Sesamoids of the foot

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\textbf{Summary} Sesamoids are inter-tendinous bones and the constant ones are the medial and lateral sesamoids of the first metatarsophalangeal joint. Accessory sesamoids occur elsewhere and are rare. Sesamoiditis, infection, fracture and bipartite sesamoid are the common associated conditions. Treatment should be conservative in the first instance. Sesamoidectomy may be necessary but removal of both big toe sesamoids in contra-indicated.

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\textbf{Introduction}

The term 'sesamoid', coined by Galen,\textsuperscript{1} is derived from the flat, oval seeds of \textit{Sesanum Indicum}, an ancient East Indian plant used by Greek physicians as a purgative.\textsuperscript{2}

Sesamoids occur in the substance of tendons and may be completely or partially ossified or fully cartilaginous bodies. The degree of ossification is responsible for their radiographic presence or absence and the appearance of bipartism.\textsuperscript{3} The patella, the largest of the sesamoids, ossifies between 3 and 6 years, but the ossification of the sesamoids of the foot occurs quite late. However, the exact timing of ossification is unclear.\textsuperscript{4} Their function is to modify the direction of muscle action.

\textbf{Anatomy}

Some sesamoids are described as 'constant', e.g. the sesamoids of the first metatarsophalangeal (MTP) joint contained within the tendons of flexor hallucis brevis, which play a significant role in the function of halluc.

The 'variable' or 'accessory' sesamoids are often described as 'accessory' bones or ossicles. They occur relatively infrequently beneath any weight-bearing bone of the foot, especially the lesser metatarsal heads or phalanges and are rarely of
clinical significance except by causing diagnostic confusion! Hence it is important to be able to differentiate them from an acute fracture or injury. (Table 1).

Sesamoids of the first meta-tarsophalangeal Joint

The sesamoids of the first MTP joint are the most important sesamoids of the foot as they play a significant role in the function of the hallux. They absorb the majority of the weight of the first ray, protect the tendon of flexor hallucis longus under the first metatarsal head and help to increase the fulcrum of the intrinsic musculature of the first ray to provide a strong plantarflexion force at the first MTP joint.

Anatomy

The two sesamoids within the double tendon of flexor hallucis brevis are entirely intratendinous except dorsally, where they articulate with the plantar facets of the first metatarsal head. A crista or inter-sesamoidal ridge separates the two metatarsal facets and provides intrinsic stability to the sesamoid complex. They are connected to the plantar base of the proximal phalanx through the plantar plate and are suspended by a sling-like mechanism formed by the collateral ligaments of the MTP joint and the sesamoid ligaments (Fig. 1) on both the medial and lateral aspects of the MTP joint.

The plantar aponeurosis is attached, with the capsule, to the sesamoids. On the medial side of MTP joint, the abductor hallucis tendon inserts into the plantar-medial base of the proximal phalanx as well as medial sesamoid and provides stability. On the lateral aspect, the adductor hallucis tendon inserts into the lateral base of the proximal phalanx and into the lateral sesamoid to provide lateral stability to the sesamoid complex. The inter-sesamoidal ligament that forms the base of the tendinous tunnel around the flexor hallucis longus tendon connects the two sesamoids.

The medial sesamoid is slightly larger, 9 and11 mm in width and 12–15 mm in length. It lies more distal than the lateral sesamoid which is between 7 and 9 mm wide and of 9–10 mm.5

Blood supply

Pretterklieber and Wanivenhaus6 described three types of arterial circulation of the sesamoid bone. The type A (52%) is supplied from the medial planter artery and the plantar arch. The less common type B (24%) is supplied predominantly from the plantar arch, and in type C (24%)
circulation was derived from the medial planter artery.

Sobel et al. showed that the major vascular supply enters the sesamoids from the proximal and plantar aspect, with a minor arterial supply entering through the distal pole of the sesamoids from its capsular attachments. The proximal arterial supply enters via the flexor hallucis brevis supplying one to two thirds of the sesamoid. There is an anastomosis between the proximal and distal supplies.

