The case:

A 35-year-old male athlete presented with acute pain plantar to the hallux metatarsophalangeal joint following jumping to catch a basketball.

Figure: Coned-down internal oblique radiograph of the hallux metatarsophalangeal joint.

Your diagnosis?

For answer see page 706
Diagnosis:
Acute Fibular Sesamoid Fracture: One Part of the Spectrum of Sesamoid Pathologies

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Answer to Radiologic Case Study
Case facts appear on page 650

The internal oblique radiograph of the left foot (Figure 1) shows a complete transverse cleft through the fibular sesamoid of the first metatarsal head with open-ended trabeculae and sharp margination, indicating an acute fracture. There is minimal distraction of the fracture fragments. Soft tissue swelling is difficult to appreciate, given the natural fullness of the ball of the foot, although clinical examination verified this finding. Acute fracture is only one of the many pathologies that can affect the hallucal sesamoids, and imaging plays a major role in diagnosis prior to treatment that can be conservative or surgical.

Anatomy and Function
The sesamoid bones are integral for stability of the first metatarsophalangeal joint with weight bearing. The proximal phalanx has a small articular facet that does not provide sufficient stability during weight bearing. Contrarily, the hallucal sesamoid complex allows the metatarsophalangeal joint to bear 40% to 60% of body weight during walking. During strenuous activity, it can even bear multiple times the body weight.1

Two sesamoid bones are located at the plantar aspect of the first metatarsophalangeal joint. The tibial sesamoid is usually larger and bears greater weight than the fibular counterpart, accounting for the greater incidence of injury.2 The sesamoid bones ossify between ages 7 and 10 years. The sesamoids often have multiple ossification centers that may not fuse, resulting in bipartite or tripartite sesamoids. The sesamoids are multipartite in up to one-third of the general population, usually involving both sesamoids. If only one is involved, it is usually the tibial sesamoid.2,3

Each sesamoid has limited arterial supply. The first plantar metatarsal artery is the main resource for the tibial and fibular sesamoid bones, an artery derived from the medial plantar artery, the plantar arch, or more commonly, a combination of the two. The medial branch of the first plantar metatarsal artery supplies the tibial sesamoid bone. The fibular sesamoid is supplied by the main branch of the first plantar metatarsal artery that continues distally along the lateral side of the bone. The arteries penetrate the sesamoid bones on their proximal, plantar, and distal sides. Capillary vessels do not provide significant blood supply to the sesamoids. This limited arterial supply may account for the high rate of delayed union and nonunion of fractures.3

The medial (tibial) and lateral (fibular) sesamoids lie within the medial and lateral
heads of the flexor hallucis brevis tendon. The medial abductor and lateral adductor hallucis tendons also attach to the tibial and fibular sesamoids, respectively. The sesamoids articulate with the medial and lateral first metatarsal facets that are separated by a ridge called the crista. The transverse sesamoid (intersesamoidal) ligament is a thickened band of the central plantar plate that extends between and connects the 2 sesamoids and is an integral part of the plate.\(^3\) There are also medial and lateral sesamoid ligaments that originate from the medial and lateral first metatarsal and attach to the outermost tibial and fibular sesamoids. These attachments form the medial and lateral margins of the plantar plate and are thicker than the central plate. The flexor hallucis longus tendon courses plantar to the plate between the 2 sesamoids (Figure 2). Functionally, the sesamoids provide leverage for the flexor hallucis brevis tendon in dorsiflexion, while giving a mechanical advantage to the flexor hallucis longus to act as a hallux stabilizer against ground reactive force. The sesamoids also absorb shock during forefoot load, distributing the ground reactive forces and thus protecting the metatarsal head.\(^2\)

**Overview of Sesamoid Abnormalities**

There are numerous causes of sesamoid pain, including acute and chronic trauma, inflammation, infection, and osteonecrosis. The differential diagnosis of regional pain includes nerve impingement, bursal pathology, and arthritis. Differentiating first metatarsophalangeal pain due to sesamoid pathology from these other disorders can be difficult because signs and symptoms may be similar.

