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## The functional anatomy of the ankle-joint

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Studies of the functional anatomy of the ankle-joint have often placed strong emphasis on the geometry of the talar cochlea and the ankle-fork. However, this geometry is far from regular and congruent. This implies not only a surface area which varies during motion but also a considerable kinematic significance of ligaments as motion-guiding structures; these kinematic properties, however, are constantly changing during motion because they are partly determined by the constantly changing direction of the ligament fibres.

The situation is even more complex because the ankle-fork is not a rigid structure, and contraction of the muscles inserting on or originating from the fibula can change the configuration of the bones and ligaments.

In view of these considerations, the value of axis determinations performed on unstressed anatomical specimens is dubious. Moreover, the configuration of the ankle ligaments indicates the great significance of the ankle-joint in transferring leg rotations to the talus so that the tarsal mechanism can convert them to tilting of the foot. In this way these tilt motions become actively controllable. This does not imply a kinematic association between flexion/extension in the talocrural joint and the tarsal mechanism.

## Kinematic analysis of the talocrural joint in relation to ligament lesions

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A kinematic analysis of the talocrural joint in relation to the lateral ligament capsules was performed on foot-leg specimens processed to skeletal ligament specimens. Supinatory deformation of the foot was induced by external rotation of the tibia in 10° steps, from 0° to 30°. While the lateral ligament capsules were still intact, this supinatory deformation was induced with the foot in neutral position, in 10° dorsal flexion and in 10°, 20° and 30° plantar flexion. This was repeated after successive severance of the anterior talofibular ligament with capsule, the calcaneofibular ligament with capsule, and the posterior talofibular ligament. A very precise description of motions of bone fragments could then be achieved by radiophotogrammetry, because these bone fragments were marked with tantalum pellets.

All motions of rigid bodies can be described as screw motions. A screw motion can be defined as a combination of rotation on and translation along the screw axis. The preliminary results of the study were the following.

Tibiotalar delay, calculated as component along the vertical axis of relative rotation of the tibia versus the talus, increases especially when the anterior talofibular ligament with capsule is severed during external rotation of the tibia from 0° to 20°. The talocrural screw axes are projected onto three principal planes. In external rotation to 20°, severance of the anterior talofibular ligament in the sagittal and in the transverse plane causes maximal directional changes.

In the frontal plane the directional change is not maximal until the calcaneofibular ligament with capsule is severed as well.

## Radiological diagnosis of sprained ankle

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About two-thirds of all patients with a sprained ankle show a lateral ligament rupture, and in 40 percent of these patients there is a rupture of both the anterior and the middle lateral ligaments (and sometimes of the posterior talofibular ligament as well).

Standard radiographs were required to demonstrate/exclude a fracture (or avulsion fracture). The finding of a wedge-shaped articular space and/or marked soft tissue swelling around the malleolus suggests the presence of a ligament lesion.

Results of an examination under stress are determined by a large number of factors; there is a considerable percentage of false positive and especially of false negative findings. In 50 percent of patients with a combined rupture of the talofibular and the calcaneofibular ligament, the tilt angle is less than  $6^\circ$  (in 25 percent it is more than  $10^\circ$ ); and in almost 70 percent the difference in tilt angle from that of the contralateral ankle is less than  $6^\circ$  (in 14 percent this is more than  $10^\circ$ ). In 10 percent of the patients with a lateral ligament rupture the contralateral talus tilts at least  $3^\circ$  more than the ipsilateral talus. In "recurrent cases" this percentage is 16, and in 13 percent of these patients the contralateral talus tilts more than  $10^\circ$ . The margin of error in tilt radiographs is wide.

Arthrography of the ankle-joint within 5–7 days of the injury determines the presence or absence of a ligament lesion, but not always its extent (if there is leakage of contrast medium ventrolateral to the lateral malleolus with filling of the tendon sheaths of the peroneus muscles). A peroneal tenogram is more precise: filling of the talar joint with contrast medium from the tendon sheath almost certainly indicates that the calcaneofibular ligament is ruptured (as well).

The extent of diagnostic radiographic work in the case of a sprained ankle is determined by the therapeutic strategy of the attending physician. If he gives all patients with a sprained ankle uniform treatment, regardless of whether a ligament lesion is present or absent, then standard roentgenograms are sufficient. Their exclusive purpose is to exclude fractures or dislocations.

If therapy depends on the severity of the injury, then arthrography is sufficient: filling of the peroneus tendon sheath suggests a severe ligament lesion which may require operative treatment. If the therapeutic strategy differs with regard to rupture of one or several ligaments (e.g. operation in the case of a talofibular ligament lesion), then a peroneal tenogram is indicated in addition in some cases.

## Analysis of sources of error in talar tilt and drawer sign radiography of the ankle-joint

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The diagnostic value of the stress examinations commonly used in clinical work was tested in skeletal ligament specimens, using two possible sources of error as variables:

- a) The angle between the beam of rays and the specimen;
- b) The measuring points and measuring methods used for quantification.

