CHAPTER 33

SESAMOID BONES OF THE FIRST METATARSAL: A Literature Review

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The metatarsal sesamoids of the great toe can be responsible for situations of formidable diagnostic and treatment challenge. Due to small size and limited visualization of these ossicles on routine foot radiographs, clinicians may ignore them and discount their etiologic significance. However, there is increasing interest for high impact recreational and sports activities in the general population. Consequently a higher incidence of traumatic sesamoid disorders is being seen. In addition, there is greater awareness of the anatomic, embryologic, pathologic, and biomechanical implications of the hallucal sesamoids. The understanding of both traumatic and non-traumatic conditions of these sesamoids has gained new ground.

The purpose of this paper is to review the historical accounts, describe the anatomy, embryology, biomechanics, and pathology of the ossa sesamoidea halluces, and discuss clinical presentations, and diagnostic and treatment modalities of various conditions associated with the hallucal sesamoids.

HISTORY

The sesamoids were named by the anatomist Galen, circa 180 A.D.,because they resembled the seeds of the herb "sesamum indicum".[1] Later, Rabbi Uschaia described the tibial sesamoid as "luz", representing an indestructible seed from which the body would be resurrected on the Day of Judgement. For centuries, Uschaia's parable was an accepted explanation for the existence of the sesamoids.

In the beginning of the eighteenth century, Nesbitt of London demonstrated that the ossification centers of the sesamoids are present beneath the first metatarsal head by the 12th fetal week.[2,3] Embryological dissections later revealed that the sesamoids are recognizable as islands of connective tissue in their normal position under the first metatarsal head by the eighth week of fetal life. At ten weeks, this connective tissue becomes a precartilaginous mass that eventually shows a definite chondrification center. According to Helal,[3] Placentini offered the first anatomic description of the sesamoid bones in 1656. The same author also states that Bizzaro believed sesamoids exist as a result of both phylogeny and function, and they are not residual tarsal bones. They were thought to be persistent structures in mammals.

EMBRYOLOGY

Although chondrification of the sesamoids begins in the 12th week of fetal life, ossification does not commence until the 8th year, with completion by the 12th year.[1] Jahss states that ossification of the hallucal sesamoids is variable and they usually ossify at age 11 in boys, and earlier in girls.[4] In his update, Laventen[5] states that sesamoids ossify at age 8 in girls and at age 12 in boys. Helal[3] finds ossification in boys to occur at age 10. Variation in the pattern of ossification is also common.[1]

There are multiple ossification centers, and these may or may not coalesce.[6] Bipartite, tripartite, quadripartite, or multipartite sesamoids may be present in the adult. The incidence of bipartite sesamoids is reported in significant variations. The percentages of bipartite sesamoids range from 10.7% to 34.%, according to Scranton.[6] One author reported one bipartite sesamoid in 1000 radiographed feet. Jahss states that a bipartite sesamoid is present in approximately 10% of individuals, and that most of these occur in the tibial sesamoid.

Partition of the tibial sesamoid is believed to be about ten times more frequent than partition of the fibular sesamoid.[5] Partition of the sesamoids generally occurs slightly more frequently in women then in men.[1] Bilateral occurrence of this anomaly has also been reported with significant variability; the frequencies range from 13.5% to 85%.[1,7]

The etiology of sesamoid partition is unknown. Jahss[7] states that partition is the result of a failure of fusion of the multiple centers of ossification. One theory, as mentioned by Sobel et al.,[8] views vascular disturbance at or before sesamoid ossification as the cause of sesamoid partition. The authors present previous observations that lines of ossification are significantly influenced by the position of blood vessels. In light of the observations presented above, these researchers conducted a histologic examination of two specimens with bipartite sesamoids. When the findings were compared to the results of non-partitioned sesamoids, they noticed striking differences between the vascular anatomy of non-partitioned and bipartite sesamoids.

Saxby et al.,[9] reported on an occurrence of a bilateral coalition of the hallucal sesamoids in a 19-year-old college student. On a dorsoplantar radiograph, one heart-shaped sesamoid bone was seen. Jahss[7] states that there has been a report of a congenital absence of the tibial sesamoids associated with secondary clawing, due to inadequate function of the flexor halluces brevis muscle. Agenesis and hypogenesis has also been seen with little to no clinical significance.

