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Mobility of the lateral malleolus

A roentgen stereophotogrammetric analysis

In nine children and adolescents, the motion of the distal fibula in relation to the tibia was measured by roentgen stereophotogrammetry. Between the extremes of ankle flexion, the fibular epiphysis moved on average 1.4 mm.

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We have measured fibular displacements during movements of the ankle from plantar to dorsiflexion using roentgen stereophotogrammetric analysis (RSA) described by Selvik (1974).

Patients

Nine children (4 boys and 5 girls) participated in the investigation. All had 4 (3–5.5) years previously suffered an ankle injury, and the post-traumatic growth pattern had been evaluated by RSA after bilateral implantation of tantalum balls in the distal tibia and fibula (Kärrholm et al. 1982a). At the time of the present examination the girls were 9–15 years and the boys 13–17 years; five of them now had open and four had closed growth plates in the distal tibia and fibula (Table 1). All but Case 4 were examined on the previously fractured side.

The RSA examinations were performed in a Plexiglas calibration cage, with the ankle in an adjustable splint. Examinations were performed with the patient in the supine position and the ankle in full plantar flexion, in the neutral position, and in full dorsiflexion. Two x-ray tubes were used for simultaneous exposures. The walls of the calibration cage were supplied with tantalum markers. The markers inserted into the two walls facing the two roentgen tubes were used to calculate the positions of the two roentgen foci, and the markers in the two walls facing the film cassettes defined the laboratory coordinate system to which all measurements were referred.

The roentgen films were evaluated in a photogrammetric instrument (Wild Autograph A8). By computer processing, the positions of the tantalum markers and both roentgen foci were calculated and transformed into the laboratory coordinate system. Six to eight tantalum balls in the distal tibia were used as the reference segment to obtain maximal accuracy. Since one tantalum ball was inserted into each distal fibular metaphysis and epiphysis, respectively, it was possible to calculate the translations of both the metaphyseal and the epiphyseal fibular bone markers.

The total translation of the fibular tantalum markers between the examinations, calculated in each patient, was separated into three components:

(a) Along the transverse axis which was perpendicular to the longitudinal axis of the bone, running through the medial malleolus and the centre of the fibula.
(b) Along the longitudinal axis, which was parallel to the longitudinal axis of the bone.
(c) Along the sagittal axis which was perpendicular to both the transverse and the longitudinal axis.

The error of the translations was about 30–50 μm for each examination (Selvik 1974, Kärrholm et al. 1984).

Results

All ankles showed a significant translation of the distal fibula when the ankle was moved from full plantar flexion to full dorsiflexion. The transverse and the sagittal translations of the epiphysis were in most cases larger than those of the metaphysis, whereas the magnitude of the longitudinal translations was almost the same.

Table 1. Cases examined by roentgen stereophotogrammetry.

A	B	C	D	E	F	G	H	I	J	K
1	F 9	SA II	III	I	–	C	C	3,2	o	45–110
2	F 12	SE IIIb	II	–	c	C	Ɔ	4,8	c	40–110
3	F 13	SA II	III	I	o	C	→	3,1	o	35–105
4	M13	[4]	–	–	–	–	–	4,8	o	50–110
5	M14	SA II	IV	I	–	Ɔ	→	5,6	o	45–110
6	M14	SE I/IIb$_3$	–	IV (z)	–	→	C	5,7	o	45–105
7	F 15	SE IIIb	II	–	–	C	C	4,7	c	40–100
8	F 16	SE IIIb	II	–	–	C	Ɔ	4,4	c	30–115
9	M17	SE IVb	II	–	c	C	C	3,3	c	50–105

A Case number. B Sex and age (yr) at present examination. C Type of injury, traumatologic classification[1], D anatomical classification[2], distal tibia and E distal fibula. F treatment, c closed, o open. Growth pattern[3], G distal tibia and H distal fibula. I time since injury (yr, mo). J Growth plates open (o) or closed (c) at examination. K Plantar dorsi-flexion (degrees).

[1] Kärrholm et al. 1982a; 1982b
[2] Salter and Harris 1963
[3] C initial and temporary growth stimulation
Ɔ initial and temporary growth retardation
→ symmetrical growth
[4] measurements performed on the intact side

Total translation (Figure 1)

The total translation was the sum of the transverse, the longitudinal, and the sagittal displacements in the same ankle. Case 4 (intact ankle) showed a 1.2 mm displacement of the epiphysis when the ankle was moved to a neutral position from full plantar flexion. Further dorsiflexion of the anke resulted in a 0.7 mm increase of this displacement. The corresponding metaphyseal displacement was 0.8 and 0.1 mm, respectively. The other eight ankles showed a similar displacement of both metaphysis and epiphysis; further dorsiflexion of the ankle joint resulted in increased displacement of the epiphysis in all patients and of the metaphysis in six patients.