In addition, a radiophotogrammetric study was made in an effort to obtain – on the basis of screw axes – an objective impression of the nature and extent of the "abnormal" excursion involved in stress examinations. The specimen studied contained an isolated lesion of the anterior talofibular ligament with capsule and of the calcaneofibular ligament with capsule. The angle between the beam of rays and the specimen in the horizontal plane ( $\alpha$ ) varied in  $10^\circ$  steps from  $-20^\circ$  to  $+20^\circ$ , and that in the vertical plane ( $\beta$ ) in the same way from  $-10^\circ$  to  $+10^\circ$ . Given a lesion of the anterior talofibular ligament, a variation of  $\alpha$  caused the talar measuring results to vary from  $10^\circ$  to  $13.5^\circ$ , while a variation of  $\beta$  caused them to vary from  $8^\circ$  to  $16^\circ$ . With a lesion of the anterior talofibular ligament and the calcaneofibular ligament with adjacent capsule, the talar tilt measuring result varied from  $11.5^\circ$  to  $16^\circ$  and from  $10.5^\circ$  to  $15.5^\circ$  respectively. The measuring results with a drawer sign also proved to depend on the ray direction, but in addition showed a wide range due to measuring errors.

## Classification of ankle-joint fractures

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The classification of Dupuytren (1819) was in use during the pre-radiographic period. A more extensive classification was introduced by Cooper in 1918. Another classification was introduced by Ashhurst & Bromer in 1922, and has been widely used in the American literature until recently.

Two fracture classifications have come to the fore in recent decades: that of Weber and that of Lauge Hansen. The Weber classification is somewhat arti-

cial and proceeds from the postulate that the fibula is the key-stone of fracture severity and the primary determinant of therapy. The Lauge Hansen classification is based on the aetiology of the fracture and proceeds from the position of the foot at the time of the injury and the movement of the foot from that position as a result of the violence inflicted. The magnitude of the force applied determines the number of fractures and ligament lesions which develop, given a particular position and subsequent movement of the foot.

The author considers the Lauge Hansen classification to be superior.

### Functional instability of the ankle-joint

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The most common residual disability after ankle-joint injuries is "functional instability", i.e. recurrent sprains and/or a feeling that the ankle is giving way. Because functional instability mainly affects active persons and athletes, these groups were studied. Techniques to evaluate postural control during stance were developed (using force-plate and optoelectronic registration of motion), as was an isokinetic method to measure muscle strength in pronation and dorsal flexion.

Ankle-joint function is correlated to the ability to maintain postural equilibrium in single limb stance. If the pattern of postural control is insufficient, then corrections are made by moving upper segments.

The ability to maintain postural control is impaired in football players with functional instability of the ankle-joint. Postural control was not found to be affected by an ankle injury *per se*. It was not affected by mechanical instability or by ankle taping. Ipsilateral pronator muscle weakness was found in patients with unilateral functional instability.

Football players with a history of ankle problems suffered more ankle sprains than those with no such history. Impaired postural control as demonstrated by stabilometry indicated an increased risk of ankle-joint injury even in previously uninjured football players. Coordination training on an ankle disc improves postural control and pronator muscle strength, and reduces the feeling that the ankle is giving way.

Two efficient methods to prevent ankle-joint injuries are presented. An ankle orthosis provides mechanical support. Ankle disc training of players with functional instability interrupts the vicious circle of

recurrent sprains, muscular atrophy and impaired postural control.

### Surgically treated ankle ligament lesions. Clinical results correlated to arthrograms and tilt radiographs

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A follow-up study was performed on 86 patients whose severe ankle ligament lesions had been surgically treated 1979–1983. Preoperative diagnostic radiography had comprised arthrography in 66, bilateral tilt radiography in 26, unilateral tilt radiography 43 and tilt radiography as well as arthrography in 15 cases.

An arthrogram was considered indicative of a grade 2 to grade 3 ankle ligament lesion if the peroneus tendon sheath filled (rupture of the calcaneofibular ligament); this was the case in 59 of the 66 patients examined by arthrography; 36 of them had a positive arthrogram (sensitivity 60 percent). On the other hand, seven had no grade 2 or grade 3 rupture; peroneus tendon sheath filling was observed in four of them (specificity 45 percent).

There seemed to be no correlation between unilateral tilt radiographs and the extent of the surgically demonstrated lesion. Of the 26 patients with bilateral tilt radiographs, 23 in fact had a grade 2 or grade 3 rupture. In 19 of them the difference in tilt between the affected and the contralateral ankle was 6° or more (sensitivity 83 percent). No statement can be made about the specificity of bilateral tilt radiography.

The follow-up revealed that – regardless of the severity of the injury, age, athletic activity and duration of follow-up – one out of six patients complained about a fear of giving way of the ankle. This was not more frequently encountered in patients with a severe than with a less severe lesion. All patients reporting this fear had been in a plaster cast for 6 weeks or longer postoperatively.