Thus the distal part of sesamoid has the most tenuous blood supply, and this may lead to delayed healing or nonunion after fracture. The number of arterial branches may affect both healing and the incidence of avascular necrosis (Fig. 2).

Common Conditions of the First Metatarsophalangeal Sesamoids

They may be affected by congenital anomaly, arthritis, trauma, infection, osteochondritis and sesamoiditis (see Table 2). Additionally the position of the sesamoid is important in the assessment and correction of hallux valgus deformity.

Clinical findings

Symptoms and signs arising from the sesamoids of the MTP include pain on direct palpation or on movement of the first MTP joint, restricted range of motion, swelling of the first MTP joint and decreased plantar/dorsiflexion strength. Synovitis of first MTP joint may be noted and sometimes a plantar callosity may be present under the sesamoids.

A hallux valgus or varus deformity should be noted as progressive hallux valgus or varus may develop secondary to disruption of the sesamoid by trauma, particularly fracture or following surgical excision.

Examination of the digital nerves of the first ray is important to diagnose a compression that may present as isolated neuritic symptoms or numbness; a positive Tinel’s sign may be elicited along the border of the sesamoid.

Radiological examination

Radiological examination is useful in the assessment of sesamoid pathology. However, routine antero-posterior and lateral views provide limited information. The lateral sesamoid is best demonstrated in lateral oblique views (Fig. 3). The medial sesamoid is best seen in medial oblique views (Fig. 4).

Often the most useful X-ray is the axial sesamoid view (Fig. 5A & B). Bone scans may demonstrate increased uptake before any significant radiographic change such as sclerosis, fragmentation, or disintegration.

The Research committee of American Orthopaedic Foot and Ankle Society has proposed a method for the assessment of the degree of displacement of

<table>
<thead>
<tr>
<th>Conditions affecting Sesamoids.</th>
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<tbody>
<tr>
<td>Sesamoiditis</td>
</tr>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Fracture</td>
</tr>
<tr>
<td>Bursitis</td>
</tr>
<tr>
<td>Subluxation and Dislocation</td>
</tr>
<tr>
<td>Bipartite sesamoid</td>
</tr>
<tr>
<td>Hypertrophied sesamoid</td>
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<tr>
<td>Intractable plantar keratosis</td>
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Table 2 Conditions affecting Sesamoids.
sesamoids in hallux valgus deformity on a weight-bearing anteroposterior radiograph (Table 3). The classification is helpful in assessing the degree of deformity and correction achieved after metatarsal osteotomies.

Bipartite sesamoid
The incidence of this condition is relatively rare and 80% of bipartite sesamoids involve the medial sesamoid. It may be difficult to differentiate between a bipartite sesamoid and a fractured sesamoid. It is not clear in the literature whether these bipartite sesamoids, especially if asymmetrical, have a congenital origin or they are actually fracture nonunions.

Congenital absence
Absence of a medial sesamoid may lead to the development of a progressive post-operative hallux valgus deformity or produce a clawing of the hallux. However, in general, the congenital absence of a sesamoid is usually asymptomatic.

Distorted or hypertrophic sesamoids and plantar keratosis
An irregularity in shape or congenital hypertrophy, especially over the plantar surface may lead to the development of symptomatic plantar keratosis. Subsequent ulceration and chronic osteomyelitis may result. Unrelenting pain with ambulation is the most common presentation.

Diffuse keratosis underneath the head of the first metatarsal is usually associated with a plantar flexed first ray and a cavus deformity. Conservative measures such as a metatarsal pad or custom orthotic device may redistribute the weight and alleviate symptoms. However, in refractory cases, sesamoid shaving and very rarely, sesamoidectomy may be considered. The associated deformities,
especially in cases of intractable plantar keratosis may also require correction.

Fracture
Fracture is rare but may occur after significant trauma to the first MTP joint e.g. a fall, sudden loading of the foot or a crush injury. Pain exacerbated by weight bearing is the predominant symptom. Passive dorsiflexion and plantar flexion of the big toe reproduces the pain. X-rays help in diagnosis but are very often difficult to interpret.

