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Sesamoids

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The hallucal sesamoids may seem minute in proportion to all the other bones of the body, but they are a major factor in the function of the first metatarsophalangeal joint. A review of the literature reveals that many have written of the mystique of the sesamoids, particularly the medial sesamoid.¹⁻⁵ It was believed that the medial sesamoid was an indestructible seed from which the body would be resurrected on the day of judgment. Helal quotes the writings of Rabbi Ushaia in AD 210 from the book *Bereschit Rabbi*²:

This bone (Luz) can never be burned or corrupted in all eternity for its ground substance is of celestial origin and watered with heavenly dew, wherewith God shall make the dead rise as with yeast in a mass of dough.

The name "sesamoid" itself is said to have been coined by Galen, stemming from the flat, oval seeds of the *Sesamum indicum* plant.¹ These seeds were used by the Greek physicians for purging.

The presence of the sesamoids at the third fetal month was detected by Nesbitt in 1736,¹ yet the belief of their existence secondary to trauma of the tendon held on through the late 1800s. Nesbitt's findings were finally confirmed in 1892 by Pfizner.¹ Through the following years, the question of their origin arose. Some believed their anlage was from that of the tendon, yet others believed it to be from the joint capsule. In any event, the consensus of their constant presence from fetal life was established.

EMBRYOLOGY AND OSSIFICATION

As mentioned, Nesbitt first published the finding of sesamoid anlage in the third fetal month. Jahss³ writes that the sesamoids are formed in separate cartilaginous centers and are not from articular budding. Inge and Ferguson¹ noted islands of undifferentiated connective tissue as early as 8 weeks of fetal growth. At 10 weeks, this tissue is recognized as precartilaginous, with centers of chondrification at the twelfth week. These authors^{1,3} go on to state that by the fifth month these bones reached normal adult shape and only develop further in size. The sesamoids remain as cartilaginous tissue and only begin ossification about 8 to 10 years of life; they ossify earlier in girls than in boys, at 8 to 9 versus 10 to 11 years of age, respectively.

Vranes⁶ and Wisbrun, as reported by Inge and Ferguson,¹ report the histologic findings are unique. The trabecular pattern of the sesamoid bones is vertically directed in the dorsal aspect with a horizontally directed pattern in the plantar aspect of the bones. They also noted that the most posterior aspect of the sesamoids appears more dense in relationship to the anterior. Vranes however was not addressing this issue and therefore gave no reasoning for this histologic difference. Wisbrun correlated this histologic difference to a "greater percentage of weight-thrust" being directed through this portion of the sesamoid. The

forces placed upon the sesamoids results from their anatomic position, the structural location of tendon attachment, and vector stresses. Indeed, this would follow Wolfe's law of stresses and explain the unique finding.

ANATOMY

The sesamoids, located inferior to the metatarsal head, articulate via two separate cartilaginous surfaces that are separated by a crista on the metatarsal head. The medial sesamoid is larger than the lateral, both varying in shape and size.

The medial sesamoid ranges in size from 12 to 15 mm. by 9 to 11 mm. and 7 to 20 mm by 5 to 12 mm, and the lateral sesamoid varies between 9 to 10 mm. by 7 to 9 mm. and 6 to 16 mm. by 4 to 14 mm.^{6,7} Their general radiographic appearance on the anteroposterior is ovoid view, and on axial view a concave plantar surface and convex or flat superior surface is noted.⁷ The sesamoids can be bi-, tri-, or quadripartite, with the medial sesamoid having a greater incidence of this finding. Partition is covered later in this chapter.

The sesamoids are housed within an intricate network of ligaments, tendons, and capsular structures, all of which function uniformly about the first metatarsophalangeal joint (Fig. 10-1). The sesamoids are enveloped within the flexor hallucis brevis muscle tendon with the exception of the superior aspect, which is covered with hyaline cartilage to articulate with the first metatarsal. The articulating surface on the metatarsal is about 1.2 times greater than that of the corresponding sesamoid.⁸ The sesamoids are separated by a crista on the metatarsal head, and the tendon of the flexor hallucis longus muscle passes between them.

