DANE (JOHN)

A STUDY OF FLAT-FOOT:

With Special Attention to the Development of the Arch of the Foot.

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A STUDY OF FLAT-FOOT, WITH SPECIAL ATTENTION TO THE DEVELOPMENT OF THE ARCH OF THE FOOT.[1]

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I. THE NORMAL FOOT.

Anatomy. — According to "Quain's Anatomy," the mechanism of the human foot shows a system of three arches, "capable of being flattened somewhat by pressure from above, thus securing elasticity." Two of these arches run longitudinally, and one transversely. The outer arch is formed by the os calcis articulating with the cuboid and the two outer metatarsals. As calculated by Lorenz, "the highest point of this arch is at least two centimetres from the ground in a good ligamentous preparation. It is six centimetres to the hinder bearing of the os calcis, and to the corresponding base of the head of the fifth metatarsal, eight centimetres; thus giving the arch a total length of fourteen and two-tenths centimetres. The hinder point of the outer arch [the calcaneo cuboid articulation] thus lies somewhat behind its middle."[2] (Fig. 1.)

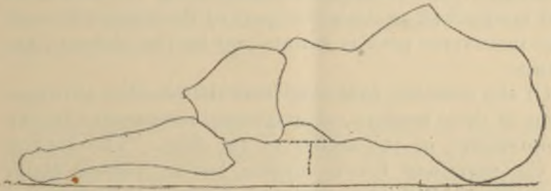

FIG. 1. (After Lorenz.)

The internal arch starts together with the external from a common base, the tuberosity of the os calcis,

[1] Being a thesis presented for graduation in the Harvard Medical School.
[2] Lorenz, p. 35.

and is made up of the astragalus, scaphoid, three cuneiforms, and the three inner metatarsal bones. This arch, while it has much the same span as the outer, is considerably higher.

The third, or transverse arch, has hardly any existence till the middle of the tarsus is reached. It is made up of the scaphoid, three cuneiform and cuboid bones from the tarsus, and the five metatarsals.

Although all the ligaments of the foot by binding the several bones together help to maintain its arched character, certain are more directly concerned in it. The outer arch owes much of its stability to the strong inferior calcaneo cuboid ligament. This consists of two distinct layers:

(1) The so-called "long plantar ligament," which is superficial; (2) The short plantar ligament, scarcely an inch long and lying close to the bone.

The inner arch is fastened together principally by the inferior calcaneo scaphoid ligament. The scaphoid bone and the os calcis being separated by the head of the astragalus, this ligament not only has to bind together two bones, but also to resist the direct downward pressure of the head of the astragalus which rests upon it. It arises from the sustentaculum tali of the os calcis, and is attached to the under part of the scaphoid bone. The transverse arch is maintained by the plantar ligaments.

Of the muscles, four are, from the peculiar arrangement of their tendons, of maximum importance in the maintenance of the arches of the foot. The tendon of the peronæus brevis muscle, having passed under the external malleolus, continues forward to be inserted into the base of the fifth metartarsal bone, thus spanning almost the entire external arch. The peronæus longus, keeping in company with the brevis in its course under the malleolus, passing over the external surface of the os calcis "winds around the outer border of the foot to enter the groove on the lower surface of the cuboid."[3] From this it crosses the sole obliquely to its principal insertion on the posterior part of the first metatarsal bone. The outer and middle arches are both strengthened and bound together by this long tendon.

On the inner side of the foot there is first, the tendon of the tibialis posticus, which, after passing behind the external malleolus, runs forward to be inserted into the scaphoid bone; in its course resting directly against the inferior calcaneo scaphoid ligament, which in its turn bears against the head of the astragalus.

The tendon of the flexor longus hallucis likewise turns around the internal malleolus. From this it passes in a groove under the sustentaculum tali of the os calcis, and runs forward in the sole of the foot to its insertion in the terminal phalanges of the great toe.

Thus the arched character of the normal foot depends upon a grouping of small bones, which, with the exception of the three cuneiforms, show no special evidence in their structure of their being intended to form an arch held together by many strong ligaments, and thoroughly reinforced by the tendons of four of the muscles of the leg.

II. THE PATHOLOGICAL FOOT.

Frequency.— In the affection known in English as flat-foot, the arched character of the normal foot is, to a greater or less extent, lost by a partial dislocation of its bones. Hoffa, in the *Münchner Polyklinik*, has collected the following interesting statistics upon its frequency:[4]

[3] Quain, p. 252.
[4] Lehr: Buch. Orth. Chir., p. 679.

Of the 17,619 surgical affections, 338, which equals .49 per cent., were flat-foot; of the 1,444 deformities, 338, which equals 23.41 per cent., were flat-foot. Out of 235 cases he found 10, or 4.5 per cent., were congenital, and 225, or 95.7 per cent., acquired. Of the 225 acquired cases

11=4.9% were traumatic;
7=3.1% were paralytic;
7=3.1% were rachitic;
200=88.9% were static.

Thus it will be seen that it is the static form of acquired flat-foot that has by far the greatest surgical importance. This is the form that is commonly understood by the term "flat-foot," and over which so much difference of opinion, both as to cause and treatment, has found its way into literature. The other forms are easily recognized and have caused much less discussion.

