CHAPTER IV

"Dupuytren's Contraction" of the Plantar Aponeurosis

Closer investigation of the material reported here, consisting of patients suffering from Dupuytren's contraction in the hands, revealed that similar changes were present in the feet in several cases. Both with regard to its localization and to other symptoms, the nature of this disease when it occurs in the foot arouses particular interest in the anatomical structure of the plantar aponeurosis.

1. Anatomy and Embryology of the Plantar Aponeurosis

A. General Survey of the Anatomy

On the basis of comparative anthropological investigations, Loth (1908) differentiated between a lateral and a medial part of the plantar aponeurosis. The lateral part, also termed *aponeurosis plantaris fibularis*, is rudimentary in man. It is, however, of interest since phylogenetically it must be regarded as the primary structure. Its tarsal part occurs consistently and stretches from the os calcis to the tuberosity of the fifth metatarsal bone, whence the true fibular aponeurosis continues in the metatarsal region. It is lacking in 10 per cent of human beings.

Aponeurosis plantaris tibialis dominates and forms what is commonly referred to under the name of the ***plantar aponeurosis***. It arises as a strong fibrous band from the inner tubercle of the os calcis and consists of two layers; one superficial with extensions to the four lateral toes, and one deep layer running in a lateral-medial direction and partly appearing on the medial side as a separate band for the big toe. In contrast to the conditions in the hand, this extension occurs consistently. It is shorter and broader than the extension to the other toes.

In the metatarsal region the aponeurosis has become broader and

In Skoog, T: Dupuytren's Contraction With Special Reference To Aetiology And Improved Surgical Treatment Its Occurrence In Epileptics Note On Knuckle-Pads. Acta Chirurgica Scandinavica 1948;vol 96, Suppl 139.

thinner and divides into five processes corresponding to the toes. A superficial insignificant part of these attaches to the skin and merges into the natatory ligaments and the fasciae of the toes. The main portion of each process divides into two slips, which embrace the flexor tendons of the toe, and are inserted into the sides of the metatarsal bones (GRAY 1864). These series of arches, through which the tendons of the long and short flexors pass, correspond to the much thinner paratendinous septa of the hand. According to BRAUS (1929) their total transverse section is so large that it could support a load of approximately 150 kg. Each septum is about two mm thick and extends from the anterior edge of the transverse portion of the adductor hallucis muscle up to the level of the metatarsophalangeal joints. A number of fibres are crossed dorsally of the flexor tendons, and many of them merge into the accessory plantar ligament but no continuation onto the toes has been described.

In response to the special task of the sole of the foot, which is to bear the weight of the body and also to act as protection and support for the tissues in the foot, a subcutaneous tissue of a particular nature has developed in the supporting points corresponding to the os calcis and the anterior metatarsal region. In these regions the fatty tissue is prevented from being shifted towards the sides by the fact that it is enclosed in a fibrous network whose vertical fibres issue chiefly from the plantar aponeurosis and are tightly connected with the covering skin. In the hollow of the foot, these connexions are loose, so that the skin can be lifted in folds and the aponeurosis can be exposed by blunt dissection. (A detailed description of the finer structure of this tissue has been given by BENNINGHOFF 1939.)

Two septa penetrate from the medial and lateral borders of the plantar aponeurosis deep into the sole of the foot, dividing the sole into three fibrous compartments. TESTUT and JACOB (1906) described how the medial septum in the posterior region allows passage to the long flexor tendons to the foot, and also how the tendon to the flexor hallucis longis once more penetrates this after its course along the lateral side of the septum. HENKEL (1913) observed in addition a band from the central part of the medial region of the aponeurosis, directed distally and dorsally, and dividing into two slips. The lateral one partly inserted into the 3rd cuneiform and partly merged with the tendon of the flexor hallucis brevis muscle. The other slip (not shown