### Results of primary operative treatment of lateral ankle ligament lesions

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Primary operative treatment of a ligament rupture promotes early functional recovery by adequate adaptation. The importance of the anterior talofibular ligament of the ankle-joint is usually underestimated. With these considerations in mind, a prospective clinical study was performed of the results of primary operative treatment of both isolated and multiple lesions of the lateral ligaments of the ankle-joint.

Arthrography of the ankle-joint was performed in a total of 732 patient with a recently sprained ankle, mostly young active athletes. Isolated or multiple lateral ligament lesions were diagnosed in 337 patients on the basis of a positive arthrogram (filling of the peroneus tendon). At surgical exploration the following lesions were found: isolated lesion of the anterior talofibular ligament in 155 patients; dual lesion (anterior talofibular and calcaneofibular ligament) in 147 patients; triple lesion (all ankle ligaments) in 30 patients; isolated rupture of the calcaneofibular ligament in 3 patients; isolated capsular rupture in 2 patients.

Primary operative repair was performed by adaptation of the rupture ends with Vicryl 000, followed by postoperative immobilization in a plaster cast for 3 weeks. Removal of the plaster cast was followed by a training programme aimed at resumption of athletic activities within 4–6 weeks.

A follow-up was performed after 6 and 12 months. The population studied comprised 87 percent athletes, and in 76 percent of cases athletic activities had been the cause of the injury. Resumption of athletic activities therefore was an important parameter in assessing the therapeutic results. In this series 90 percent of the surgically treated patients were able to resume their athletic activities. Ten percent could not or did not resume their athletic activities, but only 2 percent for reasons related to the accident or residual complaints. Athletic activities were resumed after an average of 8 weeks. The follow-up after 6 months revealed the following residual symptoms: pain during stress in 6 percent, functional instability in 8 percent, recurrence of sprain in 4 percent, and swelling in 25 percent. The follow-up after 12 months revealed: pain during stress in 2.5 percent, functional instability in 5 percent, recurrence of sprain in 2.5 percent and swelling in 9 percent of cases.

It is concluded that primary operative treatment of lateral ankle ligament lesions followed by immobilization in a plaster cast for 3 weeks ensures complete and asymptomatic recovery in a large percentage of cases. This approach would seem to be preferable for the individual patient for whom it is important to recover without residual symptoms from both isolated and multiple lateral ankle ligament injuries, i.e. especially for athletes.

## Comparison of the results of conservative with those of operative treatment of ankle ligament lesions

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A prospective comparative study was performed of 223 ankles with ligament lesions treated by operation or by immobilization in a plaster cast. Results were assessed at least 1 year after the accident. Of the 223 ankles, 101 had been treated conservatively and 122 operatively. Parameters assessed were pain, swelling and subjective restrictions. The last-mentioned complaint occurred in 29 percent of the conservative and in 32 percent of the operative group.

The patients were also asked questions about subjective instability, and in this respect the difference between the two groups was likewise very small: 13 percent of the conservative and 10 percent of the operative group. The same applied to reported resumption of athletic activities or heavy manual work: 89 percent of the conservative and 92 percent of the operative group.

Renewed stress examination of the affected ankle was compared with the contralateral ankle and with the findings immediately after the accident. It was found that the operative group showed slightly less talar tilt than the conservative group.

The differences in results seemed to small to warrant a preference for routine operative treatment. This should be reserved for selected patients, i.e. athletes for whom stability of the ankle-joint is of special importance.

## Isolated lesions of the tibiofibular syndesmosis

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Lesions of the distal tibiofibular syndesmosis are usually features of a complex of fractures and dislocations of the ankle-joint. Isolated lesions of the syndesmosis are rare. They may result from an injury in external rotation, with the foot either in supination or in pronation, very often during athletic activities and in our patients mostly during ice-skating.

An isolated lesion of the syndesmosis was found in

10 out of 250 ankle ligament lesions treated by operation. The diagnosis was established on the basis of an arthrogram of the ankle-joint. A specific feature was leakage of contrast medium along the syndesmosis. In eight cases therapy consisted of ligament suture followed by 6 weeks' immobilization in a plaster cast. Two patients required insertion of an adjustable screw because of marked instability of the ankle-fork (to reduce the strain on the sutured ligament).

The follow-up period was 3–5½ years. All patients were free from symptoms with the exception of one with dystrophy (who in addition had sustained another injury).

The value of arthrography in diagnosis is stressed.

### Treatment of 176 ankle ligament ruptures by taping; results after 2–3 years

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Of 277 ankle ligament ruptures diagnosed in 1982, 229 were treated by taping for 6 weeks. The ruptures were encountered in 176 patients, including 95 percent active athletes. There was a history of previous sprains of the same ankle in 35 percent (recurrent in 20 percent); 26 percent regarded their ankles as weak even before the injury. At follow-up (average follow-up period 27.3 months) the following data on these patients were collected: 90 percent were walking normally 6 weeks after the injury, 97 percent were able to walk up and down stairs, 96 percent could ride a bicycle, 95 percent could drive a car and 90 percent could work. After 12 weeks, 96 percent had resumed running exercises, 94 percent had resumed technical training, and 87 percent had resumed athletic activities.