Signs and symptoms most often include swelling and pain, specifically at the ball of the foot under the first metatarsophalangeal joint. Although the various pathologies may have a similar clinical presentation, the initial history, including onset and duration, can be used to differentiate traumatic and atraumatic etiologies. The results of physical examination are also similar in several entities, consisting of tenderness to palpation and loss or decrease of active dorsiflexion or plantar flexion at the metatarsophalangeal joint.\(^2\)

The hallux sesamoids have been reported to be involved in 9% of foot injuries. One study reported the incidence of specific sesamoid abnormalities: stress fracture, 40%; sesamoiditis, 30%; acute fracture, 10%; osteochondritis, 10%; osteoarthritis, 5%; and bursitis, 5%.\(^3\)

Imaging of symptomatic patients begins with weight-bearing anteroposterior, oblique, and lateral views of the foot with additional axial sesamoid radiographs. In the early stages of nontraumatic pathologies, the radiographs may yield normal findings. Computed tomography (CT) provides enhanced bone detail and visualization of peri-articular calcifications. However, magnetic resonance imaging (MRI) is more sensitive for bone pathology and has the advantage of providing detailed demonstration of affected bone, ligaments, nerves, and soft tissue. Bone scan is also sensitive for bone pathology, but nonspecific with poor anatomy depiction. Sonography can demonstrate soft tissue injuries of the hallucal sesamoid complex, but is user-dependent.

**Sesamoiditis**

Sesamoiditis is a generic term applied for acute or chronic sesamoid pain when alternative diagnoses have been excluded. By definition, the etiology is unknown but is generally considered to be mechanical due to repetitive axial loading. Postulated risk factors include excessive dorsiflexion, repetitive axial loading (especially in athletes), and increased forefoot pressure caused by wearing high heel shoes.\(^4\) Pain exacerbated with weight bearing is common. On physical examination, there may be redness, swelling, and pain with direct palpation or with passive dorsiflexion of the first metatarsophalangeal joint.\(^3\)

Initial radiographs yield normal findings in sesamoiditis, even on axial sesamoid views.\(^5\) Magnetic resonance imaging is much more sensitive, with increased bone marrow signal indicating fluid in the affected sesamoid bone.\(^5\) Computed tomography images are not useful for diagnosing sesamoiditis, but can demon-
Sesamoiditis in a young woman with subacute nontraumatic medial forefoot pain. Axial (A) and dorsal-plantar (B) radiographs of the right hallux metatarsophalangeal joint showing uniform sclerosis of the tibial sesamoid (S) without fracture. 99mTc-methylene diphosphonate nuclear scintigraphy focused at the right foot (C) showing focal intense tracer deposition (red arrow) at the tibial sesamoid.

Figure 4: Evolution of an acute fibular sesamoid fracture in a young athlete. Dorsal-plantar coned-down radiograph of the hallux metatarsophalangeal joint showing an acute nondisplaced fracture (blue arrow) of the fibular sesamoid (S) (A). Repeat radiograph 6 weeks later showing increased distraction (red arrow) and nonunion (B).

Figure 3: Sesamoiditis in a young woman with subacute nontraumatic medial forefoot pain. Axial (A) and dorsal-plantar (B) radiographs of the right hallux metatarsophalangeal joint showing uniform sclerosis of the tibial sesamoid (S) without fracture. 99mTc-methylene diphosphonate nuclear scintigraphy focused at the right foot (C) showing focal intense tracer deposition (red arrow) at the tibial sesamoid.

Strate sclerosis due to other pathologies such as stress fractures or osteonecrosis. Finally, 99mTc-methylene diphosphonate (Tc-99m-MDP) bone scan will show focal increased radiotracer uptake localized to the region of the plantar hallux sesamoid (Figure 3). Single photon emission computed tomography (SPECT), with improved spatial resolution compared with planar imaging, shows mildly increased uptake of the affected sesamoid with sesamoiditis.

Treatment options are generally conservative, including rest, nonsteroidal anti-inflammatory medications, spica taping of the hallux, and custom orthotics. Specific orthotic modifications include a reverse Morton’s extension, dancer’s pad, or carbon fiber plate for short durations of immobilization. Also, pneumatic cam walker boots have been used for immobilization of sesamoid complex after conservative treatment options have failed. Injectable steroids remain controversial in acute fracture, but can be used for treatment of sesamoiditis. A newly reported trend in sports medicine involves hyaluronic acid injections, commonly used for osteoarthritis of the knee, for chronic sesamoid pain. This is controversial, and these injections are not Food and Drug Administration approved for use in the first metatarsophalangeal joint. However, hyaluronic acid injected around the affected sesamoid(s) has been shown anecdotally to reduce pain and restore function to the sesamoid complex. Surgical excision of the affected sesamoid bone is reserved for patients who do not respond after 6 months of conservative treatment.

Traumatic Injuries

Acute. Traumatic injuries of the hallux sesamoids include acute fracture, dislocation, and stress fracture. Acute fractures of the hallux sesamoids are due to trauma to the first metatarsophalangeal joint, often hyper-dorsiflexion of the joint or an abrupt axial load to the forefoot. The tibial sesamoid is fractured much more often than the fibular sesamoid because it bears the majority of axial loading. Also, the fibular sesamoid can slip into the joint on metatarsophalangeal dorsiflexion and thus avoid direct contact with the plantar surface of the metatarsal head.

