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(Head: Professor Veikko Laine, M.D.)

Rheumatoid Arthritis in the Pantalar Joints

A Follow-up Study of Triple Arthrodesis
on 292 Adult Feet

VEIJO A. J. VAHVANEN

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I. INTRODUCTION

Research concerning the rheumatoid disease and its treatment has made great advances in the last few years. Interest in these problems has increased everywhere in the world. Rheumatoid arthritis may be said to be a generalized disease causing joint changes which often disable the patient and may require surgical treatment. In the subtalar and midtarsal joints rheumatoid arthritis is of frequent occurrence and often causes radiological changes also. According to VAINIO (1956) such changes are present in these joints in 66.9 per cent of cases. In the literature rheumatoid arthritis has only been mentioned in a few instances as an indication for triple arthrodesis of the foot. No follow-up studies of extensive series have been published.

The need of surgical treatment is reflected in the striking rise in the frequency of operatively treated cases in Finland, too. Since the Hospital of the Rheumatism Foundation, with 317 beds, was opened at Heinola in 1951, the number of operations performed in the Hospital has risen steadily, even abruptly during the last few years, so that the annual number now exceeds 2 000. This is due to the fact that both medical and surgical skill are represented in the same hospital. This kind of team work also offers a better opportunity for research and the development of new methods of treatment.

The purpose of the present study was to offer a contribution to the understanding of the changes occurring in the pantalar joints of the rheumatoid foot, since these joints are the most important from the standpoint of the statics of the foot, and to analyse the effect of arthrodesis on the function of the foot.

II. PROBLEMS

1. *What are the clinical and radiological changes caused by rheumatoid arthritis in the panlalar joints?* How do the clinical and radiological symptoms and signs in the subtalar and talocrural (TC) joints develop in different duration groups of the disease? What changes appear as the initial signs?

2. *What are the practical consequences for the rheumatoid patient of arthrodesis of the subtalar and midlarsal joints (triple arthrodesis)?*

In order to answer this question it was necessary to follow up both operatively and conservatively treated patients. Particular attention was paid to the following points:

The possible, general activation of the rheumatoid process as a result of operation. Changes in the clinical symptoms in both the TC and the subtalar joints. The development of osteoporosis and periosteal reaction in the subtalar area after operation. The relationship between periosteal changes and the rheumatoid process. The development of union and the duration of immobilization. The development of the radiological changes in the talocrural joint after triple arthrodesis. The anatomical results of operation.

3. *Do rheumatoid arthritis or arthrodesis of the subtalar and midlarsal joints cause instability of the talocrural joint?* If instability appears, how does this influence the function of the foot?

4. *Does arthrodesis of the subtalar and midlarsal joints lead to the development of osteoarthritis of the talocrural joint?*

5. *What are the functional results of operative treatment?*

6. *What is the most favourable time for the performance of triple arthrodesis from the standpoint of the development of the disease and the best possible result?*

III. MATERIAL

Triple arthrodesis, including the talocalcaneal, talonavicular and calcaneocuboid joints, was performed on 229 rheumatic patients at the Hospital of the Rheumatism Foundation, Heinola, during the years 1953—1964. In 63 cases this operation was carried out bilaterally. Thus, the total number of feet on which triple arthrodesis was performed was 292. Eighty-one feet belonged to male patients, 211 to female patients. The total number of left feet was 140, while the number of right feet was 152, the distribution being thus very even in this respect. Triple arthrodesis was carried out on female patients almost three times as often as on male patients. The ratio females/males was somewhat higher than the corresponding ratio in rheumatoid arthritis (RA), which is 2/1 according to LAINE (1953).

Furthermore, for the sake of comparison a series of conservatively treated feet was also studied. This consisted of the less inflamed feet, totalling 166, of the above-mentioned 229 patients and of 38 feet belonging to a further 38 patients. The total number of feet in this series was thus 204, and the total number of patients included in the present study was 267.

Both in the text and in the tables the designations Op I and Op II are used for the operatively treated feet. Op I stands for the observations made immediately before operation, Op II for those made postoperatively, at follow-up. Similarly, Non-op I means the observations made on the conservatively treated feet at a point of time corresponding to that at which the observations in group Op I were made, and Non-op II stands for the observations made at follow-up examination of the conservatively treated feet.

The series comprises only patients whose rheumatoid arthritis began after the age of 15. This age limit was adopted because other investigators, e.g. LAAKSONEN (1966) in his doctor's thesis »A Prognostic Study of Juvenile Rheumatoid Arthritis», and SIEVERS (1965), used 15 years as the borderline between juvenile and adult rheumatoid arthritis.

The distribution of the Op I group over different duration groups is shown in Table 1. By duration is meant the time of illness in years from the

TABLE 1. *Distribution of the material according to duration of the disease (= interval in years between the onset of symptoms of RA in the tarsal or ankle joints and operation).*

Sex	Left/ Right	<3	4—6	7—10	>10	No. of feet
Male	L	16	6	11	8	41
	R	13	9	8	10	40
No. of feet		29	15	19	18	81
%		35.8	18.6	23.4	22.2	27.7
Female	L	32	25	15	27	99
	R	40	26	23	23	112
No. of feet		72	51	38	50	211
%		34.1	24.2	18.0	23.7	72.3
Total no.		101	66	57	68	292
%		34.6	22.6	19.5	23.3	100.0

onset of symptoms in the joints of the ankle or foot until operation. Initial symptoms in the joints of the toes are disregarded. The distribution is fairly even, although the first group (3 years) is the largest. This reflects the endeavour to institute treatment in the initial stage of the disease.

The diagnosis of rheumatoid arthritis was based on the criteria introduced by ROPES et al. (1956, 1959), which have been generally adopted and which were accepted by a Committee of the American Rheumatism Association. A diagnosis of «definite rheumatoid arthritis» requires that 5—6 of 11 specified criteria are satisfied, and a diagnosis of «classical rheumatoid arthritis» that 7—8 of these criteria are satisfied. It should be noted, however, that all patients who showed any of the features listed by ROPES as typical of other diseases were excluded.

The present series includes only «definite» and «classical» cases. In the operatively treated series there were 50 diagnoses of definite RA (21.8 per cent) and 179 (78.2 per cent) of classical RA.

The series included 22 wheel-chair patients with severe lesions. In these cases the goal of the operative program was to rehabilitate the patient as far as possible, i.e. to make him ambulatory with the aid of crutches.

The mean duration of hospitalization was 101 days. Treatment of this length was found necessary both for the accomplishment of adequate medical therapy and for the performance of surgical procedures with subsequent rehabilitation. At the time of discharge it was often possible to evaluate the

immediate operative result. Since the patients of the Rheuma Hospital frequently come from distant domiciles, it is sometimes difficult to carry out follow-up studies. Many patients return later, however, because of inflammation of some other joint, and can thus be followed up for years. Of the present patients 150 (65.5 per cent) had been hospitalized more than once.

The mean age of the men at onset of rheumatoid arthritis was 35.9 years, the mean age of the women 33.3 years. The initial symptoms most frequently occurred in the joints of the fingers and toes. In the foot, inflammation was not long in spreading to the ankle and other joints.

The mean age of the men was 37.8 years, that of the women 34.7 years, when the first symptoms of rheumatoid arthritis were noticed in the ankle or in the foot proximal to the toes. The interval between onset of the disease and involvement of the ankle was 1.9 years among the men and 1.4 years among the women.

The mean age of the men at operation was 44.5 years, the mean age of the women 42.4 years. The mean interval between the onset of symptoms in the ankle and operation was 6.7 years among the men and 7.7 years among the women.

IV. METHODS

Previous investigations

The views concerning the range of movement of the TC joint are somewhat conflicting. In the present study a dorsal flexion of over 15 degrees and a plantar flexion of at least 40 degrees were regarded as normal. According to v. LANZ and WACHSMUTH (1938, 1959), the normal total range is 40—50 degrees; according to STEINDLER (1955) it is somewhat wider. This author regarded a dorsal flexion of 15—20 degrees and a plantar flexion of 40—50 degrees as normal. In VAINIO's (1956) control series the dorsal flexion of the ankle was an average of 12.5 degrees in the men, 14.7 degrees in the women, and the corresponding figures for the plantar flexion were 36.1 and 40.6 degrees. NIEDERECKER (1959) stated that the total range of movement may be as much as 100 degrees, but then the knee is semiflexed and the leg muscles are not stretched.

According to NIEDERECKER (1959) and others, the total range of movement of the subtalar joints of the normal foot is about 60 degrees, and supination is always wider than pronation. In VAINIO's (1956) control series this movement was accurately measured, the mean values being 42.3 degrees of supination and 20.0 degrees of pronation for the men, 45.9 degrees of supination and 23.6 degrees of pronation for the women.

In a normal foot bearing weight the maximum size of the angle between the calcaneus and the leg is 5 degrees according to PITZEN (1924) and v. LANZ and WACHSMUTH (1938). In VAINIO's (1956) control group the mean calcaneal valgus angle was 4.6 degrees in the women and 5.4 degrees in the men. According to NIEDERECKER (1959), the maximum size of the calcaneal angle is 6 degrees.

According to SCHEDE (1924), the axes of the first metatarsus, the first cuneiform, the navicular and the talus are on the same straight line in a normal foot. According to NIEDERECKER (1959), the average angle between the longitudinal axis of the talus and the horizontal weight-bearing surface

(the talus-floor angle), measured on radiographs of the normal weight-bearing foot, is 23 degrees. In the flat foot the talus-floor angle was found to average 32 degrees, in congenital cases even more. The head of the talus is depressed (subluxated) in these feet, and the longitudinal axis of the talus becomes steadily more vertical. When this axis no longer coincides with the axes of the other bones located on the medial ray of the foot, there is a break in the line.

A classification from 0 to 4 (stages) was used by STEINBROCKER, TRAEGER and BATTERMAN (1949) in the evaluation of radiological findings. A similar classification from 0 to 4 was used by LAINE (1962) in the evaluation of clinical and radiological findings.

The tilting of the talus on stress radiographs has already been examined by many authors. These studies will be surveyed in another chapter.

SIEVERS' (1965) investigation »The rheumatoid factor in definite rheumatoid arthritis» was used as a basis for the evaluation of the rheumatoid factor in this study.

LAINE and VAINIO (1964) mentioned in their study that a high erythrocyte sedimentation rate (ESR) is no contra-indication to operative procedures, and after operations the ESR dropped to the previous level or below it.

ROPES et al. (1956, 1959) suggested the following criteria for the histological diagnosis of RA on the basis of synovial specimens: 1. Marked villous hypertrophy. 2. Proliferation of superficial synovial cells, often with palisading. 3. Marked infiltration of chronic inflammatory cells (lymphocytes or plasma cells predominating) with a tendency to form »lymphoid nodules». 4. Deposition of compact fibrin either on surface or interstitially. 5. Foci of cell necrosis.

According to Ropes, at least three of these criteria have to be satisfied to justify a patho-anatomical diagnosis of »typical rheumatoid arthritis».

Present investigation

Data concerning the present patients were obtained from the following sources:

- 1) Hospital records and patients' charts from outpatient departments,
- 2) radiographs, 3) laboratory examinations, 4) patho-anatomical examinations, 5) operative findings, 6) photographs, 7) replies to questionnaires, and 8) follow-up examinations.

In the present study all changes including deformities and X-ray findings were classified under stages 0—4.

Evaluation of the clinical observations

Pain. Stage 0: No pain at rest. Stage 1: Slight pain occasionally after motion, or the patient was uncertain on this point. Stage 2: Definite, moderate pain, occurring intermittently at rest. Stage 3: Marked pain. Stage 4: Violent, almost continuous pain.

Swelling of the ankle and the soft tissues of the foot was evaluated by inspection and palpation. Stage 0: No swelling observed. Stage 1: Slight swelling or uncertain finding. Stage 2: Moderate swelling. Stage 3: Marked swelling. Stage 4: Excessive swelling.

Pain on motion and weight-bearing in the TC and subtalar joints. This symptom was studied during passive and active movement of the joints, by palpation, and by recording the patient's reactions to walking. Stage 0: No pain. Stage 1: Diffuse pain on walking and slight tenderness on palpation. Stage 2: Moderate pain on palpation, motion and weight-bearing. Stage 3: Marked pain on motion and weight-bearing; a definite limp. Stage 4: Very marked pain; walking without support or without a considerable limp impossible.

Range of motion of the TC and subtalar joints. As regards the TC joint, this implies movement as measured to the nearest degree, dorsal and plantar flexion separately. The measurements were performed when the knee was maximally stretched. Then the movement occurs in a plane perpendicular to the longitudinal axis of the leg, 90 degrees being the zero from which the range of movement is measured in both the dorsal and plantar directions. No pronation or supination was allowed. During measurement, the leg and sole of the foot were gently supported. The measurement was performed from the lateral aspect of the ankle. The evaluation of dorsal flexion was as follows: Stage 0: Over 15 degrees. Stage 1: 10—15 degrees. Stage 2: 5—9 degrees. Stage 3: 1—4 degrees. Stage 4: No movement. Plantar flexion: Stage 0: 40 degrees or more. Stage 1: 30—39 degrees. Stage 2: 20—29 degrees. Stage 3: 1—19 degrees. Stage 4: No movement.

Movement of the subtalar joints in this study means the combined active movement, supination and pronation, of the talocalcaneal joint and Chopart's joint. The performance of this movement proved to be difficult for many patients, however, and could sometimes only be accomplished with the assistance of the examiner, who helped by gently moving the foot with one hand, supporting the leg above the ankle with the other.

Pronation and supination of the foot were measured in the plantigrade plane with a square rule. The knee was kept in maximal extension, and the

talocrural joint was kept at right angles, or in the position in which it was ankylosed. At follow-up examination the subtalar movements were measured by the author.

The subtalar movements were evaluated as follows: Stage 0: No limitation. Stage 1: Uncertain finding or a limitation of up to one third of the normal range (about 60 degrees being regarded as the normal). Stage 2: Limitation up to two thirds. Stage 3: Limitation up to three thirds, the foot being then rigid. Stage 4: No movement.

Deformity was evaluated as follows: Stage 0: No deformity observable on clinical examination. Stage 1: Uncertain finding or slight deformity. Stage 2: Moderate deformity. Stage 3: Severe deformity. Stage 4: Extreme deformity.

Calcaneovalgus up to 5 degrees (physiological) was classified as stage 0, valgus of 6—10 degrees as stage 1, 11—15 degrees as stage 2, 16—20 degrees as stage 3, and valgus over 20 degrees as stage 4. The measurements were made with an inclination meter, constructed by the author, of the same type as was used by VAINIO (1956) for similar measurements. The results were corrected taking into account the angulation of the calcaneus in relation to a vertical line drawn from the middle point of the fossa poplitea downwards.

The degree of valgus position of the calcaneus was measured by determining the angle made by the lateral surface of the calcaneus with the vertical plane, when the patient was standing on the floor or another hard surface.

The degree of *calcaneal varus* position follows from the above-mentioned measurements. When the valgus position is physiological, varus is = 0. Stage 1, according to the evaluation used in the present study, means that the angle is almost zero. Stage 2 = an inward angulation of the lateral surface of the calcaneus of 1—5 degrees, stage 3 = 6—10 degrees, and stage 4 = over 10 degrees. The measurements were made to the nearest degree. When a patient shows varus of the forefoot, he is unable to walk on the full sole of the foot; he keeps the inner border more or less elevated. The metatarsus primus is often elevated. Sometimes callosities are present laterally on the sole of the foot. Varus of the forefoot was not measured in degrees, the severity of the deformity was estimated, as it was in the few cases of cavus-calcaneus that occurred.

At follow-up examination attention was, moreover, paid to the stability of the talocrural joint. The patient's ankle was placed in 90 degrees angulation and the knee in semiflexion, the leg proximal to the ankle was firmly held by the left hand of the examiner, while the posterior portion of the sole of the foot was supported with his right hand. Then

the examiner tried to move the foot from side to side at the ankle. In a normal foot there is no lateral movement in the mortise of the TC joint under these conditions, but during the tests a slight but definite «click» was often heard and felt in the ankle, as if two wooden blocks had knocked against each other. This never caused the patient any pain, nor did it seem to affect his walk. Furthermore, during the examination the calcaneus was turned inward and outward, with the ankle first in 90 degrees angulation and then in plantar flexion. Sometimes abnormal mobility was observed. For this reason as many ankles as possible were radiographed under stress.

Radiological investigations

The following views were taken:

1) An anteroposterior view and 2) a lateral view of the foot also showing the talocrural joint. This view was always taken with the patient standing with weight evenly distributed between the feet. 3) Anteroposterior views of both talocrural joints were taken simultaneously on the same film with the patient lying on his back on the examination table. 4) For the purpose of determining instability of the talocrural joint, radiographs were taken while the ankles were subjected to stress. These studies were in all cases carried out by the author.

Furthermore, during hospitalization radiographs of the chest and hands were taken in almost all cases.

Special radiological investigations of ankles subjected to stress were performed by the author. The procedure was as follows: The patient lay on his back on the examination table with each leg in turn fixed to a wooden device by means of four strong screws furnished with broad end plates, as shown in Plate 1. The end plates, which were pressed against the skin, were padded with superlon. The two proximal screws were firmly tightened against the distal portion of the leg on both sides, so as to prevent lateral movement of the leg. The distal screws, applied against the lateral and medial aspects of the calcaneus, were tightened in turn. Thus the calcaneus and talus were inverted and everted, respectively, and when the maximum was reached, radiographs were taken in the anteroposterior projection. For the sake of uniformity the same exposure values were used as when ordinary anteroposterior views of the ankles were taken. The supporting device was fixed to the table by two strong straps which prevented it, and at the same time the leg, from moving. During exposure the ankle was positioned at 90—100 degrees. The distal strap was placed on the plantar side of the foot, so as

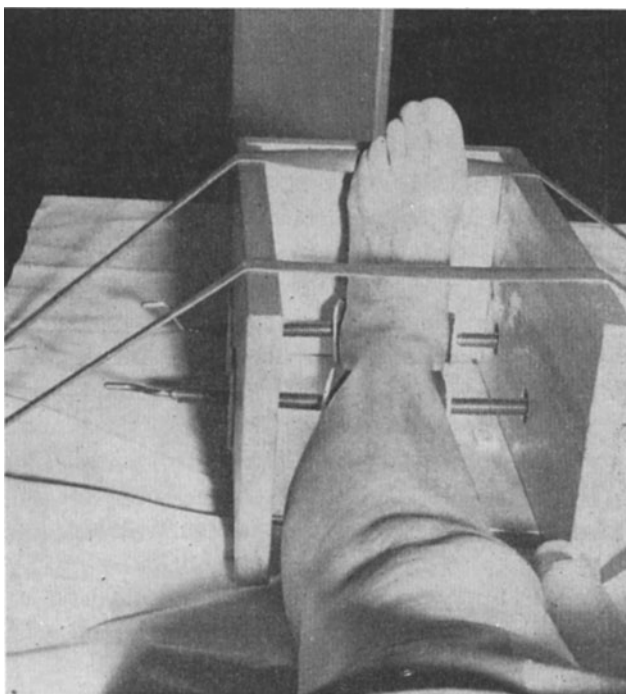


Plate 1. Wooden case lacking front and top parts and furnished with screws, between which the foot was fixed on stress examination. The case was firmly strapped to the X-ray examination table.

to prevent the ankle from bending into plantar flexion. The inverting and everting effect obtained with the screws is very strong, and exposures were made when they were tightened as much as the patient could tolerate for a moment. An endeavour was made to apply maximum tightening in all cases. The studies were throughout performed without anaesthesia, and the ankles were investigated in turn. If the ordinary X-ray examination revealed union of the talocrural joint after arthrodesis, no stress study was performed. A radiological stress examination was, moreover, carried out with the ankles in maximal plantar flexion (64 ankles).

In addition, anteroposterior instability of the talocrural joint was investigated. The patient was positioned in lateral recumbency, on the side to be studied, with the knee in slight flexion and the X-ray cassette under the ankle. The other leg was bent away from the exposure field. The examiner took a firm grip of the distal part of the leg under study, with one

hand above the ankle, and with the other hand round the heel, pushing it as forcibly as possible forwards, trying to luxate the talus in the anterior direction. Both ankles were thus examined in turn without anaesthesia. Care was taken not to rotate the ankle, nor to invert or evert it; the ankle joint was in slight plantar flexion. Just as in the examinations described above, care was taken not to injure the foot. The same exposure values were used as in the lateral projection. The examination here described was performed on 53 ankles on which triple arthrodesis had been performed and on 68 ankles which had not been operated upon.

In order to test the methods of investigation, corresponding radiological stress examinations were carried out on completely normal subjects. Furthermore, ordinary anteroposterior and lateral views were taken of normal ankles. This control series consisted of members of the hospital staff who had no diseases or lesions of the joints. The control material consisted of 60 ankles.

It was also found that the radiographs taken of the ankle in different positions (stress examination) were helpful in evaluating erosion. By the aid of these it was possible to confirm findings which would have remained uncertain on the basis of ordinary anteroposterior and lateral views alone.

Evaluation of the radiographs

Attention was paid to the following features: 1) decrease in calcium content, 2) narrowing of the joint space, 3) erosion, 4) periosteal reactions, 5) osteoarthritis, 6) alignment changes, 7) instability of the ankle joint as estimated from the tilting of the talus during stress examination, 8) fusion.

Each feature was evaluated as follows: Stage 0 = no change; stage 1 = slight, uncertain change; stage 2 = definite change; stage 3 = marked change; stage 4 = very marked change.

1) *Osteoporosis*. The observations were compared with the corresponding findings in the other foot and with previous radiographs of the same foot.

2) *Joint spaces* of the talocrural joints were measured on the anteroposterior view to the nearest 0.1 mm using a nonius. The measurements were always performed at the middle point of the joint. In addition, the symmetry of the joint spaces on the lateral view was taken into account. Narrowing was classified as stage 2 only when the joint space was clearly diminished in both projections. Stage 3 indicates a practically rigid joint, or incipient fibrotic ankylosis, with a joint space only just distinguishable. On evaluat-

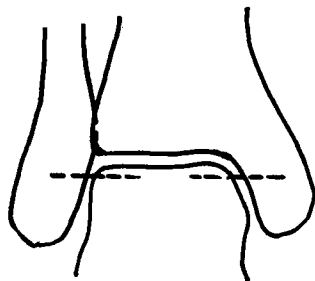


Fig. 1. The mortise of the talocrural joint. The area above the dotted line is the midpart of the joint; the lower part of the mortise consists of a medial and a lateral part. Erosion in the midpart of the joint is described as «surface» erosion, in the lower part of the mortise as «marginal» (medial or lateral) erosion.

ing the change, the joint was always compared with the corresponding contralateral joint and with the state on previous radiographs. The joints of the foot were studied on lateral views. When evaluating the talonavicular joint, attention was also paid to the cuneonavicular joint. As this is more distal, the space is not in any event broader than that of the talonavicular joint.

3) Erosion. A fresh area of erosion is always very well demarcated on radiographs. Later, however, it may become less distinct, and the joint surface may assume a rough appearance owing to the accumulation of calcium and/or hypertrophy (SOILA 1958). The distinguishing of erosion at the border between the articular cartilage and the cortical bone and/or in the bone surface may be rendered still more difficult by the occurrence of a periosteal reaction, which may cause marked unevenness, cyst-like formations and hypertrophy.

The evaluation of erosion was made as follows in respect to the different joints:

In the *talocrural joint* the erosive and periosteal changes were separately evaluated in three different areas of the joint, i.e. 1) in the midpart of the joint (surface erosion), 2) in the medial part of the mortise, and 3) in the lateral part of the mortise. When surface erosion occurs in the TC joint, it involves the horizontal joint surface, including the two angles of the TC mortise. In the present study the medial malleolus and the opposing medial part of the talus are regarded as belonging to the medial part of the mortise, the lateral malleolus and the opposing lateral part of the talus as belonging to the lateral part of the mortise (Fig. 1).

The erosive changes were classified as follows: Stage 0 = No changes observable; the surface was smooth, even if osteoporosis was present. Stage 1 = The surface corresponding to the articular cartilage or the surface of the marginal zones was clearly rough, although definite, typical erosion was not yet discernible; in the distal parts of the malleoli small cystic formations were sometimes seen. Stage 2 = Definite erosion, more abundant cystic formations in the malleolar surface. Stage 3 = Deep, extensive erosion in a limited area, or many small areas of slight erosion; the outline of the distal apices of the malleoli was blurred; a considerable degree of osteolysis was sometimes present. Stage 4 = Marked erosion, destruction, or large cystic spaces.

Erosion of the talocalcaneal, calcaneocuboid and talonavicular joints was classified as follows: Stage 0 = No changes, the joint surface was smooth. Stage 1 = Uncertain finding, unevennesses possibly present. Stage 2 = Slight, but definite erosion. Stage 3 = A limited area showing marked erosion, or several small areas of erosion. Stage 4 = Marked destruction.

4. **Periosteal reaction** in this paper means reactive changes of the periosteum either at the margins of the joint and/or for some distance along the bony surface.

The periosteum may form sharp spicules, projecting upwards or downwards from the margins of the joint, or it may show hypertrophy or even cauliflower-like formations. These may later become sclerotic owing to the accumulation of calcium.

The periosteal changes characterized by roughness of the surface were classified as follows: Stage 0 = No changes, with the exception of osteoporosis. Stage 1 = Slight roughness of the surface. Stage 2 = Clearly elevated osteophytes, moderate roughness of the surface, definite periosteal growth. Stage 3 = Marked periosteal changes; marked, active reaction. Stage 4 = Very marked reactive changes.

When the posterior process of the talus was clearly enlarged, this was noted as a periosteal change of the tc joint. This lesion may restrict the movement of the talocrural joint.

5. **Osteoarthritis**. It was difficult to classify the findings by different stages. Just as in the case of osteoporosis, the evaluation was greatly hampered by technical differences between the radiographs taken at different times. When the accumulation of calcium had clearly increased and sclerosis was present, the change was discernible. Slight changes could not be distinguished with certainty.

The osteoarthrotic changes were also classified by stages 0—4, stage 1 standing for an uncertain finding and stage 2 for a definite finding.

6. **Alignment changes.** When the ligaments and joints of the foot are damaged by RA, weight-bearing gradually leads to structural changes and deformities. These appear on radiographs taken in lateral projection during weight-bearing as lowering of the arch of the foot. The position of the bones in relation to each other is altered. In the present investigation the changes in the longitudinal axis of the calcaneus and talus were studied on all lateral views. The angle between the longitudinal axis of the talus and the weight-bearing plane (the horizontal plane) was measured to the nearest degree.

7. **Tilting of the talus.** In the present study the tilting of the surface of the talus in relation to the articular surface of the tibia was measured to the nearest degree. The tilting of a straight line, passing the two tuberculi of the talus, against a line passing the depressions of the tibial articular surface, which correspond to the tuberculi of the talus, was measured with a protractor.

The results were classified by stages 0—4 as follows: Stage 0 = No change or a change of less than 1 degree. Stage 1 = Talar tilt of 1—5 degrees. Stage 2 = Talar tilt of 6—10 degrees. Stage 3 = Talar tilt of 11—15 degrees. Stage 4 = Talar tilt of over 15 degrees.

When lateral views were taken during the radiological stress examination, an attempt was made to luxate the talus forward by pressing the calcaneus backward. Subluxation would be indicative of insufficiency in the ligaments. The radiographs showed whether the symmetry of the articular surfaces of the talus and tibia was disturbed by the stress. A shift in position of the talus was evaluated by comparing the location of constant points on the talus and tibia. Both ankles were always radiographed, and the radiographs were compared. The result was regarded as positive only when the talus was clearly dislocated forward and the articular surfaces showed lack of symmetry. The distal tibiofibular syndesmosis was studied on anteroposterior views of the ankle. It had clearly broadened in only two cases, but these ankles were clinically stable, and the tissues showed cicatrices resulting from protracted disease. On follow-up investigation the location of the staple and the possible changes occurring in the surrounding bone were closely studied on the radiographs.

8. **Fusion.** The following joints were examined from the standpoint of fusion: the talocrural, talocalcaneal, calcaneocuboidal, talonavicular and cuneonavicular joints.

The joint was regarded as completely fused when no joint space was discernible, the bone trabeculae having grown homogeneously across the

site of the space. When part of the articular surface was visible and the trabeculae had grown over the joint space only in certain areas, the joint was regarded as showing partial union. When the joint was clearly open in spite of operation, the term »non-union» is used, and when movement was observed, the term »pseudarthrosis» is applied.

Laboratory findings

From the standpoint of the present study the most interesting features were the occurrence of the rheumatoid factor and the behaviour of the erythrocyte sedimentation rate in the patients operated upon. The Hgb, the postoperative temperature, the results of physical examination (e.g. height and weight, which may be of significance for the evaluation of the operative results) were also recorded, however.

Special attention was paid to the Waaler-Rose and the latex fixation tests.

In the present study the serological tests for the rheumatoid factor were of importance mainly for the reason that a positive result is one of the criteria listed by the Committee of the American Rheumatism Association. Rheumatoid factor was regarded as being present if the reaction to the latex fixation test was clearly positive or/and the Waaler-Rose titre was elevated at least in a dilution of 128. If Waaler-Rose was positive in a dilution of 500, the disease was regarded as very active from the serological standpoint. In 180 cases (85.2 per cent of 211 examined patients) the reaction to the latex fixation test or Waaler-Rose was significantly positive.

Histological criteria

The present material of histological specimens was examined by RITAMA, Helsinki. Synovial specimens were taken from 142 (48.6 per cent) of the 292 feet on which triple arthrodesis was performed.

The following criteria were applied by RITAMA: 1. The occurrence of characteristic vasculitis. 2. Infiltration of plasma cells and lymphocytes with a tendency to form folliculoid foci without a germinal centre. 3. Proliferative activity, often with palisading of the marginal synovial cells. 4. Occurrence of necrosis.