<table>
<thead>
<tr>
<th>Grade 0</th>
<th>No displacement of medial sesamoid relative to the axis of first metatarsal</th>
</tr>
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<tbody>
<tr>
<td>Grade 1</td>
<td>Overlap of &lt; 50% of medial sesamoid to the axis of the first metatarsal</td>
</tr>
<tr>
<td>Grade 2</td>
<td>Overlap of &gt; 50% of medial sesamoid to the axis of the first metatarsal</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Medial sesamoid completely displaced beyond the axis of the first metatarsal</td>
</tr>
</tbody>
</table>

**Figure 5** (A) Position of foot and direction of X-ray beam for an adequate sesamoid view. (B) Sesamoid view showing tibial and fibular sesamoids.
Orthotic devices and metatarsal pads may help in relieving symptoms. Taping of the first toe to reduce dorsiflexion may also diminish pain. Sesamoidectomy may be necessary if conservative methods fail.

**Bursitis**

Any form of prolonged irritation (cavus deformity, excessive ambulation etc) may result in chronic inflammation of a bursa present under the metatarsal head and sesamoids. The treatment is usually conservative.

**Nerve compression**

Impingement of either the medial or lateral plantar digital plantar nerve by sesamoids may be the cause of local pain. Occasionally Tinel’s sign may be elicited. The treatment is the same as for any other condition involving medial or lateral sesamoids.

**Arthritis**

Degenerative arthritis of the first metatarsal sesamoid articulation may present as pain, swelling, erythema and localised tenderness around the joint. This may follow localised trauma, sesamoiditis or chronic conditions like rheumatoid arthritis, psoriasis, diffuse idiopathic skeletal hyperostosis etc. Insoles, metatarsal pads and anti-inflammatory medication are the initial treatment. Resection of the involved sesamoid may be necessary in cases not responding to conservative magement. Resection of both sesamoids is contraindicated as it disturbs the intrinsic musculature and causes clawing.

**Subluxation and dislocation**

This is commonly seen in patients with a moderate to severe hallux valgus deformity, especially those associated with pronation of the great toe and medial migration of the metatarsal head. The sesamoids tend to maintain their relationship with the second metatarsal while subluxating or dislocating from the first metatarsal head. The intersesamoidal ridge is eroded in severe cases. Surgical correction of hallux valgus may restore the relationship of sesamoids to the first metatarsal head. The release of adductor tendons and capsular structures may also become necessary.

**Infection**

Trauma, plantar keratosis and neuropathic conditions like diabetes, myelodyplasia etc, may lead to the development of chronic osteomyelitis of sesamoids and/or infection of the MTP joint.

Pain, especially on ambulation and passive joint movement, localised tenderness with swelling and erythema are the presenting clinical features. The symptoms and signs (e.g. reduced sensibility in diabetes) of the underlying cause may also be present.

Treatment of the underlying cause combined with conservative measures may help in the initial stages. However, sesamoidectomy with wound debridement and irrigation is necessary in advanced cases. A double sesamoidectomy should be avoided for the reasons mentioned before.

**Osteochondritis of the sesamoids**

Local trauma is the most common cause of osteochondritis of the sesamoids. Any injury, causing disruption of the intra-osseus circulation of the sesamoids, may predispose an injured sesamoid to osteonecrosis. Pain and tenderness are localised to the involved sesamoid and the metatarsal head is usually non-tender. A radiological examination may show fragmentation, mottling, flattening and elongation of the sesamoid. However, a bone scan may be required if the X-ray findings are normal and there is a high clinical suspicion of this condition. The bone scan usually shows high uptake without MTP joint involvement.

The treatment recommendations are the same as for any chronic disorder of sesamoids. Conservative measures include orthoses, metatarsal pads, anti-inflammatory medication. Sesamoidectomy, is reserved for sesamoids showing collapse and fragmentation.

