Acta orthop. scand. 54, 721–729, 1983

POST-TRAUMATIC GROWTH DISTURBANCE OF THE ANKLE TREATED BY THE LANGENSKIÖLD PROCEDURE

Evaluation by Radiography, Roentgen Stereophotogrammetry, Scintimetry and Histology: Case Report

J. Kärrholm[1], L. I. Hansson[1], S. Laurin[2] and G. Selvik[3]

Departments of [1]Orthopaedics, [2]Diagnostic Radiology and [3]Anatomy, University Hospital in Lund, Lund, Sweden

Progressive growth retardation and varus tilting were observed in a child with an ankle fracture of supination-adduction type initially treated by closed reduction and pinning. The patient was later operated with the Langenskiöld procedure.
Preoperatively, roentgen stereophotogrammetric analysis showed decreasing growth rates especially medially in the distal tibia, radionuclide scintimetry manifested reduced activity on the injured side, and tomograms showed a bony bridge medially. The evidence of growth in the distal tibia indicated the existence of an osseofibrous bridge between the epiphysis and the metaphysis. This was also confirmed by the findings at the operation and partly by microscopical investigation of the removed osseofibrous bridge.
Postoperative stereophotogrammetric analysis showed reduction of the varus position in two steps. Roentgen stereophotogrammetry permits early detection of a growth disturbance, and evaluation of the effects of therapy.

Key words: ankle fracture; children; epiphysis; growth plate; roentgen stereophotogrammetry; surgery

Accepted 21.iii.83

Surgical correction of growth deformity of the ankle has been performed using an osteotomy of the distal tibia and/or distal fibula (Ollier 1867, Rose 1888, Gill & Abbott 1941, Langenskiöld 1967a). In 1967 Langenskiöld (1967b) introduced fat interposition after surgical resection of bony bridges. Later, the operation was successfully tried in several cases (Langenskiöld 1975, 1981). The experimental basis for the operation was comprehensively investigated by Österman (1972), but the movements of the epiphysis immediately after the operation and the detailed growth pattern during resumption of growth have not been known.

The present case report concerns a 6-year-old girl with a supination-adduction ankle fracture resulting in a varus deformity. Fifteen months after fracture the Langenskiöld procedure was performed. Information about the preoperative course was obtained from radiography, tomography, scintimetry, roentgen stereophotogrammetry, and microscopical investigation of resected parts of the osseofibrous bridge at the operation. The results of the operation were judged from radiography and roentgen stereophotogrammetric analysis (Selvik 1974, 1978, Aronson 1976, Kärrholm et al. 1982a–c).

a b

Figure 1. Supination-adduction injury Stage II. a – Lateral projection. b– AP. Physeal fracture of the distal fibula, Salter-Harris Type I. Minimal fragment at the tip of the lateral malleolus. Fracture of the medial malleolus running in a zigzag pattern detaching a minimal metaphyseal fragment (Z or Salter-Harris Type IV).

METHODS

Roentgen stereophotogrammetry

In order to register the growth pattern tantalum balls 0.5 mm in diameter were inserted at fracture healing. Tantalum balls were inserted in the metaphysis and in the epiphysis of the distal tibia and fibula bilaterally. Further markers were inserted in the distal tibia during the Langenskiöld operation. Roentgen stereophotogrammetric examinations (Selvik 1974) were performed at intervals of 1–4 months. Daily longitudinal growth (Kärrholm et al. 1982a) and movements of the distal tibial epiphysis on the fractured side about the cardinal axis were analysed (Kärrholm et al. 1982a).

Radionuclide scintimetry

The scintimetric analysis was performed using Tc^{99}-methylenediphosphonate (Tc^{99m}–MDP) (Bylander et al. 1982).

Histology

The biopsies from the osseofibrous bridge were decalcified, sectioned, and stained with haematoxylin-eosin.

