Metatarsalgia

Essay

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Orthopaedic Surgery

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Introduction

Metatarsal bones are long bones extending from Lisfranc's joint "tarsometatarsal" to the anterior portion of the foot. The diaphysis of each one has a cylindric form, the distal epiphysis shows an enlargement in the form of drumstick, developed more along the planter surface than the dorsal one, and constitutes the metatarsal condyle. The length of metatarsal bones varies in relation to the first one. (18)

Metatarsalgia means pain in the metatarsal head region. The three basic types of metatarsalgia include:

1. Metatarsalgia of the first metatarsal head region.
2. Metatarsalgia of the region of the four lateral metatarsal heads.
3. Generalized metatarsalgia. (29)

There is a spectrum of normal and anatomical variance, the relationship between subtle variations in metatarsal anatomy and the development of metatarsalgia is often unclear. Congenital deformities, developmental abnormalities can potentially contribute to diminution in gait efficiency, so evaluation of patient's gait should be done. (52)

Metatarsalgia from medical causes usually present as one symptom of the general illness. They may be called plantalgias, and are not accompanied by structural displacement except in the case of a neurological disorder. Pain in the foot is most often due to a metatarsalgia. Pain in the anterior metatarsal region, and is associated with problems of weight-bearing by the forefoot. This results in excessive forces on the sole which in turn produce callosities under the metatarsal heads. (80)

Metatarsalgia is a common cause of consultation both foot surgeons and with general practitioners. The usual cause is a structural problem in the foot, but it is important to remember other possible etiologies, particularly inflammatory. The indications for treatment depend on the severity of the lesion and the symptoms they cause the patient. It is worth using an insole in the first instance, but if symptoms persist after a year of conservative treatment, then surgery should be offered. (29)

آلام مشطيات اصابع القدم

رسالة

توطئة للحصول علي درجة الماجستير في جراحة العظام

مقدمة من

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Features of metatarsal Bones

There are 5 metatarsal bones in the foot. Each bone has a base, a shaft, and a head. The base is situated proximally and articulates with the distal row of tarsal bones. This articulation is called the Lisfranc's joint. The first metatarsal articulates with the medial cuneiform bone; the second metatarsal, with intermediate cuneiform bone; the third, with lateral cuneiform bone; and the fourth and fifth metatarsals, with cuboid bone. (1) As the metatarsals extend distally to the metatarsophalangeal joints, they fan-out. At the metatarsophalangeal level all five metatarsal heads are on the same horizontal level. (2)

All of the metatarsals articulate with dome-shaped heads on the proximal phalanx of the toes. The metatarsal heads have an articular surface that extends more proximally on the plantar more than on the dorsal surface. The first metatarsal is the broadest and the shortest of the 5 metatarsals. (3) The second metatarsal is the longest but the first is the largest in the terms of its bulk. No anatomist has recorded the first metatarsal as dominant. The accepted normal metatarsal formula is 2>3>1>4>5. (4)

The first metatarsal bone: The first metatarsal bone is remarkable for its great thickness, and is the shortest of the metatarsal bones. The body is strong, and of well-marked prismoid form. The base presents, as a rule, no articular facets on its sides, but occasionally on the lateral side there is an oval facet, by which it articulates with the second metatarsal. Its proximal articular surface is of large size and kidney-shaped; its circumference is grooved, for the tarsometatarsal ligaments, and medially gives insertion to part of the tendon of the Tibialis anterior; its plantar angle presents a rough oval prominence for the insertion of the tendon of the Peroneus longus. (5) The shaft of the first metatarsal is prismatic and has three surfaces. The lateral surface is plane and slightly concave, smooth, and vertical. It provides part of the origin for the first dorsal interosseous muscle that orient proximo-distally. The inferior surface of the first metatarsal is bounded by medial and lateral borders. It is concave on its long axis and the plantar tubercles of the medial and lateral angles of the base exaggerate this feature. The dorsomedial surface is smooth, convex, and becomes more dorsally oriented distally. The shaft demonstrate three borders; the superior border is smooth, rounded, and separates the dorsomedial and lateral surfaces. The medial and lateral borders marginate the inferior surface and are well defined. (6)