After 2–3 years 83 percent were entirely free from symptoms, the remainder still complaining about fear of giving way, a feeling of instability and fatigue. Of the 176 patients, 8.5 percent had regular and 1.7 percent virtually constant complaints, interfering with daily activities. Recurrence of ligament lesions and sprains was reported in 24.7 percent of cases. Of the 163 athletes, 25 percent had ceased athletic activities for reasons other than the ankle injury. Of the remaining 138 athletes, 126 (91.3 percent) had resumed athletic activities at their former level. The 12 top athletes in the group and 97.5 percent of the competitive athletes were not inconven-

iened during their athletic activities; 30 percent, however, were wearing a preventive bandage during these activities.

The subjective results were: 93 percent were satisfied with the results of treatment by taping; 8.5 percent required supplementary physiotherapy.

Treatment of ankle ligament ruptures by taping ensured a reduced period of absence from work, and in a large group of patients the functional result after 2–3 years could be described as good.

### Operation, and then ...? Plaster cast or taping?

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Between April 1979 and April 1982, operations were performed on 191 patients with severe ankle ligament lesions. Operative indications were based on clinical features and on a radiological stress angle difference of at least 12° (standardized with the aid of a stress apparatus).

Postoperative treatment initially consisted of 7–10 days in a plaster cast, followed by 6 weeks in a walking cast (Group I). With the development of taping techniques a switch was made to functional postoperative treatment, i.e. 3 × 2 weeks taping instead of 6 weeks in a walking cast (Group II).

A follow-up was performed on Group I after an average of 18 months (94 percent response to summons) and on Group II after an average of 30 months (85 percent response). The follow-up comprised an inquiry by questionnaire and clinical and radiographic examination of the ankle.

*Results.* Before operation the two groups did not differ significantly in stress angle: 23° and 24° respectively; after operation the corresponding values were 6° and 7°. Clinically unstable ankles were seen in 4 percent in both groups. No or only very slight complaints were reported by 95 percent in Group I and by 90 percent in Group II. In Group I 10 percent reported the ankle giving way more than five times since the operation, versus 3 percent in Group II. Satisfaction with the final result was expressed by 92 and 90 percent respectively. Total absence from work was 36 and 21 days respectively. Resumption of athletic activities in 88 and 92 percent respectively. Physiotherapy was required in 12 and 7 percent respectively.

The results show that functional postoperative treatment of ankle injuries is to be preferred to postoperative treatment with a walking cast, as the results in the two groups did not differ significantly.

## Evaluation of ankle injuries using the Cybex II Dynamometer

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During the season 1979–1980 the pattern of injuries was studied in a population of 9,940 competitive athletes (volleyball, handball, basketball). A total of 1,889 injuries were registered, and one-third of these involved the ankle ( $n=624$ ).

Three years (36–40 months) after the accident the ankle injuries given specialist treatment ( $n=249$ ) were entered in a follow-up study of four treatment groups:

Group I : operation with brief immobilization ( $\leq 3$  weeks).

Group II : treatment by taping.

Group III: operation with long immobilization ( $\geq 6$  weeks).

Group III: mobilization only ( $\geq 6$  weeks).

The follow-up included the following activities.

- 1) Measurement of the *strength* (peak torque at 60° angle velocity) of the musculature around the talar and the subtalar joint, using the Cybex II Dynamometer; the ratio between the peak torque of the invertors and evertors as well as that of the plantar and dorsal flexors showed a significant difference between the injured and the contralateral ankle in Groups III and IV, but not in Groups I and II. This difference in ratio can be interpreted as an expression of muscular imbalance.
- 2) Measurement of the *excursion of motion* (using the Cybex II Dynamometer) of active, unstressed plantar-dorsal flexion and of contuned eversion/abduction – inversion/adduction. In Groups I and II the restriction of motion of the injured ankle versus the contralateral ankle was  $\leq 5^\circ$  in all cases (for both excursions). In Groups III and IV the restriction of plantar-dorsal flexion was  $\leq 5^\circ$  in 65 percent of cases, and 6–10° in 35 percent, while that of eversion/abduction – inversion/adduction was  $\leq 5^\circ$  in 45 percent of cases and  $> 10^\circ$  in 25 percent.
- 3) Determination of residual complaints during athletic activities. The patient was scored for stiffness, swelling, pain and feeling of instability (on a 5-point scale), and "minor complaints" were catalogued as well. Group II indicated most residual complaints (some 50 percent of cases), and Group III the least (some 30 percent of cases).

**Summary:** In a population of competitive athletes whose ankle injuries were treated by immobilization for 6 weeks or longer (alone or in combination with primary operative suture), muscular im-

balance remained after 3 years, with restriction of motion of the talar and subtalar joints; in a significant percentage of cases, moreover, there were residual complaints during athletic activities, which were most frequently expressed in the group treated by taping.