CASE REPORT

A 6-year-old girl fell from a swing and suffered an ankle fracture. Radiographs showed a supination-adduction Stage II injury (Gerner-Smidt 1963). According to Salter & Harris (1963) there was a Type I injury through the lateral malleolus, and in addition, a minimal fragment at the tip of the lateral malleolus. The medial malleolar fracture ran in a zigzag pattern (Z or Type IV), detaching the medial malleolus with a minimal metaphyseal fragment attached to it. Proximal and medial displacement of about 2–3 mm and a considerable rotation of the medial malleolus were registered (Figure 1a and b). Due to blistering of the skin, closed reduction and percutaneous pinning medially was performed. Postoperative radiograms showed almost no displacement. Plaster fixation was for about 5 weeks. The fracture healed without problems.

The patient developed a progressive varus deformity of the injured ankle which could be suspected radiographically about 6 months and was obvious 12 months after fracture. A desphyseodesis operation and fat interposition according to Langenskiöld (1967b, 1975, 1981) was performed about 14¾ months after fracture. The patient was followed clinically and by roentgen stereophotogrammetry for 3 years after fracture.

Figure 2. Lateral tomograms. a – Medially. Bony bridging of the growth plate at a distance of about 1 ½ cm. No visible condensation line. b – Laterally. Asymmetrical condensation line at a distance from the growth plate posteriorly but not anteriorly.

Frontal tomograms. c – Anteriorly. Bony bridging of the growth plate medially. Sclerotic bone mainly at the epiphyseal side. Asymmetric condensation line ending in the sclerotic region. d – Posteriorly. Condensation line ending at the sclerotic region. Small step at the tibial joint area.

RESULTS

Preoperative investigations: Tomography

Tomograms (Figure 2a–d) 14½ months after fracture showed a bony bridge, a condensation line at a variable distance from the growth plate, and posteriorly, a step in the ankle joint.

Roentgen stereophotogrammetry

(2–14 months after fracture).

I. Growth analysis (Figure 3)

In the distal tibia and fibula an initial and progressive growth retardation was registered.

On the intact side the growth rates varied between 22 and 28 μm/day in the distal tibia, and between 20 and 24 μm/day in the distal