Causation. — Unfortunately, at the very start, before leaving the domain of physiology, the first difference of opinion is reached. All are agreed that the foot normally presents two longitudinal arches; but as soon as we ask which of the two is normally the more heavily loaded, we find that authorities are not agreed. In 1883 Dr. Adolph Lorenz published a most elaborate monograph on flat-foot. In it he distinctly states his view of this subject as follows:[5] "The foot owes its arched character wholly to the outer foot arch, that is to say, to the exceptional union of the os calcis and cuboid with the metatarsals. The bones of this arch are wedge-shaped, (and) so put together as to allow very little motion." He goes on to say that the inner arch is composed of more bones less firmly held together; "the whole arch, therefore, aims at greater mobility with less firmness," and that the weight of

[5] Lorenz, p. 35.

the body does not come directly upon this arch. The subsequent German orthopedic writers, of whom Schreiber and Hoffa have published the best known works, have contented themselves with quoting Lorenz.

In direct opposition to this view is the statement made in "Quain's Anatomy," in the latest edition of which we read:[6] "The arch may be considered as double in front, with a common support behind. The internal division of the arch is that which bears the greater part of the weight of the body, and is most raised from the ground, etc."

As this question of the normal weight-bearing arch comes out still more prominently in the consideration of the pathology and treatment of flat-foot, its further consideration will be left until speaking of those subjects.

As upon almost all surgical diseases, there have been many and quite widely different opinions as to the cause of this affection, and yet a growing similarity. Stromeyer was one of the earliest writers, and he arrived at the conclusion that the first etiological factors in its production were atony of the planter aponeurosis and weakness of the muscles, especially those in the sole of the foot and the tibialis posticus in the leg.[7] But upon dissection the aponeurosis has been found thickened rather than thinned. Hüter[8] regarded it as a developmental deformity, an abnormal growth of the joint: but this is obviously incapable of explaining the cases that arise later in life; nor do we find the changes similar to his description upon dissection of the feet.

Reisman considers it as primarily an insufficiency of the plantar flexors caused by over-exertion, followed

[6] Quain's Tenth Edition, vol. ii, p. 138.
[7] Beitrage zur operatven orthopädik, p. 99.
[8] Virchow's archiv., xxv, p. 572.

by a contracture of the extensors, and subsequently of the pronators.[9]

Henke, who next to Lorenz has probably given the most attention to this subject, says that it starts as a fatigue of the muscles of the calf and the tibialis posticus, for he believes the arched character of the foot depends first upon them. When they cease to do their work the strain falls upon the ligaments of the foot, which, when unaided, are unable to resist it. As a result of the joint changes the foot is pronated and flexed at the talo-crural joint, and, finally, the forepart of the foot is bent backwards to compensate for the flexion. He, therefore, designates the affection as "pes flexus pronatus reflexus."

Against this theory the only objection that has been urged is that it does not take sufficiently into account the part played by the muscles, bands and ligaments of the foot itself, and lays too much work upon comparatively feeble muscles. With this modification the theory is accepted by Lorenz and his followers. To use Lorenz's own words,[10] "Valgus acquisitus is that deformity of the foot which is caused by pressure, and consists of a sinking of the external portion of the arch of the foot, together with a sliding off of the internal from the external arch of the foot." This pressure to which Lorenz refers is that of the weight of the body, usually from standing; on this most authors agree. Thus to quote from some of the latest: Schreiber[11] says, "There can be no doubt that the etiological cause of pes valgus adolescentuim is abnormally frequent and long-continued pressure, and especially constant standing." Hoffa[12] says, "There is thus no doubt that steady loading of the foot brings flat-foot into being."

[9] Langenbeck's archiv., ii, iii, p. 722, 1869.
[10] Lorenz, p. 137.
[11] General Orthopedics, Wood's Trans., p. 292.
[12] Loc. cit., 686.

In America the same opinion prevails. Bradford and Lovett, in their "Orthopedic Surgery," say, "There can be now no question that the deformity results from the superincumbent weight falling upon an ankle and foot unable to sustain it. It is the result of a disproportion between the body weight and the apparatus for sustaining it."[13]

Of all the modern English writers, Whitman of New York has done by far the most careful work on this subject, and published in the last few years a series of articles which take up minutely this subject of etiology. Having enumerated the causes already set forth, such as general weakness from diseases of all kinds; general fatigue from long standing; dancing; running and the like, he lays special stress upon "attitude," especially the "attitude of rest," which had already been noticed at length by Lane.[14] He shows how the position of strength and action is with the toes well adducted; for that brings all the muscles into play to support the arch of the foot, and moreover, at every step the weight of the body has to be raised over the great toe. The least muscular support, on the other hand, is given to the arch when the feet are spread and the toes turned outwards. This position tends not only to relax the muscles and bring the strain directly upon the ligaments; but by increasing the pronation brings the weight still farther over towards the inner border of the foot, and aids a natural predisposition towards a tipping over of the os calcis and slipping off inwards of the astragalus; in short, the breaking down of the internal arch. This it is that Lane calls the "attitude of rest."

This brings us back again to the question of which arch gives way first, and the answer seems clear. It is the internal arch. The weight of the body is nor-

[13] p. 728. [14] Guy's Hospital Reports, vol. xxix, p. 256.

mally transmitted through the astragalus upon the os calcis at a point internal to its base. This will, therefore, tend constantly to roll over, and, as it were, to tip the astragalus off its back in a direction inwards and forwards. This tendency is as constantly counteracted by ligamentous and muscular action. But when the muscles are tired and so having hard work to give the arch the necessary support, if the toes are turned out to try and relieve them, that is, if the "attitude of rest" is assumed, then the weight is transferred still farther towards the inner border, the strain is increased, while, at the same time, the resistance is lessened, and a flat-foot is the result.