ANATOMY

The first metatarsophalangeal joint involves two different articular surfaces, the large distal and dorsal regions where the proximal phalanx articulates, and the plantar facets where the sesamoid bones articulate.[10]. The plantar facets of the first metatarsal head are separated by a bony ridge called the crista. Thus, the medial and lateral sesamoids are also separated by this ridge. The lateral plantar facet is angulated inward and upward. It becomes more transversely oriented with dorsiflexion of the first metatarsophalangeal joint as in propulsion. The tibial sesamoid is generally larger than the fibular sesamoid, and is located distal to the fibular sesamoid.[11] The tibial sesamoid is generally more elliptical than the fibular sesamoid. Both bones are constantly occurring and develop within the capsule of the first metatarsophalangeal joint by intracartilaginous bone formation.[12]

In addition to the four bones mentioned above, six tendons and seven ligaments also contribute to the first metatarsophalangeal joint. The only unpaired ligament, the deep transverse ligament, also known as the intersesamoid ligament, is located between the sesamoids[2] David et al.[11] made transverse and sagittal sections of six cadaveric specimens of feet to study the anatomical complex of the first metatarsophalangeal joint. They found the structure of the intersesamoid ligament to resemble the trilateral arrangement of a girder, composed of an upper wing and two plantar wings, one medial and one lateral. It was also observed that there is no symmetry in relation to the dorsoplantar plane passing between the sesamoids in the axis of the dorsal wing of the ligament. The upper wing, located opposite the sagittal ridge of the metatarsal head, is the shortest and thickest of the three. The plantar wings, stated the authors, seem to support the inferior aspects of the sesamoid bones and to separate them from the tendon of the flexor halluces longus muscle. On the basis of the authors' anatomical findings, the intersesamoid ligament acts as an axis of cohesion. Between the three wings defined previously, there are three distinct spaces. The sesamoid bones are lodged in the upper spaces, while the plantar space forms a groove for the flexor halluces longus tendon.

Medial and lateral sesamophalangeal ligaments, extending from respective sesamoids to the inferior aspect of the base of the proximal phalanx, are the first of the paired ligaments of the first metatarsophalangeal joint. In this category are also a pair of collateral ligaments, strong rounded cords, each attached to a respective epicondyle on the side of the head of the metatarsal bone and extending forward and downward to reach the corresponding side of the base of the proximal phalanx. The third set of paired ligaments is represented by the suspensory or metatarsoglenoid ligaments.

According to Weil and Hill,[2] this ligament was described by Sarrafian as a fan-shaped structure that has fibers descending vertically in the posterior part, and obliquely in the anterior part, that eventually insert on the plantar plate. The significance of these and the collateral ligaments seems to be stabilization of the metatarsophalangeal joint in the transverse plane.

LaPorta[12] states that the ligaments associated with the sesamoids collectively form a triangular mass that assists in retaining the sesamoids in their functionally proper locations at the plantar aspect of the first metatarsal. He further describes a fibrocartilaginous pad plantarly as a thickening of the plantar aspect of the joint capsule. Also presented is the fact that the plantar aponeurosis sends strong fibrous slips that pass partially into the tibial and fibular sesamoids. These slips and the previously mentioned ligaments form a tunnel through which the tendon of the flexor halluces longus muscle extends to its insertion on the distal phalanx of the hallux.

There are several extrinsic and intrinsic muscles that influence the first metatarsophalangeal joint. On the dorsal aspect of the foot, the extensor halluces longus and the extensor halluces brevis cross this joint. The extensor hood or expansion fibers run transversely perpendicular to the extensor tendons at the level of the first metatarsophalangeal joint. These fibers do connect the extensor tendons with the sesamoids and the first metatarsal neck. On the plantar aspect there are muscles of greater influence, the flexor halluces longus, the flexor halluces brevis with its two heads, the abductor halluces, and the adductor halluces with its two heads forming a conjoined tendon. The adductor halluces muscle has two separate muscle bellies, a large oblique head and a small transverse head. As stated by Weil and Hill[2] the oblique head arises from the bases of the second, third and fourth metatarsals, and the sheath of the peroneus longus and divides into three components. The medial slip blends with the flexor halluces brevis and inserts on the lateral sesamoid. The central slip, which is the deepest, attaches to the inferior portion of the lateral sesamoid. The lateral component inserts on the lateral sesamoid and the plantar lateral aspect of the base of the proximal phalanx. The oblique head then extends in a medial and oblique direction and blends with the lateral aspect of the flexor halluces brevis muscle.

The transverse head of the adductor, however, which is also known as the adductor transversus muscle, forms a conjoined tendon with the oblique head, originates from the plantar metatarsophalangeal ligaments 2 through 5, and transverse metatarsal ligament and runs transversely to blend with the oblique head. In turn, the conjoined tendon, along with the flexor halluces brevis tendon, partially inserts into the lateral sesamoid, then continues distally to insert on the lateral aspect of the base of the proximal phalanx.