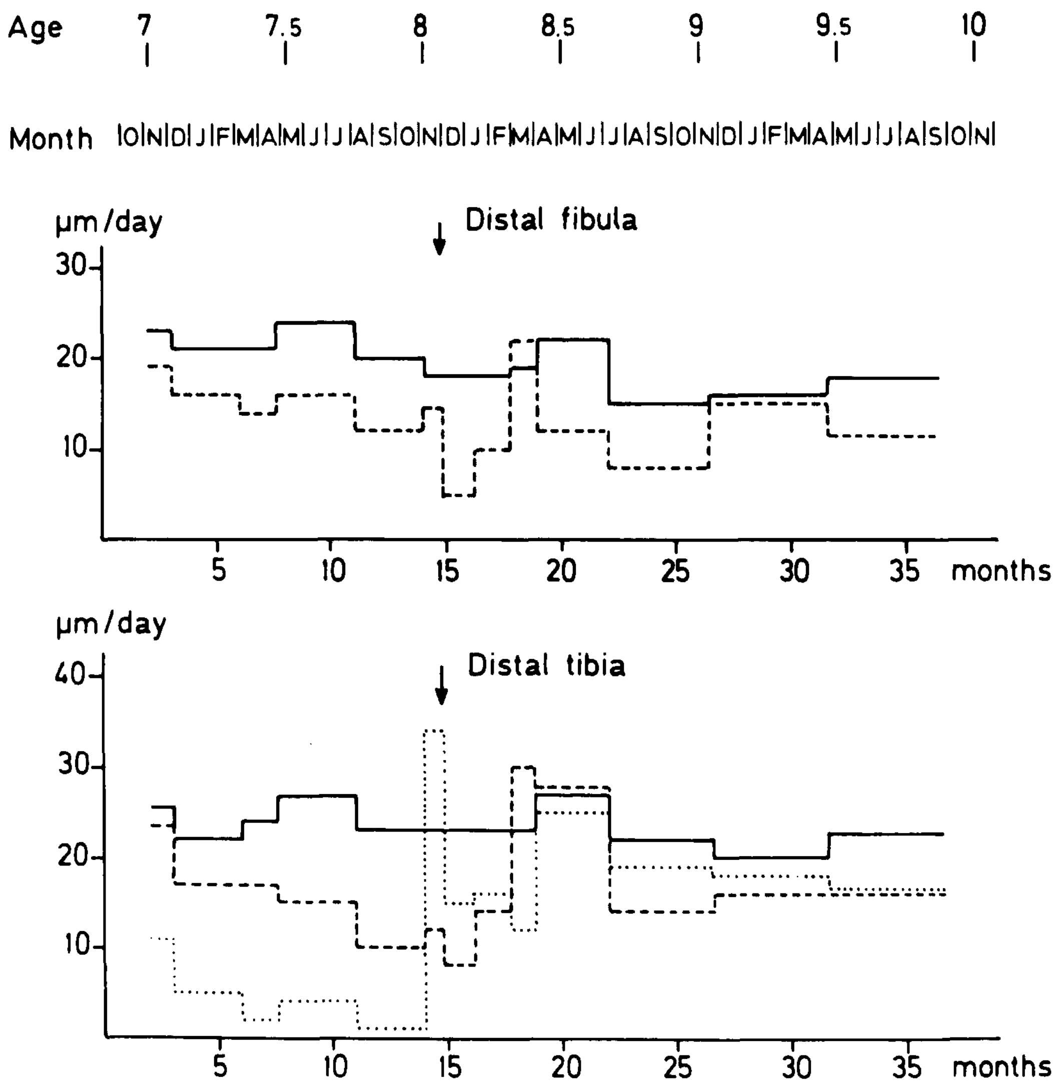

Figure 3. Growth diagram. Top – distal fibula. Bottom – distal tibia. Above age in years and time of the year. Arrow indicates Langenskiöld operative procedure. Full line – intact side. Dashed line – fractured side distal fibula and fractured side distal tibia laterally. Dotted line – fractured side distal tibia medially.

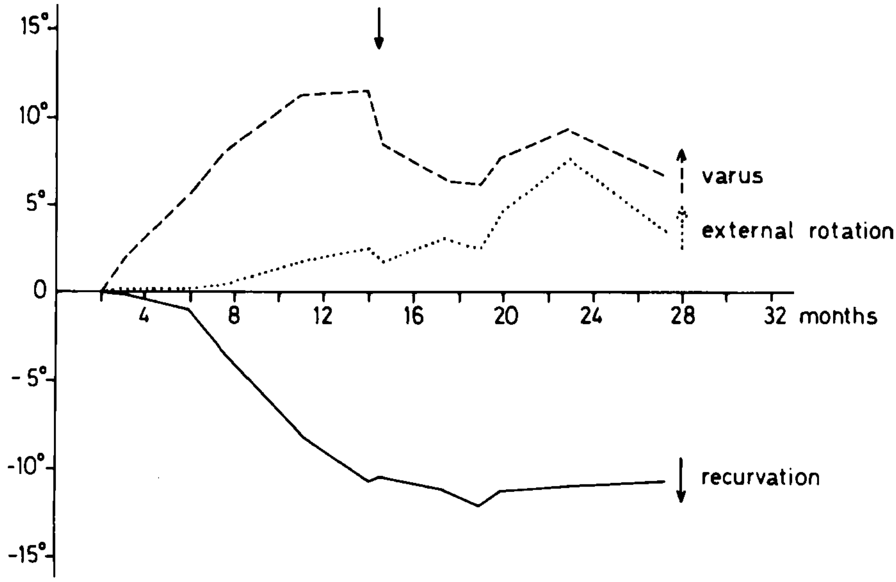

Figure 4. Rotational displacement of distal tibial epiphysis according to Kinema analysis. Full line – movement about transverse axis. Dashed line – movement about sagittal axis. Dotted line – movement about longitudinal axis. Arrow indicates the Langenskiöld operative procedure.

fibula. The highest values were registered during the first period and during the spring and summer months.

II. Kinema analysis (Figure 4)
Kinema analysis showed a progressive recurvation and a varus position, which before the operation had reached about 11°.

Radionuclide scintimetry

Thirteen months after fracture Tc^{99m}–MDP scintimetric evaluation was performed. Quantitative analysis showed numerical ratios between fractured and intact side of 0.61 and 0.51 in distal tibia and fibula, respectively. No significant regional differences within the growth region of distal tibia were found.