Translation along the transverse axis (Figure 2)

When the ankle was moved from plantar flexion to the neutral position, the epiphyseal lateral displacement in Case 4 was 1.2 mm and the metaphyseal 0.8 mm. Further dorsiflexion resulted primarily in increased lateral displacement of the epiphysis. Results in the other patients were similar.

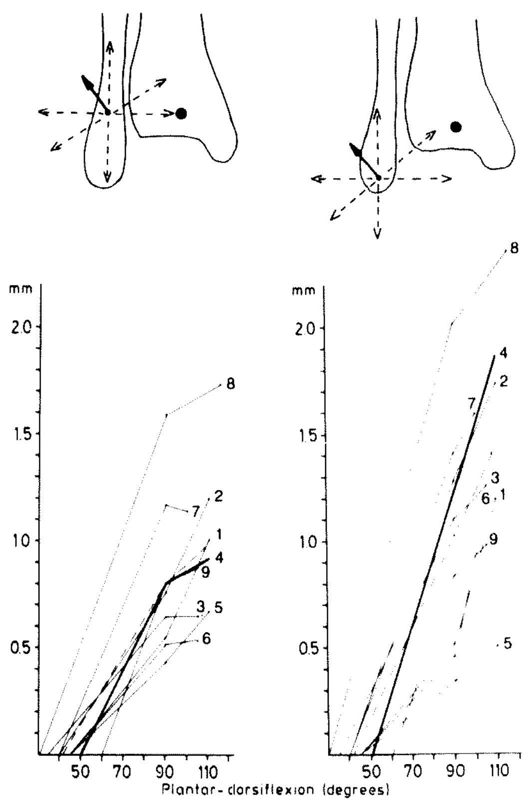

Figure 1. The total translation of the distal fibular metaphysis A, and epiphysis B. The reference segment consisting of all markers in the distal tibia is indicated by a large dot. The tantalum markers in the distal fibular metaphysis and epiphysis are indicated by a small dot. The dashed line indicates average values. The thick line is Case 4 with no previous injury to the ankle.

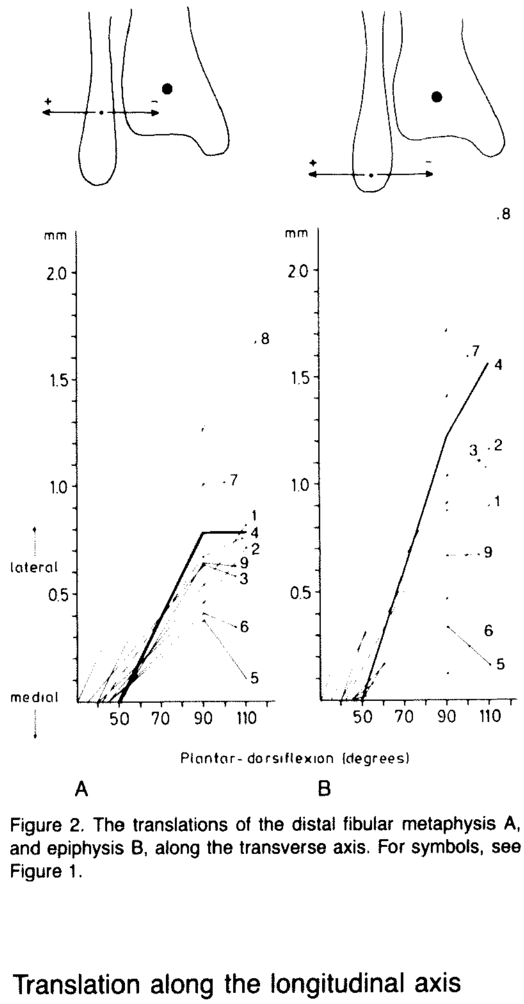

Figure 2. The translations of the distal fibular metaphysis A, and epiphysis B, along the transverse axis. For symbols, see Figure 1.

Translation along the longitudinal axis (Figure 3)

A slight distal displacement (0.5 mm) of both the metaphysis and the epiphysis was observed in Cases 4, 5 and 6 when the ankle joint was moved from full plantar flexion to full dorsiflexion, whereas Case 9 showed a proximal displacement of about 0.4 mm when the ankle was moved from plantar flexion to the neutral position. Further dorsiflexion resulted in a distal displacement of about the same amount. In the other patients the displacements were small (0.1 mm).

