THE ANATOMY OF HALLUX VALGUS

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The morbid anatomy of hallux valgus was studied carefully in the nineteenth century, particularly by Volkmann (1856), Lane (1887), Payr (1894) and Heubach (1897), and has been reviewed by Simon (1918) and Hohmann (1925) with adequate references to the literature. Stein (1938), who gave the most extensive review in the English language, based his work on general considerations and on observations made at operation rather than on necropsy or dissecting room materials. His contribution was well documented and embodied in a consistent whole the knowledge of his day, and few structural details have been added since. But a leisurely examination of material specially chosen for the purpose might reasonably be expected to fill out the pathological picture and to allow the correction of some points not easily determined at operation or by radiography. Such has indeed proved to be the case, and the findings have further suggested that some change of emphasis in the normal anatomy of the forefoot might be necessary, following the lines of a preliminary survey already published by one of the present authors (Haines 1947).

NORMAL ANATOMY OF THE FIRST METATARSO-PHALANGEAL JOINT

The metatarso-phalangeal joint of the great toe differs from the joints of the other toes in its sesamoid mechanism. The head of the metatarsal carries a large, rounded, cartilage-covered prominence, wider than the base of the phalanx with which it articulates (Figs. 1 to 6). On the plantar surface two grooves are developed for articulation with the two sesamoid bones, and these are separated by a rounded ridge (Fig. 1). On either side the cartilage overlaps on to the lateral aspect of the bone, to form a smooth surface for the ligaments of the joint. The shaft narrows from the head, but carries a pair of shoulders or epicondyles (Fig. 2) from which the joint ligaments spring. The basal phalanx has an elliptical concavity for articulation with the metatarsal, and a swollen base which receives the muscular and ligamentous attachments.

The sesamoids, compared to coffee-beans by Heubach (1897), are embedded in the plantar pad (Fig. 3), a mass of dense fibrous tissue, rectangular in outline. The distal margin of the pad is attached firmly to the base of the phalanx, its lateral margins receive ligamentous and muscular attachments, and its proximal border receives a part of the short flexor (Fig. 4) and is attached by a few loose fibres to the distal end of the metatarsal. From the dorsal surface of the pad project the cartilage-covered articular surfaces of the two sesamoids, each concave longitudinally to fit the metatarsal head, but convex from side to side. Between the sesamoids is a groove (Fig. 5) lined with a little synovial tissue, and into this groove the ridge on the head of the metatarsal fits. The plantar surface of the pad is raised on either side by the two sesamoids so as to form a groove in which the long flexor tendon plays, held in place by its fibrous tunnel. In standing, the sesamoids transmit a part of the pressure from the skin to the head of the metatarsal, relieving the flexor tendon from excessive compression.

Most recent authors have considered the sesamoids as developing in the two heads of the flexor hallucis brevis as they passed to their insertions on the basal phalanx. Many of
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Figure 1—Anterior view of head of metatarsal and sesamoids in their grooves (a woman of forty-six).

Figure 2—Same specimen. Medial view of joint.

Figure 3—Same specimen. Joint opened by slitting plantar pad.

Figure 4—Joint opened by cutting ligaments (a man of sixty).

Figure 5—Metatarsal head and sesamoids after removal of phalanx (a man of eighty-six).

Figure 6—Same specimen. Plantar view of articular surfaces on metatarsal.
the fibres of the muscle do in fact insert through the sesamoids, but so do some of the muscular fibres of the abductor and adductor of the great toe, and so also a very strong band of the plantar aponeurosis. Moreover a similar pad, though smaller, is found at the interphalangeal joint of the great toe, and a sesamoid, single in this case, may develop in it (Fig. 2) though here no muscles are inserted through the pad. So it seems best to return to an older conception, following Matzen (1949), and to regard the sesamoids as ossifications in the substance of the plantar pad—Matzen’s “lamina fibrocartilaginea plantaris”—just as similar sesamoids, the lunulae, may be found in the menisci of the knee of many animals (Pearson and Davin 1921).

