

Symptomatic Bipartite Sesamoids

The great toe sesamoids have been well reported in the literature, in every aspect. Much has been written about the normal anatomic variation of partite metatarsophalangeal sesamoids. It is the purpose of this article to present a theory explaining the common occurrence of a symptomatic partite sesamoid. The authors believe there is a high rate of occurrence of symptomatic partite sesamoids, especially when associated with hallux abducto valgus. Presented is information concerning the internal and external structural components of a bipartite metatarsal sesamoidal joint, which may inherently lead it to symptomatology.

Jared P. Frankel, DPM, FACFS¹
Joan Harrington, DPM²

The sesamoid bones of the great toe, which are small and may appear as insignificant bones, can be the site of disabling pathology. Because of the anatomic placement of these bones, they receive the brunt of the body's weight with each step. Therefore, any structural abnormality can cause discomfort in gait, not to mention athletic activities. It is at this time, when symptoms arise, that pathologic conditions of these bones can be overlooked and the patient is diagnosed as having "sesamoiditis." Hence, one must be aware of anatomical variations as well as pathologic states that can present with the classic symptoms of "sesamoiditis," such as symptomatic partite sesamoids, stress fracture, and osteochondritis.

Although it may appear elementary to diagnose pathology such as the above mentioned few, an area of confusion lies with a painful sesamoid that displays a divisionary line. This, in the past, has been argued to be either a fractured sesamoid or a normal bipartite anatomical variation. Golding (1) reported three cases of painful sesamoids that radiographically demonstrated a sesamoid bone with its two halves separated. He states, were they congenitally bipartite bones? This is improbable, because in this condition, separation would be unlikely to occur (1). The purpose of this article is to present that a normally occurring partite sesamoid can progress to a symptomatic sesamoid with a high rate of occurrence due to movement of adjacent parts against one another or fracture of the fibrocartilage union between the two osseous units.

From the Department of Podiatric Surgery, Leyden Community Hospital, Northlake, Illinois.

¹ Diplomate, American Board of Podiatric Surgery, Residency Director.

² Submitted during first year residency. Address correspondence to: 365 E. North Avenue, Northlake, Illinois 60164.
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Anatomy

Within the seventh or eight week of embryonic life, both sesamoid bones of the hallux appear as islands of undifferentiated connective tissue within the tendon of flexor hallucis brevis. During the twelfth week of gestation, chondrification begins, but ossification will not occur until 8 to 10 years of life (2). There may be two or more ossification centers, and these may or may not coalesce. Thus, bi-, tri-, and even quadripartite sesamoids may be present in the adult.

The classic article by Kewenter (3) reported a 35.5% incidence in 1588 feet of partite sesamoids, with the bipartite variation most frequent, and the medial being affected 34% of the time compared to a 2% incidence of the lateral sesamoid. Jahss (4) reports a 7.8 to 33.5% incidence of bipartite sesamoids, with a tenfold incidence of tibial sesamoid involvement as compared to the fibular sesamoid. He also stated that 85% of partite sesamoids have bilateral involvement. Inge and Ferguson (5) strongly disagree and state that 75% of bipartite sesamoids are unilateral.

A vast amount of research has been performed on the frequency of partition (2, 3, 5-9). Therefore, it is not the authors' purpose to propose any new statistics on this matter. It is relevant only that we agree that partition is a relatively common finding in first metatarsophalangeal joint (MPJ) sesamoids.

The sesamoids, enclosed within the tendon of flexor hallucis brevis, are held in place in their grooves beneath the first metatarsal head by the plantar plate. The plantar plate consists of the intersesamoidal ligament, medial and lateral capsular ligaments, medial and lateral metatarsal sesamoidal and phalangiosesamoidal ligaments. The flexor hallucis brevis has a check-rein association with the adductor hallucis and the abductor hallucis as they insert into the medial and lateral sesamoid complex, respectively.