## Techniques of reconstruction of lateral ligaments of the ankle-joint

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There are more than 20 different operative techniques described for treatment of late instability of the lateral ligaments of the ankle-joint. Four principal groups can be distinguished:

1. *Tenodeses*, often using the tendon of the peroneus brevis muscle (e.g. the Evans procedure). The disadvantage is that the entire peroneus tendon is sacrificed. Moreover, the graft is biomechanically unfavourable because its course is far lateral to the axis of rotation of the talar and the subtalar joint. This gives rise to an unphysiological lever action with regard to these joints, which may lead to secondary complaints especially in young, active athletes.
2. *Local reconstructions*. Practical experience has shown that even several years after rupture and cicatrization it is possible to strengthen the lateral ankle ligaments with the aid of reefing and/or reinsertion graft. Broström and Solheim reported good results in 85 and 86 percent respectively in the treatment of late ankle ligament lesions.
3. *Repair using free grafts* (corium, fascia lata, plantaris tendon). These techniques aim at reconstruction of the lateral ankle ligaments with the aid of grafts. The disadvantage is that prolonged immobilization of the joint is required because of slow ingrowth of the grafts. The results are variable.
4. *Combined reconstructions*, i.e. those using both free grafts and tendinous material such as the peroneus tendon. The best-known procedure is that of Watson-Jones. Its disadvantage is, however, that the insertion of the peroneus brevis muscle on MT-5 remains intact and that the untoward consequences of the Evans procedure are added to the improved stability of the talar joint. The most physiological combined reconstruction is that of Chrisman and Snook, using a free graft from a part of the tendon of the peroneus brevis

muscle. This ensures improved stability of the talar as well as the subtalar joint. However, in these procedures it is difficult to predetermine the exact degree of stability of the lateral ankle ligaments. A well-known complication is excessive tightness of the ankle-fork, as a result of which the physiological varus tilt may be reduced or even abolished (often also as a result of secondary cicatrization of the site of reconstruction).

### Results of operative treatment of old ankle ligament lesions according to Duquenois

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The technique which Duquenois introduced in 1980 to reconstruct the anterior talofibular ligament long after ankle ligament injuries is a variation of the reefing technique recommended by Broström & Sundel (1966). In a prospective study of 32 patients the Duquenois technique was used in a standardized version. The principal complaint was chronic giving way of the ankle.

The study comprised 16 men and 16 women with an age of 22 (14–40) years; the duration of symptoms was 0.5–8 years. The postoperative follow-up was 2.4 (1–4.5) years. Standardized stress radiographs and anteroposterior drawer sign radiographs were obtained in all cases.

The postoperative results were: talar tilt diminished from 16° (0–30°) before to 6° (0–14°) after the operation. The anterior drawer sign diminished from 10 (6–16) mm to 6 (0–10) mm.

Subjective results: 22 of the 32 patients were entirely free from symptoms (no pain, swelling or giving way); 25 patients were very satisfied with the result, four were fairly satisfied, and three were not satisfied. Three patients reported regular giving way of the ankle-joint. Seventeen patients had discontinued their athletic activities, while 15 had resumed these activities on their previous level after the operation. Ankle mobility was good in all cases.

The conclusion is that the Duquenois procedure has the advantage of sparing the peroneus brevis tendon and reconstructing the anterior talofibular ligament, leaving the subtalar joint intact. The postoperative results are satisfactory.

### Comparison of the Watson-Jones with the Weber technique of reconstruction of ankle ligaments long after injury

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A clinical follow-up was performed on 38 patients with reconstructed ankle ligaments: according to Watson-Jones (WJ) in 25 and according to Weber (W) in 14 cases. Male: female ratio 2:1; average age 27 years. Sports-related injuries were involved in 75 percent. The follow-up period averaged 5.7 years for the WJ group and 2.8 years for the W group. Freedom from symptoms in 71 percent; aggravated condition in one case, the remaining patients describing ankle stability as improved. Residual complaints: stiffness (5 cases in the W group) and giving way, but less frequently than before the operation. At follow-up there was no significant loss of function in comparison with the unaffected ankle.

*WJ group:* 82 percent asymptomatic; *W group:* 43 percent. *Stiffness:* no case in the WJ group and 29 percent in the W group, possibly because the follow-up period in the latter group was shorter. Five patients resumed athletic activities at the former competitive level; 21 were active in recreational sports; 11 had discontinued sports; 9 had retained their former level and 1 attained a higher level after the operation. *Discontinued athletic activities:* 20 percent in the W group and 35 percent in the WJ group.

No patient had had to change work. Absence from work averaged 12 weeks in the WJ group and 8 weeks in the W group.