Medially, the abductor halluces muscle arises from the medial process of the tuberosity of the calcaneus, the flexor retinaculum, and the plantar aponeurosis. It courses distally along the longitudinal arch and narrows into a tendon which sends its inferior lateral fibers to unite with the fibers of the medial head of the flexor halluces brevis muscle. It inserts on the tibial sesamoid, as well as on the medial plantar tubercle of the proximal phalanx of the hallux. The superomedial fibers of the tendon blend with the extensor aponeurosis.[13] The flexor halluces brevis is made up of two separate muscle bellies and tendons. One is located medially, the other laterally. Each arises from the first metatarsal and first cuneiform, and each inserts in the plantar aspect of their respective sesamoids. The tendons continue on to insert into the plantar-most aspect of the proximal phalanx on their respective sides.

The flexor halluces longus is an extrinsic muscle whose tendon passes on the plantar surface of the intersesamoidal ligament between the two sesamoid bones, and inserts into the plantar base of the distal phalanx. This muscle does not have attachments to the sesamoid bones and, therefore, cannot be considered a sesamoid muscle.

THE VASCULAR SUPPLY

The arterial supply of the sesamoid bones of the hallux has been investigated by several researchers. In one study by Pretterklieber and Wanivenhaus,[14] the arterial supply of the hallux sesamoids was investigated in 29 human feet with anatomical dissection. Eight of these feet were subjected to radiographic analysis prior to dissection. These investigators found that sesamoid arteries branch-off from the digital plantar arteries of the hallux, which in turn are derived from the medial plantar artery and the plantar arch (type A), the plantar arch (type B), or the medial plantar artery (type C). The respective frequencies of types A, B, or C were 52%, 24%, and 24%. It was further observed that the number of sesamoid arteries varied from one (55%) to three (10%), and that the number increased with the size of the sesamoid.

An earlier study of the dimensions and the arterial supply of the sesamoids of the hallux by Pretterklieber[15] showed that 63% of the medial and 58% of the lateral sesamoid bones were supplied by a single artery (≈ 60% of total). Twenty-six percent of the medial and 32% of the lateral sesamoids received two arteries (≈ 30% of total). In left feet only, three sesamoid arteries were found to supply 11% of the medial and 10% of the lateral sesamoid bones (≈ 10% of total). The number of sesamoid arteries corresponded to the "dimensions and compactness (robusticity)" of the sesamoids and to other parameters, such as sex, predominant functional foot or "footedness," and the anthropometric dimensions of the individuals.

Sobel et al.,[8] present another view of the microvasculature of the hallucal sesamoids. They found that the fibular and tibial sesamoids are equally vascularized. The major supply appeared to come from the first plantar metatarsal artery, which divides into medial and lateral branches. These, in turn, supply the proximal and plantar portions of the sesamoids.

Distally, the blood vessels enter the sesamoids through the distal synovial and capsular attachment, but provide minimal vasculature to the sesamoid. It was also found that the lateral attachments of the sesamoids to the plantar plate and the joint capsule were relatively avascular. The authors further suggested that injury to the proximal or plantar aspects of the sesamoids could disrupt the vascular supply of these bones. If the injury occurs prior to ossification, this could lead to partite sesamoids.

BIOMECHANICS

Recently, there has been more literature regarding the function of the sesamoids and their importance for first metatarsophalangeal joint biomechanics.[2,11,16-19] Root et al.[20] described this joint as movement in two separate planes, transverse and sagittal. Each of these planes has its own axis. Normally, there is no action in this joint in the frontal plane. The range of motion in the transverse plane is very small, and has little importance during gait. In the sagittal plane, the first metatarsophalangeal joint has a significant amount of motion and functions as a ginglymoarthrodial-type joint.

The sesamoid bones play a significant role in muscle coordination and in the overall dynamics of this joint. When the first metatarsal plantarflexes during the propulsive phase of gait, the sesamoids act as a pulley to increase the mechanical advantage of the flexor halluces brevis muscle.[16] This muscle, in turn, will stabilize the hallux in the sagittal plane against the ground reactive force.

The sesamoid bones also act as shock absorbers for the first metatarsal. There is independent range of motion of the first ray with the metatarsal being elevated in swing and early stance phases of gait. During stance, the first metatarsal plantarflexes and becomes increasingly weight-bearing on into propulsion, as weight is shifted from the lateral surface of the foot medially. Due to their anatomical positions, the sesamoids and the intermetatarsal ligament also protect the flexor halluces longus as it passes beneath the first metatarsal head.