Translation along the sagittal axis (Figure 4)

A minimal anterior displacement (0.1 mm) of both the epiphysis and the metaphysis was observed in Case 4. During dorsiflexion from the neutral position, especially the epiphysis was displaced posteriorly (0.7 mm).

The other ankles showed either an anterior or a posterior displacement of the distal fibula when the ankle was moved from plantar flexion to the neutral position. Dorsiflexion from the neutral position resulted in a posterior displacement of both the metaphysis and the epiphysis in all cases but Case 5.

Discussion

The importance of the distal fibula and the tibiofibular ligaments for normal joint motion has been stressed in the literature (Weber 1972, Ramsey & Hamilton 1976), and special attention has been paid to the result of injury of these structures (Klossner 1962, Cedell 1967, Leeds & Ehrlich 1984). Previous investigations (Close & Inman 1952, Grath 1960) of tibiofibular displacement during ankle motion found individual variability of the fibular displacement when the ankle was moved from plantar flexion to dorsiflexion, and Grath (1960) also found a difference between the left and right ankles in one individual. The normal

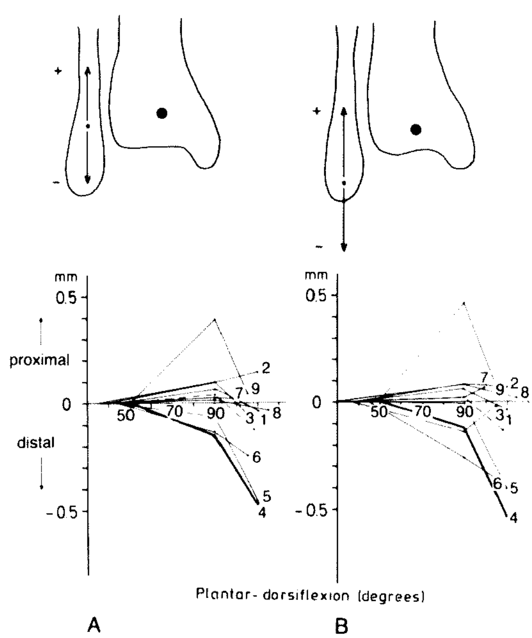

Figure 3. Translations of the distal fibular metaphysis A, and epiphysis B, along longitudinal axis. For symbols, see Figure 1.

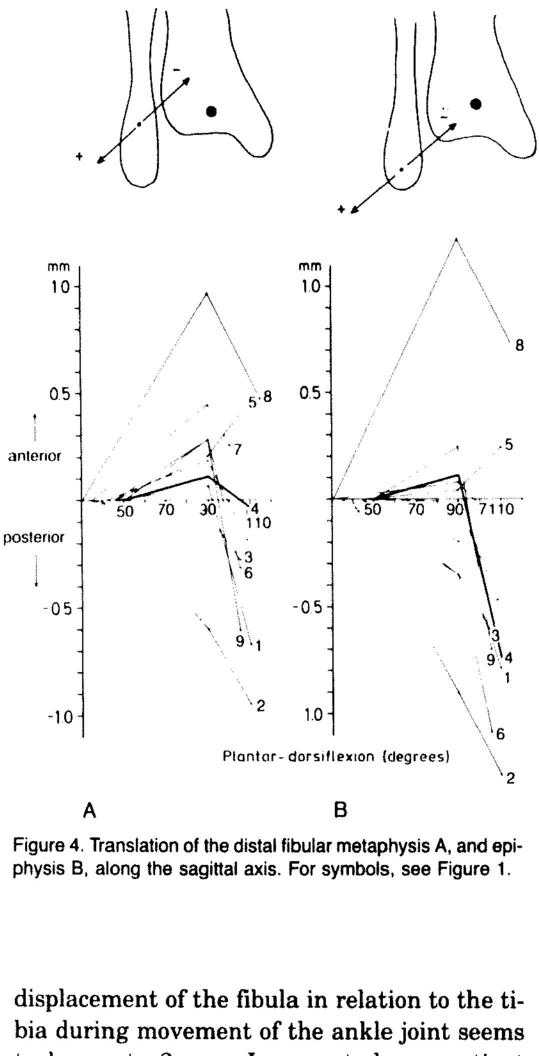

Figure 4. Translation of the distal fibular metaphysis A, and epiphysis B, along the sagittal axis. For symbols, see Figure 1.

displacement of the fibula in relation to the tibia during movement of the ankle joint seems to be up to 2 mm. In our study no patient showed a total displacement less than 0.5 mm, and the maximum displacement was 2.4 mm. The average total epiphyseal displacement in our study was about 1.0 mm in the neutral position and about 1.4 mm in maximum dorsiflexion. The average total epiphyseal displacement was similar to those described by Close & Inman (1952), whereas Grath (1960) reported slightly lower values.