According to RITAMA, a histological specimen from some part of an inflamed joint, particularly the talocrural joint may even be normal in appearance. In any event, the degree of inflammation varies in different areas of

the same specimen. Hence the evaluation must be based on the total appearance of the specimen. In chronic cases the diagnosis offers greater difficulties. Typical round cell infiltration may be lacking in cases of old standing, but proliferative cellular activity and tissue necrosis may also occur in chronic cases. The intermittent character of the disease is reflected in the histological picture.

Statistical methods

The results have chiefly been expressed as arithmetical means and percentages. In connection with certain means, the standard errors have also been indicated.

In testing the statistical significance of the results the levels .05 (significant), .01 (most significant), and .001 (highly significant) were used. When possible, one-tailed tests of significance were applied, otherwise two-tailed tests.

On comparing the various groups obtained by classifying the material according to the duration of the disease, the significance of the differences between the means was tested using the one-way variance analysis (FERGUSON 1966, p. 289—291). The significance of the trend reflecting the development of the disease was also tested by variance analysis, applying linear trend analysis (FERGUSON 1966, p. 343—345). As regards the results of these tests, the number of the degrees of freedom, the F value and the corresponding level of significance are mentioned in the text. On account of their skew distribution certain variables were analysed by the non-parametric equivalents of the parametric methods mentioned above. Instead of parametric variance analysis, the variance analysis of KRUSKAL and WALLIS, based on ordinal numbers, was applied (FERGUSON 1966, p. 362—363). This means that the significance of the results was determined by means of the χ^2 distribution. The χ^2 value obtained and the corresponding level of significance are indicated in the text. As an equivalent of linear trend analysis, the non-parametric trend analysis suggested by Ferguson (FERGUSON 1966, p. 366—367) was applied. The significance of the result was then evaluated on the basis of the normal distribution, and in the text the z value referring to the normal distribution and the corresponding level of significance are indicated.

The significance of the difference between the results of two different determinations performed by one and the same person was tested by the t test of dependent groups (FERGUSON 1966, p. 169—171). The t value and the corresponding level of significance are mentioned in the text.

Owing to the skew distribution of the variables in question, the significance of the difference between the mean values obtained in different groups was tested by the U test of MANN and WHITNEY, which is based on ordinal numbers (FERGUSON 1966, p. 358—360). The significance of the result was evaluated on the basis of the normal distribution. The z value and the corresponding level of significance are indicated in the text.

V. PREOPERATIVE CLINICAL FINDINGS

Previous investigations

Swelling, pain and range of motion. Tenderness of the inflamed joints, pain at rest, pain on motion, and swelling of the soft tissues are very typical symptoms and signs of rheumatoid arthritis, as has been observed by many authors, e.g. LAINE (1953, 1956, 1962), COPEMAN (1955), ROPES et al. (1956, 1959), COBB et al. (1957, 1960), ANSELL and BYWATERS (1959), KUHN (1960), BERKOWITZ et al. (1961), HOLLANDER et al. (1961), KELLGREN (1962). These symptoms are also among the criteria for the diagnosis of rheumatoid arthritis adopted by the American Rheumatism Association (1956, 1959).

ISEMEIN and FOURNIER (1952, 1963) pointed out that evolution of the rheumatoid process leads to ankylosis which is complete when the two bones fuse.

VAINIO (1956) established that dorsal and plantar flexion of the ankle as well as subtalar motion (inversion and eversion) were clearly reduced in both men and women with increasing duration of RA. Of the pantalar joints, the talonavicular joint was most often affected, but ankylosis was found to be a late change. SOILA (1958) also stated that bony ankylosis is a late change, and he found, moreover, that the talocrural and talocalcaneal joints were very resistant to ossification.

Deformities. As was stated by VAINIO (1956), the most frequent deformities of the foot caused by rheumatoid arthritis are: 1) Pes planovalgus. 2) Pes varus, i.e. varus deformity of the hindfoot (the calcaneus) or varus of the forefoot. These features may occur in the same foot, varus position of the forefoot being associated with pes planovalgus. 3) Pes equinus, either in the form of a pure equinus deformity or associated with a varus-valgus component. 4) Pes cavus or calcaneus, which may be associated with varus or valgus. 5) Flail foot, which is of common occurrence in juvenile rheumatoid arthritis.

HARALDSSON (1962), in a follow-up investigation of operatively treated planovalgus feet in children, utilized NIEDERECKER's observations in evaluating the depression of the medial arch of the foot.

FORESTIER (1963) stated that valgus deformity may develop at a very early stage, and that it may be due to spasm of the peroneus muscles caused by the inflammation.

ISEMEIN and FOURNIER (1963) also found that downward displacement of the talus was very common in RA, and that the foot sometimes became flat as a result.

Present investigation

The subtalar joints

Swelling

The degree of swelling is dependent on the activity of the disease and weight-bearing. Furthermore, the occurrence of swelling is influenced by circulatory factors. Rheumatoid patients, however, also show a persistent swelling due to periarticular soft tissue thickening caused by the inflammation. During the active stage of the disease abundant formation of intercellular and intra-articular fluid may occur. The soft tissue thickening caused by RA is encountered round the TC joint of the ankle, round the malleoli along the tendons, and in the area of the tarsal sinus. Swelling of the tarsal sinus is a very typical feature. Furthermore, soft tissue thickening also occurs round the anterior tibial, peroneal and Achilles tendons. The area of the tendons located behind the medial malleoli is also frequently swollen (Figs. 2, 3, 4).

Even after the inflammation has subsided, swelling observable by inspection often remains in these typical sites. The synovial mass in the joints prolapses in the direction where the joint capsules and articular ligaments best give way, i.e. to the lateral side of the joint. In addition to soft tissue thickening, tenosynovitis and the hyperplastic synovial tissues prolapsing from the joints affect the configuration of the surface. In chronic cases deformation of the joints and osteoarthritis also cause swelling after stress. In the present series of operatively treated feet swelling was observed in all cases. In 287 feet (98.3 per cent) the swelling was moderate or marked, while in five feet slight thickening was seen on the lateral side of the ankle, in the area of the tarsal sinus. In these cases the inflammation had become chronic and caused slight changes in the ankle joints. As may be seen in

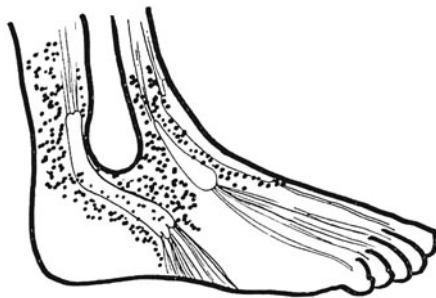


Fig. 2.



Fig. 3.

Fig. 2. The lateral aspect of the foot. The most marked swelling occurs round the lateral malleolus, particularly anteriorly, underneath and posteriorly, and round the peroneal and Achilles tendons. Marked swelling also occurs in the area of the tarsal sinus. The tendon sheaths are thickened.

Fig. 3. Medial aspect of the foot. As a rule swelling is less than in the lateral aspect, but when it occurs it is typically located round the malleolus and follows the tendons in particular.

Fig. 4. Anteroposterior aspect of the foot. Swelling is most marked round the malleoli and adjacent tendons.

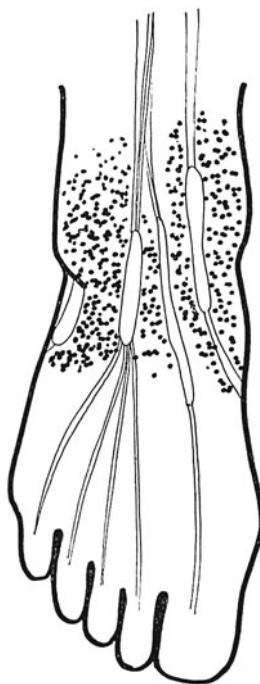


Fig. 4.

TABLE 2. *Swelling, pain on motion and total range of movement preoperatively in the subtalar joints in the different duration groups.*

Duration groups (years)	No. of feet	Swelling Stages					Pain on motion Stages					Total range of movement Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	101	0	0	34	66	1	0	0	6	49	46	0	6	37	58	0
	%	—	—	33.7	65.3	1.0	—	—	6.1	48.5	45.4	—	6.1	36.5	57.4	—
4-6	66	0	0	21	44	1	0	1	2	28	35	0	3	17	45	1
	%	—	—	31.8	66.7	1.5	—	1.5	3.0	42.5	53.0	—	4.5	25.8	68.2	1.5
7-10	57	0	0	22	34	1	0	0	3	34	20	0	1	12	44	0
	%	—	—	38.5	59.7	1.8	—	—	5.2	59.7	35.1	—	1.8	27.1	77.1	—
>10	68	0	5	28	34	1	2	1	5	33	27	0	0	18	49	1
	%	—	7.2	41.1	50.2	1.5	3.0	1.5	7.2	48.5	39.8	—	—	26.5	72.0	1.5
Total	292	0	5	105	178	4	2	2	16	144	128	0	10	84	196	2
	%	—	1.7	35.9	61.0	1.4	0.7	0.7	5.5	49.3	43.8	—	3.4	28.8	67.1	0.7

Table 2, these five chronic cases belonged to the over 10 years' duration group.

Pain on motion and tenderness

Tenderness and pain vary with the intensity of the disease. In the active stage, the inflammation may cause pain even at rest, but as a rule this is not very acute. In the present series of feet on which triple arthrodesis was to be performed (292), moderate or marked pain at rest was experienced in 182 (62.3 per cent), according to the patients' statements. In the remaining cases the patients indicated that they experienced no pain at rest. Walking was associated with marked pain in 144 feet (49.3 per cent), in which moderate pain occurred on motion even without weight-bearing. Very marked pain on motion without weight-bearing was present in 128 feet (43.8 per cent). In these the pain associated with weight-bearing was so acute that walking, especially outdoors, was impossible without the aid of sticks. In 16 feet only (5.5 per cent) was the pain on motion and weight-bearing moderate. In four cases (1.4 per cent) the statement regarding pain was uncertain. In these four cases no movement, or very slight movement, was observed in the subtalar joint. In Table 2 pain is correlated with the duration of the disease. The duration was over ten years in three of these four cases, and over three years in one.

Pain was a salient feature in all duration groups. In the last two groups, however, a decrease in pain was noticeable in the severest stage (stage 4). This phenomenon is obviously due to destruction of the cartilage and to ankylosis of the joints, corresponding to a marked decrease in the range of motion in stages 2 and 3 in the last duration group, as may be seen in Table 2. Pain on motion was a prominent feature even in the first duration group, all feet belonging to this group being painful.

Range of motion

Rheumatoid arthritis leads to a reduction in the range of motion of the joints, which initially is due to the swelling and to avoidance of movement because of the pain. Later, changes in the joint surface, narrowing of the joint space, erosions and loss of cartilage gradually result in ankylosis. In the present study a definite decrease of inversion — supination and eversion — pronation (total motion) of the ankle was observed in 282 feet (96.6 per cent). Thus, there were only 10 feet (3.4 per cent) in which a decrease in the range of motion was not observed with certainty, or no clear statement to

this effect was found in the hospital records. In 84 cases (28.8 per cent) the range of motion was moderate, and in 198 cases (67.8 per cent) lateral motion was greatly reduced (the foot being rigid) or did not occur.

Table 2 discloses a gradual decrease in the range of motion with increasing duration of the disease: the range became slighter after six years. This is due to the development of fibrous ankylosis. Entirely immobile, ankylotic subtalar joints were observed in only two cases, which shows that the progression toward bony ankylosis is very slow. As long as the power of movement is preserved, the foot is painful on weight-bearing.

Deformities

The distribution of preoperative deformities in the present series of 292 operatively treated feet is shown below.

Deformity	Stages 0—1		Stages 2—4	
	No. of feet	%	No. of feet	%
Planovalgus (flat-foot)	37	12.6	255	87.4
Calcaneovarus	265	90.8	27	9.2
Varus of the forefoot	235	80.6	57	19.4
Cavus or calcaneocavus	272	93.1	20	6.9

Varus deformities were associated with planus and cavus. Varus of the forefoot was most frequently associated with pes planovalgus. The various deformities were combined as follows:

Planovalgus (in 37 feet combined with varus of the forefoot)	255 feet	87.4 %
Calcaneovarus (in 20 feet combined with varus of the forefoot and in 10 feet combined with pes calcaneocavus)	27 feet	9.2 %
Cavus, calcaneocavus	10 feet	3.4 %
Total	292 feet	100.0 %

All planovalgus feet of course showed depression of the longitudinal arch of the foot. In 35 feet (12.0 per cent) the arch of the foot was completely depressed, flat-foot being present. In certain cases the depression of the talus was so marked that the region of the Chopart joint was the lowest point of the foot, the first to touch the ground, the fore- and hindparts being elevated. This is called a »rocker-bottom foot». Ninety-three feet (31.8 per cent) showed severe planovalgus, the sole of the foot being rather like a board.

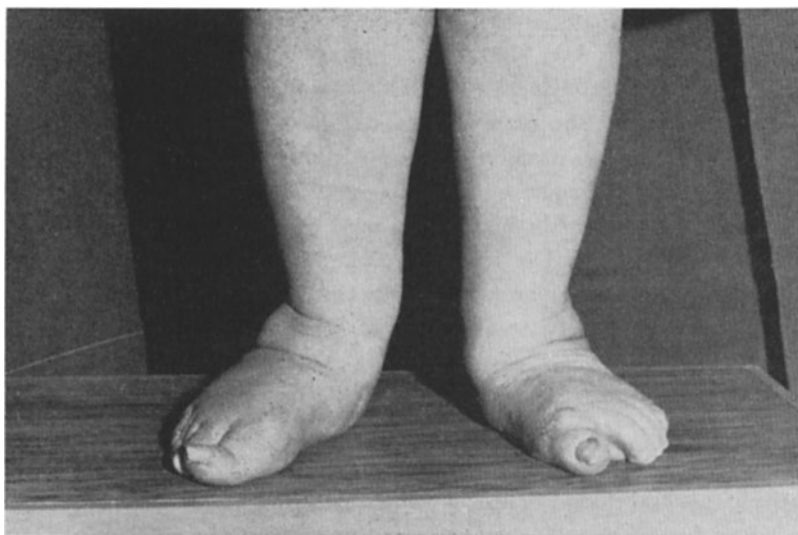


Plate 2. Feet of a rheumatic patient showing extreme planovalgus. Anterior view.

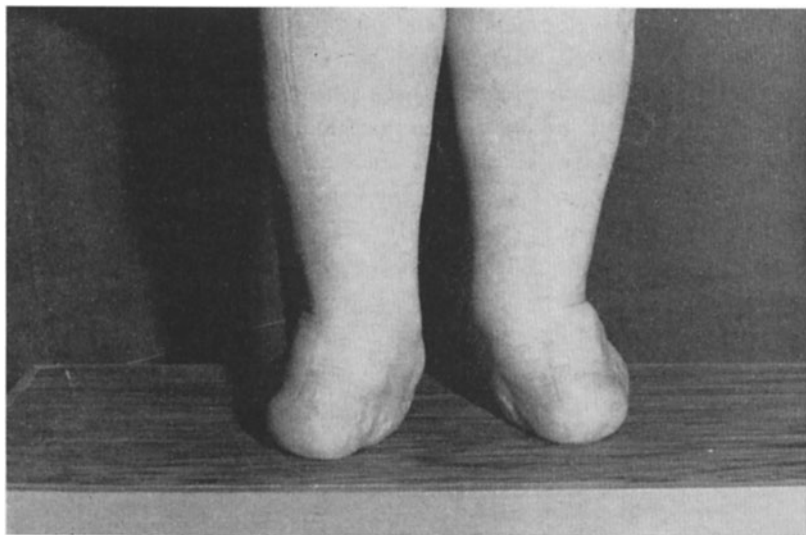


Plate 3. Posterior view of the same feet as in plate 2.

In 127 feet (43.6 per cent) the deformity was moderate, definite depression of the arch of the foot being observed. In 29 cases (9.9 per cent) no definite depression of the arch of the foot was observed, or it was very slight, and 8

feet (2.7 per cent) appeared to be normal also on weight-bearing (Table 4).

In the varus feet, too, slight or moderate depression always occurred, except in 10 feet exhibiting cavus. The present series clearly shows that planovalgus is by far the most typical deformity of the RA foot. Bending of the forefoot into an obvious varus position was of frequent occurrence, being encountered in almost every fifth case. This phenomenon is an essential feature associated with the development of planovalgus.

In the present study the talus-floor angle was measured on the lateral radiographs of 227 weight-bearing feet in the operatively treated series and 170 in the conservatively treated series. In the former, the angle varied from 15 to 64 degrees, the mean being 30.6 degrees. The talus-floor angle of the other, healthier foot varied from 12 to 48 degrees, the mean being 28.0 degrees (Table 3). According to NIEDERECKER (1959) the corresponding mean value in normal feet is 23 degrees. In the present, small control group of entirely normal feet the mean talus-floor angle was 21.5 degrees (the range being from 15 to 25 degrees). In this respect the difference between the feet which were to be operated upon and the contralateral feet was very slight.

In Table 4 the development of the planovalgus deformity is correlated with the duration of the disease. It appears that planovalgus is an early change, developing within the first three years of the illness. Then the deformity becomes rigid, no further major changes being possible. Only in the most advanced stage (stage 4) is there any steady impairment of the deformity (rocker-bottom foot) with increased duration of the disease. In Table 6 this relationship is statistically analysed. The differences between the values in the various duration groups were insignificant, which shows that only slight changes occurred during the course of the disease. *The deformity developed within three years from the onset of RA.*

The varus and cavus deformities seemed to follow similar patterns of development, no marked differences being observable between the different duration groups (Table 5). As the number of cases was small, the statistical significance was not tested.

TABLE 3. *Talus — floor angle (on weight-bearing).*

Group	No. of feet	Range	Mean value
Op I	227	15°—64°	30.6°
Non-op I	170	12°—48°	28.0°
Controls	36	15°—25°	21.5°

TABLE 5. *The distribution of varus and cavus deformities (stages 2—4) over the different duration groups.*

Deformity	No. of cases	0—3 yrs.	4—6 yrs.	7—10 yrs.	>10 yrs.
Calcaneovarus	27	8	6	4	9
Varus of the forefoot	57	17	15	11	14
Cavus, calcaneocavus	20	8	4	4	4

TABLE 6. *Preoperative distribution of planovalgus in the different duration groups. Analysis of statistical significance.*

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	4.04	3	1.35	2.11	insignificant
Linear	1.95	1	1.95	3.05	»
Deviation	2.09	2	1.05	1.64	»
Within	182.93	288	0.64		
Total	186.97	291			

$$M_1 = 2.47 \quad M_2 = 2.33 \quad M_3 = 2.49 \quad M_4 = 2.68$$

TABLE 7. *Deformities in the conservatively treated feet (group Non-op I, total no. of feet 204).*

Deformity	Stages 0—1		Stages 2—4	
	No. of feet	%	No. of feet	%
Planovalgus (flat-foot)	41	20.1	163	79.9
Calcaneovarus	194	95.1	10	4.9
Varus of the forefoot	190	93.1	14	6.9
Cavus, calcaneocavus	197	96.6	7	3.4

TABLE 8. *The distribution of combined deformities in 204 conservatively treated feet (group Non-op I).*

Planovalgus (in 9 cases combined with varus of the forefoot)	163 feet	79.9 %
Calcaneovarus (in 5 cases combined with varus of the forefoot)	10 feet	4.9 %
Cavus, calcaneocavus	7 feet	3.4 %
Total no.	180 feet	87.2 %
No deformities.	24 feet	12.8 %

TABLE 9. *The distribution of planovalgus (stages 0—4) over the different duration groups in the conservatively treated series (group Non-op I).*

Duration groups (years)		No. of feet	Stages 0—1		Stages 2—4	
<1		33	10	30.3 %	23	69.7 %
2—3		46	8	17.4 %	38	82.6 %
4—6		32	9	28.1 %	23	71.9 %
7—10		41	6	14.6 %	35	85.4 %
>10		52	8	15.4 %	44	84.6 %
Total		204	41	20.1 %	163	79.9 %

Summary

The feet which were to be operatively treated (Op I group) nearly all showed moderate or severe deformity, mostly planovalgus, which was present in 87.4 per cent. Severe varus or cavus deformities were hardly ever observed. Planovalgus is clearly the dominant deformity of the adult RA foot. In the present series planovalgus was moderate in 127 feet (43.6 per cent), severe in 93 feet (31.8 per cent), and extremely severe in 35 feet (12.0 per cent).

In the conservatively treated feet (Non-op I group) the development of deformities showed a similar pattern, but severe forms were markedly less frequent (Tables 7, 8, 9). *The symmetric involvement of both feet clearly appears from the fact that moderate or severe planovalgus was present in 87.4 per cent of the Op I group and in 79.9 per cent of the Non-op I group.* Nor were any definite differences between the various duration groups observed in the Non-op I group. This also reflects the development of planovalgus during the first few years of the disease. The occurrence of planovalgus in 69.7 per cent of feet in the under one year's duration group reveals the rapid development of this deformity (Table 9).

The difference in the talus-floor angle between the Op I and Non-op I groups is also indicative of the somewhat slighter degree of severity of planovalgus in the latter. The strikingly high mean value for the talus-floor angle in both groups shows the marked depression of the talus, and at the same time constitutes evidence of the violence of the inflammation, which secondarily leads to the development of flat-foot.

The talocrural joint

Swelling

The swelling of the tarsal sinus and the surrounding tissues is combined with the swelling of the TC joint. As regards the location of the swelling, no sharp distinction can be made, the TC and talocalcaneal joints being closely connected by the joint capsules and articular ligaments. The lateral ligaments of the TC joint are not readily distinguished from their capsules. The inflamed tissue of the tarsal sinus surrounds the anterior talofibular and calcaneofibular ligaments. According to BROSTRÖM et al. (1965) an open anatomical connection between the TC joint and posterior part of the talocalcaneal joint is sometimes normally present (in about 15 per cent). Consequently, inflammation of the subtalar joints also affects the TC joint capsule and obviously irritates the synovial aspect of the latter. In the present series of operatively treated feet, swelling of the talocrural region was observed in 186 ankles (63.7 per cent). No swelling was discovered, or the finding was uncertain, in 106 ankles (36.3 per cent). No case of the severest degree of swelling was observed.

Table 10 shows the distribution of the various degrees of swelling in the different duration groups. In this respect, too, the first duration group had almost the highest ratio (67.3 per cent). A higher ratio (73.6 per cent) was only obtained, for some reason or other, in the third duration group (a reflection of the variability in the progression of the disease). In the last (fourth) duration group, swelling was only noted in 51.3 per cent of cases. This pattern corresponds to the distribution of pain in the various duration groups.

Pain on motion and tenderness

According to the hospital records, pain on motion and weight-bearing was present in the TC joint of 157 ankles (53.8 per cent). The remaining 135 ankles (46.2 per cent) were either entirely painless or the symptom was uncertain. The frequent occurrence of pain is striking, considering that the material was collected mainly with a view to examining the symptoms of the subtalar joints. In many cases the patient's statement regarding the presence of pain was uncertain, particularly as regards its location. Movement of the TC joint often feels painful when the subtalar joints are violently inflamed, or the whole ankle is swollen. The pain caused by weight-bearing is still more difficult to distinguish from subtalar pain. In the whole series severe pain of the TC joint was only noted in 31 ankles (10.6 per cent), and in no case was pain of stage 4 observed.

TABLE 10. *Preoperative swelling, pain on motion and range of movement in the talocrural joint in the different duration groups.*

Duration groups (years)	No. of feet	Swelling Stages					Pain on motion Stages					Dorsiflexion Stages					Plantar flexion Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	101	11	22	58	10	0	21	25	47	8	0	22	56	19	4	0	30	43	21	7	0
	%	10.9	21.8	57.4	9.9	—	20.8	24.8	46.5	7.9	—	21.8	55.4	18.0	4.8	—	29.7	42.6	20.8	6.9	—
4-6	66	8	17	32	9	0	12	18	29	7	0	13	32	16	5	0	16	26	23	1	0
	%	12.1	25.8	48.5	13.6	—	18.2	27.2	44.0	10.6	—	19.7	48.5	21.2	7.6	—	24.2	39.4	34.9	1.5	—
7-10	57	5	10	37	5	0	7	13	28	9	0	10	27	15	4	1	5	24	23	5	0
	%	8.8	17.6	64.8	8.8	—	12.4	22.8	49.0	15.8	—	17.6	47.4	26.2	7.0	1.8	8.8	42.1	40.3	8.8	—
>10	68	9	24	26	9	0	15	24	22	7	0	14	28	19	5	2	12	27	22	6	1
	%	13.1	35.6	38.2	13.1	—	22.0	35.6	32.1	10.3	—	20.8	41.1	27.9	7.2	3.0	17.8	39.8	32.1	8.8	1.5
Total	292	33	73	153	33	0	55	80	126	31	0	59	143	69	18	3	63	120	89	19	1
	%	11.3	25.0	52.4	11.3	—	18.8	27.4	43.2	10.6	—	20.2	49.0	23.6	6.2	1.0	21.6	41.1	30.5	6.5	0.3

Table 10 shows the distribution of pain of various stages in the different duration groups. Pain of stages 2—4 was present in as many as 55 ankles (54.4 per cent), even in the first duration group.

The percentage of painful joints was about the same in the next duration group. Then a small increase was noted, and in the last group (over 10 years' duration) a clear decrease was observed. Consequently, pain appears to be an early symptom, which sets in at the same time as inflammation of the subtalar joints.

Range of motion

The range of motion of the TC joint was assessed by different examiners and found to be as follows:

No. of ankles	Dorsiflexion			Plantar flexion		
	0°—9°	10°—15°	>15°	0°—29°	30°—39°	>40°
292	90	143	59	109	120	63
%	30.8	49.0	20.2	37.3	41.1	21.6

Limitation of motion occurred in dorsiflexion in 233 feet (79.8 per cent), in plantar flexion in 229 feet (78.4 per cent). The figures show almost complete agreement. In only three feet in the whole series was no dorsiflexion observed, and in one case of over seven years' duration the joint showed no plantar flexion at all (stage 4). The largest group consists of feet with a dorsal flexion of 10—15 degrees and a plantar flexion of 30—39 degrees. Table 10 shows the increase in the limitation of motion associated with prolongation of the disease. As regards dorsiflexion, a steady increase is observable, but in regard to plantar flexion, the limitation did not progress evenly. The most steady progression was associated with stage 1.

The decrease in the range of motion associated with prolongation of the disease is consistent with the decrease in swelling and pain.

VI. PREOPERATIVE RADIOLOGICAL FINDINGS

Previous investigations

STEINBROCKER, TRAEGER and BATTERMAN (1949) based their assessment of the stage of the disease on the functional capacity of the patient and the roentgenological picture. The various changes caused by the disease were classified into five stages. FLETCHER and RAWLEY (1952) put forward the view that erosions are typical of rheumatoid arthritis and that this radiological finding is pathognomonic of the disease, although it is probably not the first sign. VAINIO (1956) mentioned narrowing of the joint space as an example of the radiological changes encountered in the rheumatoid foot. Narrowing of the TC joint space was thus observed in a total of 8.9 per cent in his series. Radiological changes of the talocalcaneal, calcaneocuboid and talonavicular joints occurred in 66.9 per cent. The difference between men and women was insignificant. With prolongation of the disease the changes progressed in all joints. Narrowing of the joint space was by far most frequently observed in the talonavicular joint. The talonavicular joint was quite clearly the one most often affected. According to VAINIO erosions and osteophytes at the edges of the talocrural joint appear very late.

SOILA (1958) mentioned that if inflammation persists, osteoporosis of the ankle bones may extend further, so as to involve the whole foot. A decrease in calcium concentration is first discernible in the close vicinity of the affected joints. SOILA only occasionally observed narrowing of the talocrural joint space, while narrowing was very frequently seen in the talonavicular, talocalcaneal, calcaneocuboid and cuneonavicular joints. He found that erosions in the talocrural and subtalar joints were a relatively infrequent finding, and that it was typical of the erosions of the ankle region that they were localized at points where the weakened bone tissue is exposed to strain. In the frontal projection of the ankle SOILA observed some cases of thin periosteal swelling in the contours of the tibia or fibula. In the area of the tar-

sals no periosteal swelling originating in the bone was seen. According to SOILA arthrotic changes most often occur in the talonavicular joint, while in other joints the changes are slight.

In a series of 226 rheumatoid patients who had received protracted cortisone treatment, GASCON and GRIGNON (1960) observed 26 pathological fractures, and osteoporosis of degree III in 46.2 per cent of cases and of degree IV in 14.1 per cent (classification by I—IV).

SERRE, SIMON, GIVAUDAUD and BENA-MARA (1962) assessed the radiological changes in the feet of 60 patients with RA, using STEINBROCKER's et al. (1949) classification, and noted typical changes in 38 cases.

According to ANSELL (1963), cyst-like erosive changes in the malleoli may be regarded as early signs of RA in the ankle joints. As time elapses, calcium accumulates in these spaces, giving an appearance resembling that of arthrosis. She pointed out that narrowing of the joint space due to loss of articular cartilage in appositional areas may be the first sign of involvement of the ankle and tarsus, particularly in the subtalar, talonavicular and calcaneocuboid joints. In some rheumatoid patients Ansell observed periosteal elevation and ossification along the outer aspect of the tibia, above the medial malleolus. She found that secondary degenerative changes may supervene without obvious erosive changes having been visualized.

In a study on 430 rheumatoid patients ISEMEIN and FOURNIER (1963) observed both clinical and radiological signs in the feet in 68 per cent. Attention was mainly directed to the joints of the toes, and to »bony signs». The articulation between the talus and scaphoid seemed to be severely affected.

SOSMAN (1963) mentioned that, according to his experience, one of the common lesions of the foot is in the talonavicular joint, second only to the metatarsophalanges. The talonavicular joint is also, however, a common site of osteoarthritis. SOSMAN pointed out that periostitis in the leg bones above the ankle does not always arise from rheumatoid arthritis, and that carcinoma of the lung must be ruled out as a cause by the aid of chest radiographs.