The first metatarsal head supports two sesamoids bones. The tibialis anterior serves to elevate the first metatarsal, and the peroneus longus acts to plantar-flex the head. [7] (Fig. 1)

The Second Metatarsal Bone: The second metatarsal bone is the longest of the metatarsal bones, being prolonged backward into the recess formed by the three cuneiform bones. Its base is broad above, narrow and rough below. It presents four articular surfaces: one behind, of a triangular form, for articulation with the second cuneiform; one at the upper part of its medial surface, for articulation with the first cuneiform; and two on its lateral surface, an upper and lower, separated by a rough non-articular interval. Each of these lateral articular surfaces is divided into two by a vertical ridge; the two anterior facets articulate with the third metatarsal; the two posterior (sometimes continuous) with the third cuneiform. A fifth facet is occasionally present for articulation with the first metatarsal; it is oval in shape, and is situated on the medial side of the body near the base. [5]

The shaft has prismatic contours with dorsal, medial, and lateral surfaces. Its medial surface gives origin to the first dorsal interosseous muscle. The inferior border which Concave longitudinally, dorsolateral, dorsomedial borders present to delineate the three surfaces. [6] (Fig. 2)

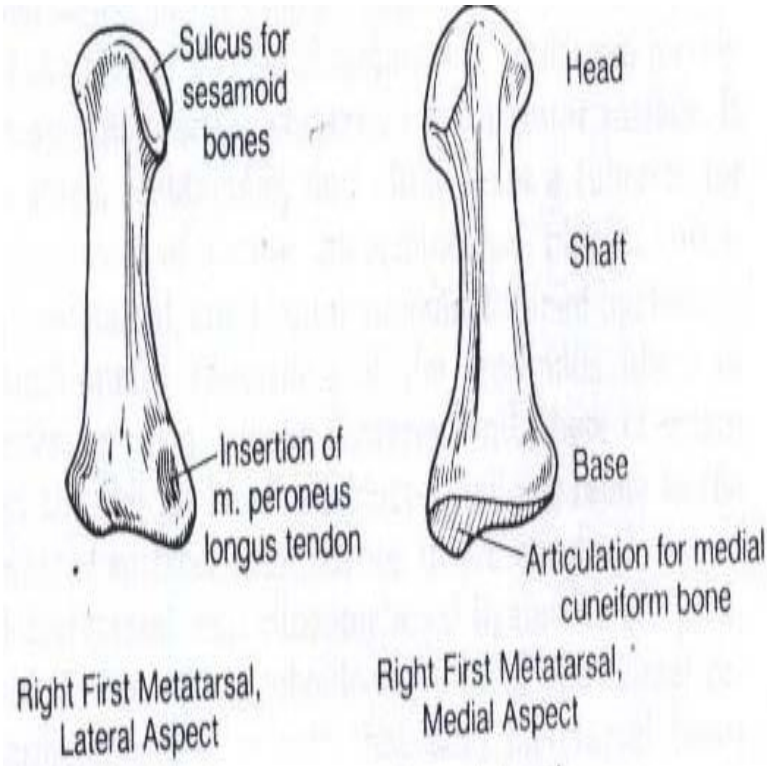

Fig. 1: The first metatarsal bone [8]