Function

The sesamoids of the hallux function as points of insertion for intrinsic muscle-tendon units and act as pulleys around which muscle-tendon units continue to the base of the proximal phalanx (10). The angle of the flexor tendons as they insert into the digit is altered by the position of the sesamoids, and they provide a fulcrum by which the efficiency of flexion of the great toe is increased. The sesamoids serve as shock absorbers by dispersing impact forces on the metatarsal head. The sesamoids also provide protection for the flexor hallucis longus tendon as it courses between them.

Pathophysiology

As the first MPJ goes through its range of motion in the sagittal plane, the sesamoid complex moves in conjunction. In midstance, the MPJ is in flexion, and the sesamoids lie inferior and slightly proximal in relation to the head. At toe-off, the MPJ is in maximum extension and the sesamoids shift distally and lie directly inferior to the head of the metatarsal. It is in this position of full extension that injury can occur to the sesamoids. The medial sesamoid tends to be involved in injury more often than the lateral one, since weight is normally transmitted through the medial bone and the medial bone is mainly stressed in MPJ extension (11).

It is normal for the body's weight to be transferred from the lateral aspect of the heel to the medial aspect of the hallux as the foot goes through the gait cycle, in relation to the sagittal plane. One must also be aware of the rotational qualities of the first metatarsal, as this affects the weight distribution in relation to the transverse and frontal planes. In a patient with normal first MPJ range of motion, without any angular deformity, as the peroneus longus functions to plantarflex the first ray at toe-off, the first ray plantarflexes and everts around its axis of motion, and the tibial sesamoid becomes more prominent plantarly (Fig. 1). In a patient with an angular deformity present at the first MPJ and a peroneus longus that does not function appropriately in gait, the first ray may dorsiflex and invert at toe-off. This may lead one to think the fibular sesamoid would be most prominent, but the primary deformity resulting from a nonfunctioning peroneus longus muscle at toe-off is hallux abducto valgus. The progression of the hallux valgus deformity causes the fibular sesamoid to drift into the innerspace and the tibial sesamoid becomes prominent under the first metatarsal head (Fig. 2).

Any angular change occurring at the MPJ will also affect the function of the sesamoids. A study by Scranton and Rutkowski (2) through dissections, radio-

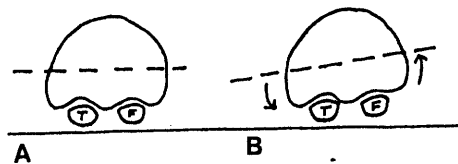


Figure 1. Illustrates a frontal plane cross-section of the metatarsophalangeal-sesamoid joint. A, rectus attitude of the first metatarsal allows even distribution of weight to the tibial (T) and fibular (F) sesamoids; B, everted attitude of the first metatarsal stresses the tibial sesamoid.

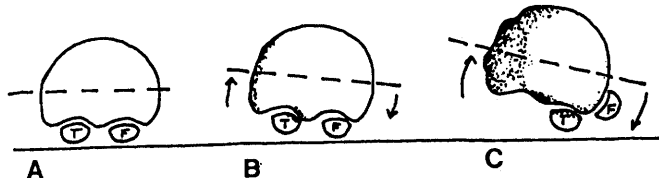


Figure 2. "Sesamoid drift" A, rectus position; B, mild hallux abducto valgus causing tibial (T) sesamoid abutment with crista, as crista erodes; C, tibial sesamoid contacts fibular (F) facet, and fibular sesamoid drifts into the interspace.

graphic study, and case reports, found a close correlation between structural malalignment and degenerative pathology at the metatarsophalangeal-sesamoid joint. They found that anatomic variations such as hallux abducto valgus, long first metatarsal, enlarged tibial sesamoid, metatarsal rotational abnormalities, and condylar anomalies are closely correlated with the incidence of chronic sesamoiditis, painful bipartite sesamoids, and chronic nonunions.