*Conclusion:* Although the Weber procedure has the theoretical advantage that no dynamic stabilizer of the ankle needs to be sacrificed, this advantage did not seem to manifest in the follow-up. Subjectively, the Watson-Jones group in fact scored better, possibly as a result of the longer follow-up period. The final result was not influenced by the type of primary treatment nor by the interval between the primary injury and the reconstruction. Resumption of competitive athletic activities was possible after both operations.

### Results obtained with the Watson-Jones procedure for ankle joint instability

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A follow-up was performed on 48 patients treated for chronic instability of the ankle ligaments by a Watson-Jones procedure during the period 1973–1983. The group consisted of 23 men and 25 women, with an average age of 25.8 years for the women and 30.0 years for the men. The principal postoperative complaints were: recurrent giving way, pain, swelling and instability. Before the operation 11 patients had been treated with a plaster cast, and six by taping; eighteen patients had had no previous treatment, and one had an unstable ankle following an ankle fracture.

Results were good in terms of ankle-joint stability in 72.9 percent. The remaining patients showed distinctly reduced stability or complained of pain. A striking finding was that in many cases the ankle-joint was too rigid after the operation. Two patients had complaints due to dysfunction of the sural nerve. One patient was excluded in the course of the follow-up in view of an "important psychological component".

### Immediate or delayed operative therapy of ankle fractures

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In a group of 92 patients with an isolated ankle fracture seen in 1982–1983, 72 received operative therapy within 24 h, while in the other 20 cases the operation was delayed because the patients presented later than 24 h after the accident and had developed considerable swelling of soft tissues. The two groups were comparable as to age and sex distribution and type of injury (isolated lateral ankle fracture in some 50 percent of the cases).

Exercise-stable osteosynthesis was achieved in 51 of the first group of 72 patients, permitting functional postoperative management. In the delayed operation group this was achieved in only seven cases. As a result, the period in hospital for the delayed operation group significantly exceeded that in the immediate operation group. However, the two groups did not differ in final results.

Functional testing of the ankle immediately before removal of the osteosynthesis material revealed optimal ankle-joint function in 64 of the 72 patients in the immediate operation group and 18 of the 20 patients in the delayed operation group. All fractures consolidated.

*Conclusion:* Delay of operative therapy of an ankle fracture because of late presentation, haematoma

formation, etc.) needs not unfavourably influence the final result, provided complete disappearance of swelling is awaited (on average 5–8 days after the initial injury).

### Internal fixation of fractures of the lateral malleolus via a dorsal approach

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Anatomical reduction and internal fixation of the lateral malleolus are pivotal in the treatment of ankle-joint injuries. However, osteosynthesis may sometimes pose problems, e.g. if there are soft tissue lesions within the field of operation or if the course of the fracture line is such that application of a supporting plate to the lateral aspect does not ensure adequate fixation. In these cases a dorsal approach to the lateral malleolus can be useful. This also applies in the case of re-osteosynthesis after secondary dislocation or non-union.

Ankle fractures involving the lateral malleolus were treated in 194 adult patients in 1983–1984; 104 received operative therapy, and the dorsal approach was used in 10 of these: four men and six women, 17 to 79 years. A Weber B fracture was present in two and a Weber C fracture in eight cases. The dorsal approach was preferred in view of the nature of the soft tissue lesions (4), fracture comminution (2), osteoporosis (2) and re-osteosynthesis (2).

A good result and good consolidation were achieved in all cases. The technique of the dorsal approach is simple. The position of the plate beneath the peroneus tendons did not give rise to complaints and caused no limitation of the passive or active mobility of the ankle-joint.

### Ten years of documented experience in operative therapy of ankle fractures

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Of 358 ankle fractures treated by operation between 1st January 1974 and 1st January 1984, 309 were available for a follow-up after a minimum of 1 year. Weber's fracture classification was used. At follow-up there were 27 type A, 155 type B and 127 type C fractures.

In addition to objective and subjective results, radiographically demonstrable osteoarthritis received special attention. Attempts were made to analyse the factors which play a role in the aetiology of post-traumatic osteoarthritis. One important cause is non-anatomical reduction of the fracture, in which the lateral malleolus plays a prominent role. Insufficient reduction leads to an incongruent ankle-fork, with osteoarthritis as a result.

The presence of a malleolus tertius fragment (Volkmann fragment) was also found to be related to subsequent development of osteoarthritis. The force involved in the injury is presumably of such magnitude, if a tertius fragment is to be produced, that chondral lesions are probably involved as well.

The osteoarthritis generally developed early, i.e. after about 1 year. At follow-up osteoarthritis was found in 40 of the 309 patients: 4 with a Weber A, 18 with a Weber B and 18 with a Weber C fracture. In four cases insufficient stability necessitated re-osteosynthesis (1 with a Weber B and 3 with a Weber C fracture). In two cases an arthrodesis was performed in view of severe osteoarthritis.

Our findings show that anatomical reduction, particularly of the lateral malleolus, is of prognostic significance with regard to the development of post-traumatic osteoarthritis. The results after anatomical reduction are good.