In radiographs the sesamoids can be shown as they lie in their grooves beneath the metatarsal heads, and the ridge on the metatarsal is very distinct (Fig. 22). Inge and Ferguson (1933) have given a comprehensive review of their history with full references to the literature, and have themselves considered a rich histological and radiographic material. There are great variations in size and in degree and manner of ossification, and a small os intersesamoideum may ossify between the two normal bones. Very rarely a sesamoid may fail to ossify (Lapidus 1939). The two bones may lie at the same level or the lateral bone may lie proximal to the medial (compare Inge and Ferguson, Figs. 1 and 12). When the sesamoids are small there may be an interval between them, filled by plantar pad tissue through which the pressure of the long flexor tendon may indent the metatarsal head (Fig. 4). In that case the ridge between the sesamoid areas carries a distinct intermediate groove.

From each shoulder of the metatarsal there passes, on either side of the joint, a fan-shaped mass of ligamentous fibres. A strong band, the collateral ligament (Fig. 2), runs distally and plantarwards to the base of the phalanx, while another, equally strong, fans out to reach the margin of the fibrous pad and sesamoid bone. The two bundles are joined by intermediate fibres, but it seems best to name them separately, and, since the fibres attached to the pad hold the sesamoids in their grooves, they may be called the ligaments of the medial and lateral sesamoids (Haines 1947). They have received scant notice heretofore, but form an essential part of the mechanism of the normal joint, and are conspicuously altered in hallux valgus.

**THE METATARSO-PHALANGEAL JOINT IN HALLUX VALGUS**

In hallux valgus the digit is displaced laterally and is usually pronated on the head of the metatarsal, the plantar pad and sesamoids are displaced with the digit, and the ligaments on the medial side of the joint are stretched (Figs. 7 to 17). In the least severe example examined by dissection (Fig. 8) the articular surface for the basal phalanx looks laterally as well as distally, and is separated by a sagittal groove, in which the cartilage is thinned, from a medial eminence over which the stretched ligaments pass. The groove for the lateral sesamoid is normal in appearance, but an erosion occupies most of the groove for the medial sesamoid and encroaches on the ridge. A line of small osteophytes follows the articular margin (Fig. 9) giving the medial eminence in anterior view (Fig. 8) a peculiar squared off appearance that contrasts with the rounded margin of the normal bone.

In another example (Fig. 10) the area of erosion has spread farther over the ridge, and the ridge is lipped so as to encroach on the groove which originally lodged the lateral sesamoid. Thus the ridge appears as if spread laterally over the metatarsal head like butter over bread. The sesamoids are displaced, the medial overriding the ridge and the lateral overhanging the lateral margin of the head (Fig. 11). The medial sesamoid usually shows an area of erosion corresponding to that on the metatarsal ridge.

Eventually the ridge is smoothed out (Fig. 13) so that there is no further bony resistance to the displacement of the sesamoids. The lateral sesamoid may continue on its lateral course (Fig. 14) or may come to lie on the lateral surface of the metatarsal head, turning on edge as it does so (Fig. 17). In either case the ligament of the lateral sesamoid shortens and it becomes impossible to push the sesamoids back into their original positions even after all other attachments have been cut.

Figure 8—Mild valgus with erosion. Figure 9—Same specimen. Medial view to show osteophytes.

Figure 10—More severe case to show lip formation. Figure 11—Same specimen, cut with saw. The arrows show the inequality of the ligaments of the two sesamoids.
The erosions that form such a conspicuous feature in less advanced cases may, when movement of the sesamoids has ceased, become filled with new tissue. In Figure 15 the depressed area is clearly an old erosion, but its floor, instead of being covered by a thin pannus as in Figure 8, is formed by a dense sheet of cartilage-like tissue. In another example (Fig. 16) the medial eminence and sagittal groove are well marked, the medial sesamoid rests on a flattened surface, the ridge is lost, there is an intermediate groove for the long flexor tendon resembling that in Figure 6 but in a new position, and the lateral sesamoid has turned on to the lateral surface of the head (Fig. 17). Yet the cartilage is everywhere smooth and healthy-looking and the section shows it to be continuous, though there can be little doubt that the cartilage was, at the time when the ridge was in process of destruction, eroded as in Figures 8 and 10.
The development of the deformities can be followed in radiographs. In a mild case (Fig. 18) the first metatarsal is deviated, but not markedly, and so is the toe, but it has not forced the second toe out of its proper alignment, nor is there any overlap of the bony parts. The bones appear normal in structure apart from an increase in density of the medial side of the first metatarsal, a bony outgrowth from the base of the terminal phalanx, and an irregularity of ossification in the medial sesamoid, but the basal phalanx is slightly displaced laterally, and the lateral sesamoid is rather more exposed in the dorsal radiograph than
normally, especially in weight bearing (Fig. 19). When the foot is enclosed in a shoe (Fig. 20), the metatarsal, supported on its medial side, is not displaced so far, but the toe and its sesamoids are pressed farther laterally. The sesamoids still lie in their grooves and the metatarsal ridge between them is only slightly flattened (Fig. 21).