It has been well documented that in the progression of hallux abducto valgus, with adduction of the first metatarsal and abduction and valgus drift of the hallux, the sesamoids will begin to lie more lateral in relationship to the first metatarsal head. The most common dislocation of the sesamoids is a relative displacement of both sesamoids, as a result of medial deviation of the first metatarsal, in hallux valgus (12, 13). Scranton and Rutkowski (2) categorized sesamoidal drift so that the sesamoids were considered subluxed if there was lateral displacement, but both sesamoids still touch the metatarsal articular surface. They were considered dislocated if the medial sesamoid articulated with the lateral metatarsal facet, and the lateral sesamoid was displaced into the intermetatarsal space (2). When subluxation occurs, tibial sesamoid position two to four, degenerative changes are caused by abutment of the medial sesamoid upon the crista of the metatarsal. The authors find this the primary cause of sesamoiditis associated with mild hallux abducto valgus (HAV). In brief review, tibial sesamoid position (TSP) describes the placement of this sesamoid in relationship to the head of the first metatarsal. Tibial sesamoid position

one describes the sesamoid positioned medial to the longitudinal bisection of the first metatarsal. In TSP two, the sesamoid touches this bisection; position three is the sesamoid crossing the bisection by one-third, and position four is the sesamoid divided in half by the bisection. In TSP five, the sesamoid is two-thirds across the bisection; and in position six the sesamoid merely touches the lateral side of the bisection. In TSP seven, the tibial sesamoid is in the fibular sesamoid position. In a case of bipartite tibial sesamoid associated with a hallux abducto valgus deformity, the same abutment occurs, but the sesamoid typically is enlarged and can elicit more symptomatology (Figs. 3 and 4). Also, as the tendons become bowstrung around the first MPJ axis, the tibial sesamoid becomes a fulcrum as it abuts against the crista. It is the authors' opinion that if this

sesamoid were a bipartite one, the inherent weakness of the fibrocartilage interphase would have difficulty withstanding the tension of the opposing tendinous forces and may allow for spreading of the cartilage bridge or shearing forces created within the interphase, causing micromovement of the opposing surfaces, creating symptoms similar to a chronic non-union (Fig. 5).

Histopathology

The histologic composition of cartilage and bone is beyond the scope of this article. However, a few important concepts are key to understanding the topic of symptomatic partite sesamoids. A number of surgically excised symptomatic sesamoids were sent for pathologic study, to be cross-sectioned and to identify the soft tissue interphase between the two separate ossification centers (Fig. 6). Of striking consistency, the report of surgical pathologic examination stated the specimens consisted of fragments of bone and fibrocartilage interphase with reactive changes. Histologic sections of one such specimen included two ossification centers with intervening fibrocartilagenous tissue showing focal areas of degeneration with irregular and frayed margins (Fig. 7). From numerous similiar reports, the authors are convinced that the interphasing tissue present between the separate ossification centers in a partite sesamoid is indeed fibrocartilage. This leads to a need for a brief discussion concerning the physical properties of fibrocartilage.

Cartilage is a form of connective tissue composed of

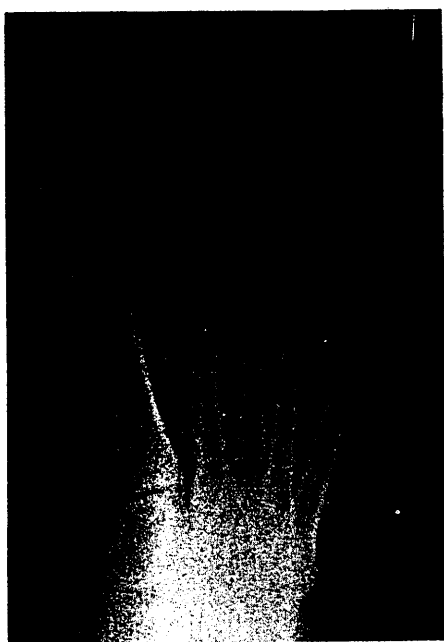


Figure 3. Anteroposterior radiograph indicates mild/moderate hallux abducto valgus (tibial sesamoid position three and four).