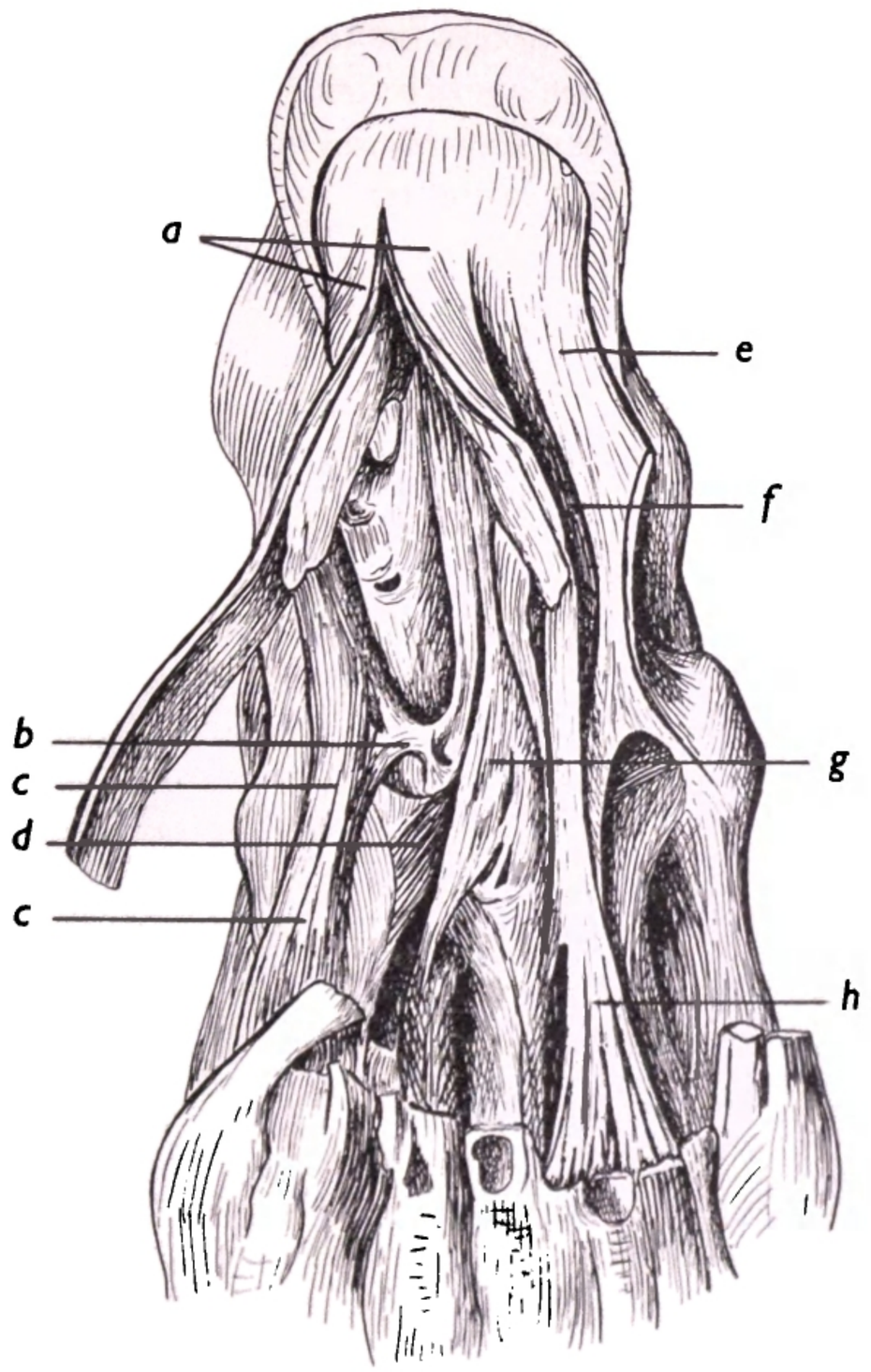


Fig. 27. Deep attachments of plantar aponeurosis (redrawn after HENKEL 1913). a — tibial portion of plantar aponeurosis; b — lateral branch of deep, vertical ligament described in text, detached from its origin at inner border of the plantar aponeurosis; c — flexor hallucis brevis; d — tendon of peroneus longus; e — fibular portion of plantar aponeurosis; f — sulcus between tibial and fibular portion of the aponeurosis; g — long plantar ligament; h — deep attachments of the aponeurosis to 4th metatarsal bone. (Processes to the other metatarsal bones removed.)

in Fig. 27) curved medially and attached itself to the plantar surface of the 1st cuneiform, forming a septum along the adductor hallucis brevis muscle.

B. The Writer's Observations

Perusal of the literature shows that the plantar aponeurosis has been studied somewhat cursorily when compared to the thorough

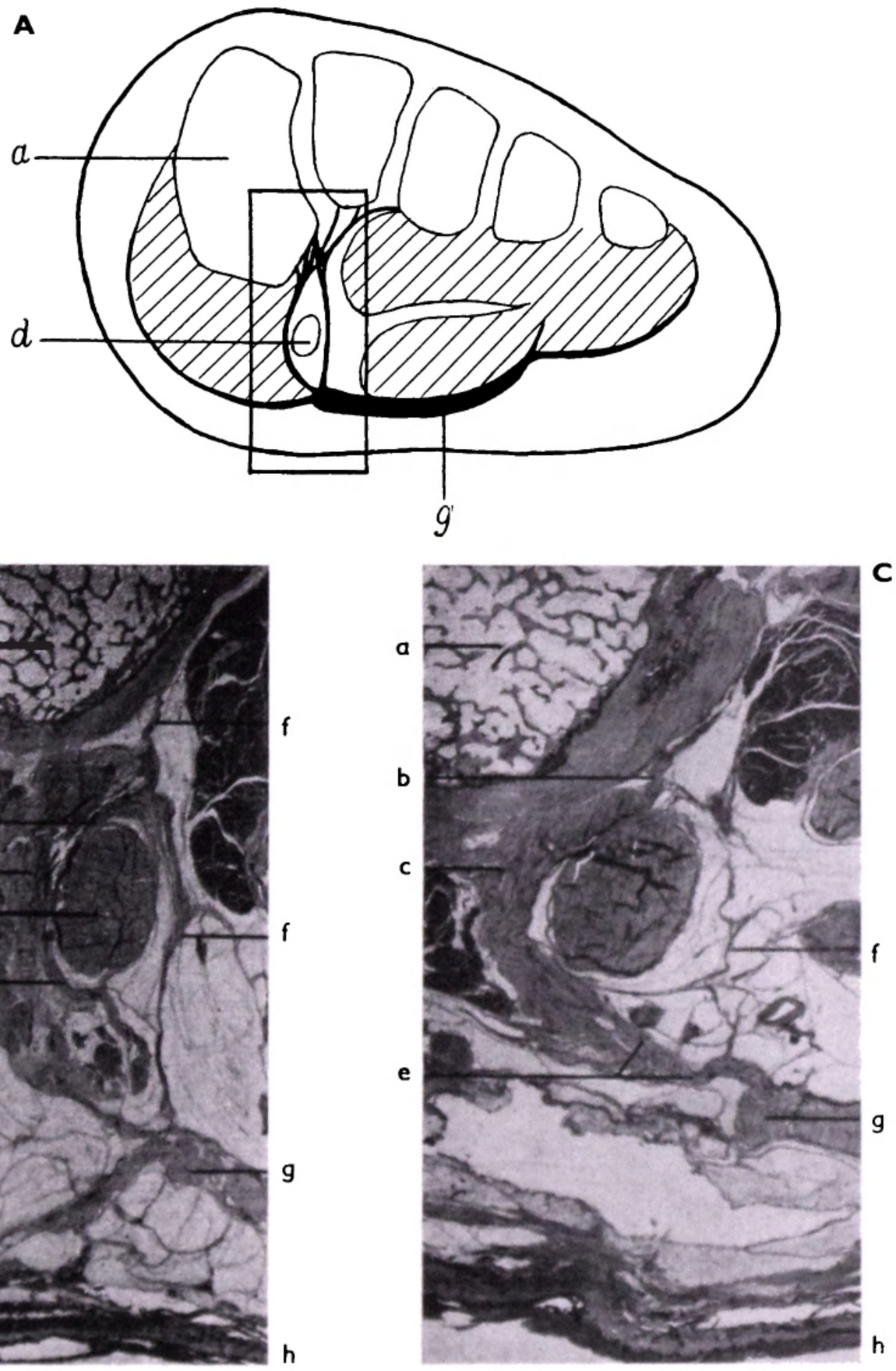
studies made by several workers on the palmar aponeurosis. The present writer has therefore endeavoured to make a closer study of the structure of the plantar aponeurosis by means of 40 dissections. The material consisted of post-mortem sections from adults of both sexes and varying ages.

It was possible, by careful dissection, to follow the continuations of the aponeurosis to the lateral aspects of the proximal phalanges, as well as to the dorsal fasciae of the toes in analogy with the conditions in the upper extremities. This was not the case as regards the big toe, since the aponeurosis there shows no distinct continuation peripherally of the metatarsophalangeal joint. The digital extensions were thin and insignificant compared to those going to the fingers.

Since the pathological changes discussed in this chapter appear particularly to take place at the medial border of the plantar aponeurosis in the hollow of the foot, special attention was paid to the structure of the aponeurosis in this region. Even before the writer had read HENKEL's above-mentioned paper, it was always possible in the dissections to isolate two bands in this region with their origin in the aponeurosis. They form oblique definite fortifications of the medial septum, about a centimetre in breadth, at the site where the tendon to the flexor hallucis longus muscle penetrates it to the medial aspect (Fig. 28). The medial slip which has its course most proximally is the most pronounced and is attached, not only to the 1st cuneiform, but also to the plantar aspect of the 1st metatarsal bone. The anatomical structure within this region is further complicated by the fact that, on the medial aspect, a tendinous partition fuses with the short medial muscles of the foot and gives partial origin to these muscles. The lateral slip shows, on the whole, the course described by HENKEL (Fig. 27). It proceeds at right angles from the medial border of the aponeurosis in a dorsal direction.