Peroperative observations: Operation

At the operation during general anaesthesia and under tourniquet the periosteum was incised medially, retracted, and a part of the metaphyseal cortex (5 × 2 cm) was removed. Metaphyseal bone was removed down to the bony bridge. The metaphyseal part of the bony bridge could easily be exposed as a bud extending from the epiphysis through the growthplate into the metaphysis. Furthermore, a minimal step of the growth plate of about 1–2 mm was found. By a Michelle core biopsy instrument (6 mm diameter) the bony bridge was removed in five cylinders (central, posterior, anterior, antero-lateral, and postero-lateral). Further metaphyseal and epiphyseal bone was carefully removed until intact growth plate was surrounding the cavity.

An autogenous free fat transplant was taken at the level of the gluteal fold and inserted into the cavity. The metaphyseal bone plate was replaced and the periosteum was sutured. No plaster fixation was used.

Roentgen stereophotogrammetry

(14–14¾ months after fracture, 20 days preoperatively up to 1 day postoperatively).

I. Growth analysis (Figure 3)
The patient had gained 0.7 mm in length medially and 0.25 mm laterally, corresponding to a move-

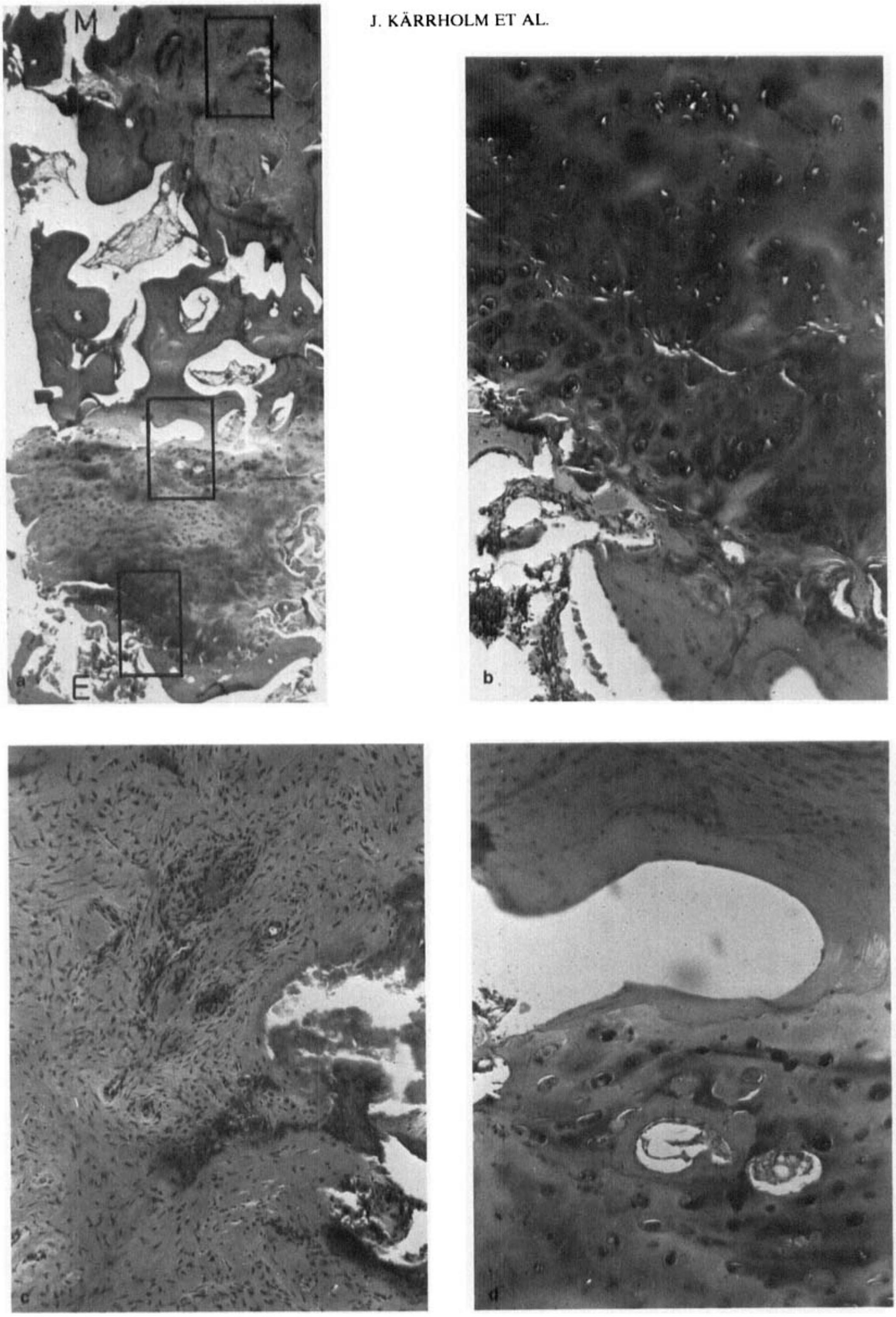

Figure 5. Anterior biopsy. a – Growth cartilage continuing through the biopsy. At the metaphyseal side (M) a large area with callus formation (×8). b – Accumulations of undifferentiated cartilage cells at the epiphyseal side (E) of the growth plate (×80). c – Calcification and ossification at the metaphyseal side of the growth plate. Bony islands within the cartilage (×60). d – Callus at the metaphyseal side of the biopsy (×80). E indicates epiphyseal side. M indicates metaphyseal side. □ shows close-up areas (Figs. b–d).

ment on the average of 34 and 12 µm/day, respectively.

II. Kinema analysis (Figure 4)

The analysis before and immediately after the operation manifested mainly a reduction of the varus position; from 11° to 8°.

Histology

In three of the core biopsies the growth plate continued through the cores. The anterior biopsy (Figure 5a) showed signs of growth (Figure 5b and c), and in the metaphysis, areas with granulation tissue and fibrosis. At a large area, newly formed bone and callus were present (Figure 5d). In two biopsies there was bone continuing from the epiphysis in a metaphyseal direction.

Postoperative investigations: Roentgen stereophotogrammetry