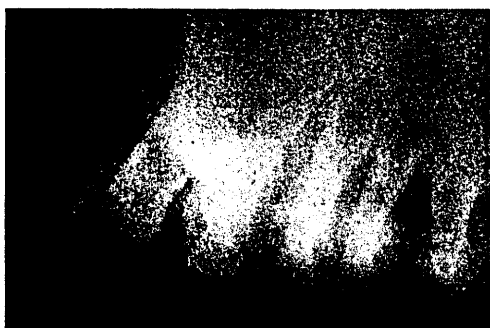


Figure 4. Axial sesamoid radiograph indicates tibial sesamoid abutment with crista, producing erosion, associated with mild-to-moderate hallux abducto valgus.

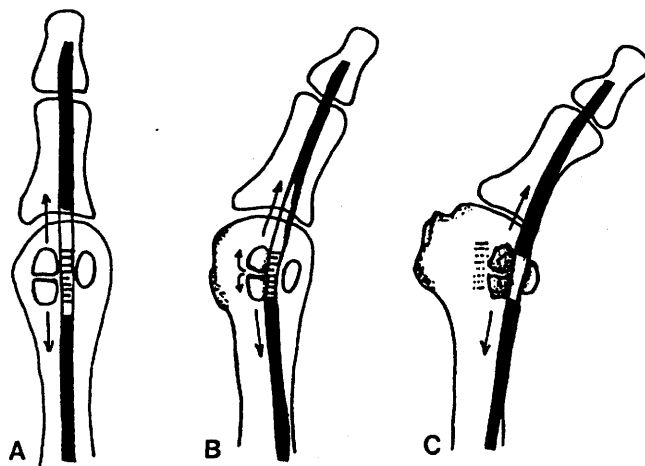


Figure 5. A, rectus joint. Note equal distraction force on tibial sesamoid. B, mild-to-moderate hallux abducto valgus. Note tibial sesamoid abutment with crista creates a fulcrum about which the flexor hallucis longus functions, causing a greater distraction force medially. C, severe hallux abducto valgus with crista erosion. Note, again, the distraction force on the tibial sesamoid is more equalized.

chondrocytes in a highly specialized extracellular matrix. The matrix of cartilage is solid and firm, although somewhat pliable, and this accounts for the special resilient properties of cartilage. The matrix of fibrocartilage contains obvious bundles of collagen fibers.

Usually, the presence of fibrocartilage indicates that resistance to both compression and shear are required of the tissue (14). The fibrocartilage bridge present in a partite sesamoid may function similar to a syndesmosis. A syndesmosis is a joint, wherein closely apposed bones are held together by an interosseous ligament, which permits only a modest degree of movement between the connected bones (15).

The strength of cartilage is consistent with the amount of collagen in the matrix. Therefore, fibrocartilage is the most resistant of all kinds of cartilage (16). Fibrocartilage is, however, much less resistant than bone tissue because of the deposition of inorganic constituents in the organic (collagen) intercellular substance.



Figure 6. Anteroposterior radiograph of a surgically excised bipartite tibial sesamoid.



Figure 7. Sections of the sesamoid reveal two ossification centers with intervening fibrocartilagenous tissue interphase. The interphase shows areas of degeneration with irregular and frayed margins (H & E $\times 100$).

Using the aforementioned facts concerning histopathology, the authors believe the following theory. The sesamoid bones of the first MPJ function to absorb stress and to direct and protect the functioning musculature surrounding the joint. This is most efficiently accomplished by a unipartite sesamoid, able to distribute the applied forces in a homogenous manner. Compare this to the same forces being transmitted through a bipartite sesamoid. As a variety of forces project through the sesamoid (compression, shear, traction) the heterogenous histologic composition of a partite sesamoid does not allow the force to be smoothly transmitted. The force must travel through bone tissue, to fibrocartilage, and again through bone tissue. As we know, the physical properties of these two tissues are different. Bone tissue transmits forces through its structure without movement of the bony architecture. However, forces transmitted through fibrocartilage produce a modest amount of movement. It is this movement produced at the fibrocartilage interphase of a bipartite sesamoid that makes the sesamoid become inflamed or symptomatic. Any angular deformity of the first MPJ will compound this theory because an angular deformity decreases the efficiency of sesamoid function and increases the stress/force to be transmitted through the sesamoids.