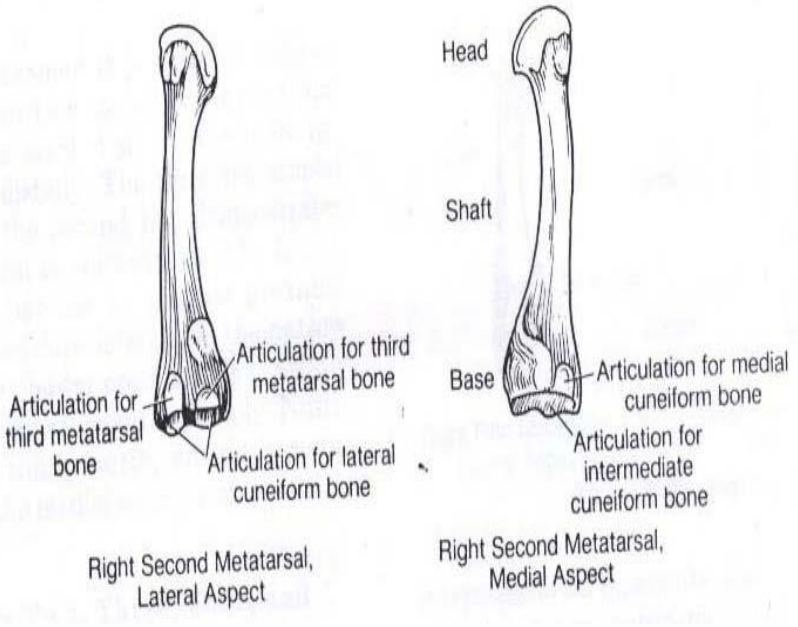

Fig. 2: The second metatarsal bone [8]

The Third Metatarsal Bone: The third metatarsal bone articulates proximally, by means of a triangular, smooth surface, with the third cuneiform; medially, by two facets, with the second metatarsal; and laterally, by a single facet, with the fourth metatarsal. This last facet is situated at the dorsal angle of the base. [5] The heads of the four lesser metatarsals demonstrate essentially quadrilateral outlines. [9] In the profile, the head of third metatarsal form an elliptical articular surface. This surface is classically condylar and is similar to the outline convexity of the first metatarsal head in that the plantar aspect extends more proximally than does the dorsal lip. [6] (Fig. 3)

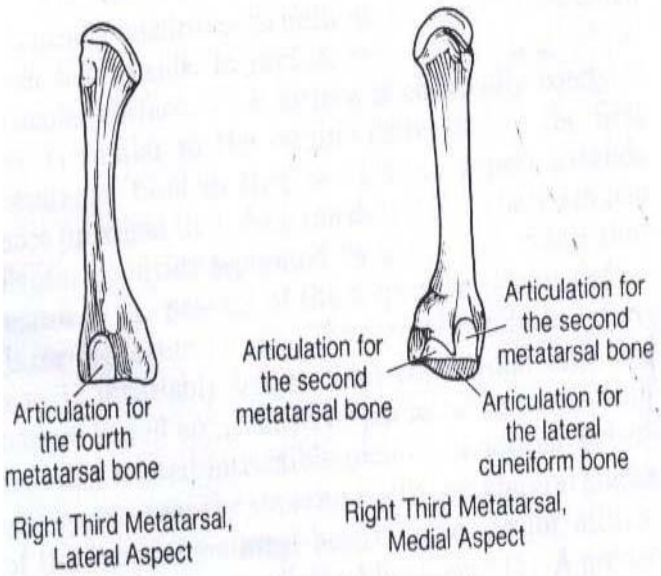

Fig. 3: The third metatarsal bone [8]

The Fourth Metatarsal Bone: The fourth metatarsal bone is smaller in size than the preceding; its base presents an oblique quadrilateral surface for articulation with the cuboid; a smooth facet on the medial side, divided by a ridge into an anterior portion for articulation with the third metatarsal, and a posterior portion for articulation with the third cuneiform; on the lateral side a single facet, for articulation with the fifth metatarsal. [5] The shaft of the fourth metatarsal has prismatic contours with dorsal, medial, lateral surfaces. The superior aspect of the lateral surface gives origin to the third dorsal interosseous muscle. The head of fourth metatarsal has two planter condyles separated by concave notch that related to the passage of the respective tendon of the flexor digitorum longus. The lateral condyle is invariably longer than the medial. [6] (Fig. 4)

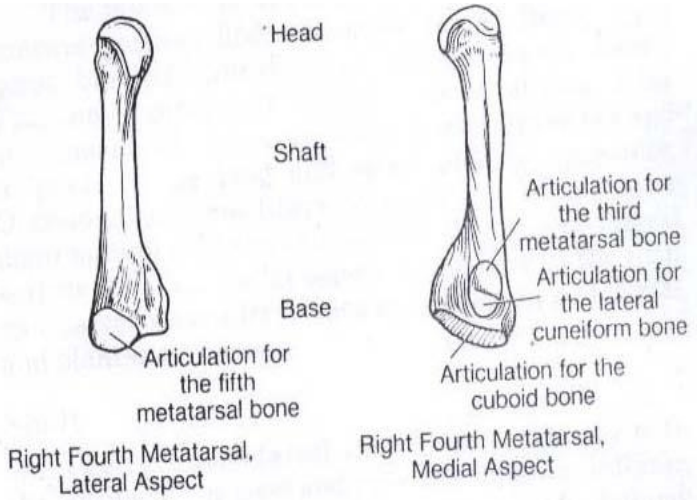

Fig. 4: The fourth metatarsal bone [8]

The fifth metatarsal bone: The base of the fifth metatarsal is essentially pyramidal [9] and distinguished from the other lesser metatarsals in that it does have major motor insertion at its base.