Present investigation

The subtalar joints

Osteoporosis

Table 11 shows the distribution of osteoporosis at various stages of development in different joints and duration groups. The material (Op I) comprises a total of 284 feet. Osteoporosis of stages 2—4 was observed round the talocalcaneal (tc) joint in 209 feet (73.6 per cent), round the calcaneocuboid (CC) joint in 257 feet (90.5 per cent), and round the talonavicular (TN) joint in 215 feet (75.8 per cent). A statistical analysis of the results is presented in Table 12, which shows that the development of osteoporosis as a function of time was linear, and that the linear rise was highly significant as regards the talocalcaneal joint. Round the talonavicular joint, too, osteoporosis showed an increase in severity which was significantly correlated with time. On the other hand, in the area of the calcaneocuboid joint osteoporosis of stages 2—4 developed as quickly as within the first three years in 90.5 per cent of the feet, and no significant progression emerged from comparison of the subsequent groups.

Summary

Osteoporosis of the areas of the TN and tc joints was found to show a linear increase in severity with increasing duration of the disease. This correlation was statistically significant.

It seems possible that marked osteoporosis of the CC area develops in the early stage of RA, although a deeper involvement may escape attention.

Narrowing of the joint space

The material (group Op I) consists of 284 feet. Narrowing of the joint space was observed as follows:

Talocalcaneal	joint	251	feet	88.3	per cent
Calcaneocuboid	»	204	»	71.8	»
Talonavicular	»	235	»	82.7	»

When the occurrence of the severest stages (3 and 4) was separately analysed the following distribution emerged:

Talocalcaneal	joint	86	feet	30.2	per cent
Calcaneocuboid	»	71	»	25.0	»
Talonavicular	»	168	»	59.1	»

TABLE 11. *Preoperative osteoporosis of the triple joints in the different duration groups.*

Duration groups (years)	No. of feet	Taloalcalaneal (tc)					Calcaneocuboid (CC)					Talonavicular (TN)				
		Stages					Stages					Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	98	8	21	62	7	0	4	6	60	28	0	8	17	66	6	1
	%	8.2	21.4	63.2	7.2	—	4.1	6.1	61.2	28.6	—	8.2	17.4	67.3	6.1	1.0
4—6	62	15	5	38	4	0	0	6	36	20	0	1	14	44	3	0
	%	24.2	8.6	61.3	6.4	—	—	9.7	58.0	32.3	—	1.6	22.6	71.0	4.8	—
7—10	57	3	15	36	3	0	1	4	46	6	0	2	13	39	3	0
	%	5.2	26.3	63.1	5.2	—	1.8	7.0	80.7	10.5	—	3.5	22.8	68.5	5.2	—
>10	67	2	6	43	15	1	1	5	37	23	1	1	13	38	12	3
	%	3.0	8.9	64.2	22.4	1.5	1.5	7.4	55.2	34.4	1.5	1.5	19.4	56.7	17.9	4.5
Total	284	28	47	179	29	1	6	21	179	77	1	12	57	187	24	4
	%	9.9	16.5	63.0	10.2	0.4	2.1	7.4	63.0	27.1	0.4	4.2	20.0	66.0	8.4	1.4

TABLE 12. *Analysis of statistical significance. The frequency of preoperative osteoporosis in the region of the talocalcaneal, calcaneocuboid and talonavicular joints in the different duration groups.*

The talocalcaneal joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	12.84	3	4.28	7.51	.001
Linear	6.26	1	6.26	10.98	.001
Deviation	6.58	2	3.29	5.77	.01
Within	160.91	280	0.57		
Total	173.75	283			
$M_1 = 1.69 \quad M_2 = 1.50 \quad M_3 = 1.68 \quad M_4 = 2.10$					

The calcaneocuboid joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	2.55	3	0.85	2.07	insignificant
Linear	0.12	1	0.12	0.29	»
Deviation	2.43	2	1.22	2.98	»
Within	116.00	280	0.41		
Total	118.55	283			
$M_1 = 2.14 \quad M_2 = 2.23 \quad M_3 = 2.00 \quad M_4 = 2.27$					

The talonavicular joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	4.23	3	1.41	3.00	.05
Linear	2.78	1	2.78	5.91	.05
Deviation	1.45	2	0.73	1.55	insignificant
Within	132.32	280	0.47		
Total	136.55	283			
$M_1 = 1.74 \quad M_2 = 1.79 \quad M_3 = 1.75 \quad M_4 = 2.04$					

TABLE 13. *Preoperative narrowing of the joint space in the triple joints in the different duration groups.*

Duration groups (years)	No. of feet	Taloalcalneal Stages					Calcaneocuboid Stages					Talonavicular Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	98	9	5	60	19	5	10	17	54	15	2	8	12	25	37	16
	%	9.2	5.1	61.2	19.4	5.1	10.2	17.3	55.1	15.3	2.1	8.2	12.2	25.5	37.8	16.3
4-6	62	7	1	41	13	0	7	14	25	13	3	3	8	8	35	8
	%	11.3	1.6	66.1	21.0	—	11.3	22.6	40.3	21.0	4.8	4.8	12.9	12.9	56.5	12.9
7-10	57	4	4	26	19	4	7	12	24	11	3	3	7	11	22	14
	%	7.0	7.0	45.6	33.4	7.0	12.3	21.0	42.2	19.3	5.2	5.2	12.3	19.3	38.7	24.5
>10	67	0	3	38	18	8	4	9	30	16	8	5	3	23	17	19
	%	—	4.5	56.7	26.9	11.9	6.0	13.4	44.8	23.9	11.9	7.4	4.5	34.4	25.4	28.3
Total	284	20	13	165	69	17	28	52	133	55	16	19	30	67	111	57
	%	7.1	4.6	58.1	24.3	5.9	9.9	18.3	46.8	19.4	5.6	6.7	10.6	23.6	39.1	20.0

TABLE 14. *Analysis of statistical significance. The frequency of preoperative narrowing of the joint space in the talocalcaneal, calcaneocuboid and talonavicular joints in the different duration groups.*

The talocalcaneal joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	9.92	3	3.31	4.41	.01
Linear	7.60	1	7.60	10.13	.01
Deviation	2.32	2	1.16	1.55	insignificant
Within	211.28	280	0.75		
Total	221.20	283			
$M_1 = 2.06 \quad M_2 = 1.97 \quad M_3 = 2.26 \quad M_4 = 2.46$					

The calcaneocuboid joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	7.85	3	2.62	2.67	.05
Linear	5.36	1	5.36	5.47	.05
Deviation	2.49	2	1.25	1.28	insignificant
Within	273.60	280	0.98		
Total	281.45	283			
$M_1 = 1.82 \quad M_2 = 1.85 \quad M_3 = 1.84 \quad M_4 = 2.22$					

The talonavicular joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	2.79	3	0.93	0.73	insignificant
Linear	2.08	1	2.08	1.64	,
Deviation	0.71	2	0.36	0.28	,
Within	355.42	280	1.27		
Total	358.21	283			
$M_1 = 2.42 \quad M_2 = 2.60 \quad M_3 = 2.65 \quad M_4 = 2.63$					

TABLE 15. *Preoperative erosion of the triple joints in the different duration groups.*

Duration groups (years)	No. of feet	Taloalcanal Stages					Calcaneocuboid Stages					Talonavicular Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	98	15	50	32	1	0	28	29	38	3	0	28	26	27	17	0
	%	15.3	51.0	32.7	1.0	—	28.6	19.6	38.8	3.0	—	28.6	26.5	27.6	17.3	—
4—6	62	8	29	23	2	0	16	20	24	2	0	14	4	19	25	0
	%	12.9	46.7	37.2	3.2	—	25.8	32.2	38.8	3.2	—	22.6	6.5	30.6	40.3	—
7—10	57	5	21	25	5	1	17	10	26	4	0	6	12	22	17	0
	%	8.7	36.8	44.0	8.7	1.8	29.8	17.6	45.6	7.0	—	10.5	21.1	38.7	29.7	—
>10	67	4	26	30	7	0	7	17	35	8	0	4	16	27	18	2
	%	6.0	38.8	44.8	10.4	—	10.4	25.4	52.3	11.9	—	6.0	23.9	40.4	26.9	2.8
Total	284	32	126	110	15	1	68	76	123	17	0	52	58	95	77	2
	%	11.2	244.4	38.8	5.2	0.4	23.9	26.8	43.4	5.9	—	18.3	20.4	33.5	27.1	0.7

TABLE 16. *Analysis of statistical significance. The frequency of preoperative erosions in the talocalcaneal, calcaneocuboid and talonavicular joints in the different duration groups.*

The talocalcaneal joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	9.11	3	3.04	5.33	.01
Linear	8.47	1	8.47	14.86	.001
Deviation	0.64	2	0.32	0.56	insignificant
Within	158.51	280	0.57		
Total	167.62	283			
$M_1 = 1.19 \quad M_2 = 1.31 \quad M_3 = 1.58 \quad M_4 = 1.60$					

The calcaneocuboid joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	11.01	3	3.67	4.65	.01
Linear	9.13	1	9.13	11.56	.001
Deviation	1.88	2	0.94	1.19	insignificant
Within	220.10	280	0.79		
Total	231.11	283			
$M_1 = 1.16 \quad M_2 = 1.19 \quad M_3 = 1.30 \quad M_4 = 1.66$					

The talonavicular joint

	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	21.72	3	7.24	6.64	.001
Linear	16.52	1	16.52	15.16	.001
Deviation	5.20	2	2.60	2.39	insignificant
Within	306.18	280	1.09		
Total	327.90	283			
$M_1 = 1.34 \quad M_2 = 1.89 \quad M_3 = 1.88 \quad M_4 = 1.97$					

In the present study narrowing of the joint space was thus most often observed in the talocalcaneal joint and least often in the calcaneocuboid joint, but the severest changes (stages 3 and 4) occurred by far most frequently in the talonavicular joint.

Narrowing became more pronounced as the disease progressed. In both the tc and the CC joints narrowing increased linearly as a function of time, and the correlation was statistically significant. In the talocalcaneal joint the progression of the change showed even higher significance than in the calcaneocuboid joint (Table 14). On the other hand, in regard of the talonavicular joint no significant correlation was found between the progression of joint space narrowing and the duration of the disease. This shows that the change had already become established in the initial stage of the disease, within three years. The subsequent changes were statistically insignificant.

Table 13 shows the distribution of the various stages of tc, CC and TN joint space narrowing in the different duration groups.

The observation that narrowing of the TN joint space was an early sign is consistent with the finding that planovalgus developed during the initial stage of rheumatoid arthritis of the ankle. It is noteworthy, moreover, that in the over ten years' duration group there were no more than eight cases (11.9 per cent) in which the tc joint space was so narrow that it could only be distinguished with difficulty in certain areas, which means that at least fibrous ankylosis was present in the joint. Likewise, the CC joint space was very narrow (stage 4) in eight cases (11.9 per cent). The TN joint space was very narrow (stage 4) more than twice as often, i.e. in 19 cases (28.3 per cent). This shows that ankylosis of the joints develops very slowly, often over a period of ten years.

Summary

In the present series narrowing of the joint space was most frequently observed in the talocalcaneal joint (88.3 per cent) and most seldom in the calcaneocuboid joint (71.8 per cent). Narrowing of the talonavicular joint space was found to be an early sign, already established during the first three years.

Narrowing of the talocalcaneal and calcaneocuboid joint spaces progressed linearly as a function of time, and this correlation was statistically significant.

Erosion

On examination of the preoperative radiographs of 284 feet, the distribution of erosions in the tc, CC and TN joints was found to be as follows:

		No erosion (stages 0—1)		Erosion (stages 2—4)	
Talocalcaneal joint		158	55.6 per cent	126	44.4 per cent
Calcaneocuboid »		144	50.7 »	140	49.3 »
Talonavicular »		110	38.7 »	174	61.3 »

As is seen above, erosion occurred most frequently in the TN joint, in which it was observed in 174 (61.3 per cent) of the 284 feet examined. In the calcaneocuboid joint this change was detected in 49.3 per cent of cases, and in the talocalcaneal joint in 44.4 per cent. The distribution of erosion in the different duration groups is shown in Table 15. It appears that erosion increased in all three joints (tc, CC and TN) with increasing duration of the disease. Statistically, the progression of erosion was highly significant, as may be seen in Table 16. As demonstrated in Fig. 7, the destructive process most often began in the TN joint, but during the course of the disease all three joints showed about the same, steady deterioration.

Summary

Erosion occurred most frequently in the talonavicular joint, in which it was observed in 61.3 per cent of the feet examined. In the calcaneocuboid joint this change was found in 49.3 per cent of cases and in the talocalcaneal joint in 44.4 per cent. The progression of erosion was found to be very closely correlated with the duration of the disease. Statistically the correlation was highly significant.

The periosteal reaction

Pure periostitis, in which the periosteum is clearly thickened and elevated from the underlying cortical bone, was not encountered round the subtalar joints. On the other hand, at the edges of the joints and/or the cortical bone, e.g. on the dorsal surface of the navicular, unevennesses in the form of osteophytes were observed.

Periosteal reaction was observed in the apices of the malleoli, at the aspects opposite to the joints and, correspondingly, on both sides of the talus. Osteophytic spicules were often seen on the apices of the malleoli and on the anterior and posterior edges of the tibia. Very typical locations were the dorsal margins of the articulation between the navicular and talus, and the calcaneocuboid joint, in particular the lower margin of the cuboid and the posterior portion of the talus, the posterior talar process. The distribution of the various stages of periosteal changes in the tc, CC and TN joints of the 284 feet examined was as follows:

Stage	tc	CC	TN
0	39	214	47
1	130	20	28
2	104	46	135
3	11	4	71
4	0	0	3
Stages 2—4	115	50	209
	40.5 %	17.6 %	73.6 %
Stages 1—4	245	70	237
	86.3 %	24.7 %	83.5 %

The clearly highest frequency of periosteal reactions (73.6 per cent) was observed in the area of the talonavicular joint. If quite minimal changes (stage 1), i.e. a barely discernible unevenness of the surface, are included, the total number of affected TN joints was 237 (83.5 per cent). In the tc joint changes of this stage occurred somewhat more often, i.e. in 245 cases (86.3 per cent). Periosteal marginal changes of the CC joint were relatively infrequent, changes of stages 2—4 being observed in only 50 cases (17.6 per cent). In the region of the CC joint the periosteal changes mainly occurred at the lower edges of the joint. The changes in the TN region were very often located in the dorsal margins of the joint, and in the dorsal surface of the navicular, often extending to the area of the cuneiform bone. The talocalcaneal periosteal changes were found at the edges of the joint, particularly in the processes, e.g. the posterior talar process, which significantly often became enlarged as the disease progressed. Table 17 shows the development and increase of periosteal changes during the course of the disease. The progression was most conspicuous in the TN region, in which the differences between the various duration groups were statistically highly significant. The differences in the tc region were also most significant, and the exacerbation was found to be a linear function of time. As may be seen in Table 18 and Fig. 8, the progression of the changes was most linear in the TN joint.

As the distribution of the changes in the CC joint was not suited for the F test, the differences between the various duration groups were tested by variance analysis, and the trend was tested by FERGUSON's non-parametrical trend analysis. The results obtained were as follows: $\chi^2 = 8.21$ ($P < .05$) and $z = 2.78$ ($P < .01$). Since the differences between the various duration groups were significant, the conclusion may be drawn that the changes increased as the disease advanced.

The statistical analysis of the periosteal changes in the tc and TN joints is shown in Table 18.

TABLE 17. *Preoperative changes of the periosteal reaction in the triple joints in the different duration groups.*

Duration groups (years)	No. of feet	Talocalcaneal Stages					Calcaneocuboid Stages					Talonavicular Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	98	16	46	36	0	0	81	4	13	0	0	22	14	47	15	0
	%	16.3	46.9	36.8	—	—	82.6	4.1	13.3	—	—	22.4	14.3	48.0	15.3	—
4—6	62	14	27	19	2	0	49	5	8	0	0	11	3	34	14	0
	%	22.6	43.6	30.6	3.2	—	79.0	8.1	12.9	—	—	17.7	4.8	54.9	22.6	—
7—10	57	5	22	26	4	0	41	4	9	3	0	7	6	24	19	1
	%	8.7	38.7	45.6	7.0	—	72.0	7.0	15.8	5.2	—	12.3	10.5	42.1	33.3	1.8
>10	67	4	35	23	5	0	43	7	16	1	0	7	5	30	23	2
	%	6.0	52.2	34.4	7.4	—	64.2	10.4	23.9	1.5	—	10.4	7.4	44.8	34.4	3.0
Total	284	39	130	104	11	0	214	20	46	4	0	47	28	135	71	3
	%	13.7	45.8	36.7	3.8	—	75.3	7.1	16.2	1.4	—	16.5	9.9	47.5	25.0	1.1

TABLE 18. *Analysis of statistical significance. The frequency of preoperative periosteal reaction in the talocalcaneal and talonavicular joints in the different duration groups.*

<i>The talocalcaneal joint</i>					
	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	6.04	3	2.01	3.65	.05
Linear	3.78	1	3.78	6.87	.01
Deviation	2.26	2	1.13	2.05	insignificant
Within	154.31	280	0.55		
Total	160.35	283			

$$M_1 = 1.20 \quad M_2 = 1.15 \quad M_3 = 1.51 \quad M_4 = 1.43$$

<i>The talonavicular joint</i>					
	Sum of Squares	Degrees of Freedom	Variance Estimate	F	Level of Significance
Between	14.67	3	4.89	4.94	.01
Linear	14.23	1	14.23	14.37	.001
Deviation	0.44	2	0.22	0.22	insignificant
Within	277.20	280	0.99		
Total	291.87	283			

$$M_1 = 1.56 \quad M_2 = 1.82 \quad M_3 = 2.02 \quad M_4 = 2.12$$

Summary

As regards the periosteal reaction, too, the most obvious and most advanced signs of rheumatoid inflammation were discernible in the region of the talonavicular joint (in 73.6 per cent of cases). The slightest changes were observed in the calcaneocuboid joint (in 17.6 per cent). The changes in the talocalcaneal joint were clearly slighter than in the TN joint, but when very slight changes were also taken into account, the frequency of lesions was about the same in the tc and TN joints.

Enlargement of the posterior talar process was another common finding in cases of old standing. The conspicuousness of the erosive and reparative processes in the talonavicular region was a very typical feature. This phenomenon could not be satisfactorily explained.

Statistically, the differences between the various duration groups were significant in regard of all three joints. The changes showed a linear aggravation as a function of time. This result, too, was significant. The most vertical rise was observed in the TN region.

Osteoarthritis

Changes in the calcium concentration of the joints were noted. The right and left feet, which were projected on the same X-ray film, were always compared.

The distribution of osteoarthritis in the tc, TN and CC joints of 284 feet was as follows:

Joint	Stages 0—1		Stages 2—4	
Talocalcaneal	188	66.2 %	96	33.8 %
Calcaneocuboid	247	87.0 %	37	13.0 %
Talonavicular	143	50.4 %	141	49.6 %

In the present material osteoarthritis occurred most frequently in the TN joint, i.e. in 141 cases (49.6 per cent). The difference as compared with the other joints is considerable. In the tc joint arthrosis was observed in 96 cases (33.8 per cent), in the CC joint only in 37 cases (13.0 per cent). In the tc and CC joints osteoarthritis showed gradual exacerbation with prolongation of the disease. In the TN joint the changes were slighter, and the highest frequency was noted in the second duration group. Table 19 shows the development of arthrosis in the different joints in the various duration groups.

The differences between the duration groups were found to be highly significant in regard of the tc and CC joints and significant in regard of the TN joint. As may be seen in Table 19, in the tc and CC joints arthrosis clearly increased with prolongation of the disease. The most marked changes seemed to occur after six years. In the last group (duration over ten years) a slight fall was observed, which may be due to (fibrous) ankylosis. This fall seemed to be most marked in the TN joint, and it was discernible as early as six years from the onset. This observation seems to indicate that in the TN joint arthrosis develops in an early stage of the disease and later it may decrease.

Statistical analysis

The osteoarthrotic changes in the different duration groups were compared by variance analysis based on ordinal numbers, and the trend was tested by non-parametric trend analysis.

Group Op I

Joint

tc $\chi^2 = 20.36$ $P < .001$ $z = 3.68$ $P < .001$ (highly significant)

CC $\chi^2 = 15.07$ $P < .001$ $z = 3.57$ $P < .001$ (highly significant)

TN $\chi^2 = 13.15$ $P < .01$ $z = 2.27$ $P < .05$ (significant)

TABLE 19. *Preoperative osteoarthritis of the triple joints in the different duration groups.*

Duration groups (years)	No. of feet	Talo calcaneal Stages					Calcaneocuboid Stages					Talonavicular Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	98	52	24	17	5	0	88	5	5	0	0	52	10	21	15	0
	%	53.1	24.5	17.3	5.1	—	89.8	5.1	5.1	—	—	53.1	10.2	21.4	15.3	—
4—6	62	28	17	15	2	0	49	5	8	0	0	17	7	22	16	0
	%	45.2	27.4	24.2	3.2	—	79.0	8.1	12.9	—	—	27.4	11.3	35.5	25.8	—
7—10	57	10	20	21	6	0	38	7	11	1	0	15	10	18	14	0
	%	17.6	35.1	36.8	10.5	—	66.6	12.3	19.3	1.8	—	26.3	17.6	31.6	24.5	—
>10	67	26	11	23	7	0	47	8	12	0	0	25	7	22	12	1
	%	38.8	16.4	34.4	10.4	—	70.2	11.9	17.9	—	—	37.4	10.4	32.8	17.9	1.5
Total	284	116	72	76	20	0	222	25	36	1	0	109	34	83	57	1
	%	40.9	25.3	26.8	7.0	—	78.2	8.8	12.6	0.4	—	38.4	12.0	29.2	20.0	0.4

Summary

Osteoarthrotic changes were most clearly observed in the TN joint (in 49.6 per cent of cases), and most infrequently in the calcaneocuboid joint (in 13.0 per cent). The development of osteoarthritis was gradual, but as regards moderate or severe changes the various joints showed different patterns. In the TN joint the maximum was observed in the duration group four to six years, after which arthritis decreased. In the tc and CC joints the maximum occurred later, i.e. between the seventh and tenth years. After this arthritis showed a gradual decrease. The differences between the various duration groups were statistically significant as regards all joints (tc, CC and TN). On comparison of the occurrence of osteoarthritis and rheumatoid changes, it was found that arthritis was a less common sign in all joints (tc, CC and TN).

Diagrams

In Figs. 5—8 the arithmetical mean for the severity of the radiological changes is expressed on the ordinate, while the duration of the disease in years, calculated from the onset of symptoms in the foot until the time of operation, is indicated on the abscissa.

The diagrams show that erosion, narrowing of the joint space and the periosteal reaction were throughout most marked in the TN joint and slightest in the CC joint, although the differences became less pronounced in cases of long standing. This applies in particular to narrowing of the joint space and erosion. As regards osteoporosis, the curves expressing the degree of severity of the radiological changes show a different pattern. Throughout, the severest changes were observed in the CC region and the slightest changes in the tc region, although in this respect, too, the differences between the various joints decreased with increasing duration of the disease. The curves show a gradual rise, and the first and last duration groups differ most from each other. The curves expressing osteoporosis have the least linear rise, which reflects the slightness of the differences between the duration groups. Osteoporosis developed rapidly as the first sign of the disease, and subsequently showed little change.

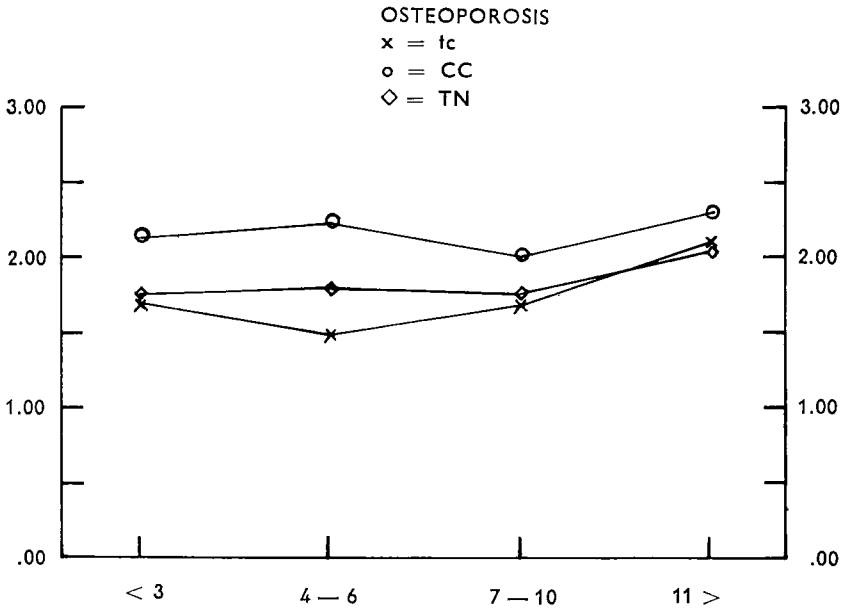


Fig. 5.

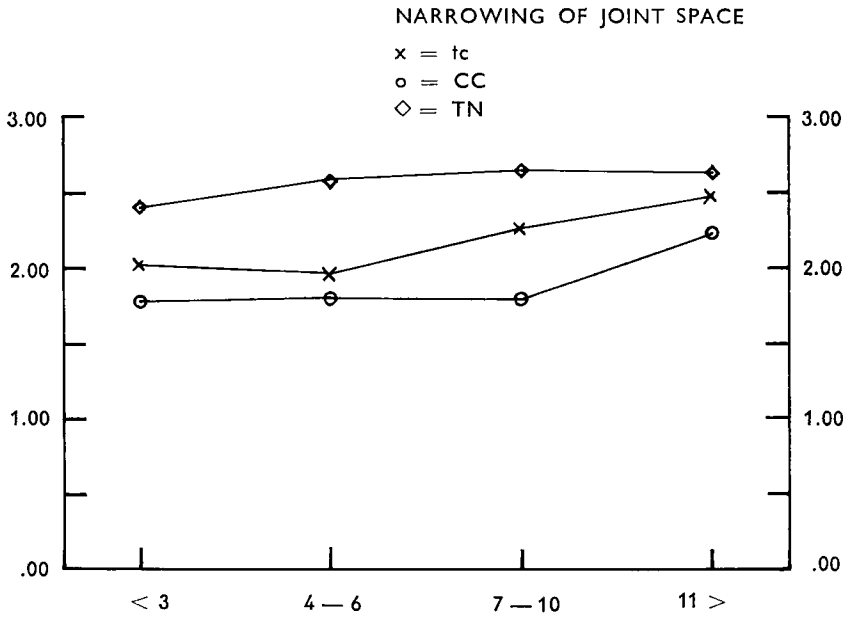


Fig. 6.

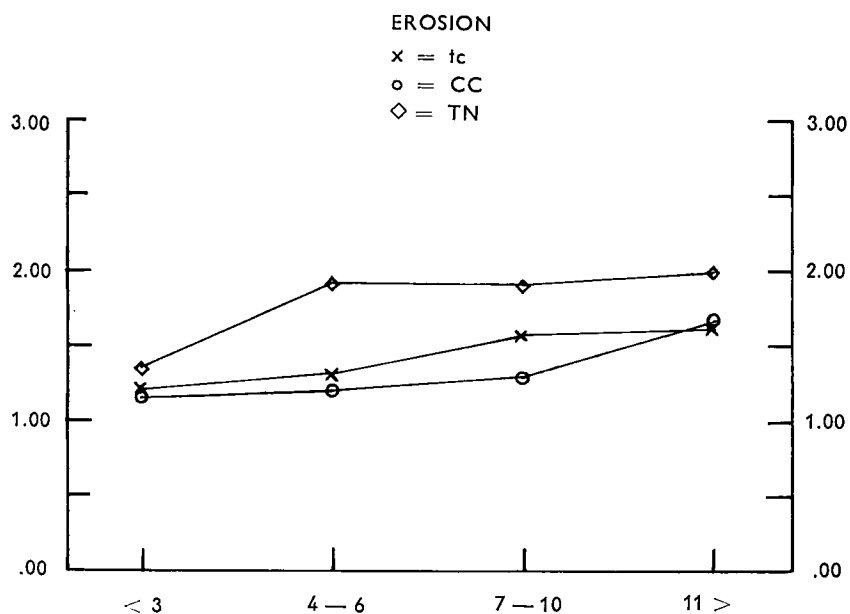


Fig. 7.

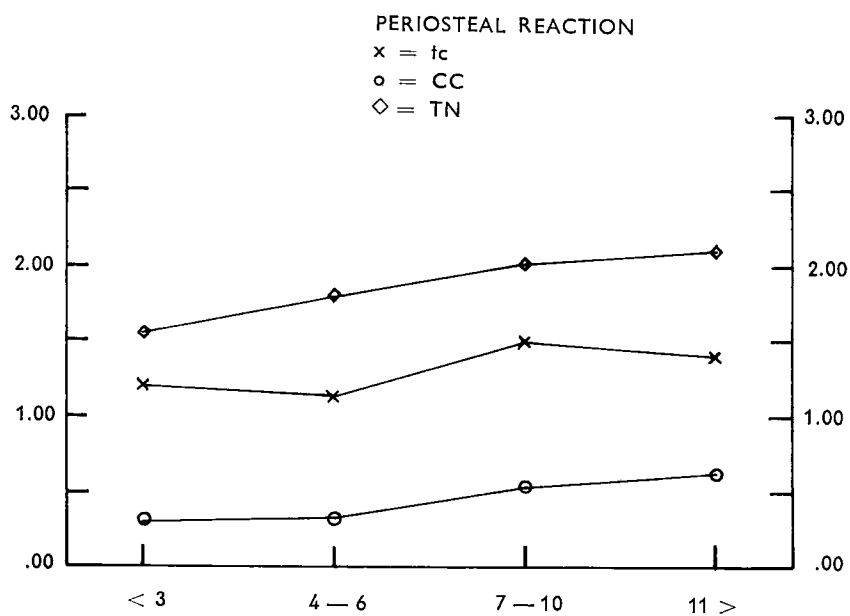


Fig. 8.

Figs. 5, 6, 7, 8. Radiological changes of various stages in the different duration groups: comparison of the tc, CC and TN joints. The arithmetical mean for the severity of the changes is indicated on the ordinate, the duration of the disease in years on the abscissa.