Radiographic Analysis

Symptomatology of many of the sesamoid pathologies (*i.e.*, stress fractures, painful bipartism, osteochondritis) are similar. They include pain localized to the plantar aspect of the first MPJ area, pain on direct palpation, and pain on weightbearing relieved by rest. Pain is increased with extreme dorsiflexion of the hallux. There may or may not be localized edema of the area. Therefore, radiographic analysis is imperative in making an accurate diagnosis, but it is not always easy. Standard views will aid in assessment, but the single most important radiograph is the axial sesamoid view (17).

Osteochondritis of the sesamoid begins as degeneration or necrosis, and is followed by regeneration and excessive recalcification (12). The radiographic appearance is as if there had been a collapse of the sesamoid (13). The sesamoid appears somewhat enlarged and irregular with areas of sclerosis, mottling and fragmentation changes of the sesamoid that can be seen over time with serial x-rays.

Diagnosis of a stress fracture is complicated by the presence of bipartite sesamoids. It has been frequently stated that, in a fracture, the dividing line is jagged and irregular, while in a bipartite bone, the outlines are regular and smooth, and the division line is smooth

(11). But a bipartite sesamoid can also be a fractured sesamoid, with the fracture line being within the radiolucent area of fibrocartilage. This type of patient will radiographically look normal, but will have symptoms of a fracture, making it easy to misdiagnose. Therefore, one must take note in the distance between fragments of the bipartite sesamoid, and if necessary, compare the gap measurement in serial x-rays. Since there is a variety of data published concerning the prevalence of bipartite sesamoids occurring bilaterally, as noted earlier, contralateral radiographs may be beneficial in the diagnosis as well as the history and physical pertaining to the bilateral extremities.

Several authors have recommended the use of bone scans to detect lesions when there are no changes on any plain x-ray views, or when the changes are obscured by the overlap of adjacent structures (4, 10, 18). Richardson (10) believes that a bone scan may be helpful in diagnosing subclinical sesamoid injury or "the sesamoid at risk." Publications by Klinman *et al.* (18), Hulko *et al.* (19), and Van Hal, *et al.* (20) showed cases where an increased uptake of technetium-99 trace was evident at the site of the stress fracture. Van Hal *et al.* (20) states that a bipartite sesamoid will be negative on bone scan. Klinman *et al.* (18) state that increased radio-nuclide uptake in a bi- or multipartite sesamoid is evidence of recent change, and they found it a very valuable diagnostic tool in distinguishing congenitally divided sesamoids from pathologic ones.

Treatment

It is not within the scope of this article to discuss treatment regimens for painful sesamoids. The authors believe that all conservative measures should be exhausted prior to surgical excision. However, if surgical excision is necessary to relieve the patient's symptoms, the physician must consider some important factors.

During the early 1900s, Speed (21) believed both sesamoids should be removed, because removal of only the symptomatic one causes undue stress on the remaining bone. Inge and Ferguson (5), in 1933, advocated removing only the involved bone to prevent a hallux malleus deformity, with which the podiatric surgeons of today are in agreement. It is in the authors' opinion that any hallux abducto valgus component should be addressed if the tibial sesamoid is being excised, so as not to exacerbate the deformity when the medial capsular structures are weakened (Figs. 8 and 9).