**Sesamoiditis**

This condition is more common in teenagers and young adults and in the past has been described as ‘chondromalacia’. Dobas and Silver defined it as the inflammation of the peritendinous structures involving sesamoids. It may be associated with trauma (dancing, wearing high heels, jumping etc). Surgical excision is only indicated if conservative treatment fails.

**Subhallux sesamoid or interphalangeal sesamoid**

It may occur as an accessory bone beneath the head of the proximal phalanx of the hallux. This is related to the substance of flexor hallucis longus tendon and articulates with the interphalangeal joint. It may be associated with a hyperkeratotic lesion. Surgical excision is indicated
Table 4  Treatment of disorders affecting medial and lateral sesamoids.

<table>
<thead>
<tr>
<th>Conservative</th>
<th>Surgical</th>
</tr>
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<tbody>
<tr>
<td>1. Reduce pressure</td>
<td>1. Sesamoidectomy</td>
</tr>
<tr>
<td>Decrease in activity</td>
<td>Plantar medial or plantar-lateral approach is used depending upon the sesamoid involved.</td>
</tr>
<tr>
<td>Low heeled shoes</td>
<td>Removal of both tibial and fibular sesamoids should be avoided</td>
</tr>
<tr>
<td>Below knee walking cast</td>
<td>2. Shaving of sesamoids — plantar keratosis</td>
</tr>
<tr>
<td>Custom made insole</td>
<td>3. Fixation of sesamoids — painful non union (rare)(^\text{13})</td>
</tr>
<tr>
<td>Metatarsal pad</td>
<td>4. Correction of the underlying condition — hallux valgus</td>
</tr>
<tr>
<td>2. Reduce inflammation</td>
<td></td>
</tr>
<tr>
<td>Anti-inflammatory medication</td>
<td></td>
</tr>
<tr>
<td>Steroids (very rarely)</td>
<td></td>
</tr>
<tr>
<td>3. Reduce dorsiflexion</td>
<td></td>
</tr>
<tr>
<td>Taping of hallux</td>
<td></td>
</tr>
</tbody>
</table>

if conservative measures fail to relieve direct pressure (Table 4).

Uncommon sesamoids and accessory bones of the foot

Accessory bones of the foot are developmental anomalies that may occur as subdivisions of normal bones or as a separate prominence of an ordinary tarsal bone.\(^\text{14}\) They may occur bilaterally or unilaterally. In general, their major significance lies in differentiating them from fractures of the adjacent bones.

Os trigonum

Rosenmuller\(^\text{15}\) first described the os trigonum. Shepherd\(^\text{16}\) initially considered it as a fracture of the posterolateral tubercle of the talus but later realised that it was not a fracture. However, forced plantar flexion may lead to a fracture of the trigonal process of the talus or may cause impingement of the os trigonum against the tibial plafond. This is especially seen in athletes. These symptoms are sometimes referred to as 'os trigonum syndrome'. Pain may be increased with direct digital pressure around os trigonum. The os trigonum may cause pain in the retrocalcaneal space aggravated by walking. Plantarflexion is the most uncomfortable position of the foot in symptomatic patients. This condition must be differentiated from retrocalcaneal bursitis in which the pain is acute and tenderness is just posterior to the Achilles tendon.

X-ray is diagnostic. However, in some cases, especially in those associated with os trigonum syndrome, MRI may give additional information.\(^\text{17}\)

Conservative measures include limitation of activity, casting and anti-inflammatory medication. Local steroids are best avoided due to proximity of the bone to the Achilles tendon. The os trigonum may be excised through a medial or lateral approach\(^\text{18-20}\) if conservative treatment fails to relieve symptoms.

Accessory Navicular

First described by Bauhin,\(^\text{21}\) this is a congenital anomaly where the tuberosity of the navicular develops from a secondary centre of ossification. It is located on the medial side of the arch of the foot in association with the navicular and has been termed as 'prehallux', 'os externum', 'accessory scaphoid'. It has been regarded as a cause of pes planus deformity\(^\text{22}\) and is occasionally mistaken for a fracture of the tuberosity of the navicular. It is closely related to the tibialis posterior tendon.