The plantar aponeurosis is thus very tensely fixed to the skeleton by means of these bands. This anchorage in the hollow of the foot certainly has a definite influence on the statics of the foot and functional significance as well. (This question will be discussed further on p. 82).

As regards the functions of the plantar aponeurosis in general, reference is made to BENNINGHOFF's text-book, particularly as regards the complicated coordination between the fibrous and muscu-



g. 28. Transverse sections of the medial portion of the foot in an adult at the l of the first cuneiform bone. B about one cm distally to C; both corresponding he square in diagram A. The photomicrographs illustrate the reinforcement by bands of the deep vertical septum from the inner border of the plantar aponeuro- one on each side of the flexor hallucis longus tendon. The lateral band is well loped only in section A. Stained with haematoxylin-eosin. (4.)

first cuneiform bone; b deep attachment of medial band from the plantar neurosis; c partial origin of the flexor hallucis brevis; d tendon of the flexor ucis longus; e medial band; f lateral band; g plantar aponeurosis; h tar skin.

lar supporting systems of the foot. If the aponeurosis is severed transversely, the arch of the foot falls.

C. Embryology

The human embryology of the plantar aponeurosis was studied by Bruno (1933) from the 11 to 48 cm stages. He was able to follow the development of a fibular and a tibial portion.

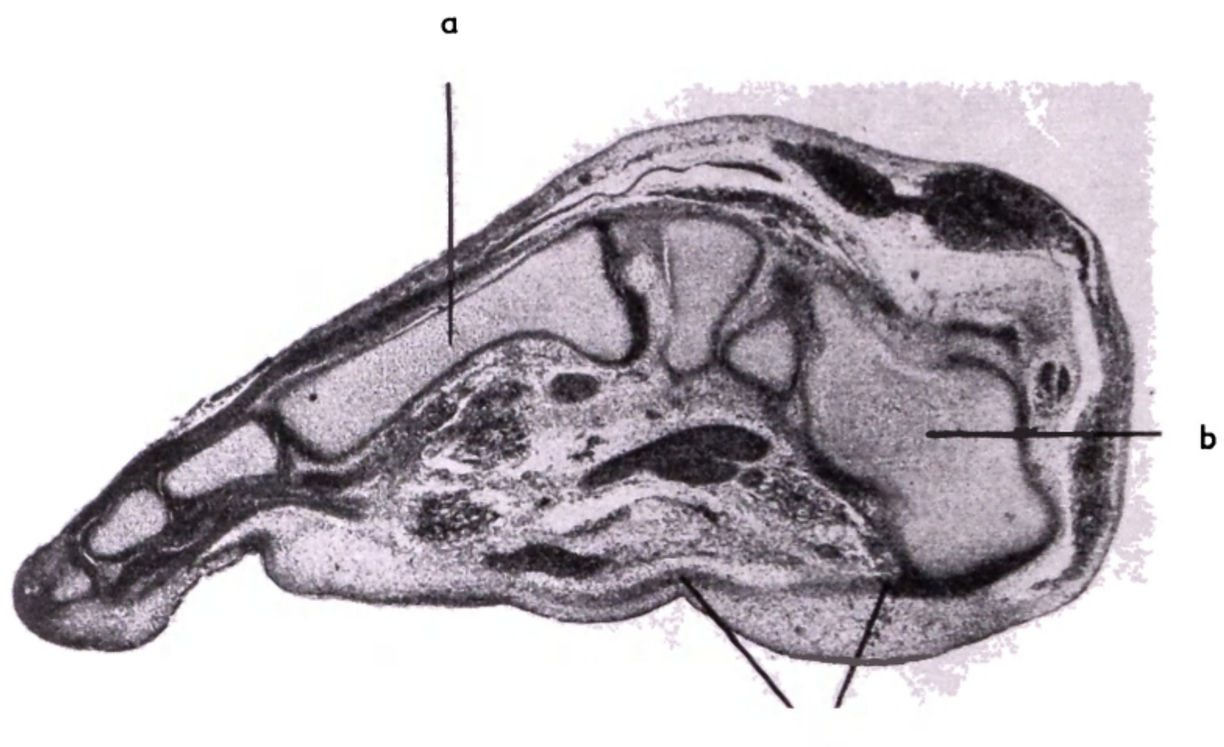


Fig. 29. Longitudinal section of medial part of the foot in a 3.3 cm human foetus. Stained with haematoxylin-eosin. (× 25.)

a — metatarsal bone; b — calcaneus; c — plantar aponeurosis.

An account of the development of the palmar aponeurosis based on an investigation of 20 human embryos and foetuses in various stages is given in Chapter I of the present paper. The plantar aponeurosis was studied in the same material. It was then observed that the development of the latter started later than that of the corresponding structures in the hands. This is in agreement with the general rule that morphogenesis occurs later in the caudal segments. Fig. 29 shows the tibial portion of the aponeurosis at the 3.3 cm stage. The development in the upper and lower extremities showed such good agreement that the description given above of the hand can serve for analagous features in the foot. Thus the natatory ligaments were formed from separate primordia.

2. Clinical Section

A. Survey of the Literature

Changes take place, as has already been mentioned, in the plantar aponeurosis similar to Dupuytren's contraction of the palmar aponeurosis. Little attention has been paid earlier to these conditions and no complete collection has been made of cases of this kind observed previously. DUPUYTREN mentioned that retraction of the toes was also caused by a shortening of the plantar aponeurosis, but he did not report any illuminating case, nor was the coincidence with genuine contraction of the fingers mentioned. It is uncertain to which pathological condition of the foot he referred.

A careful study of the literature reveals, however, that single cases with localized changes of the plantar aponeurosis analogous and concomitant to those of the palm have been reported by MADELUNG (1875), REEVES (1881), COSTILHES (1885), SOUZA-LEITE (1886), ADAMS (1892), ANDERSON (1897), FÉRÉ (1899), DAESCHLER (1903), TESCHENMACHER (1904), STEIN (1909), BYFORD (1921), SPECKLIN, STOEBER (1922), SILVA (1924), COKKALIS (1926), KINZEL (1927), AUVRAY (1929), NIPPERT (1929), ROUILLARD, SCHWOB (1931), FAIRBANK (1932), SCHRÖDER (1934), GREENBERG (1939), HOHMANN (1941), KLOSSNER (1944), VON STAPELMOHR (1947).

Among their 29 cases of Dupuytren's contraction, KANAVEL et al. (1929) reported involvement of the feet in two cases. In a third patient there was a marked cord-like thickening in the subcutaneous tissue of the soles of the feet, closely simulating the fascial thickening of the palm in cases of Dupuytren's contraction before flexion contraction has occurred. MEYERDING (1936) found feet and hands affected in four cases out of 273. BUNNELL (1944), in a material of 87 contracted hands, reported three cases with the association of a similar condition in the plantar fascia.