(14¾–36½ months after fracture, 0 to 22 months after the operation).

I. Growth analysis (Figure 3)

During the first two periods postoperatively the growth rate in the distal tibia was higher medially than laterally, whereas higher growth rates were registered laterally during the third and fourth period. During the fifth and sixth periods the growth rate of the medial part again exceeded that of the lateral. In the seventh period the growth rates were about equal.

In the distal fibula the growth rate decreased postoperatively to 5 µm/day (first postoperative period). Later on, the growth rate showed similarities to that laterally in the distal tibia on the fractured side.

On the intact side the growth rates varied during the time of the year and were again higher during summer months.

II. Kinema analysis (Figure 4)

Initially, the varus position was further reduced to about 6°, but then increased to about 9°. Later, it again decreased to about 6°. During the last periods two of the metaphyseal bone markers showed instability, making a Kinema analysis impossible. Movements about the transverse axis were small during the postoperative periods.

The accumulated difference in length was preoperatively (14 months after fracture) 2.5 mm in the distal tibia and in the fibula. At the last registration (36½ months after fracture) it had increased to 6.1 mm in the distal fibula and 9.2 mm in the distal tibia. Thus, both the distal tibia and fibula had grown less on the fractured and operated side.

Radiography

Radiograms 30½ months after fracture showed an elongation of the fat transplant, and a slight remaining varus deformity (Figure 6a and b).

DISCUSSION

In the present case the angular deformity was partly reduced peroperatively and during the following 4 months. The derotation of the epiphysis registered postoperatively could partly be because the epiphysis, earlier subjected to a forcible medial binding, was released during the operation resulting in reduced varus deformity. The reactivation of the growing cartilage to full activity probably took several months, corresponding to the maximum growth rates observed about 5 months after the operation.

During the fifth and sixth postoperative periods higher growth rates were observed medially than laterally, indicating a correction of the deformity by asymmetrical growth within the growth region and also a regeneration of the growth plate medially as was earlier experimentally demonstrated (Heikel 1961, Troupp 1961, Nordentoft 1969).