The talocrural joint

The distribution of the findings in the groups Op I and Non-op I is shown in Tables 20 and 21.

Osteoporosis of the TC joint was observed in the Op I group in 44.4 per cent of cases. When the findings in the TC joint are compared with the corresponding findings in the tc, TN and CC joints, the difference is striking: osteoporosis and narrowing of the joint space were observed in the latter in over 70 per cent of cases. As regards osteoarthrosis, the value for the CC joint (13.0 per cent) is the only one that approximates to the corresponding value for the TC joint (12.7 per cent).

As may be seen in Table 21, the edges of the TC joint (the medial and lateral aspects of the malleolar part of the mortise) showed markedly more erosive changes than the mid part (the surface) of the joint. The same phenomenon was also observed in the Non-op I group. On comparison of erosion in the subtalar joints and the TC joint the difference is obvious, since even the region of the tc joint (in which this phenomenon was rarest) exhibited

TABLE 20. *X-ray changes in the talocrural joint.*

Group	No. of ankles	Osteoporosis		Narrowing of the joint space		Osteoarthrosis	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op I	284	158 55.6 %	126 44.4 %	244 85.9 %	40 14.1 %	248 87.3 %	36 12.7 %
Non-op I	204	135 66.2 %	69 33.8 %	184 90.2 %	20 9.8 %	183 89.7 %	21 10.3 %

TABLE 21. *Erosion in the talocrural joint.*

Group	No. of ankles	Surface erosion		Marginal erosion			
		Stages 0—1	Stages 2—4	Medial part of mortise		Lateral part of mortise	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op I	284	225 79.2 %	59 20.8 %	188 66.2 %	96 33.8 %	194 68.3 %	90 31.7 %
Non-op I	204	172 84.3 %	32 15.7 %	154 75.5 %	50 24.5 %	154 75.5 %	50 24.5 %

erosions in 44.4 per cent of cases. It appears that all rheumatoid changes decrease in the proximal direction from the talocalcaneal joint.

Tables 22, 23, 24 and 25 show the distribution of the radiological changes of the TC joint in the different duration groups. In both the Op I and the Non-op I group the distribution of osteoporosis was fairly even. However, in both groups (particularly the Non-op I group) a definite decrease in osteoporosis occurred between the fourth and sixth years, after which the changes clearly progressed in both groups. The values in the Op I group were consistently higher, reflecting the progression of inflammation from the subtalar joints to the TC joint.

Narrowing of the TC joint space clearly progressed during the course of the disease in both the Op I and the Non-op I group. As may be seen in Tables 24 and 25, the changes were slighter in all duration groups in the Non-op I group.

Erosion of the TC joint, too, seemed obviously to progress with prolongation of the disease. As appears in Table 25, the only exception is constituted by the malleolar mortise in the Non-op I group, duration group 4—6 years. For some reason or other, in this group a clear improvement was discernible in the otherwise steadily progressing course of the disease. It seems possible that this «error» is due to the relative smallness of the duration groups in the Non-op group. In all duration groups the changes were invariably greater in the malleolar portion of the mortise than in the horizontal joint surface. The differences between the lateral and medial aspects were slight in both groups examined. The distribution was very even, although changes seemed to be somewhat more frequent on the medial aspect in the Op I group, at least. The progression of arthrosis was obvious in both groups. Initially it seemed to be very slow, but in the over ten years' duration group a considerable rise was noted in both the Op I and the Non-op I group. In addition, the difference between the groups had diminished. The same phenomenon was observable in respect of the other radiological changes, surface erosion excepted, which after ten years was also clearly more frequent in the Op I group.

Statistical analysis

Just as in testing osteoarthrosis of the subtalar joints, variance analysis based on ordinal numbers was applied.

The significance of the occurrence of erosion of the mortise of the TC joint was tested in the different duration groups.

TABLE 22. Preoperative X-ray changes in the talocrural joint in the different duration groups.

Duration groups (years)	No. of ankles	Osteoporosis Stages					Narrowing of the joint space Stages					Osteoarthritis Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	98	32	30	34	2	0	84	6	5	3	0	90	4	3	1	0
	%	32.7	30.6	34.7	2.0	—	85.7	6.1	5.1	3.1	—	91.8	4.1	3.1	1.0	—
4–6	62	18	22	16	6	0	52	4	3	3	0	50	6	5	1	0
	%	29.0	35.5	25.8	9.7	—	83.9	6.5	4.8	4.8	—	80.6	9.7	8.1	1.6	—
7–10	57	15	14	24	4	0	46	5	3	1	2	44	5	5	1	2
	%	26.3	24.6	42.1	7.0	—	80.7	8.8	5.3	1.7	3.5	77.2	8.8	8.8	1.7	3.5
>10	67	12	15	29	10	1	30	8	6	9	5	41	8	12	5	1
	%	17.9	22.4	43.3	14.9	1.5	58.2	11.9	8.9	13.5	7.5	61.2	11.9	17.9	7.5	1.5
Total	284	77	81	103	22	1	221	23	17	16	7	225	23	25	8	3
	%	27.1	28.5	36.3	7.8	0.3	77.8	8.1	5.9	5.6	2.6	79.2	8.1	8.8	2.8	1.1

TABLE 23. *Preoperative erosive changes in the talocrural joint in the different duration groups.*

Duration groups (years)	No. of ankles	Surface erosion					Marginal erosion									
		Stages					Medial part of mortise					Lateral part of mortise				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<3	98	66	20	8	4	0	43	26	26	3	0	50	23	22	3	0
	%	67.3	20.5	8.2	4.0	—	43.9	26.5	26.5	3.1	—	51.0	23.5	22.4	3.1	—
4—6	62	40	14	6	2	0	22	23	13	4	0	24	22	13	3	0
	%	64.5	22.6	9.7	3.2	—	35.5	37.1	21.0	6.4	—	38.7	35.5	21.0	4.8	—
7—10	57	33	13	7	3	1	26	11	16	4	0	23	16	15	3	0
	%	57.9	22.8	12.3	5.3	1.7	45.6	19.3	28.1	7.0	—	40.3	28.1	26.3	5.3	—
>10	67	24	15	20	7	1	25	12	24	6	0	25	11	23	8	0
	%	35.8	22.4	29.9	10.4	1.5	37.3	17.9	35.8	9.0	—	37.3	16.4	34.3	12.0	—
Total	284	163	62	41	16	2	116	72	79	17	0	122	72	73	17	0
	%	57.4	21.8	14.1	5.6	1.1	40.8	25.4	27.9	5.9	—	43.0	25.3	25.8	5.9	—

TABLE 24. *X-ray changes in the talocrural joint in the different duration groups of group Non-op I.*

Duration groups (years)	No. of feet	Osteoporosis Stages					Narrowing of the joint space Stages					Osteoarthritis Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<1	33	19	4	9	1	0	32	1	0	0	0	31	1	1	0	0
	%	57.6	12.1	27.3	3.0	—	97.0	3.0	—	—	—	94.0	3.0	3.0	—	—
2-3	46	26	10	10	0	0	45	1	0	0	0	46	0	0	0	0
	%	56.6	21.7	21.7	—	—	97.8	2.2	—	—	—	100.0	—	—	—	—
4-6	32	12	16	4	0	0	30	0	1	1	0	26	4	1	1	0
	%	37.5	50.0	12.5	—	—	93.8	—	3.1	3.1	—	81.3	12.5	3.1	3.1	—
7-10	41	13	13	13	2	0	34	3	0	4	0	31	6	0	4	0
	%	31.7	31.7	31.7	4.9	—	82.9	7.3	—	9.8	—	75.5	14.7	—	9.8	—
>10	52	9	13	23	7	0	35	3	3	8	3	35	3	4	9	1
	%	17.4	24.9	44.2	13.5	—	67.3	5.8	5.8	15.3	5.8	67.3	5.8	7.6	17.4	1.9
Total	204	79	56	59	10	0	176	8	4	13	3	169	14	6	14	1
	%	38.7	27.5	28.9	4.9	—	86.3	3.9	1.9	6.4	1.5	82.8	6.9	3.0	6.8	0.5

TABLE 25. *X-ray changes in the talocrural joint in the different duration groups of group Non-op I.*

Duration groups (years)	No. of feet	Surface erosion					Marginal erosion									
		Stages					Medial part of mortise					Lateral part of mortise				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<1	33	25	8	0	0	0	27	5	1	0	0	27	6	0	0	0
	%	75.8	24.2	—	—	—	81.8	15.2	3.0	—	—	81.8	18.2	—	—	—
2-3	46	39	5	2	0	0	29	7	9	1	0	29	7	10	0	0
	%	84.8	10.9	4.3	—	—	63.1	15.2	19.5	2.2	—	63.1	15.2	21.7	—	—
4-6	32	21	8	2	1	0	19	10	2	1	0	20	9	2	1	0
	%	65.6	25.0	6.3	3.1	—	59.4	31.2	6.3	3.1	—	62.5	28.1	6.3	3.1	—
7-10	41	23	9	8	1	0	17	12	11	1	0	17	10	13	1	0
	%	56.0	22.0	19.6	2.4	—	41.5	29.2	26.9	2.4	—	41.5	24.4	31.7	2.4	—
>10	52	27	7	9	7	2	24	4	20	4	0	23	6	19	4	0
	%	51.9	13.5	17.3	13.5	3.8	46.2	7.6	38.6	7.6	—	44.2	11.6	36.6	7.6	—
Total	204	135	37	21	9	2	116	38	43	7	0	116	38	44	6	0
	%	66.2	18.1	10.3	4.4	1.0	56.9	18.6	21.1	3.4	—	56.9	18.6	21.6	2.9	—

Group Op I.

Surface erosion of the TC joint.

$\chi^2 = 23.66$ $P < .001$ $z = 4.35$ $P < .001$ (highly significant)

The medial part of the mortise

$\chi^2 = 2.89$ $P > .05$ $z = 1.48$ $P > .05$ (insignificant)

The lateral part of the mortise

$\chi^2 = 7.02$ $P > .05$ $z = 2.63$ $P < .01$ (most significant)

As regards the development of erosion of the horizontal joint surface, the differences between the various duration groups are highly significant. As may be seen in Table 23, the trend of the progression is clearly the same in all duration groups.

The differences between the duration groups are insignificant in regard of erosion of the medial aspect of the mortise, but most significant in regard of its lateral aspect. In other words, as far as the medial surface of the mortise is concerned, there was no significant difference even between the first duration group, representing the initial stage of the disease, and the later groups. Erosive changes in this part are an early sign, and the changes subsequently developing do not attain statistical significance. However, a definite difference was observed between the first and last duration groups (Table 23). In cases of old standing erosion seems to increase.

On comparison of the Non-op I and Op I groups the following results were obtained (the U test):

Surface erosion of the TC joint

$z = 1.94$ $P < .05$ (significant)

The medial part of the mortise

$z = 3.30$ $P < .001$ (highly significant)

The lateral part of the mortise

$z = 2.87$ $P < .01$ (most significant)

The statistical analysis shows that erosions were more frequent in the Op I group than in the Non-op I group. The differences are significant, in particular as regards the malleolar mortise, which showed clearly more erosions in the Op I group.

Summary

In the group of ankles on which operation was to be performed (Op I), the TC joint showed osteoporosis in 44.4 per cent of cases, narrowing of the joint

space in 14.1 per cent, surface erosion in 20.8 per cent, erosion of the medial part of the mortise in 33.8 per cent, erosion of the lateral part of the mortise in 31.7 per cent, and osteoarthritis in 12.7 per cent. Osteoporosis was thus the most frequent sign. In the conservatively treated group (Non-op I) the pattern of distribution was the same, although the frequency figures were definitely lower. The changes progressed during the course of the disease. (Tables 20—21, 22—23 and 24—25).

The only exception was constituted by the erosive changes of the medial aspect of the mortise, which developed within three years and showed no appreciable advance, the subsequent changes being statistically insignificant.

VII. OPERATIVE TREATMENT

Historical review

ALBERT (1878) and v. LESSER (1879) seem to have been the first to perform arthrodesis of the ankle. But v. LANGENBECK (1864) is regarded as the pioneer as regards the resection technique which made arthrodesis possible. WHITMAN (1901, 1921, 1922) introduced astragalectomy as an ankle-stabilizing procedure in poliomyelitis patients. NIENY (1905) reported four cases in which subtalar arthrodesis was performed for lateral instability.

The transverse horizontal incision described by DAVIS (1913) may be regarded as the prototype of the tarsus-anchylosing operations. The final emergence of subtalar arthrodesis as a foot-stabilizing operation depended on the introduction of more advanced methods by HOKE (1921) and DUNN (1922). RYERSON (1923), who was the first to realize the full importance of calcaneocuboid fusion, introduced triple arthrodesis.

MACAUSLAND (1929) presented a modified horizontal incision, and MILLER (1935) and BREWSTER (1933) introduced modifications of their own of subtalar and midtarsal joint arthrodesis. BRANCH (1939) developed a combined subtalar arthrodesis and posterior bone block (arthrorrhisis) operation. Before this, CAMPBELL (1923, 1930) and NOVÉ-JOSSE-RAND (1928) had published reports on the correction of «drop-foot» by arthrorrhisis. LAMBRINUDI (1927) developed a modified operation for «drop-foot».

GRICE (1952) described a new method of extra-articular talocalcaneal arthrodesis. The operation consists in making two cortical bone grafts bridge the tarsal sinus between the talus and calcaneus, and its purpose is the correction of paralytic flat-foot in children. According to GRICE, in adult feet extra-articular arthrodesis must be combined with triple arthrodesis.

Present investigation

Indications for triple arthrodesis

The main indication for arthrodesis of the subtalar joints is pain. Violent pain results from partial or complete destruction of these joints. The foot is painful on weight-bearing, even the slightest lateral movement causes acute pain, and the patient is unable to walk on uneven ground without canes or crutches. Getting about on a rough or snowy road causes great difficulties.

Patients were formerly hospitalized in a very late stage, when marked radiological changes of the subtalar joints had already developed. During the last few years the presence of such changes has not been regarded as conditional: pain on weight-bearing has been a decisive indication for subtalar arthrodesis in cases in which the patient has been unable to manage with the aid of supports. The development of severe deformities, which may jeopardize the results of operation, has thus been avoided at the same time.

If the changes in the talocrural joint have been slight, only triple arthrodesis has been performed. In the presence of marked destructive changes in the TC joint, total (pantalar) arthrodesis has been carried out simultaneously.

Deformity causing discomfort has also been regarded as an indication for triple arthrodesis, unless the patient has adapted himself to the situation.

The following factors have been regarded as possible contra-indications to operation: General disease with severe multiple deformities. Lack of co-operation, because a better end-result is obtained when the patient himself wants the operation and has a positive attitude to it. Severe amyloidosis. The presence of cardiovascular, respiratory and other complicating diseases, and old age with severe general disease, have been regarded as absolute contra-indications. On the other hand, elevated erythrocyte sedimentation rate and cortisone treatment have not been regarded as contra-indications.

Technical considerations of triple arthrodesis

Subtalar (triple) arthrodesis, with which this study is concerned, included the talocalcaneal, talonavicular and calcaneocuboid joints. In nearly every case a cortical bone graft was applied between the talus and calcaneus in the sinus tarsi. GRICE's original method (1952), by which extra-articular arthrodesis was performed by the aid of two cortical bone grafts obtained from the proximal part of the tibia, was modified by VAINIO (1958) for rheumatoid cases. This modification also resembles CAMPBELL's technique (e.g. the fourth edition of CAMPBELL's *Operative Orthopaedics* 1963).

With the patient supine on the operating table, the different steps were usually performed in the following order:

1. After the tarsal sinus was emptied of its contents, the calcaneocuboid joint was opened after incision of its capsule, and the cartilaginous joint surfaces were chiselled away. The synovial tissue and pannus were also removed.

2. The same procedures were carried out on the talonavicular joint, and the joint surfaces were modelled so as to give a good contact with each other.

3. The cartilage was chiselled off the anterior articular process of the calcaneus, the anterior aspect of the talus, the articular surfaces of the sustentaculum tali and the anterior part of the posterior facet of the talus. The articular surfaces of the talocalcaneal joint were removed, and appropriate bony wedges were chiselled off to ensure good correction of any possible malposition.

4. As the first reconstructive step, the foot was displaced so that the debrided articular surfaces were in the best possible contact with each other, and in midposition or slight valgus. Varus position is inappropriate. Special attention was given to the position of the forefoot, which was also placed in midposition.

The calcaneocuboid joint was fixed by means of a staple (stainless steel).

5. A cortical bone graft including good spongy tissue was applied between the talus and calcaneus in the sinus tarsi, in which an appropriate groove was modelled by removing a small amount of bone tissue from the surface of both the talus and the calcaneus. The graft was modelled into appropriate shape and set firmly into its groove with the cortical side outwards, perpendicularly against the direction of movement of the subtalar joint. The spaces between the fused joints were filled with bone grafts (chips) from the portions of removed bone (if this could be used) and from the graft to be applied. The sinus tarsi, too, was packed full of chips round the graft as described by VAINIO (1958).

The graft was taken from the iliac crest just before being used. It measured about 2—3 cm (one inch) in length, 1—2 cm (about half an inch) in breadth, and about 0.5—1 cm in thickness, counted from the cortical aspect. It was shaped into a wedge in such a way that the sharp spongy aspect would become better fixed into the groove that was modelled in the sinus tarsi.

6. A below-knee well-moulded plaster cast was applied while the patient was still lying on the operating table and the surgeon was holding the foot, which he moved to the correct position and placed in alignment with the longitudinal axis of the leg.

About 14 days after operation the cast and the stitches were removed, and a new plaster cast was applied. This occasion offered an opportunity of correcting any slight deformities by re-modelling. One or two days later a heel was applied under the cast, and partial weight-bearing was allowed, at first with crutches or with a cane. The patient was encouraged to walk freely if this did not increase the pain. The duration of immobilization was eight weeks from operation, after which the cast was removed and the ankle was bound up with an elastic bandage.

Exercise of the ankle joint was immediately started, and supports were modelled.

In the majority of cases (248) the operation was carried out under general anaesthesia. Spinal anaesthesia was employed only twice owing to the risk of shock, which is particularly great in rheumatoid patients. Many of the patients had been on cortisone therapy and were therefore given cortisone routinely on the evening preceding operation and after the operation. During the last few years covered by this study, block anaesthesia has become more widely used. Combined sciatic-femoral-cutaneous femoris lateralis nerve block was used in 35 cases as described by MOORE (1954, 1962) and VAHVANEN (1964). No complications from anaesthesia occurred, one

case perhaps excepted, in which postoperative bronchitis-bronchiolitis developed, obviously due to vomiting caused by the ether.

Other procedures carried out in connection with triple arthrodesis

1) In four cases varus of the forefoot (sometimes associated with cavus) was corrected by cuneiform osteotomy in the area of the first cuneo-metatarsal joint. Owing to the fixation of the deformity soft tissue operations were excluded. At the same time elevation of the first metatarsus was corrected as suggested by VAINIO (1950).

2) Resection of the proximal phalanx of the great toe was performed twice on account of hallux rigidus. In these cases the resected bone was used as graft in triple arthrodesis.

In one case partial resection of the proximal phalanges of the second to fifth toes was carried out on account of severe digitus malleus.

3) In one case the Achilles tendon was elongated because of tension and slight varus. In another case the anterior tibial tendon was elongated on account of varus of the forefoot.

4) In one case severe medial exostosis was removed from the os naviculare.

As a rule, no other operations were performed in association with triple arthrodesis. If the foot to be operated upon showed severe digitus malleus deformities, these were usually first corrected, or they were corrected later. By the time of the follow-up examination, operations of resection type had been performed on a total of 76 feet (26.0 per cent) on account of hallux valgus or digitus malleus. Only the severest and most painful deformities of the toes were operatively treated.

Postoperative rise in temperature and ESR values

The preoperative mean temperature ranged from 36.0° to 37.5°. The postoperative temperature charts of 267 cases were studied. In 38 of these cases no definite rise in temperature was observed even on the first few days after operation. In evaluating elevation of temperature, 37.0° or the preoperative, possibly higher, level was taken as the basis. The mean rise was 0.5°, and the postoperative temperature ranged from 37.0° to 39.0°. The rise exceeded 1.0° only in 23 cases. The temperature dropped to the preoperative level within a week. Almost all of the present patients had regularly been receiving drugs of the chloroquine type or pain-relieving drugs (and often also cortisone preparations).

The ESR values ranged from 3—119 mm (Westergren) before operation, and from 2—125 mm on discharge from the hospital. The mean ESR before operation was 42.5 mm, and after a transient elevation for the first three to four postoperative weeks a mean ESR of 34.2 mm was noted. The possible, transient activation of the disease that could be noted in this series either clinically or as estimated from the ESR was not of more common occurrence than is to be expected among conservatively treated patients. This conclusion is in agreement with the results of VAINIO and HURRI (1961) and LAINE and VAINIO (1964).

Operative complications

The frequency of complications associated with triple arthrodesis (292 cases) was fairly low. Complications were observed in only 24 feet (8.2 per cent).

The distribution of the various complications was as follows:

1) Necrosis of the margins of the wound area (haematoma)	3 cases
2) Superficial wound infection	8 »
3) Infection of the deeper soft parts	4 »
4) Osteitis	6 »
5) Haemorrhage from the iliac crest	2 »
6) Bronchitis-bronchiolitis (after ether anaesthesia)	1 case
Total 24 cases	

Necrosis of the margins of the wound area was due to haematoma. Healing was rapid and no infection developed. Superficial wound infection also seemed to be mostly caused by haematoma, which burst the margins of the wound. The infection required treatment and healed in less than a month. Deep infection (as distinguished from osteitis) required more prolonged, efficient treatment. Suppuration sometimes persisted for three to six months. Osteitis developed in six cases, in three of which heterogenous, inorganic bone had been used for grafting. Thus, osteitis and a sequestrum developed in only three cases in which an autogenous graft had been applied. In these, the condition improved after trepanation and sequestrectomy. In the former cases the persistent suppuration was due to the tissue irritation caused by the heterogenous graft, not to the infection, which was entirely secondary.

Histological findings

Tissue specimens from a total of 142 feet were patho-anatomically studied. The specimens were mostly taken from synovial tissue which had prolapsed to the area of the tarsal sinus or from the hyperplastic synovial tissue of some joint. From 150 feet no tissue specimens were remitted to investigation. Among the 142 specimens examined, 123 (86.6 per cent) showed changes typical of rheumatoid arthritis. In 93 cases (65.5 per cent) the changes were even typical of very active inflammation, and in 30 cases (21.1 per cent) they were typical of chronic rheumatoid arthritis. Only 19 specimens (13.4 per cent) were too unspecific in character to warrant a diagnosis of RA.

In the above-mentioned 142 feet the serological results were positive in 84.6 per cent of cases (very clearly positive in 27.9 per cent), and negative in only 15.4 per cent. Thus, there seemed to be a fairly good correlation between positive serological results and the histological picture, which in 86.6 per cent of the cases examined showed changes typical of RA.

VIII. FOLLOW-UP STUDIES

Previous investigations

All previous follow-up studies have been performed on series in which subtalar or triple arthrodesis were carried out for reasons other than rheumatoid arthritis, chiefly residual paralysis, especially sequelae of poliomyelitis. *No follow-up study of RA as an indication for triple arthrodesis has hitherto been published.*

In HOKE's (1921) series of 104 operations, only 57 cases were followed up. The results were good in 98.2 per cent and poor in 1.2 per cent.

The most extensive series is that described by SMITH and v. LACKUM (1925). It comprised 223 patients on whom triple arthrodesis was performed. Follow-up results were reported in 155 cases as follows: good in 66.1 per cent, fair in 23.7 per cent, poor in 6.9 per cent.

GILL (1927) reported 60 cases of triple arthrodesis which were all followed up. The results were good in 73.3 per cent and poor in 26.7 per cent.

HALLGRIMSSON's (1943) series comprised 100 operations, i.e. 68 triple arthrodeses and 32 operations performed by HOKE's method. All these cases were followed up. The results were good in 69 per cent, fair in 24 per cent, poor in 6 per cent, and one patient had become worse. Pseudarthrosis was observed in 15 cases in the TN joint, which was more frequently than in the tc and CC joints.

PATTERSON, PARRISH and HATHAWAY (1950) reported a series of 305 feet on which arthrodesis was performed, including 89 cases of triple (Ryerson) arthrodesis. The indications consisted of poliomyelitis and other paralytic deformities, cerebral palsy, etc. One patient had rheumatoid arthritis. Weight-bearing was allowed after four to six weeks, and total plaster immobilization was maintained for a maximum of twelve weeks. In the 89 cases of triple arthrodesis the results were good in 48 (53.9 per cent), fair in 27 (30.4 per cent) and poor in 14 (15.7 per cent). Pseudarthrosis occurred most frequently in the TN joint, i.e. in 12 cases.

ALLDREDGE and RIORDAN (1953) performed triple arthrodesis in 63 cases, of which only 22 were followed up. They used staple and chips in each joint (three staples in each case), if possible. No complications occurred, but in two cases a staple had to be removed because it had risen under the skin and caused discomfort. No occurrence of corrosion was reported.

GRICE (1955) described 52 cases in which he used two cortical grafts obtained from the tibia, which he applied extra-articularly between the calcaneus and the talus. The series comprised only juvenile planovalgus feet, but Grice pointed out that the method could also be applied in adults if triple arthrodesis was simultaneously performed. He reported good fusion of the graft within eight to ten weeks. Partial weight-bearing was allowed nine to eleven weeks after operation. The series comprised only three failures.

VAINIO (1956) performed triple arthrodesis on 27 feet and reported good results.

In his paper »Surgery in rheumatoid arthritis», HARRIS (1956) described various operative techniques. He had used arthrodesis only in the treatment of weight-bearing joints, and he had performed this operation on six knees and three feet. The results were highly satisfactory in all cases.

GRICE's method was used by WESTIN and HALL (1957) in 62 cases in the treatment of flat-foot and other deformities (due to paralysis or other causes) in children. The authors pointed out that marked valgus affects the talocrural mortise, causing talar tilting.

ROBINS (1959) published a follow-up study on 60 polio patients on whom triple arthrodesis had been performed. The period of observation was at least ten years in all cases. At the end of the follow-up period Robins observed rounding of the edges of the talus. Only slight limitation of the range of motion of the talocrural joint was noted. Degenerative changes did not occur, provided that the valgus or varus deformities had been adequately corrected. Compensatory tilting of the lateral aspect of the talus was not associated with clinical instability or pain.

LINDHOLM (1960) published the follow-up results of 211 operations, i.e. 16 triple arthrodeses, 173 triple arthrodeses combined with tendon transfer, and 22 arthrodeses performed by LAMBRINUDI's method. The patients showed improvement in 67.8 per cent of cases, while 21.3 per cent were unaltered, and 10.9 per cent were worse than before operation.

In a series of 42 paralytic valgus feet, on which extra-articular triple arthrodesis was performed by GRICE's method, INGELRANS (1962) observed increased instability of the ankle.

CLAYTON (1963) stated that triple arthrodesis was indicated in the presence of subtalar changes in an otherwise well preserved ankle joint, and provided that the patient experienced pain and showed valgus deformity.

HOWLAND (1964) performed triple arthrodesis on 129 patients with club foot, polio, spina bifida, spastic cerebral palsy, etc. In the majority of cases (102) he used RYERSON's method. LAMBRINUDI's method was used in 15 cases, HOKE's in 10, and other techniques in two cases. Pseudarthrosis resulted in 19 cases, in 75 per cent of these in the TN joint, but mostly no subjective symptoms were caused. Staples were used in 26 cases. The mean duration of plaster immobilization was eleven weeks. Complete failure was noted in 6 cases. The author recommended midline or slight valgus positioning of the calcaneus. Arthrosis of the TC joint was observed at follow-up in one case.

POLLOCK and CARRELL (1964) treated 112 cases of paralytic valgus deformities by subtalar extra-articular arthrodesis. The results were unsatisfactory in 37.5 per cent.

RUGTVEIT (1964) utilized extra-articular subtalar arthrodesis as described by GRICE in the treatment of flat-foot in 37 children. The range of motion of the TC and Chopart's joints remained the same, and no instability was observed, nor arthrosis of the TC joint. The results were satisfactory in 78 per cent of cases.

KIVILAAKSO, LANGENSKIÖLD and SALENIUS (1965) described a series comprising 32 patients on whom triple arthrodesis was performed for post-traumatic conditions. Weight-bearing was begun one month after operation, and the longest duration of plaster immobilization was four months. The result was good in 26 cases, while pain persisted in 6. One pseudarthrosis of the Chopart joint was observed.

The most extensive series of triple arthrodeses described is that of WILSON, LAMOTTE and WILLIAMS (1965). They performed this operation in 301 cases, mostly by RYERSON's and HOKE's methods. The age of the patients ranged from 5 to 60 years, the mean operative age being 12 years. The mean follow-up period was 4.8 years. The indications for operation were 1) polio, 2) congenital deformities, 3) severe flat-foot, 4) pain resulting from subtalar or midtarsal arthritis of any origin.

In recent years staples were used in the CC joint in 50 feet, and in combination with some other device (e.g. graft, nail) in 38 feet. Weight-bearing in plaster was begun at two to 16 weeks after operation, the average being 7.4 weeks. Pseudarthrosis was found in 31 cases (10.3 per cent) in the whole series, the site in 64.5 per cent of these cases being the talonavicular joint. The development of pseudarthrosis was obviously due to early

absence of bony contact in the talonavicular joint. Superficial infection was observed in 61 cases. According to the authors, the development of pseudarthrosis was not influenced by the duration of immobilization in plaster, but it was influenced by too early weight-bearing.

Present investigation

A total of 290 operatively treated (Table 26) and 194 conservatively treated feet were clinically examined. During the interval between operation and the time of the follow-up study five patients had died. On two of these, triple arthrodesis had been performed bilaterally. However, clinical data were lacking only in the case of two operatively treated feet, i.e. two patients who had never visited the hospital after operation.