POWERS (1934), feeling that Dupuytren's contraction of the feet had been awaiting re-discovery since it was first mentioned by DUPUYTREN, found it present in 9 of 29 cases of this disease. His report must, however, be regarded with some criticism. In only three of his cases was a description of localized changes in the plantar aponeurosis given, and most of them were combined with vascular disturbances, hypertrophic skin dis-

cases and pain
contraction.

symptoms generally not associated with Dupuytren's

An interesting report on this co-existence was given by LUND (1941), who found "fibroma plantae" present in 25 of 361 *epileptics*; 22 of them also had Dupuytren's contraction of the hands. In 1,021 brewery workers examined there was only one case with a similar affection of the foot.

It can be deduced from all the above-mentioned cases, from which it is possible to form an idea of the closer localization of the process in the plantar aponeurosis, that it was limited to its medial portion, in the hollow of the foot, possibly spreading in the line of the big toe. The symptoms were usually insignificant and only occurred in some cases. These were manifested as feelings of pressure in the form of tenderness, or a burning sensation in the sole of the foot, discomfort in walking or running or carrying weights. Deformation of the foot was only mentioned in four cases. AUVRAY stated that the big toe on the affected side was in the flexion and valgus position, but it should be noted that the entire foot was in the valgus position and that the leg was atrophic. COKKALIS reported decreased dorsal flexion of the big toe in his case. FAIRBANK's case with typical thickening and contraction of the interior aspect of the plantar aponeurosis of both feet showed some degree of cavus. In only one of LUND's 25 cases had the condition caused incipient contraction of the toes.

Finally, it will be shortly summarized how the double appearance of Dupuytren's contraction in the hands and feet affected opinions on the *aetiology* of the disease. REEVES had seen contraction of the plantar aponeurosis in a sailor, "who was much in the rigging barefooted". FÉRÉ, BLACK (1915) and LUND, however, were of the opinion that when hands and feet were found to be similarly affected, this almost proved the disease to be entirely independent of mechanical cause.

SOUZA-LEITE's case had suffered from repeated strokes accompanied by transient paresis. This fact was considered to demonstrate the trophic nature of the phenomenon. NIPPERT believed that decreased tonus of the sympathetic nervous system was the cause, whilst POWER regarded it as a sign of irritation of the sympathetic nervous system. Neurogenic theories were also brought forward by SPECKLIN, STOEBER and by ROUILLARD, SCHWOB. In the latter case the cause was thought to be a vascular lesion of the spinal cord due to syphilis. FREDET (1932) and BUNNELL drew attention to the fact that the disease was more pronounced over the internal than over the external plantar nerve and that the latter corresponds to the ulnar nerve in the hand.

Endocrine disturbances owing to syphilis were assumed by SILVA

to be the cause. Syphilis in conjunction with chronic alcoholism was the theory postulated by AUVRAY.

COKKALIS, KINZEL, and KLOSSNER regarded their cases as support for Krogius' theory and interpreted the pathological tissue as degenerated rudiments of a superficial plantar muscle occurring in earlier phylogenetic stages.

Finally, DAESCHLER connected his case with metal intoxication, and HOHMANN considered that the symmetrical appearance in hands and feet was a sign of constitutional disposition. (These theories will be discussed in the chapter on Aetiology.)

B. The Writer's Observations

43 of the patients reported on here for Dupuytren's contraction of the hands were also examined with regard to involvment of the feet. Ten of them, all men, showed changes in the plantar aponeurosis. In two of them, however, the deviations from the normal were doubtful. If these two cases are excluded Dupuytren's contraction occurred in both hands and feet in 18.6 per cent. (Fig. 30 shows a typical case.) It is improbable that this material should show an exception in this respect, and several reasons to account for the fact that such a frequency was not earlier observed can be found. Such involvements of the feet have certainly often been overlooked, since their course is usually without subjective symptoms and they are not revealed on cursory examination. The subcutaneous tissue and thick skin of the sole of the foot make it difficult to detect an early stage. This is facilitated if the aponeurosis is stretched by extension of the toes.

In all cases of Dupuytren's contraction in both hands and feet the patients had pronounced changes in both hands. In 4 cases both feet were involved. The process was localized to the medial part of the plantar aponeurosis and the site of predeliction was over the base of the 1st metatarsal bone. The changes were found at this site in 7 of the cases as firm nodules varying in size from that of a pea to double that of a bean. Only in one case was there a more extensive thickening of the medial border of the aponeurosis. The skin was not involved in a similar manner to that of the hand, and the characteristic dimpling of the skin within that area was never seen in the feet.

In the four patients who were able to state when the changes occurred in the feet, they had taken place between the ages of 26 and 45, and had persisted from 6 months up to 13 years. In one case the

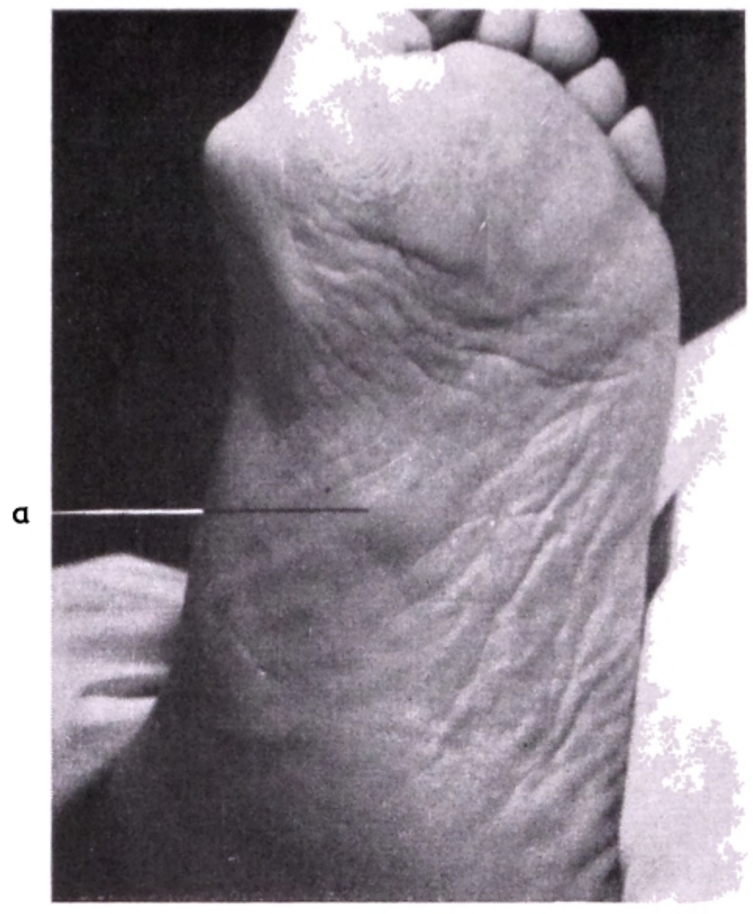


Fig. 30. Typical localization of nodular thickening (a) of the plantar aponeurosis in a patient with Dupuytren's contraction of both hands.

process had remained unchanged for 8 years, after making its appearance as a nodule in the aponeurosis of the foot (Case C. R. S. p. 75). It is interesting to note that in one of the patients the disease appeared in the foot before it appeared in the hands. The case history was as follows:

Case L. J. Naval officer, aged 43. The disease started in the right foot without known cause at the age of about 30 as a limited induration of the medial part of the plantar aponeurosis. (The patient had sustained a fracture of the right foot 5 years previously, but had otherwise suffered no trauma.) The induration was tender and hurt on walking. His condition became so disabling after about 2 years that the changed part of the foot was excised (at another hospital). A relapse occurred immediately afterwards. During the following years Dupuytren's contraction started to develop in both hands, and showed after approximately 8 years a severe bilateral deformity. The left plantar aponeurosis was then also affected.