The abductor hallucis muscle tendon and joint capsule are also attached to the medial sesamoid. The lateral sesamoid has attachments from the adductor hallucis muscle tendon (both the transverse and oblique heads) and also from the joint capsule. The ligamentous structures participating in the network include the intersesamoidal ligament, running between the sesamoids, and the deep transverse intermetatarsal ligament that attaches to the fibular sesamoid. It is also noted that fibers of the plantar aponeurosis attach to both sesamoids.⁹

David et al.¹⁰ also note that the extensor hallucis longus tendon sends expansions to invest into this complex network. These authors, in fact, refer to the extensor hallucis longus, abductor hallucis, flexor hallucis longus, and adductor hallucis as the sesamoid muscles. Overall, the sesamoids are not merely bones that absorb shock during gait but are an integral part of the function of the first metatarsophalangeal joint. Because of their contribution, any deformity that exists must be addressed if correction of this function is to be attained.

ARTERIAL SUPPLY

The vascular supply of the sesamoids has recently been noted to be primarily from the first plantar metatarsal artery.^{8,11} Pretterklieber and Manivenhaus⁸ report three variations. In type A, the sesamoids are supplied by the medial plantar artery and the plantar arch; in type B, they are supplied by the plantar arch alone; type C is solely supplied by the medial plantar artery. The incidence of these types is 52, 24, and 24 percent, respectively. Sobel et al.¹¹ more recently reported the major vascular supply to the sesamoids as the first plantar metatarsal artery; however, he also notes that the artery branches into a medial and lateral branch. The proximal one-third to two-thirds of each sesamoid was supplied via this route through a further proximal and a plantar branch. A third, distal arterial branch was noted, but was found to be inconsistent, most often only supplying the distal plantar plate. Sobel et al. also noted the absence of vascularity to the lateral capsular and intersesamoidal ligamentous attachments.

Pretterklieber⁸ notes that excessive dissection about the lateral border of the fibular sesamoid may disrupt its vascular supply. Sobel et al.¹¹ reports the arterial supply comes from a proximal location and penetrates through the flexor hallucis brevis muscle tendon before supplying the sesamoids. If the flexor hallucis brevis tendon attachment of the fibular sesamoid is preserved and only an adductor release is performed during hallux abducto valgus surgery, the sesamoid should not become vascularly compromised.