The author himself examined 255 of these feet. The remaining 35 feet were examined by other doctors on the hospital staff, or follow-up examination was made immediately after removal of the plaster cast. In these 35 cases the clinical data were checked by the aid of questionnaires.

A complete radiological study was performed on 248 operatively treated and 170 non-operatively treated feet. Radiological stress investigations were performed by the author on 255 triple arthrodesis feet and 200 non-operatively treated ankles.

The mean follow-up period was 3.7 years. Of the examined feet that had been operated upon 80 (27.5 per cent) belonged to men, i.e. 41 left and 39

TABLE 26. *Interval (in years) between operation and follow-up examination in 290 cases of triple arthrodesis.*

Sex	L/R	<1	2—3	4—6	>7	No. of feet
Male	L	9	17	8	7	41
	R	8	15	5	11	39
No. of feet		17	32	13	18	80
%		21.2	40.0	16.3	22.5	27.5
Female	L	7	54	14	23	98
	R	9	60	21	22	112
No. of feet		16	114	35	45	210
%		7.6	54.0	17.1	21.3	72.5
Total no.		33	146	48	63	290
%		11.4	50.4	16.5	21.7	100.0

right feet. The female feet numbered 210 (72.5 per cent), i.e. 98 left and 112 right feet. Table 26 shows the distribution according to duration (in years from operation). The interval between operation and follow-up was over seven years in 63 cases (21.7 per cent) and less than a year in 33 cases (11.4 per cent). In the largest group consisting of 146 feet (50.4 per cent) two to three years had elapsed since operation.

Clinical findings

The subtalar joints

Swelling, pain and range of motion

Swelling was observed in 63 feet (21.7 per cent) in the Op II group and in 109 feet (56.2 per cent) in the Non-op II group. As swelling was present before operation in 287 feet (98.3 per cent), the difference is considerable. Moderate or marked pain at rest also showed a clear decrease, being present before operation in 182 feet (62.3 per cent) and at follow-up in only 10 feet (3.4 per cent).

In the Op II group pain at rest occurred as follows:

Stage 0	143 feet	49.3 per cent
Stage 1	137 »	47.3 »
Stages 2—4	10 »	3.4 »
Total	290 »	100.0 »

In association with follow-up of the operatively treated feet, pain on stress (weight-bearing), but not on motion, as mobility was lost in all cases, had clearly decreased after operation. The distribution at follow-up was as follows:

Stage 0	226 feet	78.0 per cent
Stage 1	52 »	17.9 »
Stage 2	10 »	3.4 »
Stage 3	2 »	0.7 »
Stage 4	0 »	0 »

Before operation, pain of stages 2—4 was present in 288 feet (98.6 per cent), postoperatively in only 12 feet (4.1 per cent). In the non-operatively treated feet pain was present at follow-up in 42.2 per cent of 194 (Table 27). Pain was thus a common symptom in this group of feet also.

In the feet operated upon, no subtalar motion was observed. The joints showed either bony or fibrous ankylosis. In the conservatively treated group a definite decrease in the range of motion was observed at follow-up

TABLE 27. *Swelling, pain on motion and range of movement (Groups Op II and Non-op II).*

Group	No. of feet	Swelling		Pain on motion		Range of movement	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op II	290	227	63	278	12	290	0
	%	78.3	21.7	95.9	4.1	100	—
Non-op II	194	85	109	112	82	53	141
	%	43.8	56.2	57.8	42.2	27.4	72.6

TABLE 28. *Occurrence of planovalgus.*

Group	No. of feet	Stages 0—1 <10°		Stage 2 11°—15°		Stage 3 16°—20°		Stage 4 >20°	
Op I	292	37	12.6 %	127	43.6 %	93	31.8 %	35	12.0 %
Op II	290	31	10.7 %	193	66.5 %	53	18.3 %	13	4.5 %
Non-op I	204	41	20.1 %	120	58.8 %	31	15.2 %	12	5.9 %
Non-op II	194	32	16.6 %	111	57.2 %	40	20.6 %	11	5.6 %

TABLE 29. *Occurrence of deformities other than planovalgus.*

Group	No. of feet	Deformity	Stages 0—1	Stage 2	Stage 3	Stage 4
Op II	290	Calcaneovarus	273	12	4	1
			94.1 %	4.1 %	1.4 %	0.4 %
Op I	292	Calcaneovarus	265	15	12	0
			90.8 %	5.1 %	4.1 %	—
Op II	290	Varus of the forefoot	240	38	12	0
			82.8 %	13.1 %	4.1 %	—
Op I	292	Varus of the forefoot	235	37	19	1
			80.6 %	12.6 %	6.5 %	0.3 %
Op II	290	Cavus or calcaneocavus	270	16	4	0
			93.1 %	5.5 %	1.4 %	—
Op I	292	Cavus or calcaneocavus	272	16	4	0
			93.1 %	5.5 %	1.4 %	—

in 141 feet (72.6 per cent), which shows that inflammation was of common occurrence, although in many cases it was in a relatively inactive stage at the time of the follow-up examination.

Deformities.

The distribution of *planovalgus* at follow-up in the operatively and non-operatively treated feet (groups Op II and Non-op II) is shown in Table 28. For the sake of comparison the distribution before operation (group Op I) and at the same point of time in the conservatively treated feet (group Non-op I) also appears in the table.

The greatest differences in *planovalgus* are found between the groups Op I and Op II. The severest stages (3 and 4) have markedly decreased after operation. Correspondingly, stage 2 (valgus of 11—15 degrees) shows an increase, from 127 feet (43.6 per cent) to 193 feet (66.5 per cent). *Planovalgus* of stage 3 was present at follow-up in 53 feet (18.3 per cent), and stage 4 (the severest stage) in 13 feet (4.5 per cent).

The conservatively treated feet had remained largely as before, except that stage 3 shows a slight increase in frequency. This reflects the development of the deformity into rigidity, after which no major changes are possible.

In performing triple arthrodesis an attempt was made to place the calcaneus into slight valgus position. The severest deformities clearly decreased, but valgus of 11—15 degrees showed a marked rise.

The distribution of *other deformities* in the feet operated upon is shown in Table 29.

Calcaneovarus was still present in 17 feet (5.9 per cent), varus of the forefoot in 50 feet (17.2 per cent), and cavus or calcaneocavus in 20 feet (6.9 per cent), i.e. the same as before operation.

Calcaneovarus was in every case associated with pes planus, and in 10 cases with varus of the forefoot. In the remainder of cases varus of the forefoot was associated with *planovalgus*.

Calcaneovarus (27 feet) showed a clear decrease, but nonetheless this deformity was still present in 17 feet. Varus of the forefoot had also decreased as far as the severest forms were concerned, but milder degrees were still encountered in 50 feet.

The calcaneocavus and cavus deformities were relatively slight and caused no discomfort. Calcaneovarus, on the other hand, causes discomfort on walking. Varus of the forefoot, too, impedes walking, particularly in association with calcaneovarus, pes varus.

Evaluation of the results (Tables 30 and 31). When deformities of stages 3—4 persisted, the result is evaluated as poor. Stage 2 is regarded as a fair result, and stages 0—1 as good. However, planovalgus up to 15 degrees (stages 0—2) is regarded as good, stage 3 as fair, and stage 4 as poor.

If planovalgus of stage 2 were regarded only as fair, only 31 feet (10.7 per cent) would show good results, while the results would be fair in 246 feet (84.8 per cent), and poor in 13 (4.5 per cent).

In the group with poor results the above-mentioned deformities were more pronounced, except in five feet in which calcaneovarus was associated with marked varus of the forefoot (pes varus). In the »fair» group the deformities were also obvious and responsible for the fact that the foot was not anatomically quite good. From this group, however, must be subtracted the above-mentioned five feet which showed pes varus and therefore were poor results. The final objective anatomical results are shown in Table 31.

This classification of the results presupposes that calcaneovalgus of 15 degrees or less is regarded as good when it is not associated with other deformities. In that case the functional capacity of the foot is determined by the associated deformities, mainly by the degree of varus.

Summary

Pain on stress was present in only 12 feet (4.1 per cent), definite swelling in 63 feet (21.7 per cent). Not all anatomically poor feet caused persistent pain. When evaluated from the standpoint of the anatomy of the foot, the results are not

TABLE 30. *Results of the correction of various deformities.*

Deformity	Good		Fair		Poor	
Planovalgus	224	77.2 %	53	18.3 %	13	4.5 %
Calcaneovarus	273	94.1 %	12	4.1 %	5	1.8 %
Varus of the forefoot	240	82.8 %	38	13.1 %	12	4.1 %
Cavus or calcaneocavus	270	93.1 %	16	5.5 %	4	1.4 %

TABLE 31. *Final objective anatomical results.*

Good	142	feet	48.9 %
Fair	114	feet	39.3 %
Poor	34	feet	11.8 %
Total	290	feet	100.0 %

TABLE 32. *Clinical findings in the talocrural joint.*

Group	No. of ankles	Swelling		Pain on motion		Dorsiflexion		Plantar flexion	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op I	292	106	186	135	157	202	90	183	109
	%	36.3	63.7	46.2	53.8	69.2	30.8	62.7	37.3
Op II	290	219	71	242	48	185	105	153	137
	%	75.6	24.4	83.5	16.5	63.8	36.2	52.8	47.2

equally favourable. Only 31 feet (10.7 per cent) showed valgus up to 10 degrees, and 246 feet (84.8 per cent) showed valgus of 11—20 degrees. In other words, rather marked planovalgus of the foot was still observed in a large proportion of the patients.

The talocrural joint

Swelling, pain and range of motion

In Table 32 the observations made at follow-up examination are compared to the preoperative findings.

Swelling showed a definite decrease. In other words, the swelling present before operation was largely due to inflammation of the subtalar joints. Moderate or severe swelling was still present in 71 joints (24.4 per cent). The corresponding figure for the region of the subtalar joints was 63 (21.7 per cent).

Pain was present in 48 ankles (16.5 per cent), a clear decrease which reflects the improvement in the situation after operation. However, slight pain and tenderness on palpation was still observed in the area of the ligaments and at the corners of the joint in 162 ankles (55.9 per cent). Thus, the number of completely painless (stage 0) ankles was only 80 (27.6 per cent).

The range of motion had clearly decreased at the follow-up examination as compared with the situation before triple arthrodesis was performed. This applies in a slightly higher degree to plantar flexion than to dorsiflexion. Dorsiflexion was limited to less than 10 degrees in 105 ankles (36.2 per cent) and plantar flexion to less than 30 degrees in 137 ankles (47.2 per cent). Dorsiflexion regarded as normal (stage 0) was present in 72 ankles (24.8 per cent) and plantar flexion in 58 ankles (20.0 per cent).

Radiological findings

The subtalar joints

Osteoporosis

In Table 33 the occurrence of osteoporosis after operation (group Op II) is compared with the values noted preoperatively (group Op I). The table shows that osteoporosis was somewhat less frequent and milder in degree at follow-up than before operation, but the difference is statistically insignificant. The fact that the change was so slight is obviously due both to the shortness of the follow-up period and the severity of the disease.

Statistical analysis was performed as follows:

The t test of dependent groups

$M_c = .15$ $t = 1.10$ $P > .05$ insignificant

The conclusion may be drawn that the great loss of calcium had not yet been compensated for at the time of the follow-up examination, although the patients had been using the feet operated upon.

TABLE 33. *Osteoporosis in the subtalar joints in groups Op I and Op II.*

Group	No. of feet	Talocalcaneal		Calcaneocuboid		Talonavicular	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op I	284	75	209	27	257	69	215
		26.4 %	73.6 %	9.5 %	90.5 %	24.2 %	75.8 %
Op II	248	71	117	56	192	81	167
		28.6 %	71.4 %	22.6 %	77.4 %	32.7 %	67.3 %

TABLE 34. *The periosteal reaction in the subtalar joints in groups Op I and Op II.*

Group	No. of feet	Talocalcaneal		Calcaneocuboid		Talonavicular	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op I	284	169	115	234	50	75	209
		59.5 %	40.5 %	82.4 %	17.6 %	26.4 %	73.6 %
Op II	248	150	98	195	53	49	199
		60.5 %	39.5 %	78.7 %	21.3 %	19.8 %	80.2 %

The periosteal reaction

The possible occurrence of periosteal growth in the subtalar joints after triple arthrodesis was studied. The observations made pre- and postoperatively were compared.

Table 34 clearly shows that no significant periosteal growth occurred after the operation. In the region of the CC and TN joints a slight reaction was observed, but when the changes in the two observation groups were statistically tested, no significant differences emerged. No growth had occurred, while a significant difference in periosteal growth was observed between the different duration groups of the preoperative material (group Op I). In the talocalcaneal joint the periosteal reaction seemed rather to have decreased after operation, and the difference proved to be statistically significant ($P < .05$).

Statistical analysis

The periosteal reaction: Comparison of groups Op I and Op II by the t test of dependent groups.

Talocalcaneal joint $M_c = .09$ $t = 2.49$ $P < .05$ significant

Calcaneocuboid joint $M_c = .06$ $t = 1.36$ insignificant

Talonavicular joint $M_c = .08$ $t = 1.44$ insignificant

The arithmetic mean values of the tc changes in groups Op I and Op II were 1.31 and 1.24. The difference is only 0.07, but it shows that a slight improvement had occurred. This is to some extent in contrast to the periosteal reaction in the TN and CC joints. It is very difficult to evaluate the periosteal change in the talocalcaneal joint after arthrodesis. The dorsal margin of the TN joint and the plantar margin of the CC joint are much more readily distinguished on X-ray films. It appears that the decrease that seemed to occur postoperatively in the periosteal reaction in the tc joint may be accounted for by the difficulty in evaluating the situation properly. As a result of fusion the osteophytes unite with the normal bone tissue, the posterior talar process is pressed tightly against the calcaneus, and its length can no longer be precisely measured.

To summarize, no obvious periosteal changes, in any event no periosteal growth, occurred postoperatively in the tc, TN and CC joints.

Fusion after triple arthrodesis

Complete X-ray studies were performed on 248 feet. In 117 cases these studies were carried out two to three years after operation. In 56 cases the interval was over seven years (Table 35). The best results were observed in

the talocalcaneal joint, not a single case of non-union being found. In 58 cases (23.4 per cent) partial union had occurred. In these cases part of the posterior joint surface was visible, while the anterior portion was firmly ossified, but in practice this is of no significance. The calcaneocuboid joint showed non-union in 16 cases (6.5 per cent) and partial union in 66 cases (26.6 per cent). Complete union of the CC joint was observed in 166 cases (66.9 per cent). The talonavicular joint exhibited non-union in 23 cases (9.3 per cent), partial union in 68 cases (27.4 per cent), and complete union in 157 cases (63.3 per cent). In the cases showing partial union the lower portion of the CC joint had remained open, while the area of the staple and the upper portion had fused. On the other hand, the upper margin of the TN joint had in some cases remained open. These findings are obviously accounted for by incomplete contact of the points in question, since at operation a definite fissure, sometimes perhaps also cartilage, had been left in these sites. The TN joint seems to cause most complications, but no case of pseudarthrosis proper, with mobility of the Chopart joint, occurred. Nine feet showed non-union of both the TN and CC joints. In two of these there was an obvious varus deformity causing discomfort. One case exhibited rather marked varus of the forefoot. In one case non-union was due to infection, and five years after the first operation sequestrectomy was performed on the Chopart joint, which showed non-union. The infection healed, but at follow-up examination two years later union had not yet occurred. Fibrous

TABLE 35. *Fusion after triple arthrodesis as observed at the follow-up examination in the different duration groups.*

Duration groups (years)	No. of feet	Talocalcaneal			Calcaneocuboid			Talonavicular		
		TF	PF	NU	TF	PF	NU	TF	PF	NU
<1	32	13	19	0	6	24	2	10	19	3
2-3	117	96	21	0	82	28	7	78	27	12
4-6	43	40	3	0	36	5	2	29	12	2
>7	56	41	15	0	42	9	5	40	10	6
Total	248	190	58	0	166	66	16	157	68	23
	%	76.6	23.4	—	66.9	26.6	6.5	63.3	27.4	9.3

TF = totally fused

PF = partly fused

NU = non-union

ankylosis was present, and no mobility was observed. The remaining five cases exhibited moderate or severe planovalgus, but the functional result was good. The above-mentioned group of nine cases showing non-union of the Chopart joint includes one patient who showed non-union of the TN and CC joints of both feet. The number of patients in this group was thus eight. On three patients triple arthrodesis had been performed bilaterally and one foot had healed completely, except that one CC joint exhibited non-union.

Non-union of the TN and CC joints seems to be associated with a marked tendency towards varus deformity of the forefoot. In two cases calcaneus varus was present, but nonetheless the tc joint showed complete union. In none of the nine cases under discussion, which showed non-union of the TN and CC joints, was anything known about the possible presence of preoperative varus of the feet. In two cases slight osteolysis and sclerosis were discernible round the staple, and in a further case this finding was uncertain. In no case did the staple cause any appreciable osteal reaction leading to the formation of a cavity. Evidently the stainless steel did not irritate the tissues. Owing to the ankylosis no movement occurred in the CC joint, which could have caused osteolysis round the staple, and in no case had the staple raised the skin.

Summary

In 248 feet which were radiographically examined after triple arthrodesis, union had occurred satisfactorily. Non-union was most frequently observed in the TN joint (in 9.3 per cent) and the CC joint (in 6.5 per cent). The talocalcaneal joint showed either partial or complete union. The greatest number of cases showing non-union were found in the two to three years' duration group. Pseudarthroses proper, in which motion occurs, were not observed. In nine feet (23.1 per cent) out of 39 showing non-union of the TN or CC joints both these joints were open.

Technical considerations of the use of staple and bone graft

The use of one staple only over the calcaneocuboid joint was the routine procedure in a total of 281 operations. Furthermore, one staple was used over the talonavicular joint in one case. Two staples were used in four cases, in which they were applied over the talonavicular and calcaneocuboid joints. Three staples were used in three cases, in which they were applied over the TN, CC and tc joints. In these cases no bone grafts, but chips from the ad-

jacent bone, were used. One of these ankles showed marked valgus. In three cases no staple was applied, and no complications occurred. In these, conventional bone grafting was used.

As a rule one autogenous graft from the iliac crest was applied in the talocalcaneal joint (in 272 cases).

In one case in which resection of the proximal joints of the toes was performed for digitus malleus, an autogenous bone graft was taken from the proximal phalanx of the second toe. In another similar case the bone graft was taken from the proximal phalanx of the first toe.

Two autogenous bone grafts were used only in one case, in which they were applied between the talocalcaneal and talonavicular joints.

One talonavicular graft was used in six cases (in one of these the graft was applied over the TN and cuneonavicular joints).

All these operations were successful, although one patient complained of pain in the lateral aspect of the ankle and was dissatisfied with the result.

In four cases no graft was used, but in three of these three staples each were used, and in all four, chips from the adjacent spongy bone were applied.

Heterogenous (inorganic) bone grafts were used in a total of seven cases. In two of these the so-called Kieler graft was used. This caused no complications. Inorganic Ossar bone was applied between the tarsal sinus and the joint spaces in five cases. The Ossar bone was used both as small granules and as staples, in the same way as the Kieler bone. Of these operations only two were successful. In the remaining three the Ossar granules irritated the tissues and caused a strong reaction in the host bone. In two cases granules came out after about six months, after which the fistula healed, although a certain degree of pain persisted laterally in one of these cases. In the third case the granules are still causing irritation two years after operation, and sometimes the fistula is open and granules come out. In this case, too, the ankle is painful.

To summarize, heterogenous grafts were used in seven cases. In four cases the operation was successful, but in three cases an obvious foreign body reaction of the host tissue occurred and bone granules came out.

Autogenous bone graft was used in 281 cases. The course was uneventful except in three cases. In these, osteitis due to infection developed in the area of the graft, resulting in sequestration. In one case a suppurating fistula appeared in the tarsal sinus five years after operation, and sequestrectomy was performed. Subsequently the ankle healed and became completely symptom-free. In another case a suppurating fistula developed in

the wound area about five months after operation. After trepanation complete healing occurred within three months. In the third case a sequester and fistula developed five months after operation. Trepanation was performed, and the ankle healed completely within eight months of the first operation.

The talocrural joint

The X-ray changes in the TC joint were studied both in the operatively and the non-operatively treated ankles. The follow-up results were compared with the pre-operative findings and the findings made at a corresponding point of time in the conservatively treated feet. In other words, groups Op I and II, and Non-op I and II, were compared.

On comparison of groups Op II and Non-op II (Table 36) it appeared that stages 2—4 were throughout more frequent in the former. There was a corresponding difference at the first stage of this investigation between the feet assigned for operative treatment and those assigned for conservative treatment (Table 20). On comparison of groups Op I and Op II, and Non-

TABLE 36. *X-ray changes in the talocrural joint in groups Op II and Non-op II.*

Group	No. of ankles	Osteoporosis		Narrowing of the joint space		Osteoarthrosis	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op II	248	82	166	174	74	178	70
		33.1 %	66.9 %	70.2 %	29.8 %	71.8 %	28.2 %
Non-op II	170	84	86	138	32	134	36
		49.4 %	50.6 %	81.2 %	18.8 %	78.8 %	21.2 %

TABLE 37.

Group	No. of ankles	Surface erosion		Marginal erosion			
				Medial part of mortise		Lateral part of mortise	
		Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4	Stages 0—1	Stages 2—4
Op II	248	158	90	68	180	83	165
		63.7 %	36.3 %	27.4 %	72.6 %	33.5 %	66.5 %
Non-op II	170	129	41	89	81	97	73
		75.9 %	24.1 %	52.3 %	47.7 %	57.0 %	43.0 %

TABLE 38. *X-ray changes in the talocrural joint in groups Non-op I, Op I, Non-op II, and Op II (stages 2—4).*

Group	No. of ankles	Osteoporosis	Narrowing of the joint space	Erosive changes			
				Surface	Marginal medial part of mortise	lateral part of mortise	Osteoarthrosis
Non-op I	204	69	20	32	50	50	21
		33.8 %	9.8 %	15.7 %	24.5 %	24.5 %	10.3 %
Op I	284	126	40	59	96	90	36
		44.4 %	14.1 %	20.8 %	33.8 %	31.7 %	12.7 %
Non-op II	170	86	32	41	81	73	36
		50.6 %	18.8 %	24.1 %	47.6 %	42.9 %	21.2 %
Op II	248	166	74	90	180	165	70
		66.9 %	29.8 %	36.3 %	72.6 %	66.5 %	28.2 %

op I and Non-op II (Tables 20—21 and 36—37), it emerged that in the two series of feet, the operatively treated and the non-operatively treated, the differences between the observations made at the two different stages were of about the same magnitude. In both, the disease had progressed. In the operatively treated series surface erosion of the TC joint had increased from 20.8 per cent to 36.3 per cent. The frequency of erosions of the malleolar mortise had increased in the operatively treated series by more than twofold and in the conservatively treated series by about twofold. The percentage figure expressing the frequency of joint space narrowing was doubled in both series. The increase in osteoporosis was somewhat slighter in the operatively treated series; in the non-operatively treated series it was about twofold. When the erosive changes of the medial and lateral surfaces were compared (Table 38), medial changes were found to be somewhat more frequent postoperatively than before triple arthrodesis. The same phenomenon was observed in the conservatively treated series, although not so clearly. In other words, erosion of the cartilage and bone seems to be more pronounced in the surface of the medial malleolus and the opposite surface of the talus than in the corresponding lateral aspects. It is possible that valgus of the foot plays a part in this respect, the stress on the ligaments of the medial portion being, perhaps, heavier, so that the »normal» progress of erosion is obscured.

On analysing the distribution of the changes in the TC joint in the different duration groups (Tables 39 and 40), it was found that all symptoms

TABLE 39. Postoperative X-ray findings in the talocrural joint in different duration groups as counted from the operation to the follow-up.

Duration groups (years)	No. of ankles	Osteoporosis Stages					Narrowing of the joint space Stages					Osteoarthritis Stages				
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
<1	33	1	5	19	8	0	22	3	2	2	4	25	1	1	4	2
	%	3.0	15.3	57.5	24.2	—	66.6	9.1	6.1	6.1	12.1	75.8	3.0	3.0	12.1	6.1
2—3	117	9	29	57	22	0	68	15	13	17	4	73	15	17	10	2
	%	4.7	24.8	48.7	18.8	—	58.2	12.8	11.1	14.5	3.4	62.4	12.8	14.5	8.6	1.7
4—6	45	10	6	24	5	0	31	4	6	2	2	29	4	9	2	1
	%	22.2	13.3	53.4	11.1	—	69.0	8.9	13.3	4.4	4.4	64.5	8.9	20.0	4.4	2.2
>7	53	8	14	16	12	3	28	3	5	4	13	25	6	9	10	3
	%	15.1	26.4	30.2	22.6	5.7	52.8	5.7	9.4	7.6	24.5	47.2	11.4	16.8	18.9	5.7
Total	248	28	54	116	47	3	149	25	26	25	23	152	26	36	26	8
	%	11.3	21.8	46.8	18.9	1.2	60.1	10.1	10.5	10.1	9.2	61.3	10.5	14.5	10.5	3.2

TABLE 40. Postoperative X-ray findings in the talocrural joint in different duration groups as counted from the operation to the follow-up.

Duration groups (years)	No. of ankles	Surface erosion					Marginal erosion											
		Stages					Medial part of mortise					Lateral part of mortise						
		0	1	2	3	4	0	1	2	3	4	0	1	2	3	4		
<1	33	10	11	7	3	2	3	6	16	8	0	4	8	16	5	0		
	%	30.2	33.4	21.2	9.1	6.1	9.1	18.3	48.4	24.2	—	12.1	24.2	48.4	15.3	—		
2—3	117	38	33	32	13	1	12	20	54	30	1	16	22	61	17	1		
	%	32.5	28.2	27.2	11.1	0.9	10.3	17.1	46.1	25.6	0.9	13.7	18.8	52.1	14.5	0.9		
4—6	45	21	13	6	3	2	5	12	18	10	0	6	13	19	7	0		
	%	46.7	28.9	13.3	6.7	4.4	11.1	26.7	40.0	22.2	—	13.3	28.9	42.2	15.6	—		
>7	53	18	14	4	12	5	4	6	24	19	0	4	10	25	14	0		
	%	34.1	26.4	7.5	22.6	9.4	7.5	11.3	45.2	36.0	—	7.5	18.6	47.5	26.4	—		
Total	248	87	71	49	31	10	24	44	112	67	1	30	53	121	43	1		
	%	35.1	28.6	19.8	12.5	4.0	9.7	17.7	45.2	27.0	0.4	12.1	21.4	48.8	17.3	0.4		

showed a slow and rather steady progression. The differences between the first and the last duration groups were particularly marked. Osteoporosis, however, showed a steady improvement, from 81.7 per cent in the first group to only 58.5 per cent in the last. The latter value is clearly higher, however, than the value obtained before operation (44.4 per cent), but slightly lower than the value for the over 10 years' duration group (59.7 per cent). The strikingly high frequency of osteoporosis postoperatively is probably due to the inactivity of the ankle. In respect to osteoporosis a change for the better gradually occurs, but at the same time the disease progresses and influences the situation in the opposite direction. Joint space narrowing and osteoarthrosis showed a definite aggravation. As regards erosion, progression was relatively slow, and the greatest difference was noted between the first and the last duration groups. It is striking that a definite, although slight, tendency towards improvement was observed in the duration group 4—6 years, in which the percentages of changes of stages 2—4 were lower than in any other duration group.

As may be seen in Table 41, both in the conservatively and the operatively treated series erosions were by far most frequent in the toes (the mtp joints) and rarest on the surface of the TC joint. In the former series these changes were fairly evenly distributed over the tarsal joints. The frequency was clearly lowest in the cuneonavicular joint. In both series the medial aspect of the TC joint seemed to show somewhat more marginal erosions than the lateral aspect. In the Non-op II group the amount of erosions seemed to be about the same in the subtalar joints as in the marginal part of the TC joint. In the Op I group (Table 42) this phenomenon is not obvious. The tendency in question is not obvious, either, in the Non-op I group, but it is very obvious in the Non-op II group (Table 42). This is probably due to the difference in material, the operatively treated series comprising the most severely inflamed subtalar joints. Initially, the erosive changes in the subtalar joints were much more marked than the malleolar erosive changes. The increase in malleolar changes seems to reflect the progression of the disease.

As may be seen in Table 42, in the Non-op I group the subtalar joints showed severer erosive changes than the TC joint, even when the malleolar changes in the latter were taken into account. The same observation was made in the Op I group, although the changes in this were throughout severer. At follow-up (Non-op II) the differences had diminished, except in respect to TC surface erosion (Table 42). This shows that the weight-bearing surface of the TC joint is very resistant to the development of erosions. An

TABLE 41. *The frequency of erosions in the different joints of the foot in groups Op II and Non-op II.*

Joint	Op II Stages 2—4	Non-op II Stages 2—4
Metatarsophalangeal	229	159
(1-5)	92.3 %	93.5 %
Cuneonavicular	144	62
	58.1 %	36.5 %
Talonavicular	—	73
	—	43.0 %
Calcaneocuboid	—	72
	—	42.3 %
Talocalcaneal	—	67
	—	39.5 %
Surface of the TC	90	41
	36.3 %	24.1 %
Marginal medial	180	81
	72.6 %	47.6 %
Marginal lateral	165	73
	66.5 %	42.9 %

TABLE 42. *The frequency of erosions in the talocrural and subtalar joints in groups Op I, Non-op I and Non-op II.*

Joint	Op I Stages 2—4	Non-op I Stages 2—4	Non-op II Stages 2—4
Surface of the TC	59	32	41
	20.8 %	15.7 %	24.1 %
Marginal medial	96	50	81
	33.8 %	24.5 %	47.6 %
Marginal lateral	90	50	73
	31.7 %	24.5 %	42.9 %
Talocalcaneal	126	60	67
	44.4 %	29.5 %	39.5 %
Calcaneocuboid	140	68	72
	49.3 %	33.3 %	42.3 %
Talonavicular	174	62	73
	61.3 %	30.4 %	43.0 %

increase in erosions is an obvious accompaniment of the progression of the disease, except in the medial mortise of the TC joint, in which erosive changes develop relatively quickly, i.e. during the first three years, obviously owing to the presence of valgus deformity. Operation does not seem to influence the formation of erosions of the malleolar mortise of the TC joint, since the differences between the changes in the Op I and Op II groups, and the Non-op I and Non-op II groups, respectively, were of the same magnitude (Table 38).