David et al.,[11] in consideration of the anatomical and functional correlations of the sesamoid apparatus, divided the biomechanical function of the first metatarsophalangeal-sesamoid joint into four stages: suspension, fixation, coordination, and propulsion. These stages are all interdependent of each other. According to these researchers, the horizontal position of the sesamoids places them in the most favorable situation for development of a catapult effect, where they play the role of the sling.

The suspension stage begins with heel strike and ends when the metatarsals come in contact with the ground, as the foot plantarflexes at the ankle. In this period, the sesamoid apparatus, via the sesamoid muscles, acts like the collar of a harness passed around the first metatarsal by coordinating its forefoot contact with that of the four lesser metatarsals.[11] This is consistent with Root's description of a dorsiflexed first ray at heel contact until the forefoot contacts the ground.

The "stage of fixation" is characterized by the fixed position of the sesamoids, whereby the sesamoid apparatus becomes the reference structure around which the later stages will be organized. As the sesamoid anchorage is achieved, the flexor halluces brevis, adductor halluces, and abductor halluces muscles act by isometric contraction to produce a plantarflexion action opposed to the resistance of the ground.

Heel-off marks the beginning of the "coordination stage." Having the sesamoids "fixed" to the ground allows the adductor halluces muscles to redirect part of the forces transmitted by the dorsiflexed foot to the lateral rays. During this stage, the first ray is progressively loading. The first metatarsal head glides posteriorly upon the sesamoids. The arthrodial type of joint motion is seen with the shifting of the transverse axis of the first metatarsophalangeal joint. As the metatarsophalangeal joint is extended, the sesamoid-metatarsal complex rotates, placing the joint in good position for catapult action. The sesamoids are placed in the same transverse plane, and the flexor halluces longus tendon is placed under tension.[11]

The mechanical constraints were thus anteriorly redirected forming a structure in the shape of a catapult that will project the metatarsal head forward. The sesamoid apparatus forms the sling and the flexor halluces longus acts as the stretcher. During the propulsion stage, the catapult mechanism will go into action and the metatarsal head will be projected upward and forward. The great toe will flex by the tension of the flexor halluces longus tendon, and the propulsive forces will be transmitted to the distal pulp of the hallux. This stage concludes the action of the sesamoid apparatus during the weight-bearing phase of the gait.

CLINICAL PATHOLOGY, DIAGNOSIS, AND TREATMENT

The position of the hallux sesamoids relative to both the metatarsophalangeal joint and weight-bearing pattern of the foot makes them vulnerable to injury. During the normal gait cycle, the sesamoids bear three times the weight of the body, with the medial sesamoid accounting for the majority of the forces.[21]

Sesamoiditis

The term "sesamoiditis" has been used loosely in the literature to describe various clinical entities.[1,3-5,7,10,18] Tendonitis, synovitis, sesamoid bursitis, and chondromalacia, in the region of the plantar aspect of the first metatarsophalangeal joint are often clinically diagnosed as "sesamoiditis."[1] According to Dennis and McKinney,[22] chondromalacia of the sesamoid is the most common trauma associated with "sesamoiditis," and that it is commonly confused with stress fractures. Jahss states that sesamoiditis "consists of persistent local pain and tenderness under either the medial or lateral sesamoid."[7] Also mentioned in the monograph are the observations that sesamoiditis may occur in inactive patients with "relative depression of the first metatarsal head." In such cases "the thin walled bursa found under the metatarsal head" will be enlarged.

Interestingly, Leventen[5] describes "simple sesamoiditis" as a frequent disorder with symptoms of tenderness under the first metatarsal head, particularly medially, that persist in association with walking.

Nayfa and Sorto believe that "mechanically induced acute or chronic sesamoiditis and plantar keratoma under the tibial sesamoid are most often secondary to limited range of first ray dorsiflexion. They state that "a plantarflexed first ray, whether congenital or acquired, causes trauma to the tibial sesamoid," and that "sesamoiditis is the most common initial symptom of a plantarflexed first metatarsal."[18] Dennis and McKinney[22] observed that trauma associated with sesamoiditis is most commonly caused by jumping from a height, excessive dancing, high-heeled shoes, or an abnormally large sesamoid bone. Helal[3] states that osteochondritis of the sesamoid bones has been described as "sesamoiditis."