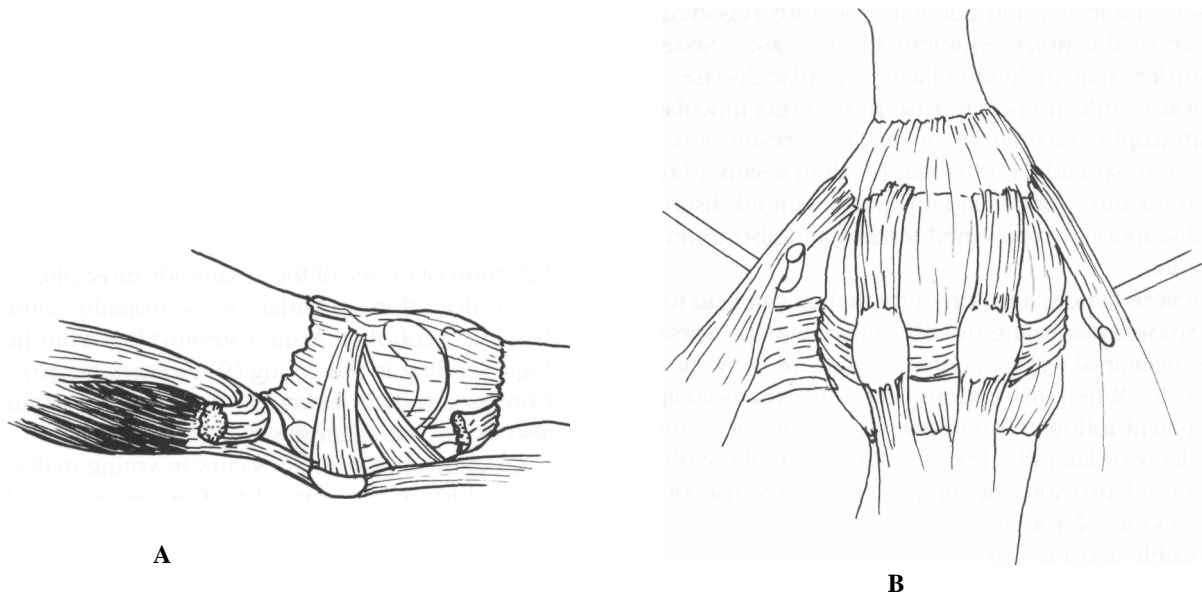


Fig. 10-1. Normal anatomy of first metatarsophalangeal joint and sesamoid apparatus (A) Lateral view; (B) plantar view.

PATHOMECHANICS

To better understand the pathomechanics of the first metatarsophalangeal joint and sesamoid function therein, one must understand the normal function of this joint. Root et al.¹² described the normal first metatarsophalangeal joint as having two axes of motion: one in the transverse plane, allowing for sagittal plane motion, and another in the sagittal plane, allowing for transverse plane motion albeit small. They further describe the joint as being ginglymus in the transverse plane and ginglymoarthrodial in the sagittal plane. The joint functions as a ginglymus joint in the first 20° to 30° of dorsiflexion, but beyond that range requires the first ray to plantar-flex. The sesamoids at this point articulate more distally with the metatarsal head. Root et al. go on to describe four primary factors necessary for normal function during the propulsive phase of gait, one of which is normal sesamoid function.

As was noted earlier, the flexor hallucis longus tendon passes between and plantar to the sesamoids. This acts as the second pulley system for the flexor hallucis longus tendon, which becomes functional after heel

lift and thus as the first ray plantar-flexes. Normal function with the metatarsal is necessary for the flexor hallucis longus tendon to maintain its most mechanical advantage in stabilizing the hallux in the sagittal plane against ground reactive forces. In addition, the sesamoids also absorb shock at forefoot load, distributing the ground reactive forces and thus protecting the metatarsal head.

The sesamoids, with all their soft tissue attachments, will for the most part remain stationary as the first metatarsophalangeal joint begins to function abnormally. This abnormally functioning joint can result in metatarsosesamoid articulation malalignment or may be a direct result of sesamoid dysfunction. Jahss³ describes disorders of sesamoids as including congenital variations, systemic disorders, heritable disorders, infection, trauma, osteochondritis, and parasesamoid disorders. With reference to congenital variations, congenital absence^{3,12,13} and also partition would fall under this category.

Inge and Kewenter, in 1936, both reported congenital absence of the tibial sesamoid, and Lapidus, in 1939, and Hulay, in 1949, subsequently reported single

cases. Zinmeister and Edelman,¹³ in 1985, reported absence of the tibial sesamoid in two cases. Systemic disorders may include collagen vascular diseases and psoriasis. Infections may arise from direct inoculation from trophic ulcerations or may be a result of hematogenous spread. Trauma may result in sesamoiditis or even fractures. Jahss explains parasesamoid disorders as disruption of conjoined tendon and also traumatic neuritis.

Severe hyperextension of the hallux can lead to the sesamoids displacing distally and eventually dorsal to the metatarsal with concomitant rupture of the plantar capsule.³ When dislocations occur, the sesamoid apparatus will follow the phalanx, which can move either medially or laterally. The lateral position of the fibular sesamoid provides better protection because of the soft tissue of the first intermetatarsal space, which probably accounts for the greater frequency of tibial sesamoid trauma reported in the literature.