Statistical analysis

Comparison of the groups Op I and Non-op I (the U test, page 66).

Comparison of the groups Op II and Non-op II (by the U test):

Surface erosion: $z = 2.75$ $P < .01$ most significant

Marginal erosion, medial part of the mortise: $z = 5.15$ $P < .001$ highly significant

Marginal erosion, lateral part of the mortise: $z = 4.76$ $P < .001$ highly significant

Comparison of the groups Op I and Op II (the t test):

Surface erosion: $M_c = -.50$ $t = 9.28$ $P < .001$ highly significant

Marginal erosion, medial part of the mortise: $M_c = -.99$ $t = 16.10$ $P < .001$ highly significant

Marginal erosion, lateral part of the mortise: $M_c = -.85$ $t = 14.28$ $P < .001$ highly significant

Comparison of the observation groups Non-op I and Non-op II (the t test):

Surface erosion: $M_c = -.33$ $t = 6.98$ $P < .001$ highly significant

Marginal erosion, medial part of the mortise: $M_c = -.77$ $t = 11.08$ $P < .001$ highly significant

Marginal erosion, lateral part of the mortise: $M_c = -.67$ $t = 10.55$ $P < .001$ highly significant

Summary

The radiological changes in the TC joint were studied in the operatively treated feet before operation and at follow-up, and in the non-operatively treated feet at corresponding points of time. On the basis of the results it may be stated that the progression of the disease is accompanied by a steady progression of all radiological changes. The progression of surface erosion was statistically highly significant, while the progression of erosion on the lateral aspect was most significant. On the medial aspect the progression was not statistically significant.

Both in the operatively and the non-operatively treated series very obvious differences emerged between the radiological findings made before operation in the former and at a corresponding point of time in the latter, and at follow-up. In the operatively treated series the changes were severer at both examinations than in the non-operatively treated series. In both, the radiological changes seemed to show the same rate of progression.

Statistically, only the erosive changes in four groups were compared: Op I and Op II, Non-op I and Non-op II, Op I and Non-op I, and Op II and Non-op II. All differences proved to be highly significant. From this the conclusion may be drawn that the differences between the Op I and Op II groups on the one hand and the Non-op I and Non-op II groups on the other were of the same magnitude. In other words, *operation does not seem appreciably to influence the development of radiological changes in the TC joint. The changes are obviously caused by rheumatoid arthritis.*

Instability of the ankle joint after triple arthrodesis

Previous investigations on the tilting of the talus in normal and injured ankle joints

BERRIDGE and BONNIN (1944) and BONNIN (1950) have shown that 4 to 5 per cent of normal subjects show tilting of the talus secondary to relaxation of the fibular collateral ligaments. This they called hypermobile ankle. Trochlear tilting, laterally forming an angle of 5–15 degrees with the tibial articular facet, was observed in some cases and caused no discomfort. No instance of similar flaccidity of the deltoid ligament was noticed.

LEONARD (1949) found that after rupture of the anterior talofibular ligament the ankle was relatively stable at 90 degrees, while the foot showed instability of the long axis as well as of the vertical axis of the talus, when held in equinus position.

According to ANDERSSON et al. (1952), and CLOSE (1956), the calcaneofibular ligament is also very important, although the greatest instability is caused by combined rupture of this and the anterior talofibular ligament. Talar tilting was estimated by ANDERSSON et al. in degrees. Rupture of the calcaneofibular ligament caused tilting of 15 degrees, and if the talofibular ligament, too, was ruptured, the resulting lateral tilting of the talus was as much as 30 degrees. Furthermore, anterior subluxation of the talus was observed in radiological stress investigations when the anterior talofibular ligament was ruptured. When the ankle was kept in 90 degrees angulation, the talus was dislocated by 2–4 mm; when the ankle was kept in equinus, the dislocation was greater.

RUBIN and WITTEN (1960 and 1964) examined the talar tilt without anaesthesia but using great stress with a device of their own. They concluded that there is a wide variation in the normal talar-tilt angle, which makes it very difficult to extract reliable information regarding rupture of the fibular collateral ligaments of the ankle.

NEVIN and POST (1964) studied 20 ankles in limbs to be amputated. The ligaments of the ankle were cut under anaesthesia. The investigators found that talar tilt of 15 de-

grees or more presupposed that all three lateral ligaments were injured. Furthermore, they stated that anterior subluxation of the talus presupposes, in addition to rupture of the anterior talofibular ligament, that the anterior portion of the posterior talofibular ligament is ruptured, or that all three ligaments are injured.

BROSTRÖM (1964) made surgical explorations in 105 cases of recent or chronic ligament injuries of the ankle. The injuries were also assessed on the basis of arthrograms. BROSTRÖM found that instability of the ankle is largely dependent on the extent of rupture of the joint capsule. In his material the average breadth of the anterior talofibular ligament was 6–8 mm and the length was about 20 mm. The calcaneofibular ligament was round in shape, with a diameter of about 4–8 mm, and strikingly long.

Furthermore, BROSTRÖM, LILJEDAHN and LINDVALL (1965) studied normal ankles arthrographically. They reported that the posterior talocalcaneal joint was filled with the contrast medium in only 15.6 per cent.

Previous investigations on the tilting of the talus after subtalar arthrodesis

Several authors have mentioned instability of the talocrural joint as a complication after subtalar arthrodesis.

SMITH and v. LACKUM (1925) reported that the talus was stable in 125 cases (63.1 per cent), instable in 63 cases (31.8 per cent), and very instable in 10 cases (5.1 per cent). The material consisted of 198 ankles on which triple arthrodesis was performed. The instability was attributed to deformity of the foot in spite of operation, or to damage of the ligaments at operation. The results were regarded as good, however, if the arthrodesis had caused stable union and the foot was sufficiently displaced under the talus.

HALLGRIMSSON (1943) and ANDERSSON et al. (1952) also mentioned instability of the TC joint after subtalar arthrodesis.

In one case in which the talocalcaneal joint was fused, LAPIDUS (1955) observed the development of abnormal lateral mobility of the trochlea of the talus against the mortise of the ankle as a result of relaxation of the lateral ligaments of the ankle.

WESTIN and HALL (1957) emphasized that severe valgus affects the mortise of the talocrural joint by causing tilting of the talus.

KLEIGER (1958) examined the tilting of the talus in paralysed feet. According to him, after subtalar arthrodesis inversion tilting of the talus is infrequent in adults without symptoms of instability, although present in 4–5 per cent of patients.

MACKENZIE (1959) pointed out that stretching of the lateral ligament of the ankle is a serious complication after LAMBRINUDI's arthrodesis and often requires arthrodesis of the ankle joint.

In discussing the complications of arthrodesis of the ankle and mid-tarsal joints, HALL (1963) stated that a movement of inversion and eversion may be found which is due to tilting of the talus. His material consisted of feet on which subtalar fusion had been performed for fracture of the calcaneus. In his book «The Locomotory System and Functional Anatomy» Hall (1965) pointed out that peritalar movement (rotation) is still possible even when the talocalcaneal and calcaneocuboid joints are fused.

Present investigation

The purpose of this part of the study was to find out whether subtalar arthrodesis caused any changes in the stability of the lateral ligaments of the ankle, and whether RA had destroyed the ligaments or altered their tensile strength. No attempt was made to measure the stress tolerated by the ligaments. On inversion and eversion of the foot at the ankle in stress examinations, tilting of the talus may occur at the mortise. The angle between the horizontal joint surfaces of the tibia and talus measured in degrees expresses the tilting of the talus on stress. As shown by RUBIN and WITTEN (1960), the tilt varies considerably even in normal feet, or between zero and 23 degrees. Hence the tilt as such does not allow of reliable estimation of the condition of the lateral ligaments. In order to draw any conclusions regarding possible changes, it is necessary to compare different series.

In rheumatoid arthritis the changes spread far into the surroundings of the joints, involving all ligaments and not only a certain area, as is often

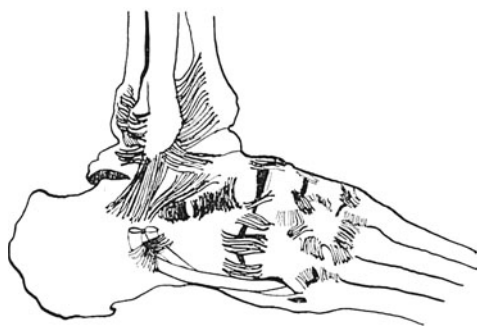


Fig. 9. The lateral ligaments of the TC joint. When the foot is held at 90 degrees, the anterior talofibular ligament is more or less horizontal and the calcaneofibular ligament is situated at an angle of about 30 degrees in the posterior direction from the vertical plane. In this position the anterior talofibular ligament is relaxed while the calcaneofibular ligament is stretched. When the foot is bent in plantar flexion, the anterior talofibular ligament is stretched while the calcaneofibular ligament is relaxed. The posterior talofibular ligament runs almost horizontally towards the posterior talar process.

the case in association with trauma. It seems possible that the stretching, wearing or destruction of the ligaments or capsules due to RA affect the stability of the ankle. RA also has a contrary effect, however, in that it leads to ankylosis of the joints. Narrowing of the talocrural joint space and ankylosis prevent the development of instability of the ankle.

In the present study the lateral ligaments were surgically explored in a total of 43 cases (in 39 by the author), in which a radiological stress examination had been performed. The exploration of the ligaments was made in connection with triple arthrodesis. The anterior talofibular and calcaneofibular ligaments were mostly measured to the nearest millimetre. In five cases the deltoid ligament was also examined. Biopsy specimens for histological study were almost invariably taken from the lateral margin of the ligaments and the surrounding tissue. The talocrural joint was simultaneously inspected, and if proliferation of the synovial membrane was observed, synovectomy and biopsy were carried out.

In studying instability of the ankle a mechanical device, constructed in the Hospital of the Rheuma Foundation, was used in order to avoid the risks of irradiation (Plate 1, p. 19).

At follow-up examination talar tilting was measured in 255 ankles on which triple arthrodesis had been performed. In addition, 200 non-operated ankles were studied. The control material consisted of 60 ankles showing

TABLE 43. *Tilting of the talus in the Op II, Non-op II and control groups.*

Group	Tilting Lat/Med	No. of feet	Degrees of tilting				
			0	1—5	6—10	11—15	>15
Op II	Lateral	255	111	86	48	7	3
		%	43.5	33.8	18.8	2.7	1.2
	Medial	255	146	96	11	2	0
		%	57.3	37.6	4.3	0.8	—
	Lateral	200	105	59	35	1	0
		%	52.5	29.5	17.5	0.5	—
Non-op II	Medial	200	129	67	4	0	0
		%	64.5	33.5	2.0	—	—
Controls	Lateral	60	22	31	7	0	0
		%	36.6	51.7	11.7	—	—
	Medial	60	30	30	0	0	0
		%	50.0	50.0	—	—	—

TABLE 44. *Tilting of the talus after triple arthrodesis as measured at follow-up examination in different duration groups.*

Duration groups (years)	No. of ankles	Degrees of lateral talar tilt					Degrees of medial talar tilt				
		0	1-5	6-10	11-15	>15	0	1-5	6-10	11-15	>15
<3	20 %	8 40.0	6 30.0	4 20.0	2 10.0	0 —	12 60.0	8 40.0	0 —	0 —	0 —
4-6	51 %	21 41.2	12 23.5	14 27.5	3 5.8	1 1.9	30 58.9	19 37.3	1 1.9	1 1.9	0 —
7-10	60 %	32 53.3	18 30.0	10 16.7	0 —	0 —	33 55.0	23 38.3	4 6.7	0 —	0 —
>10	124 %	50 40.3	50 40.3	20 16.2	2 1.6	2 1.6	71 57.3	46 37.1	6 4.8	1 0.8	0 —
Total	255 %	111 43.5	86 33.8	48 18.8	7 2.7	3 1.2	146 57.3	96 37.6	11 4.3	2 0.8	0 —

TABLE 45. *Tilting of the talus in the conservatively treated feet in different duration groups.*

Duration groups (years)	No. of ankles	Degrees of lateral talar tilt					Degrees of medial talar tilt				
		0	1-5	6-10	11-15	>15	0	1-5	6-10	11-15	>15
<3	39 %	23 58.9	7 17.9	8 20.5	1 2.7	0 —	22 56.3	16 41.0	1 2.7	0 —	0 —
4-6	30 %	15 50.0	9 30.0	6 20.0	0 —	0 —	21 70.0	9 30.0	0 —	0 —	0 —
7-10	43 %	25 58.2	12 27.9	6 13.9	0 —	0 —	28 65.1	14 32.6	1 2.3	0 —	0 —
>10	88 %	42 47.7	31 35.2	15 17.1	0 —	0 —	58 66.0	28 31.8	2 2.2	0 —	0 —
Total	200 %	105 52.5	59 29.5	35 17.5	1 0.5	0 —	129 64.5	67 33.5	4 2.0	0 —	0 —

neither trauma nor disease. The results are shown in Tables 43, 44 and 45. Lateral tilting of over 5 degrees occurred in 22.7 per cent in the Op II group, in 18.0 per cent in the Non-op II group, and in 11.7 per cent in the control group. Medial talar tilting of over 5 degrees was observed in only 5.1 per cent in the Op II group, in 2.0 per cent in the Non-op II group, and in 0 per cent



Plate 4. Stress investigation of the ankle, in which the device shown in plate 1 was used. In this case there is marked lateral tilting (of 17 degrees). The ankle is in mid position (90—100 degrees).

in the controls. In 43.5 per cent in the Op II group and in 52.5 per cent in the Non-op II group no lateral tilting angle was present. In other words, the latter group showed less tilting. It is also striking that large tilting angles, i.e. over 10 degrees, were rare in all groups.

Table 46 shows the results of anteroposterior stress investigation. In this the calcaneus was forcibly pressed backwards and an attempt was made to subluxate the talus forwards. The material comprised 53 ankles that had been operated upon and 68 conservatively treated ankles, which were compared. Obvious subluxation was observed in 14 feet (26.4 per cent) in the former group and in 13 feet (19.1 per cent) in the latter. Only cases in which the joint surfaces of the tibia and talus were clearly eccentric were regarded as positive.

During the stress examination the majority of the ankles were at an angle of 90—100 degrees, or the position that the TC joint could be placed in without heavy stress (plate 4). However, for the sake of comparison 64 ankles were studied in maximal plantar flexion (stress was carried out by examiner's hands), in which the anterior talofibular ligament is exposed to the greatest stress on inversion (plate 5). These 64 cases were chosen at random from the follow-up material consisting of both operatively and



Plate 5. Stress investigation was performed with the ankle in maximal plantar flexion. Marked osteoporosis is present. No definite erosions are seen. Unevennesses are observable in the apices of the malleoli. Marked lateral talar tilt (of 12 degrees).

conservatively treated feet. On comparison of the results of these examinations with those of the above-mentioned tests, it was found that talar tilting occurred under both types of experimental conditions, but it occurred somewhat more frequently and was somewhat more pronounced in plantar flexion. Of the 64 feet thus examined, 20 (31.3 per cent) showed lateral tilting of over 5 degrees.

The ankle thus showed maximal stability in midposition. On inversion of the foot in this position the calcaneofibular ligament is first strained, but of course twisting of the ankle is also prevented by the other ligaments and the capsule. Table 47 shows the results obtained with the TC joint in maximal plantar flexion.

In Table 44 the distribution of the talar tilt in four duration groups of the operatively treated series is shown. For the sake of comparison the corresponding results in the conservatively treated series are presented in Table 45. In this table the duration is counted from the onset of RA in the foot until follow-up examination. Tilting seems to decrease with prolonga-

TABLE 46. *Anterior subluxation of the talus.*

Group	No. of feet	Subluxation	Uncertain subluxation	No subluxation
Op II	53	14 (26.4 %)	3 (5.7 %)	36 (67.9 %)
Non-op II	68	13 (19.1 %)	5 (7.4 %)	50 (73.5 %)
Total	121	27 (22.3 %)	8 (6.6 %)	86 (71.1 %)

TABLE 47. *Lateral tilting of the talus (TC joint in maximal plantar flexion).*

No. of feet	0°	1°—5°	6°—10°	11°—15°	>15°
64	13	31	19	1	0
%	20.3 %	48.4 %	29.7 %	1.6 %	—

tion of the disease. This development is influenced by narrowing of the TC joint space (which implies a tendency towards ankylosis), a feature which is not invariably present, however. *If narrowing does not occur, tilting remains unaltered or increases.*

TABLE 48. Tilling of the talus and narrowing of the talocrural joint in groups Op II and Non-op II.

Stage of narrowing of TC joint	Op II Non-op II	No. of ankles	Degrees of lateral talar tilt					Degrees of medial talar tilt				
			0	1-5	6-10	11-15	>15	0	1	5	6-10	11-15
0	Op II	156	57	60	33	4	2	80	71	4	1	0
	Non-op II	% 138	36.5 73	38.6 40	21.2 24	2.5 1	1.2 0	51.4 91	45.5 47	2.5 0	0.6 0	— 0
1	Op II	25	6	10	8	1	0	9	11	4	1	0
	Non-op II	% 26	24.0 11	40.0 9	32.0 6	4.0 0	— 0	36.0 9	44.0 14	16.0 3	4.0 0	— 0
2	Op II	26	42.4	34.6	23.0	—	—	34.6	54.0	11.4	—	—
	Non-op II	% 15	10 38.5 4	9 34.6 7	5 19.1 4	1 3.9 0	1 3.9 0	15 57.6 9	9 34.6 5	2 7.8 1	0 0	0 0
3	Op II	25	17	5	2	1	0	21	3	1	0	0
	Non-op II	% 10	68.0 8	20.0 2	8.0 0	4.0 0	— 0	84.0 9	12.0 1	4.0 0	— 0	— 0
4	Op II	23	21	2	0	0	0	21	2	0	0	0
	Non-op II	% 11	91.4 9	8.6 1	— 1	— 0	— 0	91.4 11	8.6 0	— 0	— 0	— 0
Total: Op II 255 feet, Non-op II 200 feet.			82.0	9.0	9.0	—	—	100.0	—	—	—	—



Plate 6. Lateral ligaments of the ankle photographed in connection with triple arthrodesis. The foot is in plantar flexion. The instrument is placed under the anterior talofibular ligament and the partly frayed joint capsule. Above the ligament may be seen the thin cartilaginous surface of the lateral corner of the talus (TC joint) and the lower point of the instrument rests on the calcaneofibular ligament, which is seen as a narrow cord when the peroneal tendons are drawn downward. Round the ligaments there is an abundance of inflamed tissue, particularly in the area of the tarsal sinus and round the lateral malleolus.

Table 48 shows the distribution of the tilting values according to narrowing of the TC joint space. It is clearly seen that talar tilt decreases with a gradual narrowing of the joint space. The most obvious decrease in talar tilt is found to occur in both the operatively and the non-operatively treated feet when narrowing of the TC joint space exceeds stage 2.

Statistical analysis

The comparisons are made by means of the U test. 1) Comparison of the control group (normal ankles) and the rheumatoid material (operatively and conservatively treated feet followed up).

Lateral and medial talar tilt was separately compared.

Lateral tilt in control group $\leftrightarrow$ Op II + Non-op II group

$z = 0.49$ insignificant

Medial tilt in control group $\leftrightarrow$ Op II + Non-op II group

$z = 1.26$ insignificant

2) Comparison of the operatively treated and the non-operatively treated rheumatoid material.

Lateral tilt in group Op II $\leftrightarrow$ group Non-op II

$z = 2.02$ $P < .05$ significant

Medial tilt in group Op II $\leftrightarrow$ group Non-op II

$z = 1.76$ $P < .05$ significant

3) Comparison of the material (Op II and Non-op II) examined in maximal plantar flexion and the material (Op II and Non-op II) examined in mid position (90—100 degrees).

Only the change in lateral talar tilt was analysed.

$z = 3.71$ $P < .001$ highly significant



Plate 7. Photograph of the partly destroyed anterior talofibular ligament. The latter is thinner and narrower than normal.

4) Subluxation of the talus. Comparison of the operatively treated and the conservatively treated material.

Group Op II $\leftrightarrow$ group Non-op II

$z = 0.77$ insignificant

Operative findings in the lateral ligaments of the ankle

The anterior talofibular ligament was completely denuded and measured to the nearest millimetre in 28 cases. In a further four cases the ligament was destroyed to such a degree that measurement was impossible, and in 11 cases the size of the ligament was estimated.

As a rule, the *anterior talofibular ligament* had retained its length, since the degenerative changes made it thinner or narrower mainly in the area of the insertions. In these sites holes were sometimes seen, and they looked frayed and torn (Plates 6 and 7). The ligament could also be swollen and covered by inflamed synovial membrane. The breadth was measured at the middle of the ligament and the length in the mid longitudinal axis from one insertion to the other. The mean breadth in 32 cases was 11.4 mm. In four of these cases the ligament was so torn and destroyed that it was regarded as lacking, and in 11 cases the ligament was oedematous and appeared to be stretched, but at the same time it was clearly thinner and narrower than normal.

The mean length of the anterior talofibular ligament (28 cases) was 19.4 mm. When the four destroyed ligaments were included, a mean length of 17.0 mm was obtained (32 cases). The former figure, however, seems to express the mean length of this ligament more adequately, since the ligament loses its true length immediately when it is broken or detached from the malleolus or talus.

The *calcaneofibular ligament*, too, was inspected in all 43 cases, but its breadth was only measured in four cases, in which the mean breadth was 5.5 mm. In three cases the ligament was so completely destroyed that neither its thickness nor breadth could be measured, and in 35 cases it was oedematous, softened or frayed, although the ligament as such was strong.

The calcaneofibular ligament was much thicker and longer than the anterior talofibular ligament, but it was clearly narrower than the latter. In five cases there seemed to be no signs of inflammation or degeneration.

The *deltoid ligament* was found to be intact in the feet examined, although it was sometimes oedematous.

In those cases, totalling 7, in which the ligaments (anterior talofibular or calcaneofibular) were entirely frayed, the duration of the disease was nearly 30 years in three cases, 5 years in one case, and 3 years in three cases. It appears that in cases of long standing degeneration and persistent stress destroy what remains of the ligaments. The ankle was completely stable in six of these cases. In all these cases TC joint changes of stages 3—4 were present. In the seventh case the TC joint changes were of stage 1, and there was a lateral talar tilt of 6 degrees. In this case the duration of the disease was 5 years. The patient reported that the ankle sometimes gave way, but no major harm was caused.

On histological examination it was almost invariably found that inflamed synovial tissue had invaded the tissues round the anterior talofibular ligament or the interfibrillar spaces. In many cases the fibres of the ligaments seemed to be stretched and swollen. They also showed degenerative changes, and sometimes part of the fibres were so completely destroyed that the structure of the ligament was no longer clearly distinguishable.

Summary

In rheumatoid feet tilting of the talus seems to decrease with prolongation of the disease. Narrowing of the TC joint space is associated with decrease, and finally total disappearance, of talar tilt. This development is very obvious when the joint space shows marked (stage 3) narrowing. If narrowing does not occur, tilting may increase. On operative exploration of 43 cases only four were found in which the anterior talofibular ligament was entirely frayed; the calcaneofibular ligament was destroyed in three cases. In these cases the duration of the disease ranged between 3 and 30 years. Statistically no significant difference was observed between the normal control material and the rheumatoid material in respect to talar tilt.

On the other hand a clear, statistically verified difference in tilting was observed between the operatively and conservatively treated groups. The difference was obvious both as regards medial and lateral tilting. In other words, operation clearly caused an increase in tilting. In respect of the tendency towards anterior subluxation of the talus no significant difference emerged between the operatively and non-operatively treated ankles. Hence it appears that the anterior talofibular ligament is not injured at operation. Lateral tilting was significantly greater in maximal plantar flexion than it was in tests performed on the same ankles in midposition. This clearly shows the important part played by position in studies on the stability of the ankle.

Osteoarthrosis of the talocrural joint as a complication after triple arthrodesis

Previous investigations

Many authors have mentioned the development of osteoarthrosis in the TC joint as a possible complication.

Arthrosis of the TC joint, diminishing the movement of the joint, was reported as a complication after subtalar arthrodesis by HART (1937), BENTZON et al. (1949) and MACKENZIE (1959). The last-mentioned investigator observed arthrosis only in patients followed up for over 11 years, i.e. in 15 cases (in a series comprising 182 operations by LAMBRINUDI's method). In addition, MACKENZIE observed 17 cases of flattening of the talus, due obviously to avascular necrosis of the talus. These findings were made after an observation period of at least six years. LEIKKONEN (1950) and LINDHOLM (1960) also reported this complication after LAMBRINUDI's arthrodesis and WHITMAN's astragalectomy. In these cases the operations had been performed on poliomyelitic or otherwise paralyzed feet showing a disturbed muscular balance. The TC joint was often instable, and the conditions for the development of arthrosis were thus favourable. HOWLAND (1964) observed arthrosis of the TC joint at follow-up in one ankle (out of 129 on which triple arthrodesis had been performed). RUGTVEIT (1964), in a series of 37 extra-articular arthrodeses, observed no complications in the form of arthrosis or instability of the TC joint. WILSON et al. (1965) did not mention this complication in a report on 301 triple arthrodeses. The development of arthrosis after triple arthrodesis in an otherwise sound TC joint seems to be of rare occurrence and a very slow process.

Present investigation

No follow-up studies after triple arthrodesis on patients with rheumatoid arthritis have been published, and therefore no information is available concerning postoperative development of arthrosis of the TC joint. This might reasonably be thought to occur, since the inflammation may involve this joint, also. However, in the present series arthrosis of the TC joint was relatively rare. In the group assigned for operation it occurred preoperatively in 12.7 per cent and at follow-up in 28.2 per cent (Table 38). At corresponding points of time osteoarthrosis was observed in the conservatively treated group in 10.3 per cent and 21.2 per cent of cases. In the former group osteoarthrosis thus increased somewhat more than in the latter. Surface erosion increased from 20.8 per cent to 36.3 per cent in

the operatively treated group and from 15.7 to 24.1 per cent in the conservatively treated group. The osteoarthrosis seems to be a phenomenon secondary to inflammation. The progression of osteoarthrosis was more obvious in the operatively treated material. Instability of the TC joint was also a more common finding in the operatively treated series, in which it attained statistical significance.

Summary

The conclusion may be drawn that the development of osteoarthrosis in the feet operated upon was influenced by the triple arthrodesis and the instability of the TC joint due to the operation. In these cases flattening of the talus was sometimes observed. Osteoarthrosis was found to be relatively rare, and caused no trouble. The most serious problem is constituted by the steady progression of the rheumatoid changes in the ankle.

Functional results

The evaluation of the functional results of 290 triple arthrodeses was based on 1) the subjective view of the patient (most important), 2) clinical examination and 3) radiological findings.

Only 38 patients, i.e. 10 men and 28 women, were not quite satisfied with the operative result. In four of these cases triple arthrodesis had been performed bilaterally, and both feet caused discomfort. A total of 42 feet (14.5 per cent) were painful, and the patients' subjective estimations were based on the presence of this symptom. Only in 17 cases (5.9 per cent) was the result so poor that in the patient's opinion no benefit had been derived from operation. In 25 feet (8.6 per cent) the result was fair, in the sense that the situation was better than before operation since the pain was alleviated (Table 49).

TABLE 49. *The functional results of the 290 triple arthrodeses.*

Sex	L/R	No of feet	Final result			
			Good	Fair	Poor	
Female	L	98	83	9	6	
	R	112	96	11	5	
Male	L	41	36	4	1	
	R	39	33	1	5	
Total (227 patients)		290	248 85.5 %	25 8.6 %	17 5.9 %	

Fair and poor: 42 feet 14.5 %

The main causes of failure in these subjectively unsuccessful cases appeared to be the following (Table 50):

- 1) planovalgus: 17 feet (5.9 per cent)
- 2) pes varus or calcaneovarus: 10 feet (3.4 per cent)
- 3) Varus of the forefoot: 6 feet (2.1 per cent)
- 4) Functional impairment of the talocrural joint: 4 feet (1.4 per cent)
- 5) Other causes: 5 feet (1.7 per cent)

On anatomical examination planovalgus was found to be extreme in 13 cases, while deformity of stage 3 was present in four cases. The calcaneovarus deformity was of stage 4 in one case, of stage 3 in four, and of stage 2 in the remaining five cases. All six cases of varus of the forefoot were of stage 3. The group under discussion includes four cases in which the chief cause of discomfort was the TC joint, which showed marked swelling and erosions (stage 3). Since these four TC joints were painful and already showed obvious radiological changes at the time when triple arthrodesis was performed, it would have been better to make a pantalar arthrodesis. These cases are counted among the complications of triple arthrodesis because the operation did not benefit the patient.

In no case in the group with complications was instability present to such a degree as to be subjectively regarded as important. Lateral talar tilt of over 5 degrees was present in only 10 ankles.

Other causes of failure consisted of pseudarthrosis of the Chopart joint (two feet), pseudarthrosis of the TN joint (one case), fistulating osteitis (in one case in which heterogenous bone had been applied), and severe rheumatoid inflammation of the cuneonavicular joint (one case). All the three feet with pseudarthrosis showed varus deformity, and moderate varus of the forefoot was present in the patient with an affected cuneonavicular joint. The chronic fistulating osteitis eventually healed after trepanation and sequestrectomy which were carried out after the follow-up examination. The pseudarthrosis of the TN joint was later corrected by arthrodesis, and the foot showing pseudarthrosis of the TN and CC joints as well as varus was assigned for repeated arthrodesis. In the two severest cases of varus of the forefoot a wedge resection was planned to be performed in the area of the os cuneiforme-metatarsus I.