A radiograph from a girl of twelve shows the change from the less severe condition in the right foot to the more severe in the left (Figs. 23 to 26), the movements of the bones and the crossing of the first two toes being evident. The contrast between the positions of the sesamoids in their proper grooves on the left and their displacements on the right is most striking, as is also the smoothing out of the ridge. The sesamoids of the more severely affected foot are larger than those of the less affected foot, a condition which supports the suggestion of Truslow (1925) and others that displaced sesamoids may become enlarged, though this is usually difficult to confirm in any individual case as the normal sesamoids show such great variability. The epiphyses on the more affected side are fusing prematurely, and the internal
structure of the right first metatarsal is less dense than that of the left, but the sagittal groove is not yet conspicuous. The heads of the other metatarsals are rarefied and their shafts thinned, and the basal phalanges are dumbbell-shaped, the ends appearing enlarged on account of the thinning of the shafts.

In a similar case from another girl of twelve (Figs. 27 to 30) the loss of density in the metatarsal head and the enlargement of the displaced sesamoids are again evident. Miller and Arendt’s (1940) case also showed enlargement of the lateral sesamoids. In more severe cases the sagittal groove becomes strongly defined (Fig. 31) and osteophytes may appear on the margin of the medial eminence (Fig. 32). The eminence often has a squared-off appearance (Figs. 32 and 34) and, probably as a result of bone absorption on the medial surface of the shaft, may overhang the shaft as the cap of a toadstool its stalk (Volkmann 1856). The ridge on the metatarsal is smoothed out so that the head as a whole presents a rounded surface over which the sesamoids glide into the interspace between the first and second metatarsal heads. The lateral may come to lie vertically above the medial sesamoid with

Fig. 27
Fig. 28
Early hallux valgus in a girl of twelve. The deformity is slight in the left foot (Figs. 27 and 28) but severe in the right foot (Figs. 29 and 30).

Fig. 29
Fig. 30

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Figure 31—Severe hallux valgus in a woman of fifty-four. Note the sagittal groove and medial eminence. Figure 32—Marked hallux valgus in a woman of thirty-three showing lipping and "squaring off" of medial eminence.

Figure 33—Another case showing an eroded "coral-like" surface of the medial eminence. Figure 34—Same case showing overhang of medial eminence.

The originally medial margin of each turned towards the sole (Figs. 35 and 37) or they may lie side by side with the lateral out of all contact with the metatarsal head (Fig. 36). Eventually the phalanx may be displaced so far that only its medial edge still articulates with the metatarsal, the rest lying free in the interdigital space, as in Cleveland and Winant's (1950) case.

The displacement of the sesamoids is well known, and their replacement has been taken as a criterion of successful operation for bunion (Silver 1923). Truslow (1925) stated that they might become attached to the first or second metatarsal head, but other authors do not
Severe hallux valgus in a woman of fifty-four. The sesamoids have moved into the metatarsal space, turning on edge.

Marked hallux valgus in a man of sixty-four. The medial eminence is destroyed and the lateral sesamoid is turned on edge.

Severe deformity in a man of fifty-three. Note the new bone formation from the lateral side of metatarsal head and the displaced sesamoids, the lateral being out of contact with the metatarsal.