In an abnormally functioning foot in which the first ray becomes hypermobile, the first ray rotates in the frontal plane and adducts. This in turn causes all the soft tissue attachments and structures to rotate and thus lose their original balance and mechanical advantages. Because the sesamoids are attached to the tendon and ligaments, they remain relatively stationary. The deep transverse intermetatarsal ligament keeps the sesamoids from moving medially as the metatarsal progressively shifts in that direction. Consequently, the crista on metatarsal head will eventually wear away, thus resulting in a malfunctioning metatarsos-sesamoid joint. David et al.¹⁰ describe four stages of the loading of the foot in relationship to the functional role of the sesamoids: (1) suspension of the first metatarsal head, (2) fixation of the first metatarsal head, (3) coordination, and (4) the propulsion stage. The first stage corresponds to heel contact to forefoot load in which the first ray plantar-flexes and the sesamoid apparatus suspends the first metatarsal head, acting much like a harness. The second stage consists mainly of fixating the sesamoid apparatus on the ground, making adjustments via isometric contractions of the flexor hallucis brevis, abductor hallucis, and adductor hallucis muscles, and thus acts as the reference point for the later stages. The third stage allows motion of the proximal attachments of the sesamoid muscles with the hallux firmly fixed against the ground, preparing for the fourth stage. The final stage allows for

conversion of energy, stored within the flexor hallucis muscle tendon, into kinetic energy allowing for propulsion. David et al. concluded that the function of the sesamoid apparatus is to distribute and coordinate forces placed upon the forefoot for propulsion and balance.

INFECTION

Infection of either of the sesamoids most often results from ulceration secondary to neuropathy, either diabetic or alcoholic.³ Acute osteomyelitis from hematologic seeding in the young (9-19 years of age) is rare. Chronic infection secondary to a puncture wound may also occur but again is rare.

Osteomyelitis usually occurs in young males, often with a history of trauma, blunt or penetrating.¹⁴ Early recognition can be difficult, and the differential may include fracture, sesamoiditis, soft tissue abscess, or cellulitis. It should be pointed out that radiographic changes from hyperemic resorption may mimic osteomyelitis and thus careful review of the history and follow-up radiographs may be necessary for differentiation (Fig. 10-2).

Treatment consists of antibiotic therapy, keeping in mind that the infection may recur in subsequent weeks. If it does, then excision of necrotic bone is necessary. The most effective treatment for local ulceration and infection is conservative with local wound care and infection control.

SESAMOIDITIS

Sesamoiditis may or may not present clinically as a localized redness and swelling about the plantar surface of the sesamoid apparatus. It may present with a callus inferior to either the tibial or fibular sesamoid in cases of a plantar-flexed first ray or may result from a recent onset of athletic activities creating a pathologic process of inflammation of the subsesamoid bursae. In any event, differentiating sesamoiditis from osteochondritis, fracture, or infection is necessary.

Sesamoiditis should be differentiated also from neuritis of the medial plantar digital nerve, bursitis, and simple excessive weight-bearing.¹⁵ Radiographic

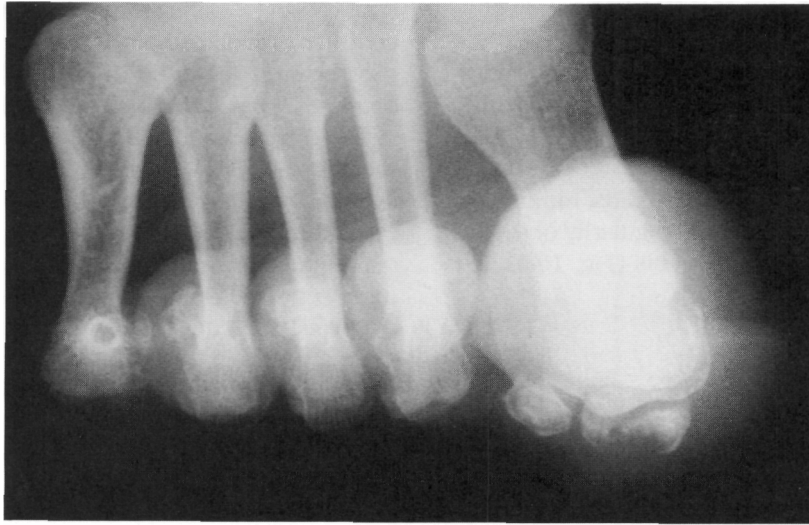


Fig. 10-2. Forefoot axial radiograph of osteomyelitis of the tibial sesamoid.