This seems clear if we assume that it is the inner arch that gives way, and not the outer; for by pronating the foot and abducting the toes we throw all the weight off the outer arch, which would consequently have no reason for breaking down so long as we assume this "attitude of rest"; and yet this has been shown to be a great predisposing cause. Moreover, the outer arch is very strongly girded by ligaments, and its span so fully filled up by the soft tissues, that it practically rests upon the ground when the weight is thrown upon the foot. Certainly it depends the least upon muscular exertion for its maintenance; then why should it break down when the muscles are tired, or when they are placed at a disadvantage by the position of the foot?

Strangely, Hoffa, while following Lorenz as to the primary failure of the external arch, nevertheless quotes the English authors in regard to this matter of attitude as a predisposing factor, and then reprints their cut of a man in this position. These two things would seem to be contradictory.

Anatomy. — If we turn to the pathological anatomy we find that the muscles of the leg are atrophied on the flexor side, while the extensors, and especially the pronators, are in a state of contraction. The plantar ligaments have been found to be not only longer but also much thicker than usual, especially the calcaneo-scaphoid. The dorsal ligaments are found in a state of fatty degeneration.

Of the bones, the tibia is usually unaltered. The tip of the external malleolus of the fibula may be rounded off, or even flattened out from pressure against the os calcis. Of all the tarsal bones the astragalus suffers the greatest changes. A large amount of plantar flexion at the inter-malleolar joint is quite a constant feature of the severe grades of flat-foot. To give this the astragalus is rotated so far forwards that only the posterior part of its trochlea surface lies in contact with the tibia. The fore portion soon loses its cartilaginous covering, thus diminishing the height of the bone considerably.

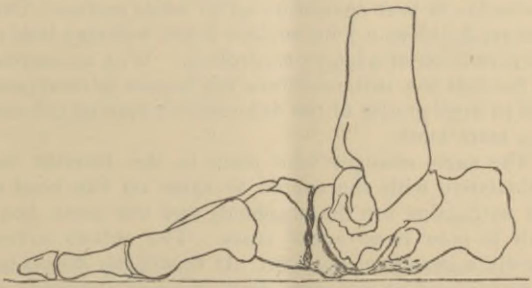

FIG. 2. (After Lorenz.)

The head of the astragalus projects sharply inwards and downwards (Fig. 2); the scaphoid is in its turn thrust so far upwards that in severe cases it may lie like a bridge upon the neck of the astragalus. It is also rotated in such a way that its tuberosity becomes its under surface. The head of the astragalus in its abnormal position rests primarily upon the inferior calcaneo-scaphoid ligament, and only articulates with the scaphoid at its upper inner angle. Corresponding to this the ligamentous facettes upon its head become altered, a low ridge divides the head into two ovals, of which the one articulating with the ligament increases with the degree of deformity at the expense of the one articulating with the scaphoid bone.

During this process a low degree of periosteal inflammation is often excited, which results in the throwing out of a wall upon the upper surface of the head of the astragalus, which increases the size of the facette for articulation with the scaphoid, and tends to prevent any further displacement.

The changes in the os calcis relate only to its surface. It falls over inwards, and brings the external malleolus to bear against its upper outer surface. This contact develops a joint surface there, and may lead to the formation of a bony overgrowth. With the advent of flat-foot the sustentaculum tali begins to disappear, and in high grades of the deformity it may be reduced to a mere knob.

The same changes take place in the facettes for articulation with the cuboid as came on the head of the astragalus for the scaphoid, and the same bony wall is seen in advanced cases. The cuboid suffers merely a change of position. It is partially dislocated upwards and at the same time inclined forward; so that it is no longer in contact with the os calcis along the whole of the joint-surface.

In cases of any degree of severity there is in addition to the changes in the tarsal bones, a "contracture in adduction" of the metatarsals, which gives the foot a most characteristic zigzag line on its inner aspect (Fig. 3).

Symptomatology. The earliest symptoms of developing flat-foot are usually an undefined sense of fatigue upon long standing, which gradually increases to the degree of pain. At first this pain is dull and general in character, and only felt when weight is being supported by the feet; but soon it becomes sharp and localized in certain definite spots, which will be found sensitive to pressure.

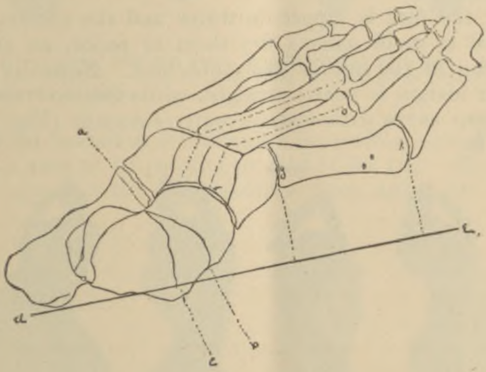

FIG. 3. (After Lorenz.)

Locality of Pain. (1) The first of these will be found over the head of the astragalus on the inner margin of the foot, and corresponds to the overstretched calcaneo-scaphoid ligament. (2) Usually second in order of appearance, but occasionally first, is localized pain (seldom sensitiveness to pressure), through the heel, just under and behind the malleoli, which as time goes on may radiate up the leg, often as far as the knee and sometimes even to the hip. It seems probable that this is due to a stretching of the lateral ligaments that pass between the tops of the malleoli and the surfaces of the os calcis; and also to the abnormal strain upon the tendons of the leg muscles that run in this situation, and play such an important part in maintaining the normal arch. (3) Next comes pain at the calcaneo-cuboid joint, due to stretching of that ligament. (4) And, finally, more diffused pain all along the dorsal aspect of the tarso-metatarsal articulation.