Woman of fifty-seven. Large bunion and new formation of bone on lateral side of metatarsal head.

mention the point nor have we seen such a condition, though Inge and Ferguson (1933) found one making a pseudarthrosis with the second metatarsal head, as in our Figure 31. The elongation of the medial and the shortening of the lateral ligaments are also well understood (Stein 1938). The early disorganisation of the sesamoid articular surfaces of the metatarsal bone is less well known, though carefully described by several early workers (Volkmann 1856, Lane 1887, Anderson 1891, Heubach 1897). Thus Silver (1923) said that, except where joint disease has existed, the articular surfaces present "little, if any, gross
change." Freiberg (1924) said that they "present no alteration of consequence," and Peabody (1931) "had been left with the impression" that the joint was "in a very satisfactory state." Stein's (1938) diagrammatic drawing of the cross-section of a joint in hallux valgus shows the two grooves and the ridge persisting in spite of displacement of the sesamoids though his Figure 5, a radiograph, shows the ridge destroyed. Such discrepancies probably arise from incomplete radiological examinations, for in dorsal view the metatarsal head may appear almost normal, while in antero-posterior view it appears grossly distorted (Figs. 23 and 24). The smoothing out of the ridge appears to be a constant and early feature of the deformity for it has been found in every case examined. We cannot agree with Inge and Ferguson (1933) that the ridge "is not high enough to prevent dislocation of the medial sesamoid laterally in severe hallux valgus" for we have found that the sesamoid moves laterally only after the destruction of the ridge. In hallux varus the sesamoids move medially (Sloane 1935), but the state of the ridge is not known.

Putschar (1937) noted regeneration of the cartilage in a fresh specimen with corresponding erosions of the medial sesamoid and metatarsal ridge, but regeneration is not discussed by other pathologists. The joint offers exceptional opportunities for this process, for, once the toe is displaced, the condition may become static while the tissues remain healthy.

**THE NATURE OF THE MEDIAL EMINENCE**

The earlier workers believed that the medial eminence was a pathological neomorph, a true exostosis. Thus Froriep (1834) suggested that a primary deviation of the toe stretched and inflamed the ligaments on the medial aspect of the metatarsal head and so caused a fibrocartilaginous outgrowth that eventually ossified. Volkman (1856) found the prominence separate from the epicondyle and intracapsular in position, and suggested that it was a primary outgrowth and pushed the phalanx aside as a secondary effect.

Lane (1887), on the other hand, considered the eminence to be not a new growth but a part of the metatarsal that had originally articulated with the phalanx, but which had become exposed as the toe was displaced laterally. He found that the exposed cartilage, out of contact with the phalanx, might become soft and inelastic, and lose its white colour, and that similar degenerative changes might occur in association with the displaced sesamoids. Anderson (1891) showed a preparation from an extreme case in which the toe made a right angle with the metatarsal and he also found tissue destruction rather than new formation in the region of the prominence. The detailed anatomical work of Payr (1894) and Heubach (1897) left no doubt that Lane's theory was correct, but these studies are seldom considered by recent authors. Silver (1923) found the prominence formed "usually only to a lesser degree by the actual bone hypertrophy," and Stein (1938) that the "so-called 'exostosis'" removed at operation was "usually a myth" (see also Elmslie 1926, and Jordan and Brodsky 1951). Most writers, however, have taken the "exostosis" at its face value.

Comparison of the two feet in Figures 23 to 26 shows that in this early case there has been no bony outgrowth on the medial side of the head on the more affected side, the prominence being entirely accounted for by the displacement of the phalanx, as Lane suggested. There is some new outgrowth on the lateral side in Figures 36 and 38 in relation to the displaced phalanx and sesamoids, but none on the medial side. Stein's (1938) Figure 10, purporting to show "hypertrophy of the medial margin of the first metatarsal head" especially on the right, actually shows the right and left bones of equal size and Truslow's (1925) Figure 7, said to show "marked redundant bone" in a deviated metatarsal shows the lateral outgrowth clearly, though Truslow himself placed the extra bone on the medial side. In all these cases the prominence appears to be a part of the normal metatarsal head which originally supported the ligaments medially and the phalanx distally, though after displacement of the phalanx the whole surface comes into contact with the stretched ligaments.
In mild cases the cartilage over the eminence is well preserved, but later the eminence may lose its cortical layer, exposing an uneven surface of spongy bone (Röpke 1904) or may be "fragmented, fibrillated and irregularly pitted" (McMurray 1936), giving the coral-like formation figured by Simon (1918), as in Figure 30. Eventually the whole eminence may be lost as in Lane's case (1887) and Figure 37.