Diagnosis of "sesamoiditis" is a clinical challenge because many symptoms of this condition can be seen with other clinical entities. Usually there is pain with direct palpation of the affected sesamoid. Pain may be elicited with first metatarsophalangeal joint motion. Dorsiflexion generally creates the most pain, but adduction and even plantarflexion of this joint can cause pain. During gait the most significant pain occurs with push-off. Some researchers state that radiographic evaluation will show no bony abnormality with sesamoiditis.[22] Others believe that radiographs or other imaging modalities (bone scan, CT scan, MRI) are important for diagnosis. According to Potter et al.,[1] the superior soft tissue visualization of MR imaging can prove important for delineation and differentiation of the various entities that may be clinically diagnosed as "sesamoiditis". However, if a bone scan is considered, one must know that acute fracture, stress fracture, and sesamoiditis may all give positive results. The differential diagnosis of sesamoiditis includes trauma (acute or repetitive stress), arthritis, infection, osteochondritis, tumor, or callous of the sesamoids.

Treatment for "sesamoiditis" may consist of rest with complete non-weight bearing of the sesamoids. This can be achieved by means of padding (dancer's pad), shoe accommodations, or foot orthoses. Local cortisone injections and non-steroidal anti-inflammatory agents may also be helpful. Persistent and intractable pain may require excision of the sesamoid bone.[18,22]

Sesamoid Fractures

Trauma to the sesamoids may be divided into acute fractures, fracture dislocations, and increasingly common stress injuries associated with activities involving repetitive forces such as high impact aerobic exercise, dance, or long distance running.[7] Acute fractures are uncommon and are caused by falls from a height,[7] direct force from a object falling onto the joint,[1] acute hyperextension of the metatarsophalangeal joint,[12] or penetration injuries. The hyperextension injuries of the first metatarsophalangeal joint have been classified into two basic types.[12,19] Type I occurs when there is dorsal dislocation. As the hallux dorsiflexes, the plantar capsule ruptures at its attachment on the plantar aspect of the metatarsal neck. The hallux then rides over the metatarsal head with the sesamoids still attached to each other and to the base of the proximal phalanx. The medial and lateral conjoined tendons remain intact and taut on either side.

Type II has two subtypes. Type IIA occurs as further dislocation occurs at the joint and the intersesamoidal ligament ruptures separating the two sesamoids. Type IIB occurs when the dorsiflexion allows the intersesamoid ligament to remain intact but results in a transverse fracture of one or both sesamoids.[23] Graves et al.[24] presented four cases where plantar plate injury to the first metatarsophalangeal joint occurred resulting in proximal retraction of the sesamoids. There was no history of a dislocation, although two of the patients had associated sesamoid fractures.

Chronic, repeated low-level trauma may result in stress fractures of the hallux sesamoids. Individuals with cavus-type feet, a plantarflexed first metatarsal, or long first metatarsal are at a greater risk to develop this kind of fracture.[21] This injury has been associated with activities involving jumping, such as ballet, jogging, basketball, volleyball, tennis, racquetball, football, soccer, barefoot walking, or exercise.

The clinical manifestation of sesamoid fractures may present as an acute onset of pain or a more gradual onset of pain beneath the first metatarsal area. The patient may be able to pinpoint the exact time and the activity when the symptoms began.[21]

In contrast, there may be an insidious onset of pain which is aggravated by activity and relieved by rest. Sometimes the patient will complain of a painful lateral calf muscle because of reflex eversion of the foot away from the area of the sesamoid.[21] Upon clinical examination the patient may have tenderness to palpation of the plantar aspect of the first metatarsophalangeal joint and may demonstrate swelling in the area. Some patients will only have pain with dorsiflexion of the first metatarsophalangeal joint. Although it is possible for a patient with a sesamoid fracture to have none of these clinical signs, the clinical examination is very important to localize pathology. However, the diagnosis cannot be based on physical findings only. Appropriate diagnostic measures must be taken and follow-up examinations should be conducted. Improper treatment of a sesamoid fracture may lead to prolonged and debilitating pain.

Radiographic criteria is of great importance in the diagnosis of sesamoid fractures.[1] Radiographs should include dorsoplantar (DP), lateral, medial oblique, and possibly lateral oblique and axial views of the sesamoid bones. The DP and medial oblique x-rays are usually the most helpful. The sesamoid view is more useful in the oblique sesamoid separations, multi-fragment separations, and long term comparison views regarding bone density. Fractures may not be seen or differentiated on the initial radiographs, thus it is important to take repeat films at a later time. The stress dorsiflexion view of the 1st metatarsophalangeal joint may be helpful in differentiation of a sesamoidal fracture. Both lateral and DP x-rays are taken with the hallux dorsiflexed to open up the fracture.