8.12. 44. *Feet:* Massive deposits in both plantar aponeuroses with large lumps of firm tissue in inner aspect along inner margin. He had pains in his feet when walking and could only walk short distances. There were no other disabilities. No deformity of feet.

9.10. 45. (Op. McI.). Bilateral excision of fibrous tissue masses which proved to be attached to plantar aponeurosis with deep continuation.

12.8. 46. No sign of recurrence. Movements of toes free. No disability in walking.

The pain experienced on walking reported by the above-mentioned patient was, in all probability, chiefly due to mechanical reasons, caused by the pressure of the firm newly-formed tissue. The process

was only widespread in this one case. The discomforts were only minor in all the other cases which is indicated by the fact that three of the patients were not aware of the changes in the plantar aponeurosis until they were revealed on examination. Subjective discomforts only occurred in one other case:

Case L. B. Army officer, aged 47. Bilateral, characteristic finger contraction, from which his father also suffered. The disease started at the age of 24 and had been treated surgically on two occasions. At the age of 45 he noticed a lump in the sole of his left foot. This gave him no disability except for itching and a stretching feeling, which sometimes woke him at night. He rubbed the foot and the feeling then disappeared in a few minutes. No pain on walking.

13.8. 46. *Right foot.* When the big toe was extended, the medial border of the plantar aponeurosis became palpable as a dense band and showed a firm nodule, slightly larger than a pea, corresponding to its middle part. There was a possible slight limitation of the extension of the big toe, but the patient was able to stand on his toes without difficulty. The foot was normal in shape. *Left foot:* normal.

Since it seemed possible that partial disablement of the right foot was imminent, the patient applied to the Ministry of Pensions to register this disease as Dupuytren's contraction. His application was refused on the grounds that a localization in the foot did not exist in this disease!

None of the patients showed any flexion contraction of the toes or other foot deformities which could be connected with the changes in the aponeurosis. The following case will, however, be discussed further in this respect.

Case C. R. S. Accountant, aged 34. No heredity of Dupuytren's contraction to the patient's knowledge. Both hands affected, starting in the right hand at the age of 21 and in the left hand eleven years later. At the age of 26 he developed a localized thickening in the left plantar aponeurosis, not increasing in size or giving any kind of disability during the following years. The cause of the disease was unknown to the patient.

On admission to hospital 13.8. 46 for operation of the right hand, a thickening slightly bigger than a pea could be felt on the inner border in the middle part of the *left plantar aponeurosis.* There was a marked hallux valgus, but otherwise no deformity or disability of the foot.

The *right foot* showed the same degree of hallux valgus but no involvement of the plantar aponeurosis. 15.8.46. (Op. T. S.) The fibrous thickening of the *left plantar aponeurosis* was excised for microscopical examination. Operation revealed that the adjacent parts of the aponeurosis were normal. The longitudinal incision healed primarily and the patient had no disability from the operation.

The last case reported is interesting in comparison with that described by AUVRAY, who reported that the big toe was drawn in the flexion and valgus position. This can hardly be ascribed to a retraction of the palmar aponeurosis. As already mentioned, the extension to the big toe is the shortest, and is attached practically only to the first metatarsal bone and to its accessory plantar ligament. If on

an anatomical preparation this extension is pulled, the dorsal flexion is prevented in the metatarsophalangeal joint, but no flexion is caused. If the big toe is adducted a pulling of the extension attempts to return the toe to its normal position. In favour of the opinion that shrinkage of the plantar aponeurosis did not cause the valgus in the big toe is the fact that in the case described by the present writer the degree of hallux valgus was the same on the other side, in which the aponeurosis showed no changes.

It can also be seen, from the cases reported in the literature, that they are only exceptionally accompanied by notable deformity of the feet. This surprising fact was considered by KLOSSNER who thought that the explanation lay in the anatomical structure of the plantar aponeurosis. He based his theory on the statements in RAUBER-KOPSCH's handbook of anatomy that the plantar aponeurosis lacks any extension peripherally of the metatarsophalangeal joints.

As mentioned above, the present writer found on dissection that this was true of the big toe but not of the other toes. Their anatomy corresponds in this respect to that of the fingers with slight but nevertheless definite extensions to the toes. The writer therefore only agrees with KLOSSNER's explanation in so far as it concerns the medial part of the plantar aponeurosis. It must also be emphasized that, even in other respects, the conditions for the occurrence of a flexion contraction of the toes differ from those of the fingers. This is because the four lateral toes are normally hyperextended in the metatarsophalangeal joints and the flexion capacity is relatively small in these joints. Moreover, such contraction is counteracted when walking. As far as the writer is aware, however, only the medial part of the plantar aponeurosis was affected in the cases hitherto described.

Theoretically, it could be expected from the anatomical conditions that a shrinkage of the digital extensions of the plantar aponeurosis to the four lateral toes would be the cause of the same faulty position as in hammer toe. Only one case appears to support the possibility of such an assumption.

Case H. L. (Fig. 31) A woman, 74 years old. Bilateral finger contraction developing during the last ten years. Typical pea-sized nodule in the medial border on the left plantar aponeurosis. Since youth bilateral hammer toe in the three ulnar toes without known cause. Examination revealed a shortening of the soft parts of the plantar aspect of these toes, but no definite cords or nodule formations. The toe joints appeared to be normal.

Fig. 31. Hammer toe position of the three lateral toes in Case H. L. p. 76.

Without microscopical examination this single case does not allow of any definite conclusions regarding the origin of this hammer toe position. The question whether the digital extensions of the plantar aponeurosis play a rôle in such a deformity is, nevertheless, worth consideration in the future.

Of 207 male *epileptics*, 7.8 per cent showed the typical localized changes in the plantar aponeurosis described above. 86 of the epileptics suffered from Dupuytren's contraction in the hands. The percentage in which the feet were involved in this latter group was 15.2 per cent, a figure very nearly in agreement with that in the cases operated on (18.6 per cent) and with LUND's observations. (For distribution according to age, and other information, see p. 99.)