The ligament of the medial sesamoid is usually thickened at the same time as it is stretched (Figs. 11 and 12), presumably as a response to the increased strains thrown upon it, confirming the observations of Anderson (1891) and others. In severe cases it is thin and softened, possibly as a result of a chronic inflammation associated with the adventitious bursa found overlying it in such cases (Fig. 38), and eventually the bursa and joint cavity may come to communicate (Clarke 1900) or the bursal walls may calcify. It seems likely that so long as the ligament is strong the pressure it exerts on the metatarsal head keeps the eminence over which it plays in a healthy state, but when it is inflamed and weakened the eminence atrophies.

The sagittal groove has been ascribed to pressure of the margin of the phalanx by Clarke (1900), Jordan and Brodsky (1951) and others, but it seems more likely that it is formed by degeneration of the cartilage where it no longer supported the bone and where the ligaments are passing with straight fibres to the sesamoid and phalanx so that they also do not press on the cartilage (Fig. 14). The weakness of the bony trabeculae deep to the groove and their arrangement parallel to the surface as seen in section (Payr 1894, Heubach 1897, Putschar 1937) suggest that the groove is a region of minimal pressure, and is a fossa nudata (Modes 1939) due to lack of adequate stimulation rather than an erosion due to excess. The more ventral part of the groove incorporates the old groove for the medial sesamoid which is no longer recognisable as a separate depression (Fig. 8).

When the phalanx is greatly displaced the groove may progress towards the lateral side, and the cartilage on the metatarsal may become restricted to the lateral half of the head. A photograph taken at operation (Fig. 39) shows particularly clearly the contrast between the polished hyaline cartilage and the dulled degenerate tissue over the medial eminence.
THE FIRST CUNEO-METATARSAL JOINT IN HALLUX VALGUS

In spite of the deviation of the first metatarsal in hallux valgus the cartilages of the cuneo-metatarsal joint appear normal, and the ligaments are strong and allow only a normally restricted range of movement (Fig. 42). Ewald (1912), from a study of radiographs, found the varus deviation usually (sixteen of twenty cases) associated with an obliquity of the articular surface of the cuneiform, more rarely (four cases) with an oblique setting of the base of the metatarsal similar to that found in the head of the tibia in genu valgum, whereas in normal individuals the joint was usually set transversely and was only occasionally oblique

(eight or ten of 100 patients without hallux valgus). Berntsen (1930) confirmed this work, finding the joint set obliquely in twenty-five of thirty-seven cases of valgus, but in only eleven of 165 normal subjects. But Simon (1918) published, side by side, radiographs of the same foot taken dorso-ventrally and ventro-dorsally, which appeared to show in the one case an oblique and in the other a transverse setting, and we have obtained similar results in dorso-ventral views taken at different angles of incidence (Figs. 40 and 41). Most later workers have not mentioned the joint.

Our anatomical preparations, however, though too few for statistical study, support Ewald’s observations. When the first cuneiform from a normal foot is dissected out and

Fig. 40
Woman of twenty-six. Two radiographs of same foot taken at different angles and with the toe held in different positions. The cuneo-metatarsal joint appears oblique in Figure 40 and transverse in Figure 41, and the sesamoids appear to be level in the one and not level in the other.

Fig. 41
laid flat on the table little of the joint surface can be seen (Fig. 43) but in bones from subjects with hallux valgus, the surfaces usually look medially as well as distally (Figs 44 and 45). Similarly the metatarsal base is often set obliquely, but by no means invariably so. Thus both cuneiform and metatarsal usually take part in the alteration of alignment, but one or the other may take the chief part, though in individual cases it is difficult to judge the proportions as the normal variations are so wide and radiographs so difficult to interpret. The results of stapling used surgically to correct the metatarsus varus in young patients (Ellis 1951) show that the base of the metatarsal can adapt itself to changed conditions of pressure without gross pathological change, and though the cuneiform has no epiphysis it also is growing in adolescence, and can alter its shape. There is no convincing evidence of any primary lesion of the joint that could be regarded as a cause and not as a result of hallux valgus.