Differentiation of a sesamoid fracture from a bipartite or multipartite sesamoid may be difficult. Downey[25] offers the following criteria that can be helpful for differentiation of a fractured sesamoid from a partitioned one. First, the previous radiographs, if available, should show no evidence of a sesamoid fracture if such a diagnosis is currently entertained. Second, the lines of separation between the fragments of the sesamoids that are indeed fractured should be irregular, jagged or serrated, although this by itself is not diagnostic. Transverse separation during sesamoid fractures is commonly seen. However, if the fracture lines are longitudinally or obliquely oriented, or if the space between the fragments is particularly large, a sesamoid fracture is more likely. This also is not pathologic. It would also be helpful to see anatomically abnormal fragment positions, multiple irregular fragments, and interrupted peripheral cortices. This may not be diagnostic by itself. Bone callous formation may be seen in later stages.

Weiss[21] states that a bone scan (technetium 99) should be performed if it is difficult to determine whether a sesamoid is partitioned or fractured. The bone scan will show increased isotope uptake as a result of osteoblastic new bone formation, and the metabolic change at an acute fracture site will be apparent before changes are seen on a regular radiograph. On the other hand, the bone scan is nonspecific, and the quality of the image limits the ability to determine the exact structure and topography of the lesion. Acute fracture, stress fracture, and sesamoiditis are difficult to differentiate via bone scans, as all may be hot. Approximately 24 hours after the injury, an acute fracture may produce a metabolic disturbance that results in a positive bone scan. Thus, a negative bone scan will be more helpful in ruling-out an acute fracture, than a positive bone scan for ruling-in a fracture.[21]

Routine or computerized tomography may offer a more detailed assessment of a sesamoid fracture, including the alignment of the bone fragments.[1] This can also demonstrate cortical irregularities and help to distinguish bone tumors or osteomyelitis.

Magnetic resonance imaging may also be used in disclosing a sesamoid fracture by identification of bone marrow edema.[1] There will be low signal intensity on T1-weighted images and high signal intensity on long TR/TE images. This diagnostic modality is expensive, and it can be considered in instances when additional information regarding the regional soft tissues and tendons is required. MRI may be useful in determining osteomyelitis of the sesamoid and/or the first metatarsal head.

Intra-articular injections of local anesthetics into the first metatarsophalangeal joint can help to differentiate between an intra-articular and an extra-articular problem.[21] Sesamoid injury will not respond to this form of therapy.

The treatment of fractured sesamoids is a subject of controversy. Weiss[21] indicates that a less aggressive treatment with a padded shoe and stiff sole, or reduction in activity is adequate treatment for fractured sesamoids. Others are convinced that true sesamoid fractures are resistant to therapy.[21] There are those who believe[25] that "in most sesamoid fractures, conservative treatment should be aggressive" and that "conservative measures frequently fail if the treatment is delayed or inadequate."

If conservative measures are attempted, three general principles are employed 1. Unweighting the sesamoids. 2. Resist distraction forces on the sesamoid (prevent dorsiflexion forces on the first metatarsophalangeal). 3. Use of anti-inflammatory agents. Downey[25] prefers a non-weight-bearing short-leg cast that extends to the end of the hallux, with cast padding material applied in a manner to maintain the first metatarsophalangeal joint in a slightly plantarflexed position, for four weeks.

An alternative is to use a weight-bearing short-leg cast in which the first ray is unweighted. The hallux still needs to be held in plantarflexion. Padding can be used to protect the soft tissues. A Jacoby splint to hold the hallux plantarflexed, coupled with a wooden sole shoe with the first ray unweighted with a korex cutout, is an alternative. Other conservative measures include adjustments in the patient's shoe to decrease stress in the sesamoid area. A rocker-bottom sole can decrease pain by reducing dorsiflexion. A sesamoid pad (dancer's pad) can be placed to free the sesamoids from weightbearing stress.

In addition, systemic anti-inflammatory medications may be prescribed.[21] These may be helpful if pain is associated with synovitis. Injection of extra articular corticosteroids, although controversial due to their adverse effects on bone healing, may relieve pain from local inflammation. In more chronic injuries, or in injuries that are seen several months after the acute incident, a bone scan is suggested to evaluate the vascular supply of the affected sesamoid and the potential to heal with conservative measures. If a cold cleft is noted at the fracture site, surgery will be necessary.

When conservative treatment fails, surgical intervention is of great importance. Richardson[26] reports that prolonged conservative therapy with a short-leg cast or molded supports is ineffective. Earlier, Para[27] reported in his monograph that " the treatment of choice in fractures of the sesamoids of the foot is surgical excision." According to Downey[25] one report indicates that more than 30% of all sesamoid fractures will eventually require surgery. Most authors will recommend excision of a fractured sesamoid if pain and discomfort persist after six months.[4,21]

If the distal fragment of the fractured sesamoid is small, partial sesamoidectomy of only this fragment can be performed.[21] As a result, the complications associated with a total removal will be avoided. Conversely, if partial sesamoidectomy fails to reduce pain, or if the sesamoid fracture is in multiple pieces, total excision of the bone may be required.