3. Pathology

A. Survey of the Literature

Only a few of the cases reported in the literature suffering from Dupuytren's contraction localized to the plantar aponeurosis have been examined microscopically. GREENBERG described the excised thickened plantar aponeurosis as extremely dense and firmly adherent to the skin and to the muscular portion of the flexor brevis

digitorum. The specimen showed "spotty hyperplasia" of the connective tissue and enormous hypertrophy of the adventitia of large veins and arteries. The case of MEYERDING et al. "presented all the appearances of normal fascia, microscopically," but around the fascial bundles there were numerous new capillaries with perivascular lymphocytes. Their description causes a suspicion that the section did not include the characteristic nodular thickening of the aponeurosis. HORWITZ examined a nodule removed from the plantar aponeurosis of a 48-year-old woman in whom the palmar aponeurosis was apparently not involved. He regarded the histological structure as similar to the fibroplasia occurring in Dupuytren's contraction. WIMTRUP, who examined LUND's cases, reached the same conclusion. KLOSSNER pointed out that the pathological tissue in the hand and the foot were identical, but interpreted the cellular areas as derivates of persistant embryonic tissue.

To sum up, it can be stated that in the few cases reported, with the exception of those of Meyerding, the microscopical structure appeared to be typical in all respects of Dupuytren's contraction.

B. The Writer's Observations

The material consisted of four preparations from different feet (Case L. J. p. 74, (bilateral); Case C. R. S. p. 75; and Case L. M. p. 79).

Macroscopical examination revealed the pathological tissue as nodular indurations of diffusely defined, firm scarlike tissue interrupting the homogeneous, longitudinal structure of the aponeurosis (Fig. 32). The cut surface showed fibrous streaks in various directions, chiefly longitudinal.

Microscopically, the process was characterized by connective tissue in forms varying from new connective tissue with little intercellular substance to fibrous tissue relatively poor in cells. In the zone of transition to the normal aponeurotic tissue, breaks in the normal structure of the collagen fibre bundles of the aponeurosis were seen. It was also possible to follow at these sites how the new connective tissue originated from the perivascular tissue of the surrounding blood vessels (Fig. 33). These blood vessels showed a definite reaction, with dilatation and a perivascular increase of cells, consisting of

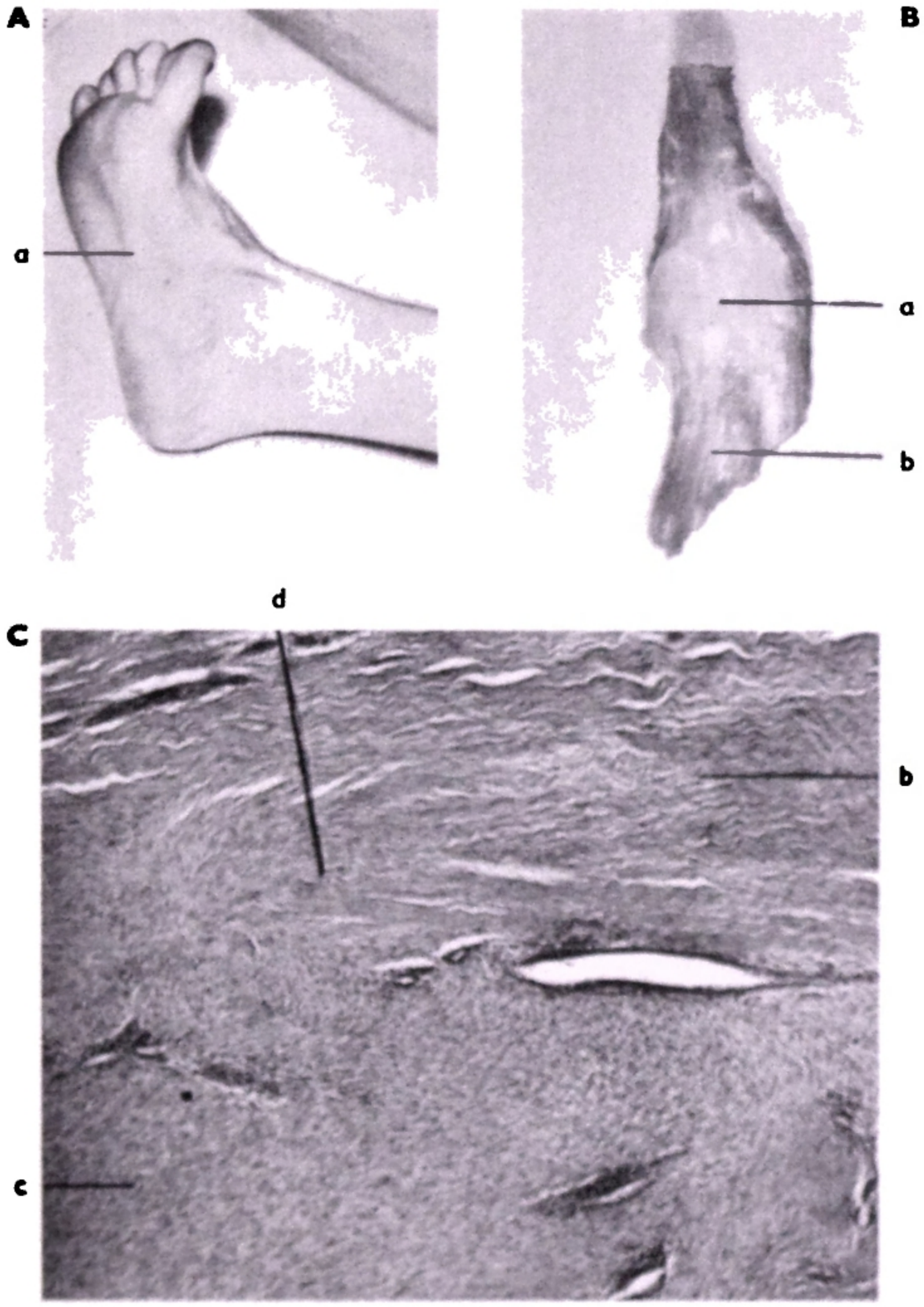


Fig. 28. Case L. M., aged 43. Severe Dupuytren's contraction of both hands began at the age of 32. 14.8.1948 admitted for operation on hands. *R. foot:* Inner border of the aponeurosis thickened by a firm painless nodule (A) giving no disability. Note free extension of the big toe. The thickening was excised and appeared to consist of localized scar-like fibrous tissue interrupting the normal structures of the plantar aponeurosis (B). Examined in 1946 there was no recurrence, but a similar small nodule had appeared in the left foot.

C — Photomicrograph showing longitudinal section of the specimen illustrated in B. Typical histological structure of Dupuytren's contraction. Stained with haematoxylin-eosin. (× 60.)

a — nodular thickening of the plantar aponeurosis; b — normal aponeurotic tissue; c — area with hypercellular connective tissue; d — borderline between the aponeurosis and the tissue of the nodule. Note how the structures of collagen fibres coming from the aponeurosis are interrupted in this zone.