Payr (1894) maintained that the presence of a joint between the bases of the first and second metatarsals, as in Figures 23 and 41, though often described as a normal variation, was in fact an acquired deformity due to hallux valgus. The point is difficult to decide without access to peoples who wear no shoes and have no trace of valgus, but would imply some lateral displacement of the base of the first metatarsal, forcing it against the second. There is no evidence of any medial deviation of the first cuneiform, or of any opening up of the first intercuneiform joint.

THE BINDING MECHANISM OF THE METATARSAL HEADS

A dissection of a normal foot from the medial surface (Fig. 46) shows the metatarso-phalangeal joint partly covered by a number of muscular expansions. The medial fibres of the expansion of the long extensor tendon, or "medial hood ligament" (Haines 1951), is a
square fibrous sheet attaching the tendon of the extensor hallucis longus to the plantar pad, to the periosteum of the proximal phalanx, and to the fibrous flexor tunnel. It covers the insertion of the short extensor into the proximal phalanx and passes deep to the conjoined tendon of the abductor and the medial head of the short flexor and to a slip of the plantar aponeurosis, all inserted on the phalanx.

Though these structures lie medial to the joint, and are to some extent blended together to form a sheath around it, they are all attached to the basal phalanx and not to the metatarsal itself. Thus when the phalanx is abducted it carries the attachments with it, so that the joint, already exposed when the toe is directed forwards, becomes more so as the toe moves laterally (Fig. 13). In fact the only structures on the medial side of the joint that tie the
metatarsal head in place are the ligaments of the joint itself, the collateral ligament and the ligament of the medial sesamoid.

On the plantar surface the aponeurosis, turned back in the dissection (Fig. 47), ends in a regular series of slips. The strongest is that already mentioned as passing partly to the medial sesamoid and partly deep to the conjoined tendon to reach the medial side of the basal phalanx. The second slip is attached to the lateral sesamoid, and its fibres help, with those of the first slip, to bridge over the long tendon and so constitute the entrance to the fibrous flexor tunnel. The third slip cuts off a compartment for the digital nerves and vessels from a compartment for the first lumbral muscle, and the remaining slips continue to build similar compartments for the corresponding structures in the other toes. The aponeurosis is thick and strong, but the great majority of its fibres are arranged longitudinally, forming one of the main elements in the support of the longitudinal arch of the foot. Only a few superficial fibres are arranged transversely to form the "superficial transverse ligament of the sole." Even such transverse

strength as the aponeurosis may possess is exerted, not directly on the metatarsal bones to which it has no attachments, but on the basal phalanges.

Deep to the flexor tendons and lumbricals is found a band of structures running transversely across the metatarsal heads, clearly concerned in their retention in proper alignment (Fig. 48). Each tendon of the flexor digitorum longus rests in a groove on a plantar fibrous pad of about the same length as the pad of the first toe but much narrower from side to side, and seldom ossified. The medial and lateral edges of the pad receive the two slips of the aponeurosis that enclose the long and short flexor tendons, and it requires great force to tear these slips away from the pad.

The five pads are jointed by the four deep transverse ligaments of the sole (Fig. 49). These separate the neurovascular and lumbar compartiments from the deeper intermetatarsal spaces which contain the interosseous muscles and, in the case of the first space, the conjoined tendon of the oblique and transverse heads of the adductor hallucis and lateral head of the

Fig. 48
Same specimen as Figure 46, deep dissection.
flexor hallucis brevis as they converge on the lateral sesamoid bone. Each ligament receives on its superficial surface the slip of the aponeurosis that separates the lumbrical from the neurovascular compartment. The ligaments are composed of parallel bundles of fibres attached together by looser connective tissue, the usual structure of true ligaments or tendons. In the

![Diagram of plantar pads and deep transverse ligaments]

**Fig. 49**
Plantar pads and deep transverse ligaments fully exposed.

![Diagram of plantar pads and deep transverse ligaments]

**Fig. 50**
Same specimen as Figure 49; plantar pads in dorsal view.

pads the fibres are closely packed and are irregular in arrangement, so that the pads do not tear easily in any direction.

Removal of the muscles isolates the ligaments which are attached to the pads but not directly to the bones. The pads are in turn attached to the phalanges, but on either side

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they are bound by the ligaments of the plantar pads to the metatarsals. Thus separation of the metatarsal heads is resisted by the transverse ligaments through pulling the pads.