### Conservative therapy of ankle-joint fractures

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In the treatment of ankle-joint fractures an attempt is made to ensure anatomical reduction and exercise-stable fixation by means of osteosynthesis in order to achieve early functional recovery. This technique is believed to prevent subsequent osteoarthritis and the complaints associated with it. A well-known study by Hughes (1979) has shown that, particularly in Weber C fractures, conservative therapy led to poor results in 63.2–77.3 percent of cases, versus only 14.7–38.2 percent poor results after operative therapy. In his study strong emphasis was placed on radiographic changes of the ankle-joint, regardless of whether these gave rise to complaints. A recent study by Lange (1984), however, revealed osteoarthritis of the ankle-joint in some 70 percent of patients 2–9 years after operative therapy of a dislocated fracture.

In this context we examined 68 conservatively treated ankle-joint fractures: 28 Weber A, 23 Weber B and 17 Weber C. Radiographic signs of osteoarthritis were found in 80 percent of the last two groups. In 20 percent of these patients function was moderate to poor, and pain was present. These results warrant the conclusion that the postulate that conservative therapy of ankle-joint fractures is to be regarded as obsolete, is still dubious.

### Diagnosis of fractures of the distal tibial epiphysis

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The distal tibial epiphysis fuses with the tibial shaft within a period of about 18 months between age 11 and 15 years (somewhat later in boys than in girls). The fusion begins centrally, then involves the medial and the posterior part, and finally the anterolateral part. This manner of fusion gives rise to some special fracture types not always readily identifiable on standard roentgenograms.

A juvenile Tillaux fracture (rupture of the anterolateral part of the distal tibial epiphysis through the syndesmosis) is a Salter-Harris type II injury; in McNealy's series of 194 patients it accounted for 14 percent of the total number of fractures involving the epiphysis.

A triplane fracture was first described by this name in 1972, by Lynn; it is a combination of an epiphyseal fracture with physiolysis. Since Cooperman's publication in 1978 we have also recognized this fracture.

Planigraphy reveals the often severe dislocation in the articular surface which sometimes seems less severe in three-quarter projections. CT-scans using the third generation CT-scanner provide an even more detailed image of the fracture.

In the course of 5 years we saw 110 children with ankle-joint fractures. More detailed diagnostic work was required in 10 (planigraphy in 6 and CT-scan in 4 cases). Five triplane fractures were diagnosed, three of which were treated by operation; in addition, two Tillaux fractures were found which likewise required osteosynthesis. Only planigraphy or a CT-scan can make a decision in favour of conservative therapy of a fracture of the distal tibial epiphysis.

## Lesions of the distal tibial epiphysis

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Fractures of the distal tibial epiphysis account for 11–20 percent of all epiphyseal fractures. Sixty children with such fractures were treated during the period 1967–1982: 36 boys and 24 girls, age 12.4 (4–17) years. An Aitkin type I fracture was present in 37 children, a type II in 11 and a type III in only two. The follow-up period was 5.4 (1–13) years.

All Aitkin I fractures except one were treated conservatively, with a plaster bandage for 6–9 weeks. At the follow-up 11 patients still had mild complaints, varying from some loss of function 5–10° in flexion or extension) to a leg length difference of 0.5–1.5 cm as measured on the radiographs. The extremity was shortened in 3 and lengthened in 3 cases. Five patients showed some form of varus or valgus deviation, with a maximum of 15°. We regard these results as moderate. All other patients were in the category "good or excellent".

All Aitkin II and III fractures except one were treated operatively, i.e. by open reduction and internal fixation. Results were excellent. The one patient given conservative therapy developed a varus deformity.

We conclude that Aitkin I fractures of the distal tibial epiphysis can generally be treated conservatively. Open reduction and internal fixation give good results in Aitkin II and III fractures.

## Osteochondral fractures of the talus-roll

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The complaints associated with an osteochondral fracture are not diagnostically specific. Diagnosis requires selective radiography, alone or supplemented by planigraphy. In the acute situation the diagnosis is often missed.

In our series of 25 patients the diagnosis was made more than 2 months after the accident (mean 41 months) in 20 cases. The lesion was anterolateral in 10 and posteromedial in 10 cases. Sixteen fractures were treated operatively, with excision of the loose fragment and forage of the defect and postoperative management in a walking cast up to the knee. *Re-*

*sults:* Freedom from symptoms and resumption of athletic activities in 11 cases; 9 patients still complained during prolonged standing and walking, and could not participate in sports.

The five patients treated immediately were treated by primary fixation using either a screw or absorbable suture material; excision of a loose fragment was necessary in one case. The results were much better than those of delayed therapy. Fixation of the osteochondral fracture using fibrin adhesive is a future development.

Osteochondral fractures are among the serious injuries of the ankle-fork; the possibility should always be borne in mind even in the case of so-called sprains. Delayed therapy gives only very moderate results.

## Pillon fractures

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Unlike ankle-joint fractures, pillon fractures do not result from pronation or supination but from axial forces. The resulting lesion is an intra-articular distal tibial fracture with or without fibular fracture.