Acute pain after trauma is the primary symptom. Physical examination findings include pain with palpation, while swelling is less frequent. Initial radiographs should include anteroposterior, oblique, lateral, and axial sesamoid views. The majority of fractures are simple transverse fracture planes with minimal or mild distraction due to the multiple regional stabilizers. Broad distraction is indicative of destabilization of the plantar metatarsophalangeal (Figure 4). Radiographs often present a diagnostic dilemma because bipartite sesamoids may resemble acute fractures. Both bipartite and multipartite sesamoid fragments have smooth, narrow, sclerotic margins, while an acutely fractured sesamoid has a nonsclerotic, irregular margin. In addition, a multipartite sesamoid is larger than a unipartite sesamoid, including sesamoid fracture fragments. Computed tomography may better show the normal corticated, smoothly margined multipartite sesamoids vs the noncorticated, irregular margins of an acute fracture. Associated soft tissue injuries such as transverse sesamoid ligament tears, tears of the medial or lateral sesamoid ligaments, and plantar plate ruptures not shown by CT can be demonstrated by high-resolution MRI. A bone scan can help diagnose a fracture, as it will show increased radiotracer uptake by fracture fragments but not by multipartite sesamoid fragments. Callus formation is visible on radiographs and CT after 2 to 3 weeks. Full healing takes approximately 6 weeks.

Sesamoid fractures are difficult to treat due to the poor...
blood supply and the location within the foot. If early diagnosis is made, 6 to 8 weeks of immobilization in a tall pneumatic cam boot or short leg cast with crutches can effectively allow for healing. It is largely presumed that the sesamoid fractures do not heal by osseous union but rather by fibrous bridging that may be asymptomatic. However, in many cases, fractures go on to delayed union, nonunion, malunion, or intra-articular arthritis. Because sesamoid fractures are known to have poor healing potential, it is common practice to prescribe a bone stimulator in conjunction with immobilization.

If there is a delay in fracture diagnosis, conservative efforts may be futile and more invasive treatment required. Partial or complete surgical excision of the injured sesamoid is well discussed in the literature and can serve as a viable treatment option if conservative measures have failed. Anecdotal concerns have been raised regarding the development of subsequent deformities after removal of a sesamoid bone: loss of hallux purchase, hallux malleus, hallux varus, and hallux valgus deformity. Because of the bone’s small size and location and the general success with excisional procedures, open reduction with internal fixation of acute fractures has not been commonly employed. Platelet-rich plasma, bone marrow aspiration injections, and autogenous bone grafting have been advocated as adjunctive measures during surgical interventions for non-union.9,10

Chronic. Chronic stress can also affect the sesamoids. The mechanism is repetitive hyper-dorsiflexion injuries associated with activity over a prolonged period. The symptoms and signs are similar to those of the patients who have acute fractures, but the symptoms are chronic and there is no history of an acute injury.

As with an acute fracture, a stress fracture is usually a simple transverse fracture. Differentiation of subacute/chronic fractures from bipartite sesamoids can be difficult on the basis of radiographs and CT. Because early fracture plane definition may be subtle, other imaging modalities are more sensitive for showing fractures but may yield similar results for both acute and chronic stress fractures.15 A nondisplaced fracture plane may be sclerotic on CT but nonsclerotic when fragments are distracted. Bridging callus formation and periosteal new bone indicate healing. Magnetic resonance imaging has the advantage of demonstrating both bone marrow and periosteal edema. The appearance is different for undisplaced and displaced fractures. The undisplaced fracture plane has globally hypointense signal on all sequences if there is bridging callus or fibrous tissue (Figure 5). There is hyperintense signal (granulation tissue or fluid) in the cleft on fluid-sensitive sequences if distraction or displacement is present.

Initial treatment of chronic fractures is conservative; immobilization and non-weight bearing for at least 6 weeks are the first steps. The cast should include the entire hallux to prevent continued metatarsophalangeal dorsiflexion.15 Orthotics such as steel shank and rocker sole boots help to reduce stress at the metatarsophalangeal joint.13 Stress fractures may take months to heal. Rates of delayed union, nonunion, and fracture recurrence are high.15

If healing is not evident after 6 weeks of conservative treatment, surgery is a consideration. Older surgical recommendations for resection of both sesamoids have been discarded due to long-term malalignment including cock-up deformity with persistent metatarsophalangeal joint extension. The current standard of care is excision of only the fractured sesamoid, but this surgery is avoided in high-end athletes. Removal of only the tibial sesamoid can lead to hallux valgus, while removal of only the fibular sesamoid has resulted in hallux varus deformity.13 Therefore, bone grafting or partial excision is recommended for athletes.3

Osteochondritis and Osteonecrosis

When referring to the sesamoids, osteochondritis and osteonecrosis are used interchangeably to indicate an ischemic vascular injury leading to necrosis. This is thought to be a sequela of chronic stress, fracture, or infection.14 Osteochondritis typically affects young women who have gradual onset of pain at the metatarsophalangeal joint with physical examination signs similar to sesamoiditis. In fact, osteochondritis or osteonecrosis is often initially misdiagnosed as sesamoiditis.14 Specific radiographic signs of osteochondritis such as fragmentation, cyst formation, sclerosis, and collapse may not be evident for 9 to 12 months after initial presentation. Bone scan is helpful and may show increased radiotracer uptake early on. However, increased uptake is nonspecific and can be found in other sesamoid.