The dorsal surfaces of the pads are best examined by the removal of the metatarsals (Fig. 50) leaving the hollows in which their heads rested. The first joint shows the two sesamoids and the two conjoined tendons, the others the smooth hollows for the metatarsal heads formed by the concave dorsal surfaces of the pads, flanked by the ligaments of the pads and by the insertions of the intersosseous muscles. The specimen from which Figures 49 and 50 were drawn was a marked example of the "Greek" type of foot, having a second toe projecting far beyond the first. The cartilages were in excellent condition in spite of the subject's eighty-six years (Figs. 5 and 6).

THE LIGAMENTS IN HALLUX VALGUS

In spite of Volkmann's (1856) clear statement to the contrary, it has often been supposed that the deep transverse ligaments were attached directly to the heads of the metatarsal bones, so that when the bones were spread the ligaments were necessarily stretched (Lapidus 1934, McMurray 1936), and the substitution of radiological for anatomical investigations has left this conclusion unchallenged. A specimen from a muscular male showing well marked spreading of the metatarsals and deviation of the marginal toes with clawing of the other three toes shows that in fact the deep transverse ligaments are neither markedly stretched nor displaced (Fig. 7). The second and third ligaments passing between the second, third and fourth pads are in their usual positions. The first lies between the normally placed second pad and the displaced first pad with its contained sesamoid bones. The first metatarsal head in moving medially has left the sesamoids behind, tied in their old position by the ligament supplemented by the adductor hallucis pulling through the lateral conjoined tendon. The ligament that has actually given way is not a transverse ligament but the ligament of the medial sesamoid. In surface view this is obviously stretched, and in a sawn section (Fig. 11) its fibres appear longer than those of the lateral ligament which is not stretched.

In dorsal view (Fig. 51) the first pad appears at first sight to contain three sesamoids, for there are three polished areas. Closer examination shows that the third "facet" is actually a polished area of the ligament of the medial sesamoid developed in relation to the eminence over which it turns (Fig. 10). The specimen also shows deviation of the fifth metatarsal, a condition mentioned by Hohmann (1925) and by Gottlieb (1930) who gave directions for its surgical correction, and by Bankart (1935) who recommended amputation. Here again it is evident that the fourth transverse ligament is still sound, whereas the lateral ligament of the fifth pad has been grossly stretched allowing the metatarsal head to leave the pad, whose position is indicated in ventral view (Fig. 7) by the position of the tendons that cross it, and in dorsal view (Fig. 51) by the small sesamoid developed in it.

THE MUSCLES IN HALLUX VALGUS

The tendons of the muscles that move the great toe are arranged round the metatarsophalangeal joint in four groups. The long and short extensors pass dorsally, the long flexor on the plantar surface. The two conjoined tendons pass medially and laterally, but much nearer the plantar than the dorsal surface, so that the dorso-medial and dorso-lateral aspects of the joint are covered only by the hood ligaments that bind the long extensor tendon in place (Fig. 46). Even in the normal foot the long flexor and the two extensors are somewhat obliquely placed so as to adduct the great toe towards the second in addition to their main actions, particularly when the toe is already adducted, and when the ligaments are stretched this adduction component becomes very strong.

In a specimen showing severe valgus with bunion formation the muscles are in reasonably good condition so far as their structure is concerned but they are displaced. The medial
hood ligament is stretched (Fig. 52) so that the long extensor tendon is displaced laterally and when it is pulled it not only extends the toe but also adducts it. The sesamoids are much displaced and the abductor hallucis has moved on to the plantar surface of the metatarsal and so lost all power of abduction, confirming the observations of Silver (1923) and Stein (1938), though we cannot agree with Stein's suggestions that it occupies the groove on the metatarsal for the medial sesamoid; for, with the obliteration of the ridge and development of the sagittal groove, the medial sesamoid groove has disappeared. Nor can we agree that it is the pressure of the muscle that has displaced the sesamoids.