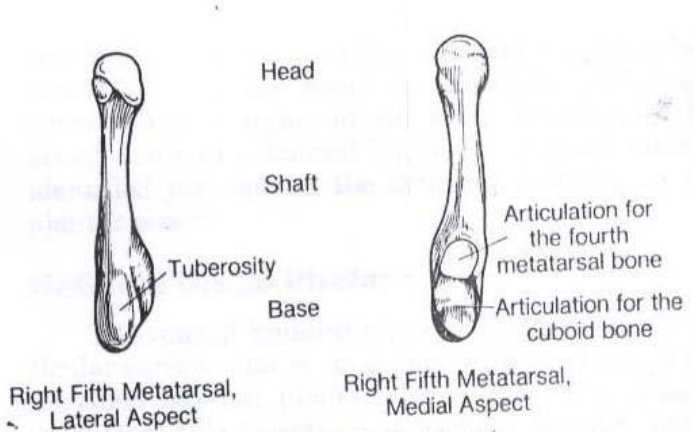

Fig. 5: The fifth metatarsal bone [8]

The peroneus brevis attaches on the dorsal aspect of the tubercle of the fifth metatarsal and the peroneus tertius attaches on the dorsal aspect of the fifth at the proximal metaphyseal diaphyseal junction. Functionally the tertius acts as balancing force to forefoot dorsiflexion counteracting the neutral inversion tendency of the tibialis anterior. The peroneus brevis serves as more of antagonist to the posterior tibialis function to maintain the position of the foot under the talus. There is strong attachment of the plantar fascia to the plantar aspect of the tubercle. The osseous blood supply to the fifth metatarsal is similar to the other metatarsals in that a single nutrient artery enters from the medial cortex at the junction of the proximal and middle third of the diaphysis and supplies the shaft. Secondary epiphyseal and metaphyseal arteries supply the base and tuberosity. (7)

The shaft of the fifth metatarsal is in continuity of the base and present superior, inferior, and medial surfaces. Its borders are variably defined; the lateral border separates the superior from the inferior surfaces, but the inferior border that separates the medial and the inferior surfaces is poorly defined. The superior border divides medial and superior surfaces. They are relatively broad proximally, but the shaft tapers to its neck just behind the head. (9) (Fig. 5)

** Axial torsion:*

On studying a double cross-section of each shaft, an element of axial torsion is found between the base and the head of each metatarsal. It is interesting to know that the second metatarsal remains "unrotated".

** Angle of inclination with the horizontal:*

This is greatest at the first metatarsal being 26º and least at the fifth metatarsal being 10º, while it is 24º at second metatarsal, 18º at third and 14º at fourth metatarsal.

** Intermetatarsal angle:*

The second metatarsal being taken as neutral, the angle of varus equals approximately the angle between the first and second metatarsals is about 17º while that between second and third is 4º , the same for the angle between third and fourth, and the angle between fourth and fifth metatarsals is 8º . (10)

Joints related to the metatarsals

Lisfranc's joint

A series of predominantly plane synovial joints, that moves by simple gliding movements, lie between the three cuneiforms and the base of the medial three metatarsals. The first tarsometatarsal joint has its own synovial cavity but the fourth and fifth metatarsals share a common joint cavity as they articulate with the cuboid. The second and third metatarsals articulating with their respective cuneiforms share a common joint but are separated from other neighbours by interosseous ligaments. Because of their peripheral location, the first and fifth tarsometatarsal joints are less restrained than the central three joints which are particularly compact and stable. The second metatarsal base is confined between the median and lateral cuneiforms where it articulates with the short intermediate bone. (11)

* Ligaments support:

1- Dorsal Tarsometatarsal Ligaments:

Normally there are eight dorsal tarsometatarsal ligaments. The dorsal medial surfaces of the base of the first metatarsal and the first cuneiform have a single, thick, strong, ligament. Three dorsal ligaments attach the superior aspect of the second metatarsal with the dorsum of the first, second, and third cuneiform by three flat bands that fan out. The adjacent dorsal articular surfaces of the third metatarsal and the lateral cuneiform have a single flat dorsal ligament. Occasionally an accessory band that makes dorsal attachments to the base of the third metatarsal, the third cuneiform, and the cuboid can be identified. The fourth metatarsal base is invested dorsally with the cuboid laterally and the anterolateral angle of the third cuneiform. The fifth metatarsal base has attachment on its dorsolateral aspect to adjacent surface of the cuboid by a single strong flat band. (9)

2- *Plantar Tarsometatarsal Ligaments:*

These are arranged with less regularity than on the dorsum. Both longitudinal and oblique fibers are apparent. The first cuneometatarsal joint has the strongest of these flat bands. No plantar ligament exists between the second cuneiform and the base of the second metatarsal. (9)

3- Interosseous Tarsometatarsal Ligaments:

No inerosseous ligaments relate to the base of the first metatarsal. There are only three such tarsometatarsal ligaments, and two relate to the second metatarsal. A constant interosseous band makes attachment between the anterolateral angle of the first cuneiform and the contiguous tibial aspect of the second metatarsal. An inconstant band makes attachment between the anteromedial angle of the third cuneiform and the adjacent base of the second metatarsal. The third makes interosseous attachments between the third cuneiform at its posterolateral angle and the contiguous aspect of the fourth metatarsal base. [9] (Fig. 6)

Normally, the tarsometatarsal joints have a modest range of motion. They may be involved in arthropathy. Secondary pathology may occur if they are required to perform excessive compensatory movements due to functional limitations in their proximal or distal neighbours e.g. where