If the foot is dipped in water and the patient allowed to stand upon a dry sheet of paper, an exact tracing of the sole is easily obtained. Normally the outer margin is nearly straight, while the inner shows a sharp curve with the convexity outwards (Fig. 4, *a* and *b*).

a *b*

FIG. 4. *a*, Male, fifteen years, suffered from flat-foot and pains, relieved by plate. *b*, Female, nineteen years, ditto.

Occasionally the outer arch may be so high that it also does not rest upon the ground (Fig. 5, *a*). As the arch in flat-foot becomes more and more broken down, this tracing is found to change. The internal line becomes gradually straight, until finally when the arch has completely given way this line is convexed inwards, and shows a marked bulging where the head of the astragalus actually rests upon the ground (Fig. 6, *a*).

a *b*

FIG. 5. *a*, Male, fourteen years, non-deforming club-foot. *b*, Female, fourteen years, suffered from flat-foot pains; completely relieved by plate.

When looked at from behind the normal axis of the foot is seen to be parallel to that of the leg. As flat-foot advances the foot assumes more and more the

a *b*

FIG. 6. *a*, Male, seventy years, left foot shows arch entirely lost; severe pain. *b*, Female, twenty years, feet painful; relieved by plates.

position of pronation; that is, the axis of the leg if prolonged falls to the inner side of the axis of the foot, the sole is turned outwards, and in high grades the outer border of the foot is even entirely raised from the ground.[15] This being the case, it is hard to see how the outer arch can have first "broken down" under weight; for if that were the case the foot would have certainly continued in the direction of the original thrust, and assumed a position of supination with an outward curve of its external border.

In the pronated foot the external malleolus appears to have been lost. On the inner side the malleolus stands out very prominently; in front of it may be seen a still more pronounced bulging corresponding to the head of the astragalus, and often a third caused by the scaphoid bone.

Flat-feet are prone to sweat profusely, to have enlarged veins, and are uniformly cold. They have lost all their normal spring, they feel heavy and cloddy; consequently, the patient shuffles along awkwardly with the toes turned out, hardly lifting the feet from the ground. Particular discomfort is felt on first using the feet after a period of rest, as on getting up in the morning; and Whitman speaks of patients who were unwilling to sit down in his office from dread of the increased pain when they again stood up.[16]

One peculiarity among the symptoms of the flat-foot needs especial emphasis. It is that the *amount of pain stands in no direct relation to the amount of deformity.* Many patients whose feet show no deviation from the normal type nevertheless suffer acute pain. This pain is not only in the areas already spoken of as characteristic of flat-foot; but it is entirely relieved by flat-foot treatment. Figs. 4, *a* and *b*, Fig. 5, *b*, show three such feet treated by the writer at the Massachusetts General Hospital last fall.

[15] Hoffa, loc. cit., p. 692.
[16] New York Medical Journal, February 27, 1892.

Again, many feet that have partly or wholly lost their arched character are entirely free from pain (Fig. 7, *a* and *b*). This fact of painless flat-foot has

FIG. 7. *a*, Male, twenty-one years; pain very slight. *b*, Male, twenty years; feet painless.

led the Germans to make a separate class for them, calling it "Platte Fuss,"[17] and regarding it as a failure of development or persistence of the infantile condition; and also as a racial peculiarity, instancing the negro and the Jew.

III. DEVELOPMENT OF THE ARCH OF THE FOOT.

With a view to finding out what the condition of the arch was in infancy and childhood a series of tracings were taken under the immediate supervision of the writer, of the feet of nearly four hundred children, whose ages range from nine days to fourteen years. The method employed was that already described, which is simply a modification of that of König. The child was allowed to dip its feet in water, and then stood for a moment upon a flat-sheet of brown paper. Wherever the feet touched, the paper would be moist-

[17] Lorenz, p. 54.

ened. The edge of this moist area was quickly marked with pencil, and the paper carefully dried.

The writer here wishes to thank the officials of the following institutions for the uniform kindness that they showed in doing all in their power to aid him in his work: The Massachusetts General Hospital; the Boston City Hospital; the West End Nursery; House of the Good Samaritan; Church Home of Orphans and Destitute Children; Marcella Street Home and St. Mary's Orphan Asylum; and also to thank most heartily Mr. S. E. Bullard and Mr. Lyman Hodgkins of the Harvard Medical School for their co-operation in taking the tracings and making the experiments upon plates.

The deductions from the drawings are not in accord with the accepted authorities. At birth the foot does not seem to be flat, as is the general opinion. There seems to be on the contrary a distinct arch in the feet of most infants, better formed in one foot than the other, and persisting until they are about eighteen months old. In this period the difference in the arch of the foot between males and females is not noticeable. After eighteen months there begins to be a distinct breaking down of the arch, which in most cases is wholly lost, the two feet suffering equally. For the next year and a half the feet remain distinctly flat, yet even during this period isolated tracings appear in which the arch is never lost. It is interesting to note that such are always females, and therefore presumably lighter children.

During the next (third) year the arch is slowly rebuilt, one foot improving before the other, and the females considerably earlier than the males. When the fourth year has been well entered upon the feet have nearly reached the adult condition; the two are about alike, and there is no marked difference between males and females. Figs. 8 and 9 are photographs from two sets of actual foot-tracings arranged to show the progressive stages in the building up of the arch, one being the male and the other the female children.[18] Corresponding squares in the two pictures are occupied, if not by exactly the same age, at least nearly enough so for all purposes of comparison.

Briefly stated, these pictures would seem to say: From one to eighteen months, arch distinct; sexes alike; one foot better than the other. From eighteen months to three years, arch mostly lost; exceptions are females. From three to four years arch building up; unequal in the two feet; females tending to form earlier. From four years upwards arch established; sexes alike; both feet equal.