Five patients were confined to wheel-chairs owing to rheumatoid changes in the hips and knees and their ankles had therefore hardly been subjected to weight-bearing. Nonetheless they were satisfied with the operative results because of the relief from pain. On 12 patients bilateral triple arthrodesis had been performed, and in each of them one foot showed moderate

or severe deformity (only four of these patients showed deformity of both feet). In all, bilateral arthrodesis had been carried out on 63 patients. The present results by no means indicate that bilateral triple arthrodesis would increase the rate of functional complications.

In the cases with complications (42 feet) the mean duration of the disease was 7.6 years, which largely corresponds to the mean duration in the whole material (7.2 years). This shows, however, that the disease was of very old standing in these 42 feet before they were operated upon. In only 10 feet was the duration less than three years.

Summary

There is a considerable difference between the anatomical and functional results. Not even moderate planovalgus seems to cause the rheumatoid patient much discomfort, and the extreme deformities observed at follow-up examination were few. This implies that the patients placed a very high value on the relief from pain. Varus is an embarrassing deformity, but in the present material it was relatively infrequent. Marked varus of the forefoot also impedes walking. Planovalgus is the most common deformity, which in severe form causes daily discomfort as soon as the patient moves about. Radiological changes of the TC joint were strikingly frequent in the present series (Table 38), but at follow-up examination only four patients complained spontaneously of marked pain. All of these also showed erosions of stage 4 in the weight-bearing surfaces of the joint. Furthermore, the cessation of the rheumatoid process in the cuneonavicular and metatarso-tarsal joints is noteworthy: Only one patient had a very painful cuneonavicular joint, on which it was planned to perform arthrodesis.

TABLE 50. *The functional results of the 290 triple arthrodeses. The main cause of failure.*

Result	No. of feet	Plano- valgus	Calcaneo- varus	Varus of the forefoot	TC inflammation	Other causes
Fair	25 8.6 %	11	6	3	3	2
Poor	17 5.9 %	6	4	3	1	3
Total	42 14.5 %	17 5.9 %	10 3.4 %	6 2.1 %	4 1.4 %	5 1.7 %

IX. DISCUSSION AND CONCLUSIONS

1. What are the clinical and radiological changes caused by rheumatoid arthritis in the pantalar joints?

Clinical findings

Swelling, pain and range of motion

Swelling of the area of the subtalar joints occurred preoperatively in almost all cases (98.3 per cent), and it developed as the first symptom of the disease. Those few cases in which only slight swelling was observed belonged to the over 10 years' duration group, and by then the disease process had become extinct in the area in question. Marked swelling of the area of the TC joint was observed in 186 cases (63.7 per cent), slight swelling in 73 cases (25.0 per cent). As may be seen in Table 10, swelling of the area of the talocrural joint decreased during the first six years, then increased in the 7—10 years' duration group, and again decreased in cases of over 10 years' duration. The marked swelling of the ankle during the initial stage of the disease is obviously due to inflammation of the subtalar joints and/or to spreading of the disease to the ankle region. In chronic cases, in particular, swelling shows a typical concentration round the joints (Figs. 2—4).

Pain. Pain at rest was surprisingly rare (62.3 per cent), and as a rule slight pain only occurred after considerable stress. Pain on motion and weight-bearing was present in nearly all inflamed subtalar joints (98.6 per cent). Pain on motion is a very typical early symptom.

Marked pain on motion was present in the talocrural joint in about half the cases (53.8 per cent), slight pain in 27.4 per cent. This symptom remained about the same for six years (Table 10), after which an exacerbation was observed. A decrease in pain was again noted in the over 10 years' duration group. Tenderness on palpation appeared to be most marked at the corners of the TC joint, round the malleoli, and in the area of the ligaments. Even in the normal TC joint the anterior corners of the mortise are

somewhat tender on palpation, probably owing to the scantiness of soft tissues in this area. This tenderness is increased by inflammation.

The *total range of motion* of the subtalar joints had clearly decreased preoperatively in 282 feet (96.6 per cent). In 198 feet (67.8 per cent) very slight movement (rigid feet) or none was observed. As may be seen in Table 2, the range of motion showed a very obvious decrease with prolongation of the disease. The development of ankylosis of these joints takes a long time, as appears from the fact that there were only two feet in the whole material in which no subtalar motion was observed. Ankylosis of the subtalar joints rarely seems to develop within 10 years (one case).

The *range of motion of the TC joint* seems to decrease with prolongation of the disease (Table 10), but the changes observed were rather slight. This shows that the talocrural joint is very resistant to rheumatoid infection, in any event much more so than the subtalar joints. The limitation in dorsal and plantar flexion was consistent with the occurrence of swelling and pain on motion.

The present observations on the importance and frequency of the above-mentioned symptoms of RA are in good agreement with previous reports, e.g. LAINE (1953, 1962), ROPES et al. (1956, 1959), VAINIO (1956), COBB et al. (1957, 1960), ANSELL and BYWATERS (1959).

The frequent occurrence of symptoms in the area of the TC joint provokes the question of whether inflammation in the *early stage* of the disease also involves the region of the TC joint, although it is less violent and causes slighter pain. In the author's opinion the pain is due to inflammation of the soft tissues, capsules and ligaments of the TC joint, which would thus be early signs, developing at the same time as the symptoms of the subtalar joints.

Deformities

The most common deformity is planovalgus, which was present in 255 feet (87.4 per cent). Patients showing slight planovalgus, i.e. of less than 10 degrees (29 feet), are not included in this number. As may be seen in Table 4, planovalgus of over 10 degrees occurred in 88.2 per cent of cases in the under three years' duration group, which shows that this deformity is an early sign of the disease. The same is found on inspection of Table 9, which shows the development of planovalgus in the different duration groups of the conservatively treated, i.e. less severely affected, material. Moderate or severe planovalgus was present in a total of 163 feet (79.9 per cent), and

in the 2—3 years' duration group in 82.6 per cent. After this no major changes occurred. Other deformities were relatively infrequent. The development of planovalgus is associated with an increase in the angle between the talus and the floor. In the author's opinion the development of planovalgus in the initial stage of the disease reflects the violence of the inflammation. The arch of the foot does not tolerate weight-bearing when the soft tissues are inflamed. When the patient avoids weight-bearing on the median ray and steps more on the lateral margin of the foot, the forefoot may twist into varus.

According to VAINIO (1956), planovalgus is by far the most common deformity of the foot in adult rheumatics. The present findings tally with his. VAINIO stated that planovalgus is an early sign. According to ISEMEIN and FOURNIER (1963) and FORESTIER (1963), valgus deformity may develop in a very early stage, and FORESTIER suggested that it may be due to spasm of the peroneus muscles.

The functional anatomy of flat-foot and the factors influencing the development of this deformity have been dealt with in numerous studies, e.g. those of v. LANZ and WACHSMUTH (1938), HOHMANN (1948), NIEDERECKER (1959), SCHOBERTH (1963). According to NIEDERECKER and SCHOBERTH, the navicular is elevated and laterally displaced, and consequently the head of the talus »falls down» toward the medial side of the foot, in the plantar direction.

The head of the talus is in part supported by the surface of the sustentaculum tali of the calcaneus, and in part it rests on the strong plantar calcaneonavicular ligament. The anatomy of the latter was studied by SOERGEL (1959), among others. According to him, the longitudinal fibres of the ligament counteract longitudinal dislocation of the talus, while the transverse fibres counteract the orthostatic pressure. Changes in the ligament immediately affect the maintenance of the position of the head of the talus.

According to the present observations, rheumatoid arthritis causes violent inflammation of the talonavicular joint and the tarsal sinus, on the deep surface of which the strong plantar calcaneonavicular ligament rests. A diffuse inflammation influences the statics of the foot as a whole. In a normal foot weight-bearing falls chiefly on the medial ray. It is therefore understandable that the rheumatoid patient, in order to avoid pain, tries to step on the outer margin of the foot. This causes elevation of the medial aspect, compensatory pronation of the calcaneus, and valgus. If the calcaneus is bent into varus in a normal foot, the interosseous talocalcaneal ligament becomes tense. If the ligament in question is weakened or destroyed,

it cannot prevent the calcaneus from slipping into varus, which may sometimes happen as a result of very strong active inflammation and an erroneous distribution of weight-bearing. Obviously the anterior tibial muscle draws the forefoot into supination, just as the short peroneal muscle draws the hindfoot into pronation, which may be due to spasm provoked by the inflammation.

Conclusions

The following conclusions may be drawn from the foregoing: When the subtalar joints become inflamed, swelling, pain at rest, pain on weight-bearing, and the development of planovalgus are early signs. The deformity develops as early as within three years from the occurrence of the first signs in the foot. This observation is statistically significant. Planovalgus is by far the most common deformity. The clinical symptoms in the talocrural joint increase when the subtalar joints are inflamed, but later they decrease, and persistent violent inflammation of the TC joint is rare.

Radiological findings

Osteoporosis

Osteoporosis occurred most frequently in the area of the calcaneocuboid joint (90.5 per cent). HALL (1960) established that in the neck of the calcaneus and cuboid the bony trabeculae exhibit changes in direction, which decrease the radiographic density of the bone. Even normally this area is therefore less dense than the region of the anterior margin of the posterior talocalcaneal joint. This source of error was eliminated in the present study by comparing the changes present in the same area at different examinations. The reliability of the results is to some extent, however, jeopardized by technical sources of error. SOILA (1958) also reported that the development of osteoporosis in the area of the cuboid tuberosities was a significant and frequent sign. In the present study statistical analysis revealed a significant impairment of osteoporosis with prolongation of the disease in the area of the tc and TN joints, while in the CC area the differences between the various duration groups were insignificant. This seems to indicate that osteoporosis in the area of the CC joint is an early sign of RA. This also appears from the diagram in Fig. 5.

In the area of the talocrural joint osteoporosis occurred in 44.4 per cent of cases, which is clearly lower than the corresponding ratios for the «triple»

joints. A slight improvement was observed in the 4—6 years' duration group, after which the condition steadily progressed (Table 22). This may in part be due to inactivity on account of inflammation of the subtalar joints, in part to the rheumatoid process in the TC joint.

Narrowing of the joint space

Severe narrowing of the joint space (stages 3—4) occurred by far most frequently in the talonavicular joint. Between narrowing of the CC and tc joint spaces and the duration of the disease a significant correlation was observed, while the corresponding relationship for the TN joint space did not attain statistical significance. This shows that narrowing of the TN joint space mainly occurs during the first three years and is thus an early sign of RA. Subsequently only slight changes occur. This observation is consistent with the finding that planovalgus develops during the initial stage of the disease.

The talocrural joint space showed narrowing in 40 cases (14.1 per cent), and this sign steadily progressed with prolongation of the disease (Table 22). Narrowing of the TC joint space was relatively infrequent. In this respect there was an obvious difference between the talocrural joint and the subtalar joints.

Erosion

The frequency of erosions was highest in the talonavicular joint (see also Fig. 7), a finding which lacks a satisfactory explanation. Perhaps mechanical factors such as depression of the talus in association with the circulatory conditions play a part. BYWATERS (1963) and MARTEL (1963) suggested that usage of the joint and mechanical factors combine to produce erosive changes. The present study showed, however, that erosion steadily progressed, although the range of motion decreased and deformities became fixed. Consequently the development of erosions must be dependent on the progression of RA. Owing to its unfavourable position, the TN joint is subjected to particularly great mechanical stress, as also appears from the fact that during a period of three years planovalgus developed and advanced to a degree resulting in subluxation. The progress of erosion in this joint was found to be significantly correlated with the duration of the disease. Probably mechanical factors do not offer a sufficient explanation of the fact that the erosive changes were severer in the TN joint than in the other joints examined. The joints of rheumatoid fingers and toes show marked erosion although the mechanical stress to which they

normally are subjected is slighter than that to which weight-bearing joints are exposed. The development of erosions may very well also be influenced by the vascular conditions and vascular necrosis.

It was decided to assess the erosive changes in different areas of the TC joint separately because it was found, during the course of the investigation, that the initial rheumatoid signs in this joint apparently consist of small unevennesses in the lateral and medial surfaces of the mortise, the surfaces of the malleoli or talus, or the surface of the marginal parts of the joint, at the border between the articular cartilage and the bone. In this area erosive changes occur as surface roughness, as tiny cyst-like formations, or as obvious erosion.

In the surface of the talocrural joint (the main weight-bearing surface) erosions were observed in only 59 feet (20.8 per cent), while erosions were noted in the medial aspect of the mortise in 96 feet (33.8 per cent), and in the lateral aspect in 90 feet (31.7 per cent). In the malleolar portion of the mortise erosions were thus clearly more frequent than in the surface of the joint. The changes obviously progressed with prolongation of the disease, at least in the joint surface and the lateral aspect. This observation was statistically highly significant as regards the joint surface and significant as regards the lateral aspect. Erosions of the medial aspect of the mortise often seem to be an early sign, since the differences between the duration groups were insignificant. This observation is consistent with the observations concerning the development of planovalgus deformity; via the deltoid ligament the latter influences the medial malleolus and may cause erosive changes.

Aggravation of the erosive changes of the TC joint was also very clearly observed in the conservatively treated feet (Tables 24 and 25).

Periosteal reaction

According to ANSELL (1963), true periostitis in which the periosteum is elevated from the bony surface seems frequently to occur in the more proximal parts, above the malleoli, as a rule at the margin of the medial aspect of the tibia. In the distal parts of the malleoli true periostitis does not seem to occur, and this phenomenon is therefore outside the scope of the present study.

The severest changes were observed at the margins of the TN joint. If slight forms (stage 1) are included, the frequency was somewhat higher in the talocalcaneal joint. The arithmetical mean of the stages of severity was

highest for the TN joint (Fig. 8). With prolongation of the disease a statistically significant increase in the frequency of changes was observed in all three joints. Periosteal changes occurred most frequently at the margins of the TN, tc and CC joints and they seemed to be caused by rheumatoid arthritis.

Osteoarthrosis

In the area of the CC and tc joints osteoarthrosis seemed to progress rather steadily, in the TN joint less steadily (Table 19). In the TN joint osteoarthrosis was observed in 36.7 per cent in the first duration group, and in 38 feet (61.3 per cent) in the second duration group (4—6 years). In this group the frequency was highest. It appears that the development of planovalgus in the first duration group leads to the development of secondary osteoarthrosis, which reaches its maximum in the next duration group. On statistical analysis the differences between the various duration groups were found to be significant also in regard to the TN joint, although the level of significance was lowest on this point. Obviously this is due to the change caused by planovalgus during the initial stage of the disease. Otherwise the exacerbation of osteoarthrosis followed the progression of RA. In the talocrural joint, too, osteoarthrosis showed an obvious aggravation with prolongation of the disease (Table 22). A similar development was observed in the conservatively treated material (Table 24), although severe changes were less frequent. Arthrosis is known to develop as a secondary phenomenon in an inflamed joint. The differences observed between the various joints as regards the development of arthrosis are due not only to mechanical factors, but also to the circulatory conditions.

Conclusions

The TC joint is very resistant to inflammatory changes, but malleolar erosions clearly occur more often than surface erosions. Erosions of the medial malleolar mortise are early signs and obviously develop simultaneously with planovalgus. Narrowing of the talonavicular joint space is also an early sign, as was clearly revealed by its frequent occurrence in the under three years' duration group. This change seems to be due to the development of planovalgus and depression of the talus. Osteoporosis of the calcaneocuboid area is an early sign. All other radiological changes — osteoporosis of the talocrural, TN and tc joints, narrowing of the talocrural, tc and CC joint spaces, erosions of the TN, CC and tc joints, and of the surface and lateral aspects of the talocrural joint, periosteal changes at the margins of the »triple» joints and osteoarthro-

sis in all the pantalar joints — show an obvious exacerbation with progression of rheumatoid arthritis.

The severest radiological changes are encountered in the TN joint, osteoporosis excepted, which is most severe in the area of the CC joint. As regards severity, the changes in the talocalcaneal joint are between those of the TN and CC joints, osteoporosis excepted. The radiological changes in the talocrural joint are slighter than the corresponding changes in the subtalar joints.

2. What are the practical consequences for the rheumatoid patient of arthrodesis of the subtalar and midtarsal joints?

Clinical findings

Swelling, pain and range of motion

Swelling was observed postoperatively in 63 feet (21.7 per cent), while at a corresponding point of time swelling was noted in the conservatively treated material in 109 feet (56.2 per cent), or in other words clearly more frequently.

At follow-up examination moderate or marked pain at rest was present in only 10 operatively treated feet (3.4 per cent). In the operatively treated series pain on motion was preoperatively present in almost every case (98.6 per cent), and after operation in only 12 feet (4.1 per cent). In the conservatively treated series pain on motion was still present in 82 feet (42.2 per cent) at follow-up examination. In the operatively treated feet no motion was observed in the subtalar joints. In the conservatively treated series motion was moderately or severely limited in 141 feet (72.6 per cent).

In the talocrural joint swelling obviously decreased after operation. Moderate or marked pain persisted in only 48 TC joints (16.5 per cent), and slight tenderness on palpation in 162 ankles (55.9 per cent). Preoperatively dorsal flexion was under 10 degrees in 90 ankles (30.8 per cent), at follow-up examination in 105 (36.2 per cent). Plantar flexion was under 20 degrees (stages 2—4) in 109 ankles (37.3 per cent) before operation, and in 137 ankles (47.2 per cent) at follow-up. The range of motion had thus decreased during the observation period.

Deformities

The most noteworthy observation was the change in degree of severity that the planovalgus deformity underwent after operation. Preoperatively moderate planovalgus was present in 127 feet (43.6 per cent), and severe or

extreme planovalgus was present in 128 feet (43.8 per cent). At follow-up, when calcaneal valgus was measured in degrees, moderate valgus (11—15 degrees) was present in 193 feet (66.5 per cent), while severe or extreme valgus (more than 15 degrees) was present in 66 feet (22.8 per cent). The most obvious change was an improvement in the severest deformities. *At operation an attempt was not always made to place the calcaneus into mid position, but an attempt was made to correct the severest forms of valgus.* In the conservatively treated group no major changes occurred. At follow-up, valgus of 11—15 degrees was present in 111 feet (57.2 per cent), and valgus of over 15 degrees was present in 51 feet (26.2 per cent). These percentage figures are higher than those noted in the operatively treated material at follow-up.

At follow-up of the operatively treated feet, calcaneal varus was observed in 17 feet, against 27 before operation. Varus of the forefoot occurred preoperatively in 57 feet, and postoperatively in 50 feet. In this respect, therefore, there had been no great improvement. The severest forms had decreased in frequency, however.

Conclusions

The patient is greatly benefitted by operation, since swelling, pain, and pain on weight-bearing were found to disappear almost completely. In addition, correction of deformities was often achieved. Slight or moderate valgus does not seem to cause discomfort on walking. In the conservatively treated series the rheumatoid process was mostly found to progress.

Marked swelling and pain in the region of the TC joint are obviously due to inflammation of the subtalar joints which involves the more proximal tissues. In addition to the rheumatoid inflammation of the joint, the mechanical stress to which the ligaments are subjected owing to persistent deformity has to be taken into account as an additional cause of the condition of the TC joint. The slight limitation of the range of motion of the talocrural joint which occurred during the time of observation is obviously attributable to the steady progression of the disease and to the swelling caused by the mechanical stress on the TC joint.

Radiological findings

The subtalar joints

Osteoporosis

In regard of osteoporosis the differences between the pre- and postoperative findings were slight (Table 33), and proved to be statistically insigni-

ficant, although a certain improvement was noted. The absence of a greater change for the better seems to be due to the severity of the rheumatoid inflammation, postoperative inactivity, and the relative shortness of the time of observation.

The periosteal reaction

Postoperatively, 98 feet (39.5 per cent) showed moderate or severe periosteal reaction at the margins of the talocalcaneal joint (owing to the triple arthrodesis it was mainly the posterior margin, the posterior process of the talus, that could be studied). The corresponding preoperative figures were 115 feet and 40.5 per cent. According to this, a slight improvement had occurred, which is attributable, however, to the lack of accuracy of observations made on an anchylosed joint. Statistically the difference is significant, however. For the margins of the calcaneocuboid joint the corresponding figures were 53 feet (21.3 per cent) at follow-up and 50 feet (17.6 per cent) preoperatively. Periosteal reaction of stages 2—4 was observed in the area of the talonavicular joint at follow-up in 199 feet (80.2 per cent), and preoperatively in 209 feet (73.6 per cent).

Conclusions

No convincing evidence of postoperative periosteal growth was obtained, which implies that after arthrodesis periosteal growth at the margins of the lc, CC and TN joints ceased. From this the conclusion may be drawn that the periosteal changes observed in these sites were due to the rheumatoid process.

Union after triple arthrodesis

The development of fusion in the different duration groups is shown in Table 35. In the under one year's duration group, comprising 32 feet, non-union of the calcaneocuboid joint was observed in two cases, and non-union of the talonavicular joint in three cases. The remaining joints showed either partial or complete union. In the whole material non-union was most frequent in the talonavicular joint (23 feet, 9.3 per cent). The staple had invariably remained in position, and only in two cases were slight osteolysis and a tiny sclerotic area observed round the staple.

Triple arthrodesis using autogenous bone graft from the iliac crest proved to be successful except in three cases, in which osteitis and sequestration occurred. The use of a staple is certainly not indispensable, but it aids in keeping the foot in the correct position during the stage of reconstruction,

as also does the use of a graft applied as a wedge between the talus and calcaneus, as described by GRICE. Obviously union would occur in the rheumatoid foot just as well without a graft, but the graft prevents the calcaneus from slipping into valgus, provided that too early weight-bearing is avoided. According to FORD et al. (1951), STRINGA (1957), and HAMMACK and ENNEKING (1960), the vascularization of the autogenous bone graft begins immediately, and osteoid bars may be observed as early as the second week. STRINGA (1957) reported that a graft 5 mm thick had become completely vascularized within 20--25 days. The reinforcement of the bone takes a longer time, however, according to CHARNLEY (1951) eight weeks, and according to GRICE (1955) eight to ten weeks, as observed radiologically.

According to LENTZ (1955), an autoplastic bone graft does not provoke any reaction against the bone formation, and under favourable conditions the graft remains vital outside the organism for about two weeks. In experimental investigations PURANEN (1966) found that the vitality of autogenous bone grafts decreases very rapidly, even within a few minutes, and recommended the taking of an autogenous graft during operation, immediately before its application. In the present series the autogenous grafts were taken just before being used. No case of aseptic necrosis of an autogenous bone graft occurred.

In the author's opinion not even partial weight-bearing should be allowed until four to six weeks from operation in order to avoid slipping of the calcaneus into valgus. Such slipping is not prevented by the bone graft and the plaster cast, since complete union of the bone has not yet occurred in two weeks, which was the time of non-weight-bearing prescribed in the present cases. Osteoporotic bone easily yields to weight-bearing. A total immobilization time of eight to ten weeks seems to be adequate, since the osteogenesis of spongy bone is very satisfactory in rheumatoid patients also. EVANS (1957) found that cancellous bone united more readily than compact bone, and that osteogenesis was good when the stress was within physiological limits.

In rheumatoid as well as other inflammations the regenerative forces are strong. The rate of bone regeneration has not been histologically investigated in rheumatoid patients, but in the present material union occurred within eight weeks from operation in the majority of cases. Some authors have immobilized their patients for ten to sixteen weeks after subtalar arthrodesis. In the extensive series described by WILSON et al. (1965), comprising 301 triple arthrodeses, only seven feet were immobilized for a shorter period than ten weeks. Partial weight-bearing was allowed an aver-

age of 7.4 weeks from operation. GRICE (1955), who performed extra-articular arthrodesis using graft, allowed partial weight-bearing nine to eleven weeks after operation.

Conclusions

Union occurred very satisfactorily after triple arthrodesis. Non-union was most frequent in the talonavicular joint, and the best results were obtained in the talocalcaneal joint, which always showed either partial or complete union. The use of autogenous bone graft may be recommended, particularly in cases of severe destruction of the joints. The use of graft and staple promotes the reconstruction of the foot, but does not prevent the calcaneus from slipping into valgus if weight-bearing is allowed too soon. From the standpoint of fusion a total period of immobilization of eight to ten weeks is sufficient.

The talocrural joint

In both the operatively and the conservatively treated series a steady progression of the radiological changes of the TC joint was observed. Hence, triple arthrodesis seems to have little influence on this joint. As may be seen in Table 39, in the area of the TC joint osteoporosis was observed in 81.7 per cent in the first duration group (under one year, i.e. immediately after operation). The high ratio may be attributed to inactivity following operation. Osteoporosis improved when the patient became ambulatory, but owing to progression of the disease a gradual increase in osteoporosis occurred again later. The joint space became narrower and erosions gradually increased, as clearly emerged at least from comparison of the two extreme duration groups.

In the conservatively treated feet the disease was milder and the changes were slighter. Table 42 shows that erosion progressed in both the TC joint and the »triple» joints, which implies that the disease became steadily, though slowly, worse.

The figures for the radiological changes correspond to the results on the limitation of motion of the TC joint, dorsiflexion being limited to less than 10 degrees in 36.2 per cent and plantar flexion to less than 20 degrees in 47.2 per cent of the ankles examined.

Marginal erosive changes were mainly responsible for the slight swelling and limitation of motion observed, and for tenderness on palpation and pain on stress. The number of entirely painless ankles was only 80 (27.6 per cent), which strikingly bears out the observations on malleolar changes of stages 0—1.

Conclusions

It appears that violent inflammation of the TC joint is relatively rare. The radiological changes steadily progress after triple arthrodesis. The most frequent signs consist of erosive malleolar changes, which are due in part to RA, in part to the stress to which the ligaments are subjected.

Postoperative complications

In the present series the ratio of complications was relatively low: 8.2 per cent (24 feet). The majority of complications (6.2 per cent) consisted of haematomata and wound infection. In many cases the use of vacuum suction would appear to be indicated. HOWLAND (1964) reported complications in 4.6 per cent of cases. In the series described by LAINE and VAINIO (1964), comprising various orthopaedic procedures on rheumatoid patients, infections occurred in 1.4 per cent. Hence it appears that the risk of infection is somewhat greater in connection with operations involving only the foot. WILSON et al. (1965) had 14 per cent complications, mostly superficial infections of the soft tissues, in an extensive series. In order to prevent infection, particular attention has to be paid to cleaning of the leg as far up as the knee. In the presence of eczema of the leg, it is advisable to protect the operative area by a sterile plastic membrane or to postpone the operation.

Operation did not activate the rheumatoid process, and after a transient elevation the ESR returned to the preoperative level, or to an even lower level if the patient stayed sufficiently long in the hospital. In only 23 cases (out of 267) did the temperature rise postoperatively by more than one degree, but this may be due to the fact that the patients as a rule were continuously given medical treatment for RA. After radical synovectomy, when an abundance of inflamed synovia had been removed (e.g. in synovectomy of the knee joint), LAINE and VAINIO (1964) found that a transient rise of the ESR could be followed by abatement of the general symptoms as well as of the joint symptoms. It may, perhaps, be suggested that a temporary improvement of the general condition results from increased adrenal function due to operative stress.

3. Do rheumatoid arthritis or triple arthrodesis cause instability of the talocrural joint?

According to many authors, deformities of the foot and triple arthrodesis affect the resistance of the ligaments to the rotational movements of the

foot, which after triple arthrodesis has been carried out mainly influence the TC joint and its ligaments (SMITH and v. LACKUM 1925, HALLGRIMSSON 1943, ANDERSSON et al. 1952, BARNETT 1955, LAPIDUS 1955, WESTIN and HALL 1957, KLEIGER 1958, MACKENZIE 1959, HALL 1963, 1965, WYLLER 1963, WRIGHT et al. 1964). In the presence of valgus, the deltoid ligament is stretched. Of particular importance are the observations made by BARNETT (1955), WYLLER (1963), and WRIGHT et al. (1964) concerning the action of the TC joint in the normal foot. WRIGHT et al. stated that the normal rotation of the subtalar and ankle joints was between 6 and 14 degrees in »stance phase», which may explain the progressive laxity observed to develop in the ankle joint after subtalar fusion.

In the present study lateral talar tilt of over 5 degrees was observed in 58 ankles (22.7 per cent) in the operatively treated series, in 36 ankles (18 per cent) in the conservatively treated series, and in 7 ankles (11.7 per cent) in the control group. Medial talar tilt of over 5 degrees was measured in 13 ankles (5.1 per cent) in the operatively treated series, in 4 ankles (2 per cent) in the conservatively treated series, and in no case in the control group. Accordingly, tilting was more frequent in the operatively than in the conservatively treated feet. But when the results were statistically analysed and compared to the corresponding results for the normal controls, no significant differences were observed. This shows that the tilting of the talus in the rheumatoid material was of no considerable magnitude. RUBIN and WITTEN (1960) found that there was a wide variation in the normal talar tilt angle. This observation is corroborated by the present results. In respect to both lateral and medial talar tilt there was an obvious, statistically significant difference between the operatively and conservatively treated series. This argues in favour of the view that triple arthrodesis affects the TC joint and its stability, and it corroborates the assumption that when the compensatory influence of the subtalar joints is eliminated, the rotational movements of the foot and ankle during the course of time may cause instability of the TC joint. In this connection it should also be recalled that the movements of the talus in the osteoporotic bone were found gradually to produce slight rounding of the corners of the TC joint. Similar evidence is constituted by the atrophy of the talus and malleoli, which is obviously responsible for the »click» phenomenon, attributed by MULLINS and SALLIS (1958) to broadening of the TC mortise. This phenomenon seemed to be much more obvious in the ankles operated upon than in the conservatively treated feet. According to GRATH (1960), even an intact deltoid ligament allows lateral movement of 2 mm.

In the present study lateral talar tilt of over 5 degrees was observed in 20 feet (31.3 per cent) in maximal plantar flexion, which was clearly more often (the difference is highly significant) than in the ankles examined in mid position. From this the conclusion may be drawn that the anterior talofibular ligament was more worn out and weaker than the calcaneofibular ligament, since in plantar flexion the anterior talofibular ligament is subjected to greater stress, while in mid position the stress mainly falls on the calcaneofibular ligament. These features of the anatomical structure and function of the lateral ligaments have been described by many authors, e.g. DEHNE (1933), LEONARD (1949), ANDERSSON et al. (1952), BROSTRÖM (1964), and NEVIN and POST (1964). In the present series of operatively treated feet, anterior subluxation of the talus was only observed in 14 cases (26.4 per cent). The corresponding figures in the conservatively treated series were 13 cases and 19.1 per cent. The difference is statistically insignificant. Hence the conclusion may be drawn that the operation had not injured the anterior talofibular ligament. The frequency of subluxation shows a fairly good correspondence with the frequency of lateral talar tilt of over 5 degrees in both the operatively and non-operatively treated series.

