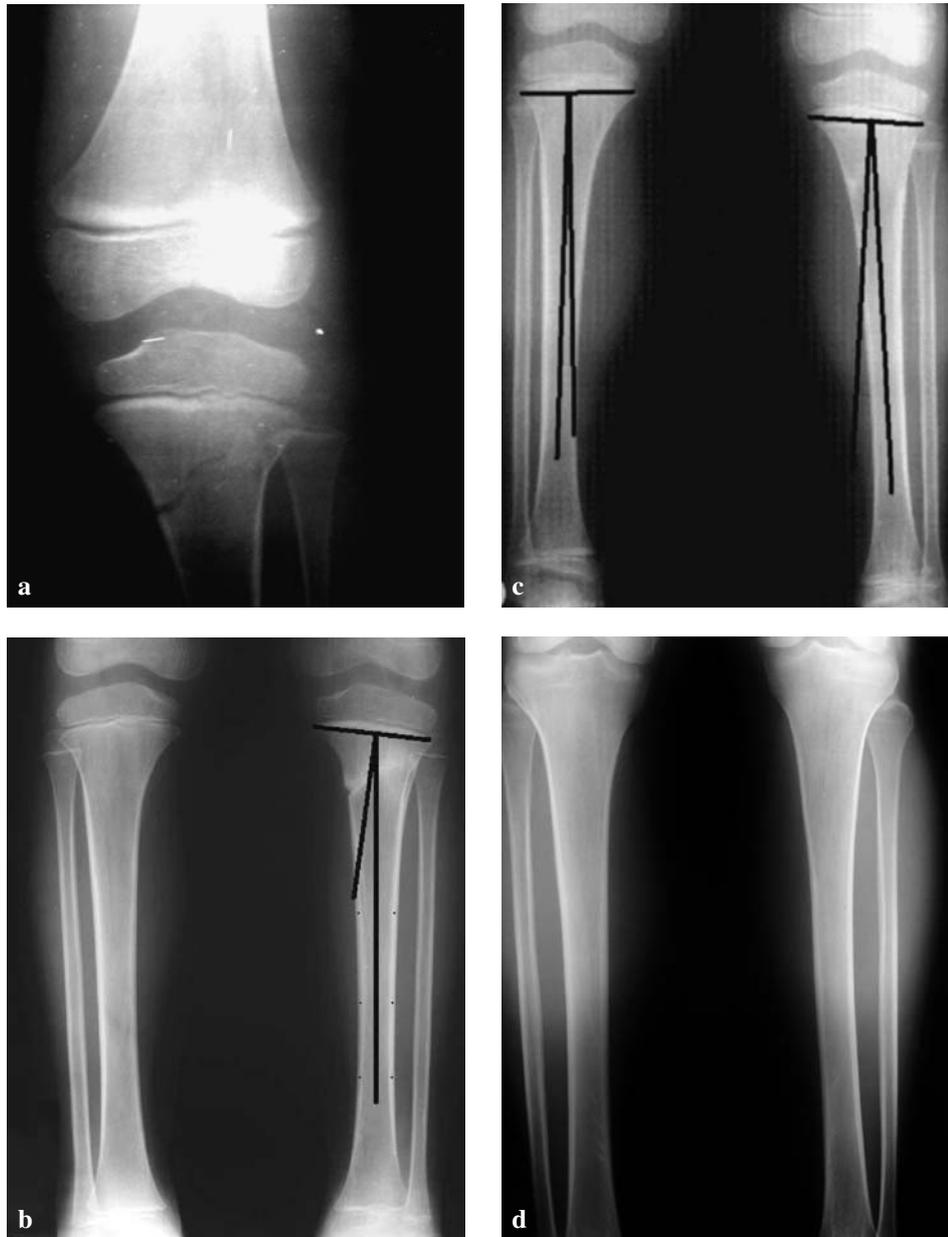


Fig. 4. — a) Fracture of the medial cortex of the upper tibial metaphysis in a 5-year-old boy treated with a long leg cast ; b) comparative radiographs in frontal view 3 months later, showing union of the fracture and valgus angulation 6° of the left tibia ; c) six months after injury valgus angulation of 8° of the left tibia compared to normal side ; d) fourteen years later almost complete remodelling was noted.

medial (compared to lateral) geniculate blood supply was a significant factor in eccentric growth of the tibia thus causing valgus deformity, and supported this concept with quantitative scintigraphic studies. Morton and Starr (12) reported that a Salter-

Harris type V injury of the lateral tibial physis contributes to post-traumatic tibia valga. Salenius and Vankka (20) demonstrated that the immature skeleton is more susceptible to develop this complication during the period in which the child's