Another point in which this series of tracings, as far as they go, seems to differ from the books is as regards the foot in rachitis. Instead of being flat it would seem to have an inner arch fully as high as the normal, and a much higher outer arch. This, as is shown by a series of four tracings in Fig. 10, gives the foot double concave sides, making a very pronounced pattern. So far as has been observed this peculiar tracing is found only in this disease; but the number of tracings is far too small to have much significance. In the few negro and Jewish feet that appear in the series the arch is up to the average for that age; but again, they are far too few to be of much value.

That tuberculosis of the vertebræ does not necessarily weaken the resistance of the system so as to produce flat foot was repeatedly shown. Fig. 11, *b*, is a tracing from a girl of four years and nine months of age, who was at the time wearing a back brace for Pott's disease. A few scattering cases show in a marked manner the production of flat foot by an injury to the

[18] Average tracing from a series of somewhat over 200.

FIG. 8. Tracings of female feet; ages four weeks, three months fifteen days, one year, one year six months, two years, two years six months, three years, three years six months, four years, five years one month, six years, eight years.

FIG. 9. Tracings of male feet; ages four weeks, three months, one year two months, one year ten months, two years, two years six months, three years, three years six months, four years, five years seven months, six years three months, seven years.

leg. Fig. 11, *a*, which is a tracing from a young man of nineteen years, who a year and a half previous had his left leg broken, shows the right foot with its arch in a normal condition, while in the left the arch has given way.

FIG. 10. Tracings of rachitic feet; ages six months, two years, three years, seven years.

IV. — TREATMENT.

Non-Mechanical Treatment. — As most of the cases come on from a fatigued state of the system, general tonic and hygiene treatment is of the first importance in dealing with flat-foot. Of measures addressed directly to the feet the simplest is the method of walking insisted upon so much by Whitman. The patient should be made to walk with the toes pointing directly forward; for this position gives the arch the greatest muscular support possible, and compels the body to be raised at every step. Next comes *Exercises.* — The admirable set of gymnastic exercises as prescribed by Ellis,[19] which consists essentially in raising the body upon the toes and slowly rotating the heels outwards. In addition to this a broad, flat, laced boot with a low heel should always be worn, which should preferably have a slight inward curve to counteract the tendency of the fore foot to evert.

[19] Lancet, September 26, 1885.

Mechanical Treatment. — The object of all mechanical devices is to prop up the arch and so prevent the os calcis from rolling over inwards, and the scaphoid and astragalus from sinking down.

Elastics. — Of these a large number have been suggested, such as elastic spring bands passed under the instep and fastened to a leather strap around the calf (Fig. 12); and short steel springs fastened to the heel of the shoe inside, and so arranged as to press up against the instep. Thomas, of Liverpool, invented a

FIG. 11. *a*, Case of traumatic flat-foot. *b*, Tracing from a case of Pott's disease.

method of his own. By means of an incline plane in the sole of the boot, running from the heel to a point just back of the great toe, he raises the inner side of the foot sufficiently to transfer the weight outwards away from the injured internal arch.

Pad. — Pads of every variety of material have been worn inside the shoe; but they soon flatten down and cease to be of much service; while, if of any hard material, the difficulty of getting them to fit accurately at first is very great. With a single exception they have all been discarded, and that has been retained only as a preliminary test. If the feet are painful and suspected of being flat, a pad is made up of sheet wadding folded several times upon itself until it is about four by five inches, and one inch thick. By means of a roller bandage this pad is held firmly in place under the middle of the sole of the foot, and worn inside the stocking. If the case be one of flat-foot, the pain will

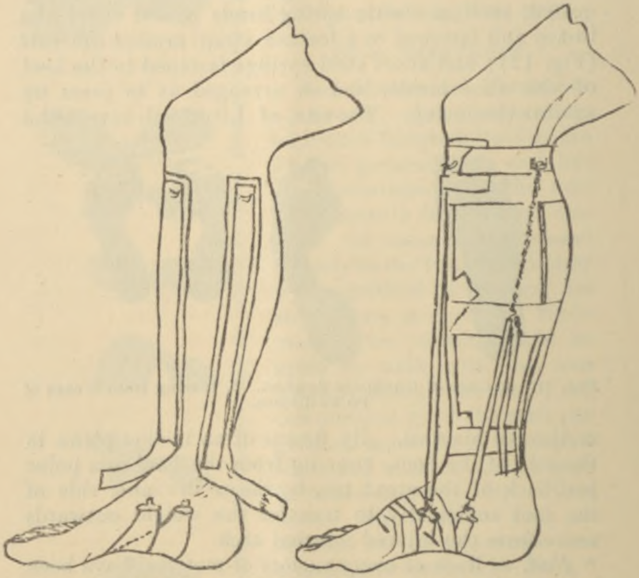

FIG. 12. Apparatus for elastic tension (after Bradford and Lovett).

generally be much relieved, and we can promise good results from the use of a plate.

Plates. — This, which is by far the best form of flat-foot apparatus, consists of a thin sheet of metal fitted accurately to the sole of the foot and worn inside the shoe, generally outside the stocking. These plates differ among themselves: (1) In their mode of manufacture; (2) In their shape; (3) In their material.

For all kinds of plates a mould or pattern of the foot must be taken. Whitman[20] has a most elaborate method for this, by which he first takes two plaster shells of the upper and under surfaces of the foot, adjusts these together, and then by filling up with plaster gets an exact production of the foot, which he sends to the foundry and has cast in iron. Upon this model the plate is forged from the best twenty guage steel.