The biopsies showed that the bridging of the growth plate was constituted mainly of bone; sometimes present as bone trabeculae, sometimes as callus. In some areas there was fibrous tissue. Microfractures according to Johnson & Southwick (1960) were not found, but the callus areas might suggest a calcification and ossification of fibrous tissue progressively reducing the longitudinal growth rate. Furthermore, the epiphyseal bony bud protruding into the metaphysis was easily uncovered during the operation, suggesting a loose fibrous connection to the surrounding parts of the metaphyseal bone

a

b

Figure 6. Radiograms 30½ months after fracture (16 months after the Langenskiöld operative procedure). a – Lateral. b – AP Elongation of the fat transplant. The defect in the epiphysis no longer visible. Slight remaining varus deformity. Growth plates open.

and permitting longitudinal growth. Thus, progressive growth retardation might indicate a bridging of the growth plate initially constituted by fibrous tissue permitting longitudinal growth for a variable time period. During the following calcification and ossification of the fibrous scar, growth rates will be registered until a solid fusion of bone has developed between the epiphysis and the metaphysis, resulting in complete growth arrest.

In conclusion, fusion of the growth plate due to trauma is a complex mechanism, which usually is progressive if continuing more than 6–8 months after fracture (Kärrholm et al. 1982a–c). The possibility to regenerate the growth plate after a Langenskiöld operation diminishes in time. With the present knowledge of the nature of a progressive growth retardation after physeal fracture in the younger child an operative procedure in order to restore normal growth will be performed earlier when the posttraumatic growth pattern is established by roentgen stereophotogrammetric analysis. This technique also facilitates the postoperative evaluation and reveals early recurrence of the deformity.

ACKNOWLEDGEMENTS

This study was sponsored by Nordiska Samfundets Stiftelse för vetenskaplig forskning utan djurförsök, Svenska Läkarsällskapet, The Swedish Medical Research Council (project 17X-2031), and Folke Bernadottestiftelsen för barn och ungdom med rörelsehinder.

REFERENCES

Aronson, S. (1976) *X-ray stereophotogrammetry of longitudinal bone growth.* Thesis. Lund, AV-centralen.

Bylander, B., Hansson, L. I., Kärrholm, J. & Naversten, U. (1982) Tc-99^m MDP scintimetric evaluation of posttraumatic and postoperative growth disturbance. *Acta Radiol. Scand.*, in press.

Gill, G. G. & Abbott, L. C. (1941) Varus deformity of ankle following injury to distal epiphyseal cartilage of tibia in growing children. *Surg. Gynec. Obstet.* **72**, 659–666.

Heikel, H. V. A. (1961) Experimental epiphyseal transplantation. *Acta Orthop. Scand.* **30**, 1–19.

Johnson, J. T. H. & Southwick, W. O. (1960) Growth following transepiphyseal bone grafts. *J. Bone Joint Surg.* **42**-A, 1381–1395.

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

Kärrholm, J., Hansson, L. I. & Selvik, G. (1982c) Roentgen stereophotogrammetric analysis of growth pattern after pronation ankle injuries in children. *Acta Orthop. Scand.* **53**, 1001–1011.

Langenskiöld, A. (1967a) Traumatic premature closure of the distal tibial epiphyseal plate. *Acta Orthop. Scand.* **38**, 520–531.

Langenskiöld, A. (1967b) The possibilities of eliminating premature partial closure of an epiphyseal plate caused by trauma or disease. *Acta Orthop. Scand.* **38**, 267–279.

Langenskiöld, A. (1975) An operation for partial closure of an epiphyseal plate in children and its experimental basis. *J. Bone Joint Surg.* **57**-B, 325–330.

Langenskiöld, A. (1981) Surgical treatment of partial closure of the growth plate. *J. Pediatr. Orthop.* **1**, 3–11.

Nordentoft, E. L. (1969) Experimental epiphyseal injuries. *Acta Orthop. Scand.* **40**, 176–192.

Ollier, L. (1867) *Traité expérimental et clinique de la régénération des os et de la production artificielle du tissu osseux.* Masson. Paris.

Rose, W. (1888) Medical Society of London. *Br. Med. J.*, 699.

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, AV-centralen.

Troupp, H. (1961) Nervous and vascular influence on longitudinal growth of bone. *Acta Orthop. Scand.*, Suppl. 51.

Österman, K. (1972) Operative elimination of partial premature epiphyseal closure. *Acta Orthop. Scand.*, Suppl. 147.

Correspondence to: J. Kärrholm, Dept. of Orthopaedics, University Hospital in Lund, S-22185 Lund, Sweden.