If the symptomatic partite sesamoid is the tibial bone, and it is associated with a hallux abducto valgus deformity, achieving satisfactory results with conservative treatment may be difficult due to the constant tibial sesamoid abutment with the crista. Conservative therapy may temporarily eliminate the symptoms, but usu-

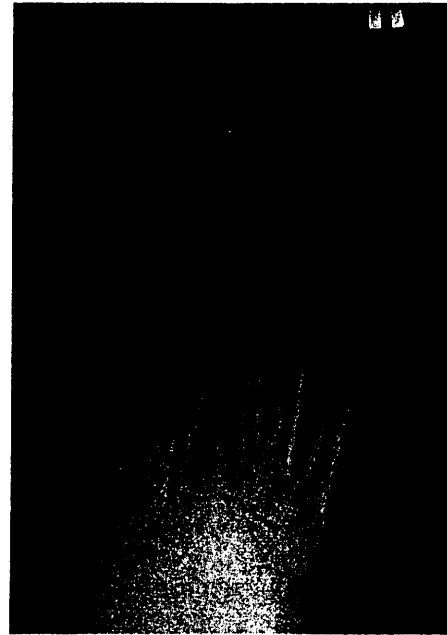


Figure 8. Anteroposterior radiograph of a patient with a symptomatic bipartite tibial sesamoid unresponsive to conservative treatment. Note mild hallux abducto valgus deformity present.

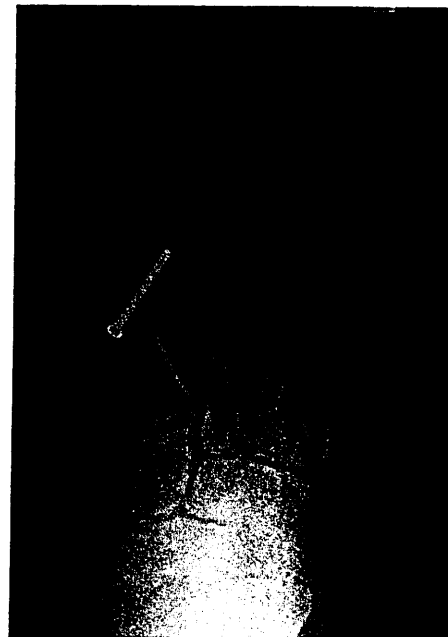


Figure 9. Anteroposterior radiograph, postoperatively, after tibial sesamoidectomy and bunionectomy with osteotomy and fixation.

ally only to give rise to another bout of symptoms when full activity is resumed.

Summary

The sesamoid bones of the foot have very critical functions in gait. The functions, however, can be altered

with angular deformities occurring at the first MPJ, such as in hallux abducto valgus. As is the case with mild hallux valgus, the tibial sesamoid lies in position two to four, with abutment of the crista. It is the authors' opinion that the common occurrence of bipartite sesamoids, most often the tibial, increases the chance of this sesamoid becoming symptomatic most easily when associated with a mild/moderate hallux abducto valgus deformity. This theory is postulated on evidence presented from surgical pathologic examination of excised symptomatic bipartite sesamoids, concluding that a fibrocartilage interphase lies between the two separate ossification centers.

An understanding of the physical properties of bone tissue *versus* fibrous cartilage tissue lead the authors to believe that micromovement occurs at this fibrocartilagenous interphase as forces are transmitted through the partite sesamoid. This micromovement leads to irritation of the metatarsophalangeal joint.

Radiographic examination of a symptomatic sesamoid is often an area of confusion. If a divisionary line is present in the involved sesamoid one must carefully correlate the history and physical findings to distinguish between fracture of a unipartite sesamoid or diagnose either irritation or fracture of the fibrocartilage bridge between ossification centers of a partite sesamoid. Bone scans have been advocated in aiding in this diagnosis.

Once the proper diagnosis has been attained, all conservative measures of treatment should be exhausted, although surgical excision of the involved sesamoid may be the definitive treatment needed. If surgical excision is performed, it is in the authors' opinion that any hallux valgus component of the deformity should be addressed to prevent further progression of the deformity. Surgical excision is sometimes the only answer to the dilemma of treatment. Conservative measures may decrease the inflammation, but only to give rise to a new episode because the etiology has not been removed, as in the case of tibial sesamoid-crista abutment in hallux abducto valgus.

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