changes are not seen with sesamoiditis, and bone scans may prove equivocal.¹⁶ Thus, diagnosis of sesamoiditis is essentially based on history and clinical presentation of localized pain and tenderness.

Treatment of sesamoiditis is conservative, and may include taping, strapping, or padding to accommodate for a plantar-flexed first ray, or orthoses to decrease

the weight-bearing of the first ray and function about the subtalar joint. Local anesthetics or steroids may be injected also. A cast may be utilized to immobilize and decrease weight-bearing of the first metatarsophalangeal joint. If pain persists after all palliative care has been tried, then a sesamoidectomy should be considered.

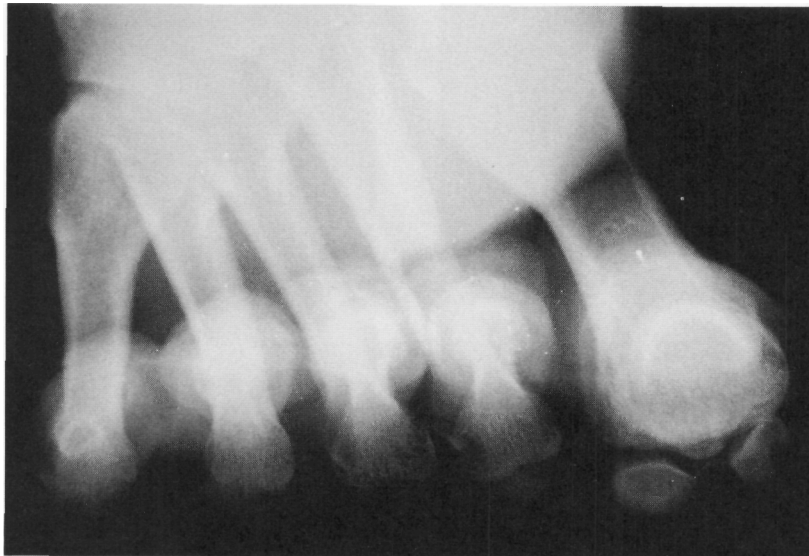


Fig. 10-3. Forefoot axial radiograph depicting osteochondritis of the tibial sesamoid.

OSTEOCHONDRITIS

Some have correlated sesamoiditis with other entities such as osteochondritis.² Osteochondritis of the medial sesamoid was first described by Renander in 1924. It may occur either in the medial or lateral sesamoid or rarely, bilaterally. Unlike sesamoiditis, radiographs will ultimately reveal lytic areas, irregularity of the sesamoids, and some areas of sclerosis (Fig. 10-3). It is advised to take multiple views.

PARTITIONS

The hallucal sesamoids resemble the other sesamoids in that they may present with more than one center of

ossification.¹ Ossification of the lateral sesamoid precedes the medial sesamoid.³ Failure of the multicentric centered sesamoid to fuse will result in a bi-, tri-, or multipartite sesamoid (Fig. 10-4).

The reported incidence of partition varies from 7.8 to 33.5 percent, with partition of the tibial sesamoid occurring with greater frequency, 10 times more often than the lateral sesamoid.^{2,3,6,14,16} Jahss³ reported 85 percent of partitioned sesamoids are bilateral whereas Inge¹ reported only 25 percent. As described earlier, ossification begins about the eighth year in girls and the tenth year in boys. Multiple centers may exist, and ossification with failure to fuse will result in a partitioned sesamoid. The sesamoids will present with irregular shapes and sizes (Fig. 10-5).