A much simpler method is to flow plaster-of-Paris into a shallow trough, and when it is about to harden to have the patient step in it. In this negative a positive of the sole of the foot can easily be run.

A most ingenious method was introduced by Dr. F. B. Harrington, of Boston. He first marks out on the foot by means of a camel's-hair brush wet with a mixture of ink or glycerine the shape of his plate. Next a piece of Canton flannel is pressed against the foot. In this way the shape is marked out on the flannel. The flannel is then cut out, soaked in plaster-of-Paris, wrung nearly dry, and applied to the sole of the foot to harden in position. When this shell is dry it is taken off, its concave surface (corresponding to the foot) filled in with fresh plaster, and when hard sent to the machinist, who uses it simply as a model to which to fit his plate. The thickness of the flannel is equal to that of the stocking outside of which the plate is to be worn.

The method used by the writer is similar to this, only sheet wax is substituted for the flannel. Such wax can be had at the dental furnishing stores. When put into hot water it becomes perfectly supple, and can be moulded to the foot and cut to the desired shape. As it cools it grows hard again, and can be greased and

[20] New York Medical Journal, February 27, 1892.

backed with plaster on either side according as a negative or positive model is wanted. The advantage of this method is, for ordinary plates, its speed, and cleanliness; while for rubber plate negatives it leaves the model much smoother and allows for the extra size needed.

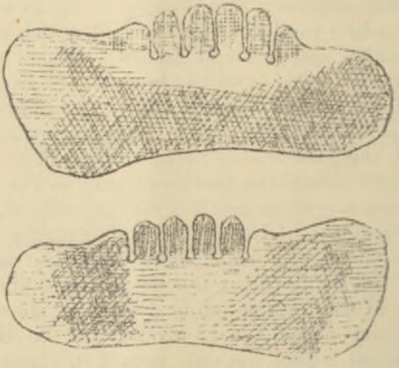

FIG. 13. Flat-foot plates (after Hoffa).

Shape of Plate. — Next as to shape of the plate. The fundamental form is simply a flat sheet of metal as wide as the sole of the foot, extending from the back of the heel to the webs of the toes and bent up slightly on the inner side. Fig. 13, from Hoffa, shows such a plate. Fig. 14, from Bradford and Lovett, shows one a a little less large, and Fig. 15 is a photograph from a plate fitted at the Children's Hospital. Held firmly by the shoe, these plates have little tendency to slip and are quite comfortable; but they give only a limited support.

Against this pattern Whitman has urged that it is unnecessarily heavy, and that it interferes considerably with the free flexion of the foot while walking. To meet these difficulties he published in the *Boston Medical and Surgical Journal*, June 14, 1888, the description of the plate which has since gone by his name (Fig. 16). He takes a point, A, "beneath the base

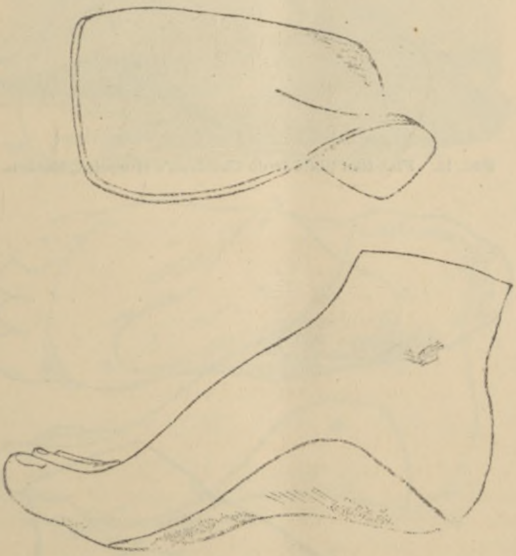

FIG. 14. Flat-foot plate (after Bradford and Lovett).

of the great toe just short of its bearing centre; a point B, just short of the bearing centre of the heel bone beneath its inner tuberosity; C, just above the head of the astragalus, a little in front and below the internal malleolus." These and a "point D, on the outer aspect of the foot just above and behind the tuberosity of the fifth metatarsal," he connects with curved lines as shown in the figures; A and B act as the two bear-

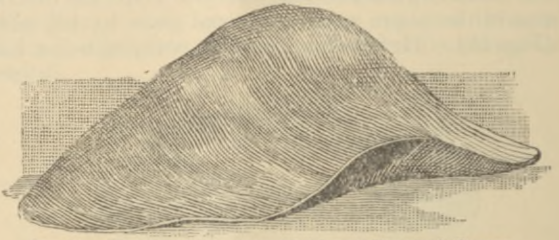

FIG. 15. Flat-foot plate from Children's Hospital, Boston.

FIG. 16. Flat-foot plate (after Whitman, 1888).

ing points for the plate, and from them, at right angles, runs the lever arm D. As weight is put upon this

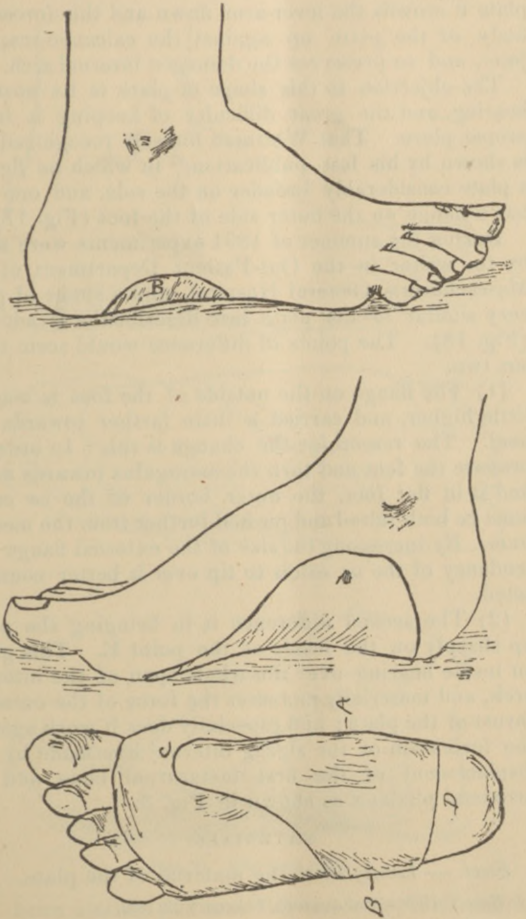

FIG. 17. Flat-foot plate (after Whitman, 1892).