At follow-up tilting of the talus on both the lateral and the medial aspect was found to correlate with narrowing of the TC joint space (Table 48) in both series. A decrease in the tilting angle was coincident with obvious (stage 2) narrowing of the TC joint space. A very obvious decrease correlated with further narrowing, and in the group showing narrowing of stage 4 there were only two operated ankles in which lateral and medial talar tilt of 1—5 degrees was measured, and two conservatively treated ankles with lateral talar tilt of 1—10 degrees but no medial tilting. The decrease in talar tilt clearly appears from Tables 44—45, in which the material is presented according to duration groups. Irrespective of the presence of planovalgus, medial talar tilt seemed to be less pronounced than lateral tilting. This is probably due to the anatomical structure of the ligaments, the deltoid ligament being markedly stronger than the lateral ligaments.

Conclusions

On comparing the postoperative results with the follow-up results on the conservatively treated feet, it appeared that triple arthrodesis seems to cause an increase in talar tilting. This is obviously due to the elimination of the compensatory influence of the subtalar joints, as a result of which the rotational movements of the foot are reflected in the talocrural joint. Rheumatoid arthritis

and secondary inflammatory changes weaken or may even destroy the ligaments of the ankle, but at the same time the disease gradually, although very slowly, leads to narrowing of the talocrural joint space and fibrosis of the tissues, which counteract tilting of the talus and stabilize the talocrural joint. The presence of instability does not depend solely on the occurrence of talar tilt; it is also influenced by muscular tonus. Nearly always, the muscular functions of the rheumatoid patient are well preserved. Slight talar tilt does not cause instability on walking. *The talar tilt resulting from triple arthrodesis does not essentially contribute to instability of the talocrural joint in rheumatoid patients.*

4. Does arthrodesis of the subtalar and midtarsal joints lead to the development of osteoarthritis in the talocrural joint?

Many previous investigators have mentioned the development of osteoarthritis of the talocrural joint as a complication to arthrodesis of the subtalar joints (HART 1937, BENTZON et al. 1949, LEIKKONEN 1950 after astragalectomy, MACKENZIE 1959 after LAMBRINUDI's operation, ROBINS 1959, LINDHOLM 1960, HOWLAND 1964, RUGTVEIT 1964, WILSON et al. 1965). In the majority of cases in these series poliomyelitic or other paralytic conditions constituted the indication for operation. LAMBRINUDI's operation or astragalectomy as described by WHITMAN have often been performed when the muscular balance of the leg has been disturbed. After a long observation period ROBINS observed slight rounding of the margins of the talus only in a few cases. Degenerative changes were not present, provided that varus and valgus deformities had been adequately corrected. In HOWLAND's series only one patient showed arthritis of the TC joint, and RUGTVEIT observed no such case. WILSON et al. do not mention osteoarthritis of the TC joint or discomfort caused by this condition.

In the present study osteoarthritis of the TC joint was observed preoperatively in 36 cases (12.7 per cent) and at follow-up in 70 cases (28.2 per cent). At corresponding points of time this condition was found in the conservatively treated series in 21 cases (10.3 per cent) and 36 cases (21.2 per cent). Osteoarthritis thus seemed to occur somewhat more frequently in the operatively treated feet. In both series the rheumatoid changes showed about the same pattern of increase. The development of osteoarthritis seems to be secondary to the inflammation of the joint. It seems possible that the greater frequency of osteoarthritis in the operatively treated series is attributable to the talar tilt which sometimes was a result of triple arthrodesis.

In cases of old standing, rounding of the corners of the talar horizontal joint and the corresponding points of the tibia and fibula was occasionally observed. This change may also be caused by the rheumatoid destructive process.

Conclusions

Osteoarthritis of the talocrural joint seems to increase with progression of rheumatoid arthritis. When the operatively treated feet were compared to the conservatively treated group from the standpoint of the development of osteoarthritis of the talocrural joint, the change that occurred from a point of time prior to operation until follow-up examination seemed to be somewhat greater in the operatively treated series. The cause of this may perhaps be that the joint in question is subjected to greater stress in feet on which triple arthrodesis has been performed.

5. What are the functional results of operative treatment?

The operative result was good in 248 feet (85.5 per cent), fair in 25 feet (8.6 per cent), and poor in 17 feet (5.9 per cent). In a total of 42 feet (38 patients) obvious functional defects remained, and the patients were not quite satisfied with the result. In many cases severe planovalgus, with calcaneal valgus of over 15 degrees, caused discomfort. Moderate calcaneovarus, and severe varus of the forefoot, also seemed to cause discomfort. No patient complained that the TC joint gave way, but they experienced discomfort on walking due to this joint, which had remained painful.

Triple arthrodesis was performed on both feet in 63 cases. The functional result was not quite satisfactory in both feet in four patients and in one foot in eight patients. These 16 feet constitute 12.7 per cent of the total number of double arthrodeses (126 feet). This does not indicate any increased risk of complications from bilateral triple arthrodesis, when the two feet are operated upon at different times.

Of the deformities varus (calcaneovarus in particular) seems to be the most harmful, but calcaneovalgus of over 15 degrees should also be avoided. The patients do not seem to mind moderate valgus as long as there is no pain. However, moderate valgus makes it necessary to wear a support in the shoes. The ideal seems to be when the calcaneus is in the normal anatomical position.

Painful non-union occurred in only three feet: non-union of the Chopart joint in two feet and non-union of the TN joint in one foot (the total number of joints showing painful non-union being thus five). Non-union was

observed in a total of 39 joints (23 TN joints and 16 CC joints). It thus appears that non-union seldom causes major discomfort. Obviously the absence of untoward effects is due to the presence of fibrous ankylosis which prevents painful movement. In all the above-mentioned three cases a disturbing varus deformity was present. It is evident that the non-union was due to poor bony contact and led to varus.

According to HALLGRIMSSON (1943), PATTERSON et al. (1950), HOWLAND (1964) and WILSON et al. (1965), pseudarthrosis most often occurs in the talonavicular joint. In the most extensive series followed up (including, in addition to the above-mentioned, those described by SMITH and V. LACKUM 1925, LINDHOLM 1960, and POLLOCK and CARRELL 1964), the proportion of poor results varied between 6 and 15 per cent. Consequently, the results of triple arthrodesis performed on account of rheumatoid arthritis can well be compared with those of subtalar arthrodesis carried out on other indications.

Conclusions

Rheumatoid patients derive considerable benefit from triple arthrodesis for the following reasons: 1) Pain is relieved in the most important joints of the foot, and the clinical symptoms of the talocrural joint are at least transiently diminished. 2) The operation stabilizes the foot and prevents aggravation of deformities. At the same time deformities may be corrected, or their ill effects may be reduced. It is advisable, however, to perform the operation within three years from the onset of steadily progressing symptoms. Attention should be attached to correct positioning of the calcaneus, the ideal being the normal anatomical position. In any event varus is to be avoided. The forefoot should be placed in plantigrade position, and quite frequently there is a varus deformity requiring correction. 3) Even though subtalar motion is lacking, if the foot is painless and in good or satisfactory position, the TC joint causes relatively little discomfort. 4) The functional results observed in the present study were even better than those reported in other series.

6. What is the most favourable time for the performance of triple arthrodesis from the standpoint of the development of the disease and the best possible result?

On the basis of the present study it may be stated that the most favourable time for triple arthrodesis can be determined by following the development of the following signs: 1) *Swelling, pain at rest and on motion (the first clinical signs).* 2) *Planovalgus.* 3) *Osteoporosis, particularly in the surround-*

ings of the calcaneocuboid joint. 4) Joint space narrowing, particularly in the talonavicular joint. These signs develop rapidly, within three years, and are thus early signs. 5) Erosions. This sign is first discernible in the talonavicular joint (in 44.9 per cent of cases in the under three years' duration group). During the first three years of the disease the medial and lateral aspects of the talocrural joint showed clearly less erosions than the subtalar joints. For this reason evaluation of the prognosis of the disease and of the best time for the performance of triple arthrodesis cannot be based on the occurrence of erosions in the talocrural joint. This sign must first be looked for in the talonavicular joint, then in the calcaneocuboid and talocalcaneal joints.

If the talocrural joint is destroyed, showing surface erosion of at least stage 2, and the joint is painful on motion, there is reason for considering the performance of pantalar arthrodesis. If synovial hyperplasia of the talocrural joint is suspected and the joint does not yet show definite surface erosions, it is the author's opinion that synovectomy of the talocrural joint, performed in addition to triple arthrodesis, is a beneficial procedure which slows down the rheumatoid process.

Conclusions

The most favourable time for the performance of triple arthrodesis depends on the above-mentioned symptoms. It is advisable to operate before the development of severe deformities and destructive changes.

X. SUMMARY

The present study is concerned with the changes in the pantalar joints caused by rheumatoid arthritis and the significance of arthrodesis of the subtalar joints (triple arthrodesis) from the standpoint of the rheumatoid patient. Furthermore, the effects of rheumatoid inflammation and of triple arthrodesis on the stability of the talocrural joint were investigated by a special radiological method.

The material consisted of two series: feet on which triple arthrodesis was performed (292) and feet which were conservatively treated (204). The majority of cases (290 operatively treated and 194 conservatively treated feet) were followed up. The average follow-up period was 3.6 years.

The various points investigated are specified in the part headed Problems and in connection with the detailed discussion of the results.

The investigated feet belonged to patients who were treated at the Hospital of the Rheuma Foundation, Heinola, during the years 1953—1964.

Preoperative study

Clinical symptoms and signs

Marked swelling, pain on motion and limitation of the range of motion were found to be typical features. The last-mentioned symptom progressed rather slowly. Preoperatively, swelling of the area of the subtalar joints was observed in 98.3 per cent of cases, pain on motion in 98.6 per cent. Pain at rest was less common, being observed in 62.3 per cent. Limitation of the range of subtalar motion was noted in 96.6 per cent. The development of ankylosis of the subtalar joints was found to take a long time, since both pronation and supination were entirely lacking in only two feet. The dorsal flexion of the talocrural joint was 15 degrees or less in 79.8 per cent of cases, and the plantar flexion was under 40 degrees in 78.4 per cent. Motion of the

talocrural joint was found to decrease very slowly as the disease progressed. The deformity most frequently observed was planovalgus, which was present in 87.4 per cent (255 feet). Calcaneovarus was observed in 27 feet, and varus of the forefoot in 57 feet. Calcaneocavus or cavus was observed in 20 feet. Planovalgus mostly occurred in combination with varus of the forefoot. Planovalgus developed in the initial stage of the disease, during the first three years, after which the deformity gradually became fixed.

Radiological findings

The subtalar joints

Moderate or severe osteoporosis occurred most frequently in the calcaneocuboid area (90.5 per cent), in which it developed during the first three years. In the talocalcaneal and talonavicular areas osteoporosis showed a statistically significant progression during the course of the disease. The highest average degree of severity of osteoporosis was observed in the calcaneocuboid area, while the severity of the changes in the talonavicular and talocalcaneal area was about equal.

Marked narrowing of the joint space was most frequently found in the talonavicular joint, but when moderate narrowing was also taken into account, the frequency figure was highest for the talocalcaneal joint (88.3 per cent). Narrowing of the TN joint space was observed in 82.7 per cent of cases, narrowing of the CC joint space in 71.8 per cent. As evaluated on the basis of the arithmetical means of the stages of severity, the TN joint space was most heavily affected. Narrowing of the TN joint space developed in the initial stage of the disease, i.e. during the first three years, and subsequent changes were slight. Narrowing of the CC and tc joint spaces showed an almost linear development with prolongation of the disease. Erosions occurred in the TN joint in 61.3 per cent, in the CC joint in 49.3 per cent, and in the tc joint in 44.4 per cent. In all three joints the progression of erosions was significantly correlated with the duration of the disease. Changes due to periosteal reaction were observed in the margins of the TN joint in 73.6 per cent of cases, in the margins of the tc joint in 40.5 per cent, and in the margins of the CC joint in 17.6 per cent. The periosteal changes showed a significant aggravation with prolongation of the disease. Osteoarthritis occurred in the TN joint in 49.6 per cent, in the tc joint in 33.8 per cent, and in the CC joint in 13.0 per cent of cases, and this condition showed a significant increase with the progression of rheumatoid arthritis. Osteoarthritis seems to develop gradually in inflamed joints.

The talocrural joint

Osteoporosis was observed in the area of the talocrural joint in 44.4 per cent of those feet which showed inflammation of the subtalar joints. In the 4—6 years' duration group osteoporosis occurred in only 35.5 per cent of cases. This drop was obviously due to increased activity. After the acute stage the patients adapt themselves to the situation and use the foot. In the later duration groups osteoporosis again increased steadily, though slowly. Osteoporotic changes were a less salient feature in the area of the talocrural joint than in the subtalar joints, however, owing to the concentration of the inflammation in the more distal joints of the ankle.

Narrowing of the joint space was observed in 14.1 per cent of cases, surface erosion in 20.8 per cent, erosion of the medial aspect of the mortise in 33.8 per cent, and erosion of the lateral aspect of the mortise in 31.7 per cent. Unevenness of the malleolar and talar surfaces was more frequent on the medial aspect than on the lateral aspect, which may be attributable to the planovalgus position.

The changes of the TC joint increased rather steadily with progression of the disease, and the increase in erosions was highly significant as regards both the horizontal and lateral joint surfaces. On the other hand, erosions of the medial aspect often developed as an early sign. Osteoarthrosis was observed in only 12.7 per cent. This lesion, like the rheumatoid changes, gradually progressed.

The radiological changes in the talocrural joint were less frequent and slighter than those in the subtalar joints.

Follow-up study

Clinical symptoms and signs

After triple arthrodesis swelling was noted in 21.7 per cent of 290 feet examined, and pain at rest was present in only 10 feet (3.4 per cent). In the conservatively treated feet swelling was present in 56.2 per cent. Pain on weight-bearing occurred postoperatively in 12 feet, i.e. 4.1 per cent, while this symptom was present at follow-up in 42.2 per cent of the conservatively treated feet. After operation no subtalar motion was observed. In the conservatively treated series 72.6 per cent of the feet showed moderate or marked limitation of motion. Swelling of the talocrural joint had clearly decreased in the operatively treated series, being almost non-existent in 71 ankles

(24.4 per cent). The range of motion of the TC joint was only slightly limited, which may be attributable to progression of the disease and not to the triple arthrodesis. Moderate or marked pain was present in only 48 TC joints (16.5 per cent).

Postoperatively the foot became practically painless, and the symptoms in the area of the TC joint were also alleviated, although they persisted in some cases.

A noteworthy result of operation was the partial correction of planovalgus deformities, the severest calcaneovalgus positions (over 15 degrees) showing a marked decrease in frequency. Preoperatively, valgus of over 15 degrees was observed in 128 feet (43.8 per cent), at follow-up in 66 feet (22.8 per cent). In the conservatively treated series no major changes occurred during a corresponding period of time; probably the deformities had become fixed. Calcaneovarus and varus of the forefoot had decreased, but calcaneovarus was still present in 17 feet, varus of the forefoot in 50 feet. The deformities causing the greatest discomfort were calcaneovarus, severe calcaneovalgus, and varus of the forefoot. These have to be corrected in order to attain a satisfactory result. The present anatomical results were good in 142 feet (48.9 per cent), fair in 114 feet (39.3 per cent), and poor in 34 feet (11.8 per cent).

Radiological findings

Osteoporosis and periosteal reaction in the subtalar region

Moderate or severe osteoporosis in the area of the ankylosed joints occurred in an average of 72.0 per cent of cases, which means that a slight improvement had occurred as a result of increased use of the foot and subsiding of the rheumatoid process. The development of the periosteal changes was arrested by the operation. In the area of the talocalcaneal joint these changes even showed a slight decrease. From this the conclusion may be drawn that the periosteal changes were due to the rheumatoid process.

Radiological changes in the talocrural joint

The severest osteoporosis of the TC joint was observed in the years immediately following triple arthrodesis. Subsequently a slow improvement occurred, but after seven years' duration the effect of RA became noticeable as a gradual increase in osteoporosis. The TC joint space showed narrowing in 74 cases (29.8 per cent), and erosion showed a steady increase as compared with the preoperative state. On this point the difference was

highly significant. At follow-up, surface erosions were observed in 90 ankles (36.3 per cent), erosions of the medial part of the mortise were observed in 180 ankles (72.6 per cent), and erosions of the lateral part of the mortise in 165 ankles (66.5 per cent). Erosions of the medial part were thus clearly more frequent than erosions of the lateral part. Obviously, valgus deformity causes heavier stress on the medial aspect via the deltoid ligament, in particular following subtalar arthrodesis, when the rotational movements of the foot most strongly act upon the TC joint. It seems possible that under the influence of stress erosions more readily develop in a cartilaginous surface affected by RA. Osteoarthritis of the TC joint showed a somewhat greater increase in the operatively treated group than in the conservatively treated ankles, and the aggravation was more marked than was to be expected on the basis of the exacerbation of the rheumatoid changes. Arthritis of the TC joint was observed in 70 feet (28.2 per cent) in the operatively treated series and in 36 feet (21.2 per cent) in the conservatively treated series. The fact that the frequency was somewhat higher than expected in the operatively treated series may be accounted for by the effect of triple arthrodesis and the resulting stress on the TC mortise. In the conservatively treated series the radiological changes in both the subtalar joints and the TC joint showed an obvious aggravation when the observations made at different points of time were compared.

Instability of the talocrural joint

In order to assess instability of the talocrural joint, the talar tilt angle was measured on radiographs taken at stress examinations. Three groups were compared: feet on which triple arthrodesis had been performed, conservatively treated feet, and normal feet. On comparison of the normal group and the rheumatoid feet no significant difference emerged in respect to either medial or lateral tilting. But after triple arthrodesis the talus tilted significantly more than in the conservatively treated ankles. It appears that in the absence of the balancing influence of the subtalar joints the ligaments of the TC joint are subjected to heavier stress than before, resulting in degeneration and decrease of the tensile strength of these ligaments. The lateral ligaments were surgically explored in 43 feet. It was found that in addition to destruction of the ligaments, RA caused fibrosity of the tissues and gradually led to narrowing of the joint spaces and ankylosis. For this reason no large talar tilt angles can develop, and thus no clinical instability appears on normal walking. A lateral talar tilt angle of over 5 degrees was

measured in 58 ankles (22.7 per cent) in the operatively treated series, and in 36 ankles (18.0 per cent) in the conservatively treated series. A medial talar tilt angle of over 5 degrees was observed in the former series in 13 ankles (5.1 per cent), and in the latter series in only 4 ankles (2.0 per cent). Anterior subluxation of the talus was observed on stress examination in only 14 (26.4 per cent) of the operatively treated feet thus examined, and in 13 (19.1 per cent) of the conservatively treated feet. Statistically the difference between these two figures is insignificant.

Osteoarthrosis of the talocrural joint as a complication of triple arthrodesis

At follow-up examination rounding of the joint surface of the talus and the mortise was observed in some cases. Osteoarthrosis was found to develop as a secondary phenomenon, following the rheumatoid changes, and to progress with prolongation of the disease. The result is ankylosis of the joint, and no new joint develops by regeneration. As already mentioned above, after triple arthrodesis osteoarthrosis seemed to develop somewhat more rapidly than did the rheumatoid changes, and this appears to be due to the greater stress to which the TC joint is exposed and to »pseudoinstability». This is of no practical significance to the patient.

Functional results

On evaluation of the operative results, the patient's own opinion concerning the function of the foot was taken into account, in addition to the possible presence of anatomical deformities or other factors causing discomfort. The result was good in 248 feet (85.5 per cent), fair in 25 feet (8.6 per cent), and poor in 17 feet (5.9 per cent).

The causes of partial failure were the following: severe or extreme planovalgus in 17 feet (5.9 per cent), moderate or severe pes varus or calcaneovarus in 10 feet (3.4 per cent), severe varus of the forefoot in 6 feet (2.1 per cent), decrease of function or severe pain in the talocrural joint in 4 feet (1.4 per cent), other causes (infection, pseudarthrosis, RA of the other, non-operated joints of the foot) in 5 feet (1.7 per cent). Triple arthrodesis was performed on both feet of 63 patients, but at different times. This did not increase the frequency of complications.

The majority of the patients were satisfied with the results of operation, although in many cases calcaneovalgus of 10—15 degrees remained. The patients attached great value to being able to step on a relatively painless, stable foot. Pseudarthroses were rare, and painful non-union was present in

only three feet. A total of 39 joints, i.e. 23 TN and 16 CC joints, showed non-union. The talocalcaneal joint showed partial or complete union in all cases.

Triple arthrodesis resulted in an almost painless ankle in a better position than preoperatively. The operation ought to be performed before persistent planovalgus or varus deformities have developed, according to the present result within three years from the onset of steadily progressing symptoms in the ankle. In this series triple arthrodesis was almost invariably carried out by RYERSON's method using bone graft (GRICE 1952) and chips (VAINIO's modification) between the talus and calcaneus. The graft, however, does not prevent the calcaneus from slipping into valgus if weight-bearing is allowed too soon, and a good plaster cast is not sufficient protection against this, either. Hence the period of non-weight-bearing ought to be a minimum of four to six weeks, and the total time in plaster about eight to ten weeks. Obviously, the use of a graft is not indispensable in all cases, since union of spongy bone occurs very satisfactorily in rheumatoid patients, also. But by the application of a graft and staple the calcaneus is more readily kept in the right position. With a view to correcting deformities particular attention should be paid to placing the foot in the correct position and to adequate modelling of the plaster cast.

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RADIOGRAPHS

Plates 8–17

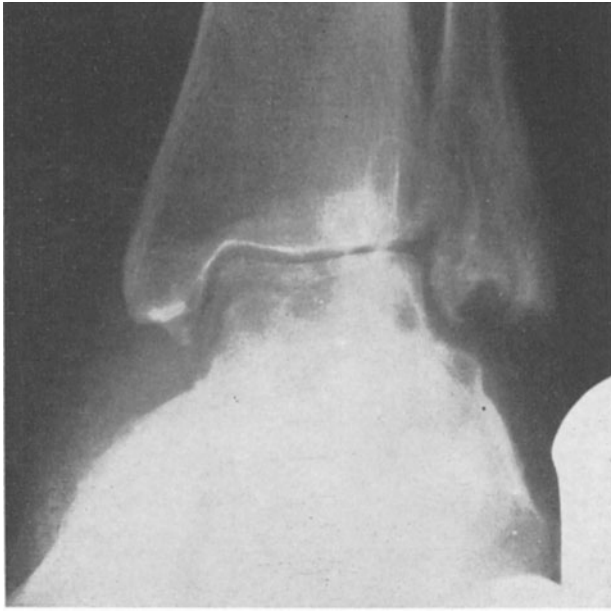


Plate 8. The medial part of a TC joint. Definite, typical erosion is seen in the apex of the medial malleolus, at the border between cartilage and bone. The corresponding aspect of the talus is rough, but shows no definite erosions. Moderate osteoporosis is present. The joint space is not narrowed.



Plate 9. Marked destruction (stage 4), particularly in the apex of the lateral malleolus. Erosions are also seen in the medial aspect of the joint and at the corners. The joint space shows considerable narrowing (stage 3). Severe osteoporosis is present.



Plate 10. Definite narrowing of the joint space (stage 2), marked erosions (stage 3) in the lateral aspect, in which the severest destruction is seen at the level of the TC joint. The surface of the medial malleolus is rough. Below the cartilaginous surface of the medial aspect of the talus is a zone of rarefaction. Marked osteoporosis.



Plate 11. Marked osteoporosis in the area of the TC joint. In the medial malleolus there is a large pseudocyst, probably the result of a subcortical destructive process originating in a small erosion. The cyst was evacuated, and histological investigation revealed a completely necrotic mass in which no original cells could be identified.



Plate 12. Destroyed TC joints in a case of over ten years' duration. Narrowing and erosions of stage 4 in both joints. In addition, osteoarthritis is present.



Plate 13 a. Two years after the onset of RA in the ankle. Planovalgus has developed, an angle being clearly discernible in the medial ray at the level of the cuneonavicular joint, resulting in depression of the arch of the foot. Osteoporosis is present particularly in the areas of the CC and TN joints. The TN joint space shows narrowing, and incipient narrowing is also observable in the CC joint.



Plate 13 b. Eight years after the onset of R.A. Marked osteoporosis is also present in the area of the TC joint. The talus shows marked depression. The metatarsus I is slightly elevated. The worst changes are seen in the TN joint. Triple arthrodesis is planned.



Plate 13 c. Two years after operation. Chopart's joint has not fused but shows fibrous union. No definite motion is observed. The staple has remained well in place. Because of pain in the TN joint a second operation is to be performed, to achieve bony ankylosis.



Plate 13 d. One year after re-operation. Chopart's joint has fused. The deformity has been corrected, the arch of the foot looks well. The foot is completely painless. As in plate 13 c. the cuneonavicular joint also shows union. Joint spaces are seen only in the metatarsotarsal joints. The staple was removed at the operation.



Plate 14 a. Less than three years after the onset of symptoms. A slight depression at the level of the cuneonavicular joint, depression also of the talus. Incipient distal mallet. Marked osteoporosis in the whole tarsal region, and a definite rheumatoid process in the distal tarsal joints. The TN and CC joint spaces show narrowing, the latter somewhat less than the former. In the plantar corner of the TN and CC joints erosions seem to be present.



Plate 14 b. After a further two years. The process shows a severe exacerbation. Marked osteoporosis is present in the whole of the foot, including the TC joint. The arch of the foot has not been further depressed, the deformity has become fixed. Digiti mallei and hallux flexus are present. The TN joint shows the worst, the TC joint the slightest, changes. The TC joint is well preserved. Since the foot is extremely painful, the performance of triple arthrodesis is decided upon.



Plate 14 c. Over five years after operation. Osteoporosis has clearly decreased and the calcium concentration has increased. The staple has remained well in place. The «triple joints» have fused so as to become painless; only the dorsal margin of the TN joint is slightly open, but this is of no significance. In spite of the changes in the toes the patient walks satisfactorily and is satisfied with the operation.



Plate 15 a. Over seven years after the onset of symptoms. The talus shows marked depression and the joint space is extremely narrow. Erosions and osteoarthritis are present, and changes are visible in the CC and tc joints, too. Osteoarthritis is most marked in the area of the TN and tc joints. The foot is painful and requires triple arthrodesis.



Plate 15 b. Eight years after operation. The subtalar joints have fused well, although fibrous ankylosis is present in a small area of the upper part of the TN joint and the posterior part of the tc joint. The staple is in place. The forefoot shows slight cavus. Digi mallei and hallux valgus. The foot is painless.

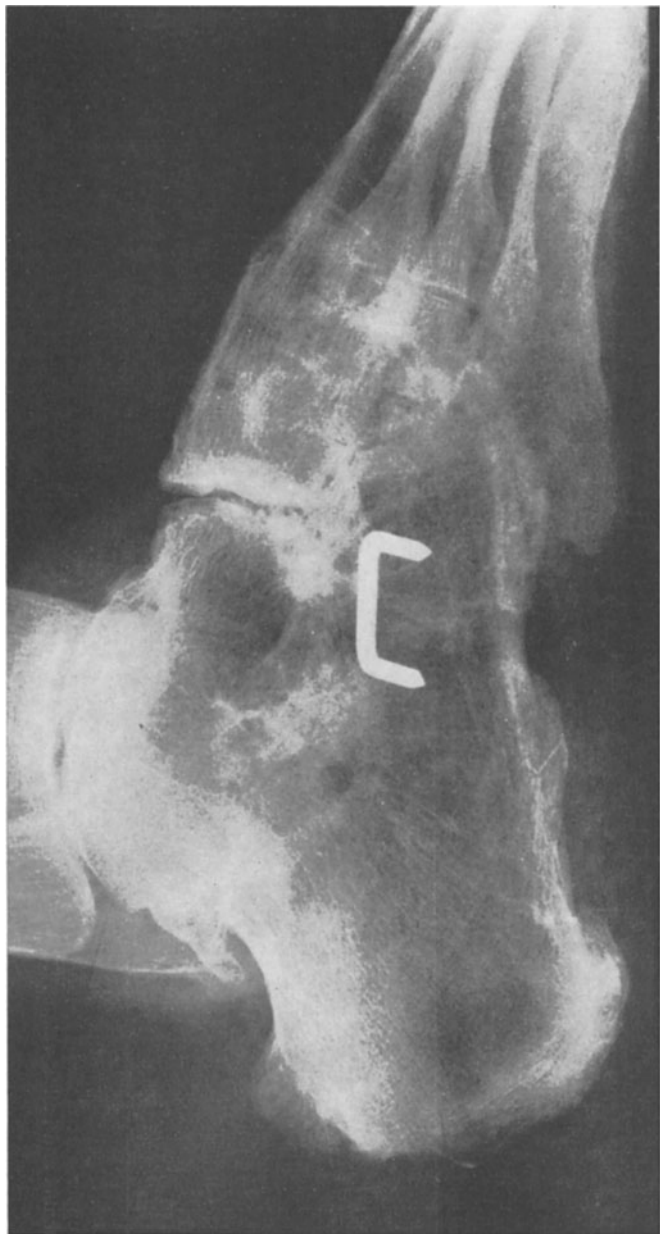


Plate 16. Two years after triple arthrodesis the TN joint shows non-union and is painful on weight-bearing. The CC and TC joints are fused. Re-arthrodesis of the TN joint was performed later.



Plate 17. Ten years after the onset of symptoms. The bone is atrophied and osteoporotic. Changes are present in almost all joints, even the TC joint spaces show narrowing. Extreme planovalgus is present (rocker bottom feet), the head of the talus has dropped into almost vertical position. Severe *digiti mallei*, dorsally luxated toes.