The long flexor tendon has moved laterally with the sesamoids and now acts as a bowstring across the angle of the joint so that tension on the tendon again increases the valgus (Fig. 53), as suggested by Volkman (1856) and many others, and the two heads of the short flexor are also displaced laterally relatively to the metatarsal head. We cannot confirm Silver's
(1923) suggestion that the adductor is shortened, for, though the lateral sesamoid and basal phalanx are displaced relatively to the first metatarsal, they are no nearer the other metatarsals than in the normal foot (compare Figs. 49 and 51). Thus in the normal foot there is already some tendency for the toe to be pulled into valgus, but while the ligamentous and sesamoid mechanisms are intact this tendency is not realised. Once the toe has begun to move, however, the deformity is likely to be progressive.

None of the muscles mentioned is inserted into the metatarsal itself, so that Girdlestone (1936) has suggested that "the forefoot is held together by the structures inserted in the proximal phalanx of the big toe, and by them alone," and he and Spooner (1937) stated that in hallux valgus "the fore-foot is splayed not through stretching of the adductor structures, but because the first metatarsal head escapes from the control exercised by the base of the proximal phalanx into which the muscles are inserted. The phalanx and the sesamoids remain held by the adductors, while the first metatarsal head drifts away out of control." We would agree in general but would point out the stretching of the medial ligaments, and lay emphasis on the transverse ligaments rather than on the adductor muscle, since the

![Diagram of the anatomy of the hallux valgus](image)

**Fig. 53**

Same specimen as Figure 52, plantar view; position of adductor hallucis indicated.

fifth toe is often affected like the first though it has no adductor. If the metatarsal were controlled only through the phalanx it would drift away after hemiphalangeectomy in Keller's operation for hallux rigidus; that it does not in fact do so shows that the adductor is not necessary for holding it in place.

**THE DIGITAL ARTERIES IN HALLUX VALGUS**

The diagrams of the earlier writers show the transverse head of the adductor hallucis arising directly from the metatarsal bones (McBride 1928, Hiss 1931, Stein 1938). It is now known that the entire head arises from the proximal margins of the deep transverse ligaments and plantar pads, leaving a series of gaps through which the plantar metatarsal arteries pass plantarwards to reach the neurovascular compartments and become the common digital arteries (Figs. 38 and 50). The gaps are also used by the nerves to the second, or second and third, lumbrical muscles. Nissen (1951) showed a good photograph of a gap taken at operation and suggested that pressure on an artery as it passed through the gap might, under certain conditions, cause ischaemic pain. This might well occur under conditions of tension in the ligaments and muscles in hallux valgus, and more especially in the case of the first artery
which has a tortuous course, winding between the two heads of the short flexor and then superficial to the lateral conjoined tendon, just proximal to the lateral sesamoid, to reach the first interspace (Fig. 7). Pain may be felt in the web between the first and second toes and pressure on this artery seems a more likely cause of pain than irritation by osteophytes, suggested by Allan (1940).

**SUMMARY**

1. The anatomy of the forefoot in hallux valgus is compared with the normal, with a review of the literature and descriptions of anatomical preparations, observations at operation and radiographs.
2. The early and essential lesions are stretching of the ligaments on the medial side of the metatarsophalangeal joint that attach the medial sesamoid and basal phalanx to the metatarsal, and erosion of the ridge that separates the grooves for the sesamoids on the metatarsal head.
3. In established hallux valgus a sagittal groove, formed where the cartilage is free from pressure by either the phalanx or the ligaments, cuts off a medial eminence, which articulates with the stretched ligaments, from a restricted area for the phalanx.
4. Apart from osteophytic lipping which squares off the outline of the eminence as it is seen in radiographs and a small amount of lipping of the ridge on the metatarsal there is no evidence of new bone growth. In chronic cases the eminence may degenerate or disappear.
5. The articular surfaces at the cuneo-metatarsal joint become adapted to the changed positions of the metatarsal without gross pathological change.
6. The four deep transverse ligaments that bind together the five plantar pads of the metatarsophalangeal joints are not unduly stretched, so that as the metatarsals spread it is the ligaments that bind the pads to the heads of the metatarsals that give way.
7. The plantar metatarsal artery to the first space pursues a tortuous course between the two heads of the flexor hallucis brevis. In hallux valgus the course becomes still more tortuous and part of the pain experienced may be due to ischaemic effects.

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