plate it crowds the lever-arm down and this forces the body of the plate up against the calcaneo-scaphiod joint, and so preserves the damaged internal arch.

The objection to this shape of plate is its unstable bearing, and the great difficulty of keeping it in its proper place. That Whitman himself recognized this is shown by his last publication,[21] in which he figures a plate considerably broader on the sole, and one that has a flange on the outer side of the foot (Fig. 17).

During the summer of 1891 experiments were made by the writer in the Out-Patient Department of the Massachusetts General Hospital, and a shape of plate very similar to the plate last described was adopted (Fig. 18). The points of difference would seem to be but two.

(1) The flange on the outside of the foot is made a little higher, and carried a little farther towards the heel. The reason for the change is this: In order to pronate the foot and turn the astragalus inwards as we find it in flat foot, the outer border of the os calcis must be both raised and pushed further from the median line. By increasing the size of the external flange this tendency of the os calcis to tip over is better counteracted.

(2) The second difference is in bringing the plate up sharply on the inside at the point E. This gives an inside bearing over the whole span of the internal arch, and materially increases the force of the outward thrust of the plate; and especially does it work against the formation of the zigzag internal line made by the displacement of the first metacarpal bone and its proximal phalanx as shown in Fig. 3.

MATERIALS.

Steel. — Lastly as to the material of the plate. As

[21] New York Medical Journal, February 22, 1892.

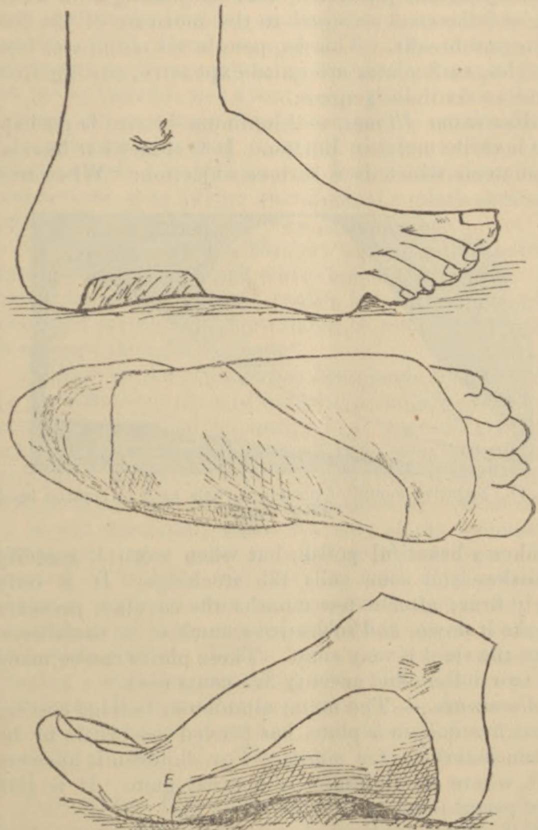

FIG. 18. Flat-foot plate.

has been stated, the material used by Whitman in New York is hammered steel, which in addition is nickel-plated or japanned. But the plating soon wears off, and the steel exposed to the moisture of the foot rusts and breaks. This happens in six months or less. Besides, such plates are quite expensive, costing from three to six dollars apiece.

Aluminum Bronze. — Aluminum bronze is perhaps the favorite metal in Boston. It is somewhat heavier than steel, which is a serious objection. When new

FIG. 19. Negative mould of plaster-of-Paris used in making hard-rubber plates.

it takes a beautiful polish, but when worn it speedily tarnishes and soon soils the stockings. It is only fairly firm; after a few months the constant pressure breaks it down, and so destroys much of its usefulness. Like the steel it may snap. These plates can be made for two dollars and seventy-five cents each.

Aluminum. — The metal aluminum, besides costing about five dollars a plate, has proved too brittle to be of much service for adults. For children it answers well, where its lightness is a great gain. It is also very permanent.

Bell Metal. — For cheap plates for out-patient clinics some experiments were tried by Dr. Bullard. A mould was taken with Canton flannel and plaster in the Harrington method, which, without backing, was sent to the foundry and used as a core for a clay mould. Bell metal was used for the casting. It gives an excellent surface and resists corrosion well. So far as tested it was about as tough as the aluminum bronze and cost only about seventy-five cents a plate. The greatest objection is in its weight, which somewhat exceeds the bronze, but for out-patients this is less serious than price; therefore, the plate seems to promise well.

Cast Steel. — A still cheaper plate was made from cast steel, smoothed on a wheel and nickel plated. Its cost was only thirty-five cents; but as it is rougher than bell metal, and more liable to wear off and rust, it was not thought so good.