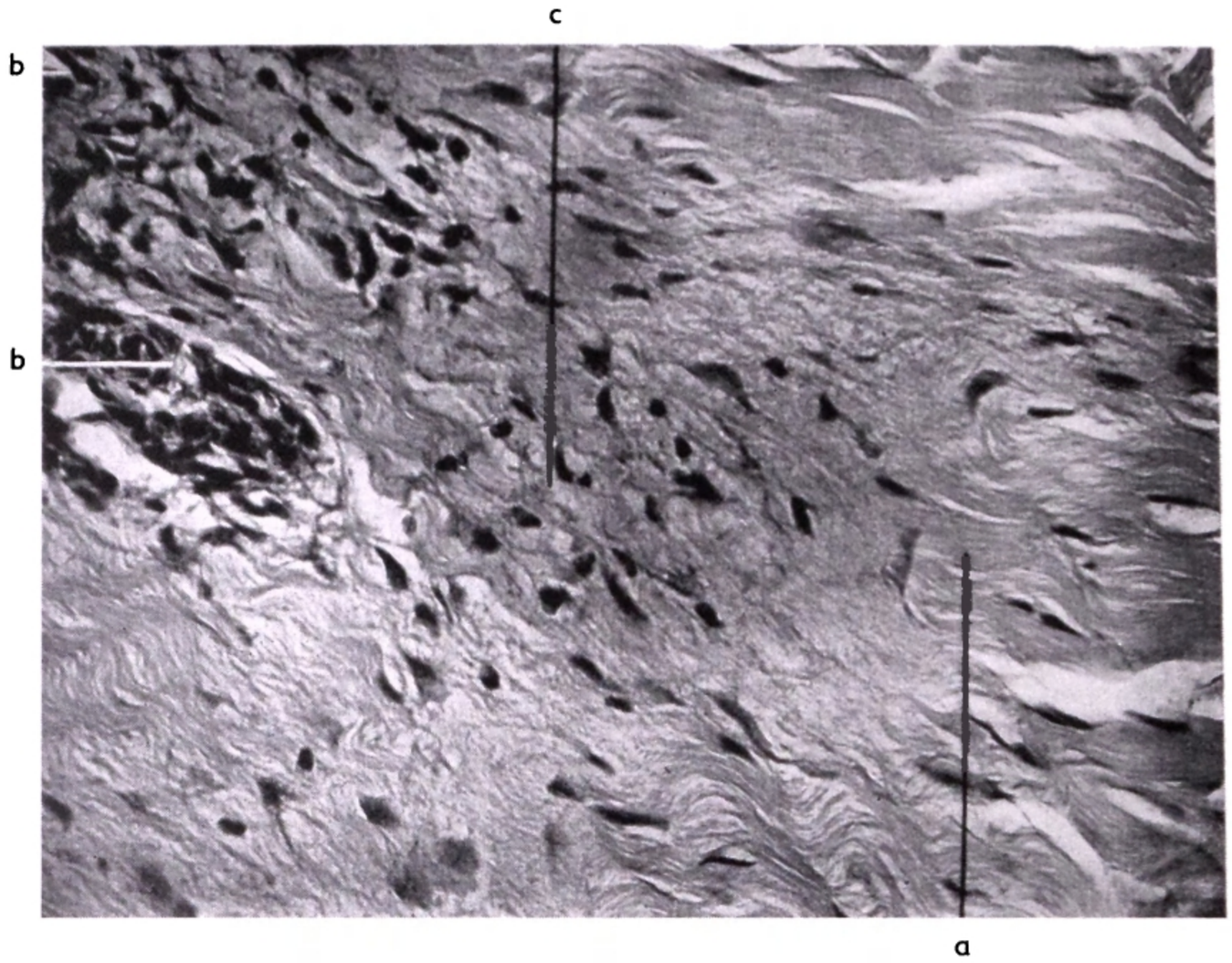


Fig. 33. Photomicrograph from the nodule in Fig. 32, showing what the writer regards as the primary tissue reaction in Dupuytren's contraction. Stained with haematoxylin-eosin. (× 370.)

The collagen fibres (right of the field) are frayed and have a wavy course breaking their normal structure (a). The adjacent area (c) which is strongly basophil has been invaded by young connective tissue cells and a few white corpuscles. This new formation of connective tissue clearly orginates in the neighbouring perivascular tissue (b) of fibroblasts.

new connective tissue with plentiful cells but also a few round cells and white corpuscles.

In the foot, in which the mechanical strain on the newly-formed tissue is chiefly longitudinal, it was not surprising to find in the later stages a preponderantly longitudinal arrangement of these structures. When the process had extended outside the actual aponeurosis, the tissue showed parts whose axial arrangement was crossed on various planes. It was possible to demonstrate the presence of iron pigment in the centre of the cellular areas.

The material appears on the whole to agree with the individual observations made by earlier workers. A comparison with corresponding preparations from the palmar aponeurosis in the writer's

material showed that they were identical in all important respects. The writer therefore refers to the statements made concerning the microscopical picture in Dupuytren's contraction in the hand for a more detailed account.

4. Pathogenesis

In all the cases reported by the writer, the changes were localized to the medial aspect of the aponeurosis and, practically without exception, to the middle of the hollow of the foot. This is somewhat remarkable in view of the varying picture shown by Dupuytren's contraction in the hands. The uniform, almost identical development of the disease in the plantar aponeurosis and its arrest at quite early stages makes an attempt to interpret the nature of the process particularly inviting.

Even the macroscopic appearance of the diffusely limited, fibrous nodules which interrupt the homogeneous tissue of the normal aponeurosis give an immediate impression of a formation of scar tissue. It is therefore easy to suppose that these nodules develop as a result of a rupture in the aponeurotic tissue. The question then arises: does the aponeurosis in those parts which are affected show a structural weakness, or are these parts subjected to particular strain? The writer was able to ascertain by dissection that the development was as powerful in the regions of predilection as in those adjacent to them but that there was a localized anatomical difference — the septum which penetrates into the sole of the foot from the medial border of the aponeurosis is strengthened at this site by bands, described in detail above.

On closer consideration it appears very probable that the functional demands are exceptional in this region. The aponeurosis stretches in the form of a fibrous arch from the os calcis to the anterior aspects of the metatarsal bones. It is most powerful and most arched on the medial aspect and slopes towards the lateral aspect. When subjected to weight, e. g. when standing, the weight of the body attempts to create a flattening of this arch. The strain is naturally greatest on the most arched, medial part of the aponeurosis. This flattening is counteracted by the septum which proceeds from the medial border of the aponeurosis and which anchors the arch to the

bony structure of the foot. The force which tends to bring the aponeurosis into a bowstring position should not, according to mechanical principles, be the same in the various transverse sections but greatest at the largest curve of the arch. The ligamentous bands which attach the aponeurosis at this point appear to afford further evidence that there is particular strain here. All these schematic details of the mechanism of the aponeurosis are not identical in all feet, since there are individual variations in the shape of the arch of the foot, the anatomical details and the interaction between the passive and active supporting structures of the foot. One important conclusion can, however, be reached from the above argument, i. e. that the plantar aponeurosis is generally subjected to the greatest mechanical strain in the middle part of its medial region, thus in that part in which the pathological changes were observed.