After a so-called low-velocity trauma (ski), the localization depends on the position of the foot in the boot. After a high-velocity trauma (traffic), the localization can be lateral or medial, dependent on whether the foot was in abduction or in adduction. The classification of these fractures is based on this localization and is primarily descriptive.

In operative management it is advisable to follow certain guidelines:

- 1) Reconstruction of the fibula, ensuring proper length and thereby alignment of the talar joint;
- 2) Provisional fixation of the joint fragments;
- 3) Filling of the resulting defect with cancellous bone;
- 4) Application of a supporting plate to the medial and sometimes also to the anterior aspect.

In the treatment of open fractures with extensive soft tissue damage it may be useful to use a joint-bridging external fixator temporarily, if necessary combined with internal fixation of the fibula. In that case secondary reconstruction after soft tissue treatment is still possible.

## Fractures of the neck of the talus

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Fractures of the neck of the talus are rare. Fifteen were treated between 1974 and 1982, nine involving a high-energy trauma. Besides forced dorsal flexion, an inversion trauma was anamnestically established in three cases; an ankle-joint fracture was the accompanying injury in three other cases. Ten of the 15 fractures were available for a follow-up. All had been treated by open reduction and fixation with one or more traction screws. Weight-bearing had not been allowed until after fracture consolidation (average 12 weeks).

The follow-up showed that two of the ten patients had developed partial necrosis of the talus. Two showed subtalar osteoarthritis without necrosis. There were no infections or pseudarthroses. Talus fractures carry a high risk of necrosis due to fracture-related devascularization. The Hawkin classification is based on this. In our cases it seemed to have a good prognostic value with regard to the incidence of necrosis. Revascularization from the viable head of the talus is possible only after anatomical reduction and stable osteosynthesis.

## Secondary reconstruction after malunion of ankle-joint fractures

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Conservative or inadequate operative therapy of malleolar fractures above the syndesmosis (Weber C) leads to shortening and external rotation of the fibula, resulting in widening of the ankle-fork and tilting and lateralization of the talus.

Secondary reconstruction is possible even years after the initial injury. In principle, the anatomy has to be restored. The fibula is lengthened and fitted exactly into the incisure. Medial revision and osteotomy of the malleolus tertius or Chaput's tubercle may be required.

A follow-up study was performed on 18 patients, on average three years after the operation. Results were excellent in five, good in three and fair in two cases.

Summarizing, secondary intervention can restore the anatomy but especially improve the statics of the

ankle-joint. An existing osteoarthritis shows no further progression and is generally well tolerated. Alternative interventions such as supramalleolar osteotomy or arthrodesis are still feasible.

## Long-term results of arthrodesis of the talar joint in post-traumatic osteoarthritis

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A follow-up was performed on 18 patients treated with ankle arthrodesis during the period 1968–1983. The techniques used had been a Charnley procedure in 13 cases, an AO procedure in 4 and a Wagner procedure with AO screws in 1 case. The average age at operation was 47 years. The mean follow-up period was 7.5 years. The duration of consolidation averaged 3 months. Complications were: delayed wound healing or pin-tract fistulae in 9 cases, and a tibial fracture in one (leading to non-union).

Function was assessed using Mazur's ankle-grad- ing system. The average score was 65 points out of 90; five patients scored less than 60 points. The age at operation was of no influence. Two patients had resumed work and three had been given lighter work.

*Subjective results.* Eight patients considered themselves better off and were very satisfied, nine remained neutral and one considered himself worse off and was dissatisfied (score 79!). Of the five patients with a poor Mazur score, three were very satisfied, one was satisfied and one remained neutral. Examination revealed varus deformity of the ankle in one and talipes equinus ( $\geq 15^\circ$ ) in three cases. Six patients showed severe osteoarthritis of the subtalar and the transverse tarsal joint (this had been present even before the arthrodesis). Four of these six had a poor Mazur score.

*Conclusion.* The Mazur score was low compared with the literature, probably due to the relatively frequent presence of osteoarthritis of the subtalar and transverse tarsal joints before the operation. This had evidently had an unfavourable effect on ankle-joint function. There was no correlation between Mazur score and patient satisfaction (patient satisfaction and subjective sense of improvement scored very high).

## Arthroscopy of the ankle-joint

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Arthroscopy of the ankle joint was performed in 20 cases: under general anaesthesia in 6 and under local anaesthesia in 14 cases. All patients complained of persistent post-traumatic pain and swelling of the ankle-joint without signs of instability or distinct radiographic lesions.

Arthroscopy revealed the following: corpora libera (5), synovitis (3), chondromalacia and synovitis (8) instability (1) and no pathological finding (1 case). In nine cases the arthroscopic findings changed the diagnosis and led to operative therapy: removal of corpora libera, cleansing or partial synovectomy.

Arthroscopy of the ankle-joint is indicated in the presence of persistent post-traumatic pain when no definite diagnosis can be established by other means.