Rubber. — An attempt has been made by the writer to get a flat-foot plate of hard rubber. This substance combines many advantages, It is exceedingly light, which for women and children is a great point; it is uninjured by water or by the perspiration of the foot, and does not tarnish or soil the stocking. Moreover, it is not absolutely rigid, its very slight amount of spring proving a great comfort to the wearer. The method of making was this: A shell of the desired shape is made of wax in the manner previously described; it is then greased and filled up on the back side with plaster. When hard the wax is removed, leaving a negative cast (Fig. 19). This is sent to the Davidson Rubber Company, who fill in the cast with a thin layer of sheet rubber, and vulcanize it at a temperature of 300° C. The price is one dollar and a half.

During the fall, upwards of thirty of these plates were put in use. The result has been only a partial success. For light women and for children the plate has answered most admirably. If made after the older patterns it proved strong enough for the heaviest patients; but when the outside was carried well up as shown in Figs. 17 and 18, the cross-strain was more than the rubber could be counted upon to stand when weighted by a heavy adult. Yet some few of the plates have even under these circumstances proved equal to the task. Further experiments are now being carried on in the hope of making the rubber plate still stronger.

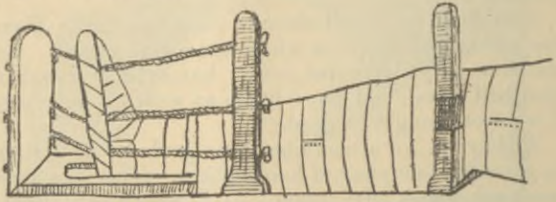

FIG. 20. Apparatus for stretching flat-foot (after Hoffa).

In addition to the advantages already mentioned rubber has one more. By holding the plate for a moment to the flame, the shape can be altered and an absolute fit can thus be easily obtained.

Whatever form of plate is used, the good derived from it is strictly negative. It prevents the arch from further breaking down, but it does not directly build it up. To do this one must first build up the general physical condition, if it is run down; then by teaching the patient a proper walk, and requiring him daily to practice the form of gymnastics already referred to, we strive so to strengthen the muscles and ligaments that they can again perform their proper work unaided. This in ordinary cases requires from six to ten months, after which time the plate can safely be omitted. A good fitting shoe will thereafter be all that is required.

Unfortunately, all cases that come for treatment cannot be thus easily cured. Owing to the length of time that the process has been going on, the extensor and abductor muscles may be in such a state of contracture as to resist all our efforts to replace the foot in its normal position. Rest in bed and massage will, however, usually be sufficient if the difficulty is with the muscles alone. Still more serious is the case when the bones themselves have become much displaced and firmly held in their abnormal relations by the products of the low grade of inflammation which accompanies the breaking down of the arch. A few forms of apparatus for gradually stretching the foot back into place have found favor. That of Hausmann, which is warmly praised by Hoffa, is show in Fig. 20.

Manipulation under Ether. — The usual procedure in such cases is to anæsthetize the patient and forcibly break down the adhesions, crowd the bones back into place, and at once restore the foot to its normal shape. When the deformity has been thoroughly reduced the foot is put up in a plaster bandage in an over-corrected position, that is, forced adduction and flexion. After four weeks' rest this plaster is taken off and active treatment begun. Such treatment aims at restoring the free and painless motions of the foot, particularly those of flexion and adduction.

The foot should be soaked in hot water and thoroughly massaged before any "twisting" is begun. The surgeon should then grasp the heel with the hand of the same side, so that the ball of the thumb may press firmly against the patient's instep; over this, as a fulcrum, the fore part of the foot is forced by steady pressure with the other hand. When the limit of action has been reached the foot should be held in the same position until the pain caused by the stretching has subsided. While the foot is still so held the patient is directed to flex and extend the toes, and to make voluntary efforts at abduction and adduction. This should be done once a day for at least two weeks. In addition to this, the cast for the plate having been taken as soon as the foot is taken out of plaster, the patient should be taught how to walk with his plate, and should be directed to go through his gymnastic exercises by himself several times daily.

Operative Treatment. — Of operative measures but three have met with much favor; first, that advised by Ogston,[22] which aims at forming an anchylosis between the astragalus and scaphoid bones. This is obtained by removing their articular surfaces, and fastening the bones together by means of ivory pegs in a correct position.

Second, a less severe operation has been advised by Mr. Stokes,[23] who proceeds as follows: Having rendered the parts to be operated on aseptic, he makes an incision an inch and a half in length along the inner edge of the foot, the centre of the incision being at the prominence formed by the head of the astragalus. Near the centre of this incision, at right angles to it and a little below the situation of Chopart's joint, is made a second incision, and the two triangular flaps of skin dissected back for about half an inch. A wedge shaped piece of bone from the enlarged head and neck of the astragalus is removed with an osteotome, and the foot is then put up in plaster in the corrected position. Both these operations are open to the objection of leaving a stiffened joint in the centre of the foot.

An operation which is rapidly gaining favor both in Germany and in this country is that advised by von Trendelenburg,[24] which is confidently spoken of as the operation of the future. It is nothing more than the

22 Lancet, January 26, 1884
23 British Medical Journal, April 18, 1885, p. 789.
24 Archiv. klin. Chir., xxxix, 4.

artificial production of bow leg. The tibia and fibula are respectively chiselled through subcutaneously a short distance above the ankle-joint. The ankle is then taken under the arm and the foot forcibly placed in the normal position. The ankle and foot are then put up in a plaster bandage, in which they remain for from ten to twelve days, after which time the bandage may be taken off and the position still further corrected if it is found necessary. No over-correction is necessary in this form of operation. After four or five weeks the patient can be allowed to walk about with some form of light apparatus. Trendelenburg claims for this operation that it not only returns the foot to its normal position, but restores its arch as well.

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