Most of our patients displayed the highest increase in width of the ankle mortise when the ankle moved from plantar flexion to the neutral position. Similar observations were also made by Close & Inman (1956) and Grath (1960). The largest width of the ankle mortise (lateral epiphyseal displacement) occurred in our study in most patients when the foot was maximally dorsiflexed. However, all ankles examined showed a maximum of fibular mobility between the position of full plantar and dorsiflexion (total epiphyseal displacement) due to simultaneous movements mainly along the transverse and sagittal axes, and to a lesser extent due to movement along the longitudinal axis of the bone. It had not been possible to perform this type of three-dimensional analysis of the fibular mobility in previous studies.

Ledermann & Cordey (1979) measured both sagittal and transverse fibular displacements but accounted only for displacements observed from the neutral position to maximum dorsiflexion. They concluded that the distal fibula in general was displaced anterolaterally during this movement, although some patients exhibited a posterolateral displacement. We found that most ankles showed a posterolateral displacement during the same movement.

In this study, measurements were performed at the metaphyseal and epiphyseal levels. In most cases the total, transverse, and sagittal displacements were largest at the epiphyseal level. This difference might be explained by elasticity of the distal fibula, permitting some deformation when the talus rotates during dorsiflexion of the ankle joint. The fibula might also be more firmly fixed to the tibia at its proximal end, implying that the tip of the lateral malleolus will displace more than the metaphysis.

Knowledge of the tibiofibular displacement may be of importance when treating patients with disturbed tibiofibular relationships due to growth, injuries of the tibiofibular ligaments, or other conditions with instability of the ankle joint.

References

Cedell, C. A. (1967) Supination – outward rotation injuries of the ankle. *Acta Orthop. Scand.* Suppl. 110.

Close, J. R. & Inman, V. T. (1952) The action of the ankle joint. Prosthetic devices research project. Institute of Engineering Research, University of California, Berkeley. *Report of the Advisory Research Council Series II* No. **22** (quoted from Grath).

Grath, G. B. (1960) Widening of the ankle mortise. A clinical and experimental study. *Acta Chir. Scand.* Suppl. 263.

Klossner, D. (1962) Late results of operative and non-operative treatment of severe ankle fractures. *Acta Chir. Scand.* Suppl. 293.

Kärrholm, J., Hansson, L. I. & Selvik, G. (1982a) Roentgen stereophotogrammetric analysis of growth pattern after supination-eversion ankle injuries in children. *J. Pediatr. Orthop.* **2**, 25–37.

Kärrholm, J., Hansson, L. I. & Selvik, G. (1982b) Roentgen stereophotogrammetric analysis of growth pattern after supination-adduction ankle injuries in children. *J. Pediatr. Orthop.* **2**, 271–279.

Kärrholm, J., Hansson, L. I. & Selvik, G. (1984) Longitudinal growth rate of the distal tibia and fibula in children. *Clin. Orthop.* **191**, 121–128.

Ledermann, M. & Cordey, J. (1979) Messung der fibularen Mitbewegung gegenüber der Tibia auf Höhe des oberen Sprunggelenkes *in vivo*. *Helv. Chir. Acta* **46**, 7–11.

Leeds, H. C. & Ehrlich, M. G. (1984) Instability of the distal tibiofibular syndesmoses after bimalleolar and trimalleolar ankle fractures. *J. Bone Joint Surg.* **66**-A, 490–503.

Ramsey, P. & Hamilton, W. (1976) Changes in tibiofibular area of contact caused by lateral talar shift. *J. Bone Joint Surg.* **58**-A, 356–357.

Salter, R. B. & Harris, W. R. (1963) Injuries involving the epiphyseal plate. *J. Bone Joint Surg.* **45**-A, 587–622.

Selvik, G. (1974) A roentgen stereophotogrammetric method for the study of the kinematics of the skeletal system. Thesis. Lund.

Weber, G. B. (1972) *Die Verletzungen des oberen Sprunggelenkes,* 2nd ed. Huber, Bern, Stuttgart, Wien.