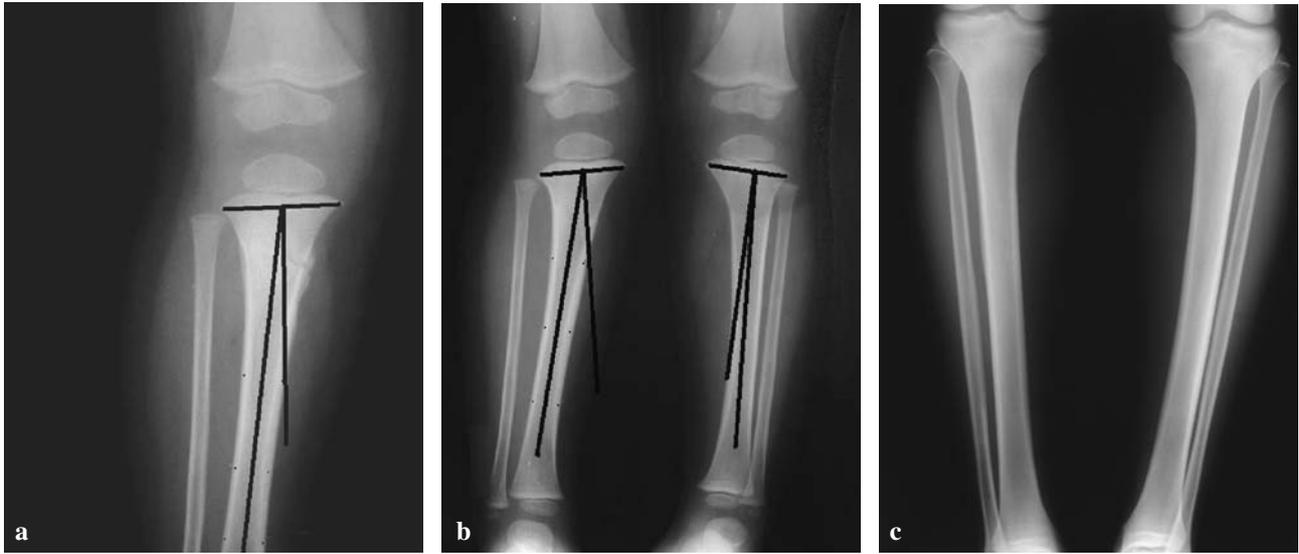


Fig. 5. — a) AP radiograph of a 3-year-old boy with fracture of the medial cortex of the upper tibial metaphysis of the right leg one month after injury ; b) comparative radiographs six months after injury, showing progressive valgus deformity, c) re-examination after fifteen years showed full remodelling.



Fig. 6. — a) Complete fracture of the proximal tibia with minimal displacement of the right leg in an 8-year-old girl ; b) after four years an “S” shaped tibia has developed.

knee is gradually shifting from a physiologic genu varum to genu valgum.

Our data analysis provided several findings of interest. Almost all patients with a fracture of the

proximal tibia developed a valgus angulation and overlengthening of the tibia compared to the fibula. According to the fracture type, we noted that undisplaced fractures developed valgus deformity to a

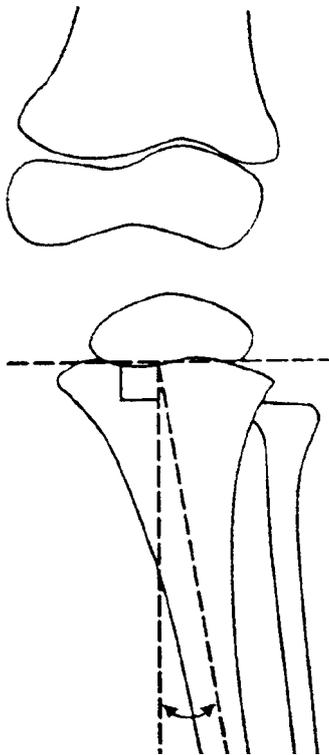


Fig. 7. — Visser and Veldhuizen method of valgus angulation measurement : The angle between a line drawn along the long axis of tibia and a line perpendicular to the proximal tibial physis is measured.

smaller degree compared to those affecting only the medial cortex fractures ($p < 0,001$) and displaced fractures ($p < 0.01$). We found no important statistical difference between medial cortex fractures and displaced fractures as far as the degree of angulation is concerned ($p > 0.2$). Nevertheless, the deformity occurred earlier in the medial cortex fractures. Another significant finding was the reorientation of the growth plate level in both tibia and fibula. This was considered as an effort of the growing skeleton to remodel the deformity. This is achieved in many cases but occasionally leads to an 'S' shaped tibia (fig 6a, b) (11, 18). We also noticed that in a few cases the onset of the valgus deformity was observed early, shortly after cast removal (6-8 weeks).

Muller *et al* (13) noticed that partial remodelling is seen only in children younger than 5 years of age and suggested aggressive initial treatment with

ORIF in older children. Nevertheless, we concluded that aggressive treatment of proximal tibial fractures in children should be basically avoided because valgus deformity partially remodels with age (6). Our findings agree with those of Steel *et al* (23) who reported that varus osteotomy has a high incidence of valgus angulation recurrence and there is always the risk of vascular complications. It is suggested that the child should be followed-up and if there is a persisting deformity it should be corrected with temporary medial tibial hemiepiphyseodesis during puberty (25).