Vranes⁶ classified the etiologies of partitioned ses-



Fig. 10-4. (A) D-P view of bipartite fibular sesamoid. (B) D-P view of multipartite tibial sesamoid.



Fig. 10-5. Hypertrophic fibular sesamoid.

moids as phylogeny, congenital, failure of fusion, heredity, constant stress/microtrauma, and biomechanical abnormalities. The results of his study indicate no sex difference, commonality among all age groups, a 19 percent frequency of finding at least one partite sesamoid, and a greater incidence of tibial versus fibular involvement. Others have found similar patterns of frequency with respect to bi-, tri-, and quadripartite sesamoids.^{1,17}

It has been mentioned that partitioned sesamoids may be caused by a vascular disturbance.^{1,11} This may result from direct trauma or constant microtrauma interrupting the plantar blood supply at the time of ossification. Sobel et al.¹¹ found that bipartite sesamoids lacked the plantar vessels, thus supporting this finding.

The frequency of incidence with partition of the tibial sesamoid and weight-bearing load may correlate with the vascular etiology.

With respect to the clinical scenario of a painful first metatarsophalangeal joint, the clinician must ascertain if it may have been direct trauma or indirect trauma. Direct trauma would be a fall from a height landing on the sesamoid apparatus. Indirect trauma may be a hyperextended hallux that thus caused undue stress on the sesamoid apparatus and possibly fracture or ligamentous injury. Therefore, it becomes evident that delineation between a fractured sesamoid and a partitioned sesamoid is necessary. Inge and Ferguson¹ note that incidental finding of a partitioned sesamoid without the complaint of pain is possible. The clinician is thus faced with treating this complaint as a sesamoiditis, fractured sesamoid, or distracted partition.

It should be noted that the radiographic findings differ between a partitioned and fractured sesamoid such that these may help in diagnosing the patient's problem. However, the findings are not always clear-cut and thus may not assist in the diagnostic impression. One should find a smooth edge between pieces in a partitioned sesamoid, whereas a fractured sesamoid will appear jagged^{18,19} (Fig. 10-6). It should also be borne in mind that if one were to reassemble a fractured sesamoid, its size should be similar to that of the other sesamoid. In addition, a bipartite sesamoid usually presents with the partition running medial to lateral on anteroposterior view. A higher suspicion of fracture is warranted in cases in which the partition courses obliquely or longitudinally¹⁹ (Fig. 10-7). Oftentimes, however, the patient does not present directly after the trauma and because of this the radiographic criteria mentioned here may not be helpful. The appearance of bilateral partite sesamoids may not help in diagnosing the fractured sesamoid because their incidence bilaterally is less common.^{4,6} The only way to ascertain a true fracture from a partition is if previous films have been obtained. To complicate matters further, it would be wise to recall that a partite sesamoid may separate when traumatized and thus become symptomatic and resemble a fracture.^{4,14,20} If this proves to be the case, a view can be taken with the hallux in forced dorsiflexion and plantar flexion and the distance between fragments then measured. This will help in delineating between fracture and partition.¹⁹



Fig. 10-6. (A) Lateral oblique view shows fractured tibial sesamoid. (B) Medial oblique view shows fractured fibular sesamoid.



Fig. 10-7. D-P view shows oblique fracture of tibial sesamoid.

SUMMARY

The involvement of the sesamoid apparatus with the function of the first metatarsophalangeal joint is more than distribution of ground reactive forces to protect the metatarsal head, shock absorption, and protection of the flexor hallucis longus tendon; the sesamoids help to maintain the highest mechanical advantage possible with respect to associated muscles and tendons. As with any precision equipment, deviation results in inefficiency and possible wear and degradation. This scenario will eventually cause progressive malalignment and abnormal function, which ultimately lead to hallux abducto valgus deformity and associated sesamoid complications.

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