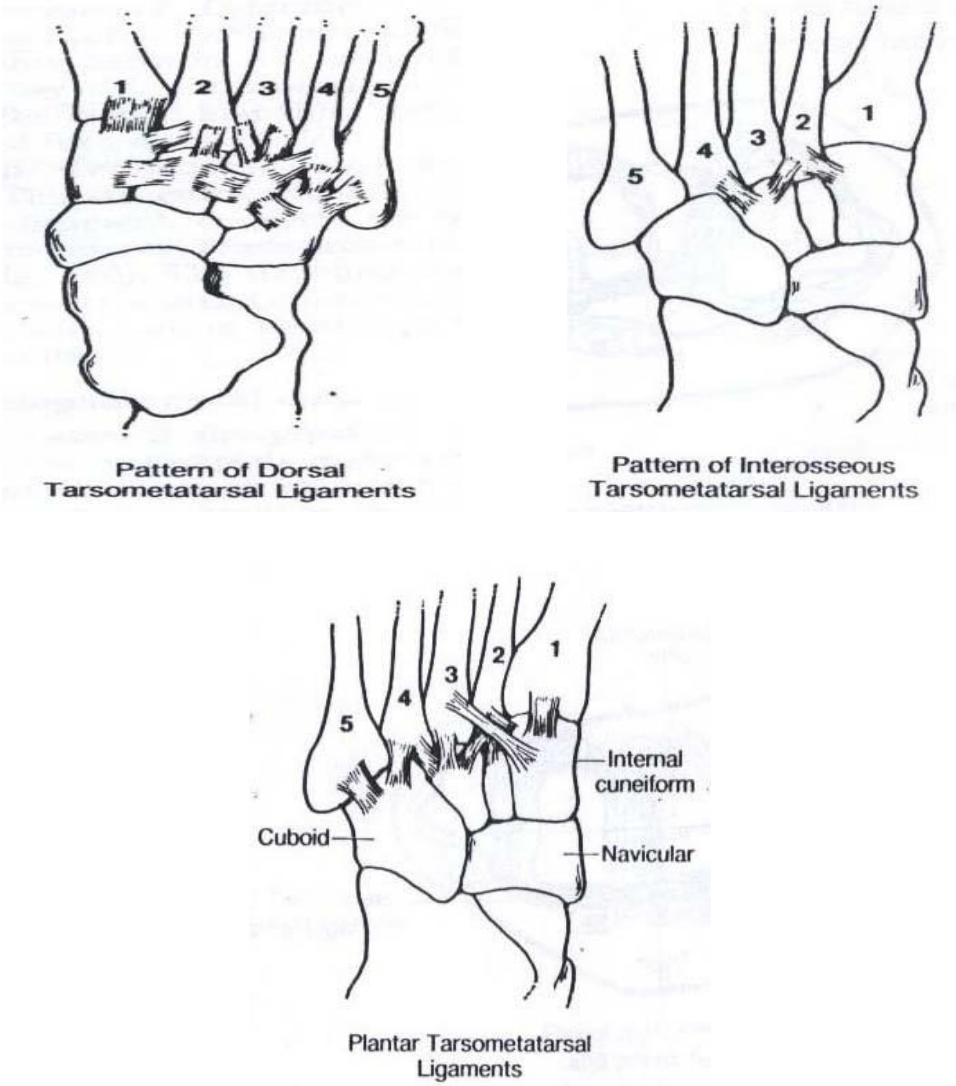

Fig.6: Tarsometatarsal Ligaments [8]

dorsiflexion of the metatarsal at its metatarsophalangeal joint is restricted, when the required movement may be imposed more proximally on the tarsometatarsal joint forcing it to undertake atypical huge movement, the resulting abnormal stress on the dorsal articular margin and adjacent periosteum may induce local reactive proliferation exostosis. (12)

Intermetatarsal joints

The synovial membranes between the second and third, and the third and fourth metatarsal bones are part of the great tarsal synovial membrane; that between the fourth and fifth is a prolongation of the synovial membrane of the cuboideometatarsal joint. (5)

* Ligaments support:

1- *Dorsal Intermetatarsal Ligaments:*

These orient obliquely on the dorsal surface of respective second and third metatarsals, the third and the fourth metatarsals (the strongest) and the fourth and the fifth metatarsals. (9) These are thin, small, and flat fibrous bands.

2- *Plantar Intermetatarsal Ligaments:*

These angle obliquely medially and slightly anterior as they make plantar attachments as described for the bases of the lesser metatarsals. They are however, stronger than those on the dorsum. (4)

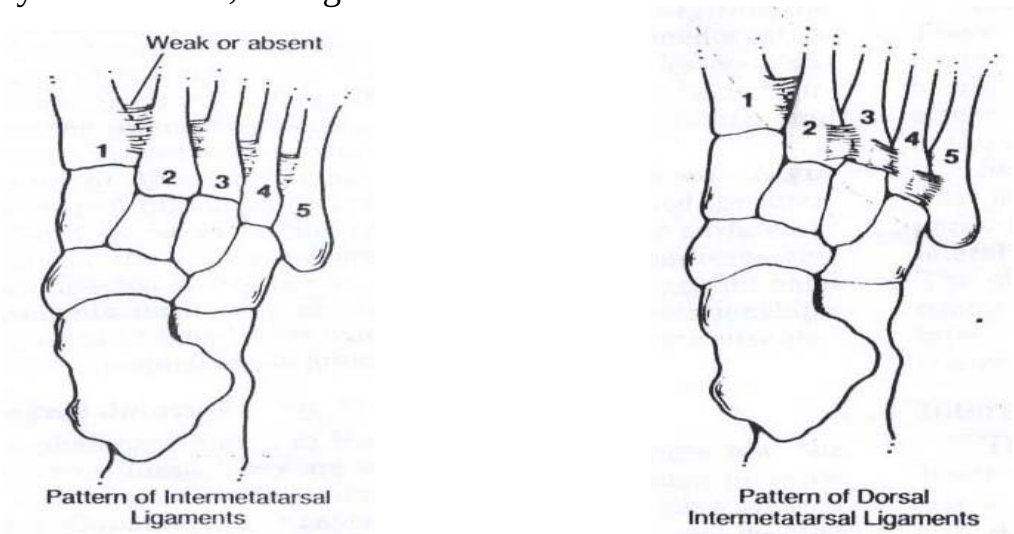

Fig. 7: Intermetatarsal Ligaments (8)

3- Interosseous Intermetatarsal Ligament:

Short but strong ligaments establish stability between the bases of the lesser metatarsals. They make attachments between adjacent surfaces of the second and third, third and fourth, fourth and fifth metatarsals. [6] (Fig. 7)