Figure 5: Chronic tibial sesamoid fracture in a middle-aged adult. Tibial sesamoid (S) is sclerotic on dorsal-plantar radiograph (A). Sagittal T2-weighted magnetic resonance imaging with fat saturation confirming low signal at the chronic transverse fracture (red arrow) and diffuse high-signal bone marrow edema (blue arrow) (B). Overlying superficial high T2 signal soft tissue edema (white arrow) is also present.
Radiologic Case Study

B

Crystalline arthropathy

In addition, there (Figure 6), while late-stage findings will include decreased signal on all sequences secondary to lack of viable cells that corresponds to sclerosis on CT and radiographs.6

Initial treatment is conservative, including orthoses and nonsteroidal anti-inflammatory medications. Joint injection with corticosteroids is controversial because it may delay or prevent diagnosis.16 Surgical removal is considered after failure of conservative treatment.

Osteomyelitis

Osteomyelitis of the sesamoid bones is uncommon, mostly seen in diabetic and/or neuropathic patients due to direct extension from a soft tissue infection or ulceration.3,6 Sesamoid osteomyelitis has also been reported following a puncture wound, in which pseudomonas was a frequent causative organism.17 Common signs and symptoms include pain, fever, redness, and swelling at the site. Patients may also have increased white blood cell count and elevated erythrocyte sedimentation rate or C-reactive protein.14

Early radiographs show no abnormalities, as is the case for acute osteomyelitis at other sites. Late findings include cortical erosion, periosteal reaction, and fragmentation.14 Magnetic resonance imaging is the preferred imaging modality for diagnosing osteomyelitis. Findings include low bone marrow signal on T1-weighted and high bone marrow signal on T2-weighted sequences, usually with periosseous soft tissue inflammatory changes (Figure 7). In addition, there is often avid enhancement of the bone marrow after intravenous gadolinium administration. An adjacent soft tissue ulcer, fistulous tract, soft tissue fluid collection, or abscess may also be encountered. A soft tissue abscess will have low T1- and high T2-weighted signal centrally with peripheral rim enhancement.6

Treatment includes intravenous antibiotics and resection of the involved sesamoid.5 As with sesamoidectomy for other etiologies, there is an increased risk of secondary metatarsophalangeal malalignment when sesamoids are resected.

Depositional Disease

Similar to other synovial joints, the hallux-sesamoid articulations can also be affected by the crystal deposition diseases. In particular, gouty arthropathy has been reported18-20 including tophaceous gout.21 Gout may be primary or secondary, with precipitation of monosodium uric acid crystals in the synovial compartment inciting an inflammatory response. The acute precipitous manifestation includes intense pain, redness, and warmth. Fever, leukocytosis, and elevated inflammatory markers are other signs. The first metatarsophalangeal joint is most often involved, but no joint is exempt.
Radiographic changes occur only after several years of clinical gouty arthropathy, with initial soft tissue tophus (with or without dystrophic calcification) adjacent to the affected bone or joint followed by well-demarcated pressure erosions of the subjacent bone (Figure 8). The scalloping effect results in the prototypic overhanging margin. Magnetic resonance imaging findings are not specific. The affected joint may show intermediate signal on T1-weighted and high signal on T2-weighted sequences due to inflammation and effusion. Calcified tophi may have complex signal characteristics or have low signal on all sequences, but they generally enhance with gadolinium. Visualization of joint aspirate under polarized light microscopy will show strong negative birefringence. Treatment of the acute pain syndrome is symptomatic, usually involving nonsteroidal anti-inflammatory drugs and corticosteroids. Long-term management is directed at systemic therapies to reduce uric acid.

**CONCLUSION**

The anatomy of the first metatarsophalangeal joint is complex, and the tibial and fibular sesamoids of the first metatarsal head are crucial for maintaining stability and function of the joint with weight bearing. Multiple pathologies can affect the sesamoids, typically with overlapping signs, symptoms, and findings on physical examination. Imaging is fundamental for diagnosing these entities and determining the extent of disease. With appropriate diagnosis, conservative or surgical management can be tailored to achieve a successful outcome.

**REFERENCES**