A plantar-medial approach is most often used to remove a medial sesamoid.[25] After a 3-6 centimeter incision is made extending from the first metatarsophalangeal joint proximally, it is deepened with care to avoid proper digital branches of the medial plantar and the medial dorsocutaneous nerve. Next, the joint capsule is incised around the margin of the sesamoid. This will allow the sesamoid to be freed from the attachments of the intrinsic tenoligamentous complex with minimum damage to these structures. However, if damage has occurred, it must be carefully repaired.

Other methods of surgical intervention have been advocated. For example, Leventen[5] writes that "refractory sesamoiditis may be a good indication for doing a partial excision of the plantar one-half of the involved bone, thereby avoiding disruption of the mechanics of the great toe joint." Long-term studies of this approach have not been well documented. Marcinko and Elleby[28] suggest removal of only the distal fragment of the fractured tibial sesamoid. They report promising results, but a long-term evaluation of this approach may be essential. After removal of the sesamoid, the capsule, the superficial fascia, and the skin are closed in layers. Subsequently, the foot is immobilized in a non-weight-bearing cast for 3 weeks. Gradual return to full weight bearing is expected after this period.

Fractured fibular sesamoids are best removed from a dorsal approach if the sesamoid is in the interspace.[25] The incision extends 3-6 centimeters from the web space proximally. Next, the incision is deepened. The adductor halluces is identified. A linear incision is made above the adductor attachments to the fibular sesamoids. A small amount of soft tissue is left attached to the sesamoids to grasp it as it is shelled out from the soft tissue attachments. The intrinsic ligamentous complex and the tendon of the flexor halluces longus muscle are protected from any possible damage. The post-operative care is essentially the same as for tibial sesamoidectomy.

If the fibular sesamoid is located under the first metatarsal head, a plantar approach is advocated. A 3-6 centimeter incision is made in the first interspace lateral to the fibular sesamoid. The incision is carried deep. The nerve that lies plantar and lateral to the sesamoid is retracted laterally. The capsule and periosteal tissue are incised and reflected medially and laterally. Once again, a small amount of soft tissue is left attached to the sesamoids to grasp it. The sesamoid is shelled out of the periosteal tendinous covering and excised en toto. The periosteal tissue is approximated and the wound is closed in layers.

Success with surgical excision is commonly reflected in the literature. However, complications of neuralgia, hallux rigidus, hammertoe, and hallux abductovalgus are also seen.[21] Nayfa and Sorto[18] presented a study where 11 patients underwent a total of 19 tibial sesamoidectomies, and after an average of 28.8 months, they observed occurrence of hallux abductus deformity in 42.1% of the cases. This points to the need to tighten and repair the void left by excision of the sesamoid to re-establish musculotendinous balance.

After the removal of a fractured sesamoid, the residual imbalance of this musculoligamentous complex becomes important. Splints and orthosis may be beneficial in the long-term management of the first metatarsophalangeal joint.

In some cases both sesamoids are removed resulting in significant muscle imbalance across the first metatarsophalangeal joint. In these situations, a fusion of the interphalangeal joint of the hallux is usually necessary. This may be combined with a Jone's tenosuspension of the extensor halluces longus tendon.[23,25]

A modified McKeever arthrodesis of the first metatarsophalangeal joint is an alternative procedure when both sesamoids are removed. Stroh et al.[17] presented such a case. The authors state that after two years of follow-up observation, the patient had a stable, pain-free metatarsophalangeal fusion site.

In geriatric populations, a Keller arthroplasty of the first metatarsophalangeal joint may be performed if both sesamoids are surgically removed.[17] Patients in this age group tend to be more sedentary and they place low demands on their first metatarsophalangeal joint. Attachment of the flexor halluces longus tendon to the proximal phalangeal stump helps to prevent cocking of the hallux in stance. Lengthening of the extensor halluces longus helps to prevent cocking of the hallux in swing phase.

Sesamoidectomies are also performed for the treatment of chronic neuropathic ulcerations.[29] A minimal incision surgical approach was used by Bartel[30] to treat "medial sesamoiditis," intractable plantar keratosis, and "lateral sesamoid problems." Long term follow-up statistics on this approach are not available, however. Theoretically, large, non-displaced sesamoid fractures may be treated with bone grafting to reconstitute the bone and preserve the biomechanical integrity of the sesamoid apparatus.[21] Tension banding techniques to loop the superficial aspect of the sesamoids are also theoretically possible to create compression across the fracture site. This is similar to techniques used to fix transverse patellar fractures.