Metatarsophalangeal joints

The heads of the five metatarsals and the base of the adjacent proximal phalanges articulate by synovial condylar joints where principal movements are dorsiflexion and plantar flexion. Located in the ball of the foot, they provide the link between the forefoot and the digits. Their integrity is essential in their role as a fulcrum whilst the heel is raised and weight is transferred forward onto the ball of the foot and the toes during propulsion just before structures leave the ground. Bursae are not infrequently found between the metatarsal heads and may be a cause of metatarsalgia. [13]

* Ligaments support:

1- *Plantar ligaments:*

The plantar capsule is thickened by a plantar plate that is supported or suspended by the collateral and suspensory glenoid ligaments. The transverse metatarsal ligament invests and interconnects contiguous metatarsal plantar plates. Additionally, the plate provides attachments for elements of the tendon sheath of muscle flexor digitorum longus and brevis. [9] Additionally, vertical and longitudinal septae from the plantar aponeurosis, the transverse head of adductor hallucis and the metatarsal adipose cushion provide support for the metatarsophalangeal joint. [4] The plantar plate makes attachments on its dorsal aspect for the metatarsoglenoid suspensory ligament: the lamina of the extensor hood apparatus (aponeurosis), and the respective interossei. [14]

2- Metatarsophlangeal Collateral Ligaments:

These make attachments on superiorly situated lateral tubercles of the respective lesser metatarsal heads. Fibers are directed anteriorly to make a distal attachment on the inferiorly placed lateral tubercles on the bases of the respective proximal phalanx. [4]

3- Suspensory or Metatarso-glenoid Ligament:

This is a fan-shaped fibrous structure having its superior attachment on the posteroinferior aspect of the lateral tubercle of the respective metatarsal heads. The obliquely directed fibers relate to those of the collateral ligaments until they diverge to make an inferior attachment to the plantar plate of the respective plantar metatarsophalangeal joints. (9)

The first metatarsophalangeal joint: Though morphologically and functionally similar to the other metatarsophalangeal joints, that of the hallux is longer, and has two special features:

A. The plantar plate contains two sesamoids, one medial and one lateral which articulate with the metatarsal head. This articulation is marked by medial and lateral grooves on the plantar and distal surface of the metatarsal head. (15)
B. The fist digital slip of the plantar aponeurosis attaches to the proximal border of the plantar plate, which tighten as winch around the first metatarsophalangeal joint during dorsiflexion of the hallux by approximating the medial longitudinal arch and increasing its height. (16)

All components of the lower extremity must function properly for efficient ambulation. Weaknesses of musculature, loss of joint motion, bony malalignment or destruction of soft tissue each produces gait abnormalities. Alterations of gait, because of impairment of one function, put excessive stress on the remaining structures to compensate for this deficiency. Thus, injury to any one component of this complex mechanism results in excessive stress on the other components and with time, this excessive stress may lead to deterioration of the uninjured parts. (17)

Distribution of stresses during standing

The weight of the body, transmitted by the lower limb, is applied through the ankle to the posterior part of the foot at the level of the trochlear surface of the talus. From there the forces are distributed in three directions towards the supports of the vault:

1- Towards the anterior and medial support, via the neck of the talus and the anterior buttress of medial arch.

2- Towards the anterior and lateral support, via the head of the talus, the sustentaculum tali of the calcaenus and the anterior buttress of the lateral arch.

3- Towards the posterior support, the body of the talus, the subtalar joint, and the body of calcaenus (the bony trabeculae underling the superior articular surface) i.e. through the common posterior buttress of the medial and lateral arches. (18)

Biomechanics of the Metatarsal Heads

All of the metatarsals sustain the body's weight. One-half of the body weight passes through each ankle minus the weight of the foot. Half of the force on the foot passes to the five metatarsal heads and the remaining half passes to the heel. If plantar weight bearing is divided into 12 units, 6 units will pass to the heel and 6 units will pass to the forefoot. Of the six units under the metatarsal head, each of the lesser metatarsals takes one unit and the first metatarsal head takes 2 units. Therefore the first metatarsal normally carries approximately twice as much weight as each lesser metatarsal. (19)(20)