The writer has already given good reasons for presuming that Dupuytren's contraction in the hands has its origin in partial ruptures in the aponeurosis. In the plantar aponeurosis, the localization of identical changes to the part on which the functional demands are greatest gives further support to this opinion. Moreover, vice-versa, this pathogenetic interpretation gives a satisfactory explanation of this typical localization in the foot. The picture of a nodule of scar-like tissue interrupting the normal fibrous bundles in the aponeurosis is also in good agreement with the theory. The presence of iron pigment in the centre of the nodules also speaks in favour of a primary tissue lesion, as does, to a certain extent, the whole microscopical picture.

An immediate objection to the above theory is the fact that the same external conditions for the cause of a rupture in the aponeurosis are present in persons who do not develop the pathological changes. This fact does not, of course, refute the pathogenetical theory brought forward but shows that, as in the case of the hands, only certain individuals are susceptible to the disease. It can be assumed that decreased strength in the aponeurotic tissue is a disposing factor in these persons in so far as exceptional injury can be excluded. In the cases investigated no such injury had occurred. The question of the aetiology of the disease will be discussed further in chapter VII. A finding made by LEDDERHOSE (1897) will, however, be reported here since it is of particular interest although Dupuytren's contraction was not involved.

LEDDERHOSE had in 50 cases observed and followed the development of nodules in the plantar aponeurosis occurring after a long period during which the leg was in splints (in nearly all cases owing to fracture of the lower leg). The nodules appeared when the patients once more began to support themselves on the injured leg. It can therefore reasonably be assumed that their cause was stretching and partial rupture of the aponeurosis. Practically without exception they appeared at the inner border of the middle part of the aponeurosis and varied in size from a pin's head to a bean.

It was stated that it was necessary to amputate the big toe in one case owing to disabling contraction. In addition, the entire anterior part of the foot was bent in contraction. It cannot be judged from the account given whether this was a result of changes in the aponeurosis. It appears, however, probable that the contraction in this particular case was tendinous or neurogenic. The localized changes usually regressed in the course of months or years. In the five cases in which they caused disability, excision was performed, without tendency to recurrence. No similar changes in the healthy foot were observed in any of the cases.

Since LEDDERHOSE's observations agree with the writer's own findings and conclusions regarding the pathogenesis of Dupuytren's contraction, a short account is given below of a similar case observed by the writer.

Case K. H. A woman, aged 50. In January 1947 she sustained an open fracture of the lower leg, accompanied by paresis of the extensor muscles of the toes. During the three months' immobilization, a slight flexion contraction developed in the toes, particularly the big toe. A few days after the patient began to walk, a bean-sized painful nodule appeared in the middle of the arch of the foot on the medial border of the aponeurosis. This caused discomfort at every step for a few weeks. Later it partly regressed and was no longer painful.

It can be asked what caused this weakness in the aponeurosis on the fractured side. LEDDERHOSE laid emphasis on a circulatory disturbance and it is possible that this may have some significance. In the case described above, an explicable shrinkage of the tissue occurred on the medial aspect of the foot as a result of tendinous contraction. It is thus not surprising that a rupture took place when weight was once more placed on the foot and the aponeurosis was stretched. In LEDDERHOSE's cases, neither the kind of fixation nor other therapeutic details were stated. *It is, nevertheless, evident that two factors were of importance for the changes in the aponeurosis, i. e.* *the injury caused by load and some predisposing factor in the aponeu-*

rotic tissue. It is also evident that the latter factor was definitely localized and transient in nature since the process only appeared on the injured side and in the majority of cases healed spontaneously. That it was not a question of a specific sequela to the fracture can be deduced from some observations made by FRANKE (1895). He described a transient condition of "Fasciitis plantaris" in five cases during an influenza epidemic, with tenderness and thickening in the medial part of the aponeurosis. He was of the opinion that a site of less resistance had occurred. The symptoms appeared, however, after the infection had subsided and when the patient started to get up.

As already mentioned, only one of the present writer's cases of Dupuytren's contraction had sustained a fracture of the leg (Case L. J. p. 74). He showed typical nodules in the soles of *both* feet in addition to bilateral finger contraction. None of the other patients reported any exceptional strain on the feet with the exception of one, who had done considerable physical training and marching in military service. The case reported by GREENBERG had sustained fractures both of the tibia and fibula and the patient was not quite sure whether involvement of the sole of the foot preceded or followed the fractures. The contraction in the left hand had its onset before the fractures in that case.

Several factors can be thought to contribute to the fact that the disease is less common and less severe in the feet than in the hands. With regard to the pathogenesis postulated in the present paper, it is evident that the plantar aponeurosis is well protected from external injury and that only its medial part is exposed to considerable internal strain. Moreover, the factors which affect the plantar aponeurosis are practically without exception in a longitudinal direction, and the tissue is of homogeneous tendon-like structure, well-suited to withstand these strains. In this respect it differs from the palmar aponeurosis with its complicated arrangement of fasciculi which are transversed on different planes and thus form a relatively weaker protection against the varying strains to which the hand is exposed. In addition, the perpetual training in walking keeps the plantar aponeurosis in good functional condition. Finally it must be emphasized that, should a rupture occur in the aponeurosis, the act of walking counteracts shrinkage of the scar tissue and thus prevents retraction which could otherwise cause fresh ruptures and thus lead to a progression of the process.

5. Treatment

KLOSSNER and VON STAPELMOHR have earlier treated one case each with excision of the affected part of the plantar aponeurosis. According to their statements, the results were satisfactory.

It was stated that treatment is seldom required. Of the eight cases observed by the present writer, only one (v. p. 74) was obliged to seek treatment owing to pain when walking. In this case excision was made since the symptoms were apparently mechanically conditioned. It is interesting to note that the symptoms were said to recur shortly after operation. The process then progressed and a new operation was necessary. It is not known whether the pathological tissue was radically excised at the first operation. At the second operation the excision extended to the normal tissue. On re-examination one year later there was no recurrence. In two cases in which the nodules caused no subjective discomforts, but in which excision was performed for scientific purposes, there was no recurrence either.

The incision should be made as medially as possible in order to avoid a disabling scar on the sole of the foot. All pathological tissue should be excised. The present writer does not, however, believe that it is necessary to make as radical an intervention as in the case of a similar condition in the hand, in which it has been found expedient to remove the entire aponeurosis and not only the pathological tissue. This opinion is supported by the following reasons:

1. A radical excision of the diseased part in three cases, one of which was bilateral, did not give rise to recurrence.
2. The progressive tendency of the disease is relatively small in the foot and does not often cause deformity. Aponeurosectomy is thus scarcely indicated since it would be accompanied by considerable functional disturbance.
3. Re-operation is easily performed should it become necessary.

Surgical intervention is only indicated on the grounds of subjective discomforts. Operation for prophylactic reasons cannot be considered justifiable since the process shows little tendency to progression and thus generally remains harmless.