REFERENCES

1. Aronson DD, Stewart MC, Crissman JD. Experimental tibial fractures in rabbits simulating proximal diaphyseal fractures in children. *Clin Orthop* 1991 ; 255 : 61-67.
2. Blount WP. *Fractures in Children*. Williams and Wilkins Co ; Baltimore PA 1954.
3. Coates R. Knock knee deformity following upper tibial greenstick fractures. *J Bone Joint Surg* 1977 ; 59-B : 516.
4. Cozen L. Fracture of the proximal portion of the tibia in children followed by valgus deformity. *Surg Gyn Obst* 1953 ; 97 : 183-188.
5. Dimitriou CG, Kapetanios GA, Symeonides PP. The effect of partial periosteal division on growth of long bones. *Clin Orthop* 1988 ; 236 : 256-269.
6. Heinrich SD. Fractures of the shaft of tibia and fibula. In : Rockwood and Wilkins (eds). *Fractures in Children*. Lippincott Williams and Wilkins ; Philadelphia PA 2001 : pp. 1078-1083.
7. Houghton GR, Rooker GD. The role of the periosteum in the growth of long bones. *J Bone Joint Surg* 1979 ; 61-B : 218-220.
8. Jackson DW, Cozen L. Genu valgus as a complication of proximal tibial metaphyseal fractures in children. *J Bone Joint Surg* 1971 ; 53-A : 1571-1578.
9. Jordan SE, Alonso GE, Cook FF. The aetiology of valgus angulation after metaphyseal fractures in children. *J Fed Orthop* 1987 ; 7 : 450-457.
10. McCarthy JJ, Kim DH, Eilert RE. Posttraumatic Genu Valgum. Operative versus non operative treatment. *J Fed Orthop* 1998 ; 18 : 518-521.
11. Ewen GD, Zions LE. Proximal tibial fractures in children. In : *Behavior of the Growth Plate*. Raven Press, New York ; 1988 : pp. 141-152.
12. Morton KS, Starr DE. Closure of the anterior portion of the upper tibial epiphysis as a complication of tibial shaft fractures. *J Bone Joint Surg* 1964 ; 46-A : 570-574.
13. Muller I, Muschol M, Mann M. Results of proximal tibial metaphyseal fractures in children. *Act Orth Trauma Surg* 2002 ; 122 : 331-333.

14. **Lehner A, Dubas J.** Sekundäre Deformierungen nach Epiphysenlosungen und epiphysenliniennachen Frakturen. *Helv Chir Acta* 1954 ; 21 : 388-410.
15. **Ogden JA.** *Skeletal Injury in the Child*. New York PA : Springer-Verlang ; 1999.
16. **Pollen AG.** *Fractures and Dislocations in Children*. Churchill Livingstone, Edinburgh, 1973.
17. **Rang M.** *Childrens' Fractures*. PA : Lippincott JB, Philadelphia ; 1983.
18. **Roberts M, Chouri N, Carlouz H et al.** Fractures of the proximal tibial metaphysis in children. Review of a series of 25 cases. *J Fed Orthop* 1987 ; 7 : 444-449.
19. **Rooker GD, Salter RB.** Prevention of valgus deformity following fracture of the proximal metaphysis of the tibia in children. *J Bone Joint Surg* 1980 ; 62-B : 527.
20. **Salenius P, Vankka E.** The development of the tibio-femoral angle in children. *J Bone Joint Surg* 1975 ; 57-A : 259-261.
21. **Salter RB, Best T.** The pathogenesis and prevention of valgus deformity following fractures of the proximal metaphyseal region of the tibia in children. *J Bone Joint Surg* 1973 ; 55-A : 1324 .
22. **Skak SV.** Valgus deformity following proximal tibial metaphyseal fractures in children. *Acta Orthop Scand* 1982 ; 53 : 141-147.
23. **Steel HH, Sandrow RE, Sullivan PD.** Complications of tibial osteotomy in children for genu varum or valgum. Evidence that neurological changes are due to ischemia. *J Bone Joint Surg* 1971 ; 53-A : 1629-1635.
24. **Taylor SL.** Tibial overgrowth. A cause of genu valgum. *J Bone Joint Surg* 1963 ; 45-A : 659.
25. **Tuten HR, Keeler KA, Gabos PG et al.** Posttraumatic tibia valga in children. A long term follow-up note. *J Bone Joint Surg* 1999 ; 81-A : 799-810.
26. **Visser J, Veldhuizen A.** Valgus deformity after fracture of the proximal tibial metaphysis in childhood. *Acta Orthop Scand* 1982 ; 53 : 663-667.
27. **Weber BG.** Fibrous interposition causing valgus deformity after fractures of the upper tibial metaphysis in children. *J Bone Joint Surg* 1977 ; 59-A : 290-292.