OSTEOCHONDRITIS

Though rare in the foot, osteochondritis or avascular necrosis of the sesamoids may be debilitating.[22] Historically, this condition has been described as "sesamoiditis," "osteomalacia," "osteitis fibrosa," "juvenile necrotic osteopathy," "traumatic osteitis," "Kohler's, Schlatter's, or Renander's disease of the sesamoids," "sesamoid insufficiency," and "osteochondropathy".[3] Ilfeld and Rosen describe the histological findings of the specimen obtained from three cases of osteochondritis.[31] They state that the bone was irregularly osteosclerotic, and marrow spaces between trabeculae were quite vascular and contained sparse fatty elements. It was also noted that the cartilaginous surfaces showed marked degenerative changes with clefting, fibrinoid change, and microvillous pannus proliferation.

Helal and Apley characterized osteochondritis as injury in a form of "crush or stellate fracture."[3] Penetration type of trauma to the sesamoids can also cause osteochondritis, and likewise, osteomyelitis must be ruled-out.

The changes in the cartilaginous surface are secondary to collapse of subchondral bone. Thus, it is not known whether the fracture or the avascular necrosis came first.[22] According to several sources, Renander first described osteochondritis of the sesamoids.[3,7,31] It may occur in either the medial or lateral sesamoid, but it rarely occurs bilaterally.[7] This condition most commonly occurs in women between 18 and 25 years of age.[22] However, it has been reported to occur in both sexes and at all ages from 13 years to the eighth decade.

Symptoms consist of persistent localized pain and tenderness in the region of the involved sesamoid resistant to conservative therapy. According to Potter et al.,[1] "in the primary idiopathic form of osteonecrosis, patients may experience sudden exacerbation of symptoms associated with a fragmentation of the pre-existing devascularized bone." Jahss[7] states that radiographic findings do not become evident for 9 to 12 months. One group of investigators, according to Dennis and McKinney, found typical radiographic changes within six months.

Rest and immobilization constitute the main methods of conservative treatment of this condition. These measures frequently fail to alleviate the discomfort, and surgical extirpation of the offending sesamoid becomes a necessity.

ARTHRITIS

The hallux sesamoids form a part of a true synovial joint, and thus may be subject to both inflammatory and degenerative arthritides. Sesamoid involvement in rheumatoid arthritis, in seronegative spondyloarthridities such as Reiter's, and in crystal deposition diseases such as gout, have been described.[1]

TUMORS

Sesamoid neoplasias are rare. There have been reports of xanthomatous tumors involving the sesamoids.[10] Ribalta et al.,[32] report on an occurrence of chondromyxoid fibroma in a sesamoid bone. The patient was a 21-year-old female who experienced localized, intermittent, usually dull but occasionally sharp pain for two months. The plain radiographs showed a small, slightly eccentric, lytic lesion in the lateral sesamoid. A segment of cortical resorption was noticed. Resection of the lateral sesamoid was performed and there was no evidence of recurrence three years after the surgery.

INFECTION

Infection of the sesamoids is not very common, but can occur with long-standing neuropathic ulcers or puncture wounds.[22] Jahss[7] believes that the lytic destruction visualized radiographically may be due to acute or chronic pyarthrosis or hyperemic resorption, rather than true osteomyelitis. MRI or CT studies may prove helpful in this situation. Conway et al.[10] reported the occurrence of osteomyelitis of a sesamoid bone in a 15-year-old male due to a puncture wound. The radiographs, taken approximately 14 day after the occurrence of puncture wound, demonstrated a complete dissolution of the lateral sesamoid. The patient was later successfully treated with intravenous antibiotics for a pseudomonas infection. Interestingly, Conway et al. stated that osteomyelitis of the hallucal sesamoids usually occurs in males under the age of 21, and that patients usually present with acute foot pain and local inflammation at the base of the great toe. The radiographic absence of a sesamoid bone should alert the clinician to a possible underlying pathological condition, because the congenital absence of hallux sesamoids is uncommon.

CONCLUSION

The sesamoid bones of the first metatarsophalangeal joint are not frequently written about. Often the reports are contradictory. Terminology associated with sesamoid conditions is at times confusing. Yet recently, these small ossicles are attracting more attention due to a new level of understanding of the conditions they are associates with. Anatomical, biomechanical, embryologic and clinical elements were discussed in light of the recent literature. Recommendations for establishing the differential diagnosis of sesamoid pain and suggestions for treatment of these entities is included.

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