Children and adults, both may present with symptoms. In children, the symptoms are primarily related to pressure or progressive arch flattening. However, adults usually present with severe tenderness over a prominence on the medial arch following trauma. Radiographs and in some cases bone scan may be helpful. The treatment is initially conservative with a cast, arch supports and sometimes, local steroid injections (Table 5).

According to Grogan et al.,\(^\text{23}\) the majority of the symptomatic cases require surgical treatment; excision of the accessory navicular (anteromedial approach) with or without rerouting of tibialis posterior tendon through the navicular (Kidner procedure).\(^\text{24}\)
### Table 5  Accessory bones and other uncommon sesamoids of the foot.

<table>
<thead>
<tr>
<th>Name (s) of the bone</th>
<th>Location/origin</th>
<th>Clinical significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Os trigonum</td>
<td>Posterior process of talus</td>
<td>• Mistaken as a fracture of the posterior process of the talus&lt;br&gt;• Os trigonum syndrome&lt;br&gt;• Fracture, when fused to the talus</td>
</tr>
<tr>
<td>Accessory navicular</td>
<td>Medial arch of the foot in association with the navicular. Congenital anomaly in which the tuberosity of the navicular develops from a secondary ossification centre</td>
<td>• Mistaken for a fracture of the tuberosity of the navicular&lt;br&gt;• Pes planus</td>
</tr>
<tr>
<td>Os peroneum</td>
<td>Substance of the peroneus longus tendon in the 'calcaneo-cuboid' region</td>
<td>• Mistaken for a fracture&lt;br&gt;• Fracture of os peroneum&lt;br&gt;• Disruption of the Peroneal longus tendon</td>
</tr>
<tr>
<td>Os vesalianum</td>
<td>Proximal to the base of the fifth metatarsal</td>
<td>• Differentiation from a fracture of the base of fifth metatarsal&lt;br&gt;• Differentiation from a failure of fusion of apophysis of the base of fifth metatarsal or apophysitis&lt;br&gt;• Differentiation from os peroneum</td>
</tr>
<tr>
<td>Os intermetatarseum</td>
<td>Between the base of the first and second metatarsals and medial cuneiform</td>
<td>• Associated with Hallux Valgus&lt;br&gt;• Differentiated from a calcified dorsalis paedis artery, osteophyte or a fracture</td>
</tr>
<tr>
<td>Os subtibiale</td>
<td>Inferior to the medial malleolus</td>
<td>• Mistaken for a fracture</td>
</tr>
<tr>
<td>Os subfibulare</td>
<td>Posterior to the tip of the lateral malleolus</td>
<td>• Mistaken for a fracture</td>
</tr>
<tr>
<td>Calcaneus accessorius</td>
<td>Lateral aspect of calcaneus just distal to the tip of the lateral malleolus</td>
<td>• Mistaken for a fracture</td>
</tr>
<tr>
<td>Os calcaneus Secondarius</td>
<td>Dorsal beak of the calcaneus close to the head of talus (antero-medial)</td>
<td>• Mistaken for a fracture of the tuberosity of the calcaneus</td>
</tr>
<tr>
<td>Os sustentaculi</td>
<td>Posterior aspect of sustentaculum tali</td>
<td>• Mistaken for a fracture&lt;br&gt;• Pes planus</td>
</tr>
</tbody>
</table>

Other rare sesamoids that may be mistaken for a fracture are:

- Sesamoids of the tibialis posterior tendon
- Sesamoid of the tibialis anterior tendon
- Os subcalcis
- Os aponeurosis plantaris
- Os cuboides secondarium
- Os talonaviculare dorsale
- Os supratalare
- Os intercuneiforme
- Os cuneo-I metatarsal-II dorsale
- Bipartite first cuneiform
- Bipartite navicular
References

15. Rosenmuller J. De mon nullis musculorum corpus humani varietatibus; vol. 8, Leipzig 1804.