The Metatarsophalangeal Joints (MR Anatomy and Pathology)
ANATOMY OF THE GREAT TOE MTP JOINT
Articular anatomy

- Metatarsophalangeal
- Metatarsosesamoid (tibial, fibular)
Capsuloligamentous complex

- **Fibrous capsule**
  - Redundant; attachments to MT head/neck junction, proximal phalangeal base

- **Collateral ligamentous complex (CLC)**
  - Main collateral ligaments (medial, lateral): MT head -> base proximal phalanx
  - Sesamoid-metatarsal ligaments (medial, lateral); aka “sesamoid ligaments”
  - Common proximal attachment (depressions in sides of MT head)

- **Sesamoid-phalangeal ligaments** (medial, lateral)

- **Intersesamoid ligament**

- **Plantar plate**
  - Fibrocartilagenous structure at the plantar aspect of the 1st MTP joint
  - Proximally, blends with intersesamoid ligament, fibrous capsule
  - Distal attachment is plantar aspect proximal phalangeal base

- **Extensor hood** (sagittal band)
  - Extends from common extensor tendons to peripheral aspects of both sesamoids
Additional supporting structures

- **Flexor hallucis brevis tendons** (medial, lateral heads)
  - Origin: cuboid, lateral cuneiform
  - Insertion: medial, lateral sesamoids

- **Adductor hallucis tendon** (transverse, oblique heads)
  - Transverse head originates from capsules of 2\textsuperscript{nd}-5\textsuperscript{th} MTP joints, deep transverse lig
  - Oblique head originates from 2\textsuperscript{nd}-4\textsuperscript{th} MT bases, long plantar ligament
  - Insertion: Lateral aspect of lateral sesamoid, lateral/plantar aspect proximal phalanx, (blends with the joint capsule)

- **Abductor hallucis tendon**
  - Origin: medial aspect of the calcaneal tuberosity
  - Insertion: medial aspect of medial sesamoid, medial/plantar aspect of proximal phalanx (blends with joint capsule)

- **Flexor hallucis longus tendon**
  - Runs between sesamoids in the groove formed by the intersesamoid ligament/plantar capsular tissue; inserts on the plantar aspect of the distal phalanx

- **Extensor hallucis brevis, longus tendons**
  - EHB inserts on dorsal aspect of proximal phalanx
  - EHL inserts on dorsal aspect of distal phalanx
First MTP joint structures (coronal plane) 1 cm proximal to the sesamoid bones
First MTP joint structures at the level of the sesamoid bones
First MTP joint at the level of the proximal phalangeal base
First MTP joint structures in the transverse plane at the level of the sesamoid bones
Distal recess of plantar plate

Joint capsule

EHL

FHL
Sesamoid-phalangeal ligament

MT-sesamoid ligament

FHB insertion
Abductor hallucis

Adductor hallucis

Flexor hallucis brevis (medial & lateral heads)
Extensor hood (sagittal band)

EHL, EHB

bursa

Abductor hallucis

Adductor hallucis

FHL

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ANATOMY OF THE LESSER MTP JOINTS
Capsuloligamentous complex

- Fibrous capsule
- Collateral ligamentous complex
  - Main collateral ligaments (attach to sides of phalangeal base)
  - Accessory collateral ligaments (attach to sides of plantar plate)
  - Common proximal attachment to dorsal tubercle of MT heads
- Plantar plate
  - Fibrocartilagenous structure at plantar aspect of joint
  - runs between metatarsal head, proximal phalanx
Additional structures

- Flexor digitorum longus and brevis
- Extensor digitorum longus and brevis
- Extensor expansion/hood
- Flexor digiti minimi brevis
- Abductor digiti minimi
- Interosseous muscles
- Lumbricales
- Deep transverse metatarsal ligament
- Superficial transverse metatarsal ligament
- Neurovascular bundles
CLC = collateral ligamentous complex
D, P = dorsal or plantar interosseous muscles (origin on sides or inferior surf MTs, insert base proximal phalanx, extensor hood)
FdmB = flexor digiti minimi brevis
O=oblique head adductor hallucis
T=transverse head adductor hallucis
EHL   EHB
EDL      EDB
Extensor hood
Joint capsule

Abductor hallucis
FHL
Deep transverse MT ligament (connects plantar plates)
NV bundle
Superficial transverse MT ligament
FDL, FDB
Flexor digiti minimi
PL fascia

Abductor digiti minimi brevis

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Main collateral ligament
Interosseous tendon
bursa
Bare area of proximal phalanx

Capsule attachment

Distal plantar plate insertion

Plantar plate

Proximal (MT) plantar plate-capsule insertion
MTP JOINT PATHOLOGY
MR protocol

- Dedicated extremity coil
- Triplanar nonfat suppressed PD for anatomy
- Triplanar PD FS or STIR for acute pathology
  - PD FS has better resolution, anatomic detail
  - STIR preferred if homogenous fat suppression cannot be obtained secondary to field inhomogeneity
- FOV 10-14 cm
- 3 mm slice thickness
Painful conditions affecting the MTP joints

- Trauma
- Degenerative
- Arthritis
- Infection
- Osteonecrosis
- Neoplastic/non-neoplastic masses
- Sesamoid dysfunction
Trauma

- Capsuloligamentous injury
  - Turf toe
  - Skimboarder’s toe
- Acute fracture
- Stress fracture
  - Fatigue
  - Insufficiency
TURF TOE

- Sprain of the plantar capsuloligamentous complex of the great toe MTP joint

- #1 mechanism is hyperextension

- Called “turf toe” after advent of artificial playing surfaces in late 1960’s led to increased use of flexible footwear with less plantar support

- MC in athletes who participate in cutting or pivoting sports, especially football
Capsuloligamentous complex:
- Plantar plate
- Fibrous capsule
- Collateral ligamentous complex
  - Main collateral ligaments
  - Sesamoid-MT ligaments
- Sesamoid-phalangeal ligaments
- Intersesamoid ligament

Spectrum of injury also encompasses:
- Osseous/osteoochondral injury:
  - Sesamoid injury (fx, diastasis, diastasis of bipartitive sesamoid)
  - 1st MT fx, chondral injury
- FHB, abd/add hallucis strain
Football injury: Complete tear of medial sesamoid phalangeal ligament with proximal retraction of the medial sesamoid, FHB strain
NORMAL ANATOMY

Sesamoid-phalangeal ligament

MT-sesamoid ligament

FHB insertion
Football injury: Bilateral sesamoid phalangeal ligament tears with edema, hemorrhage; plantar plate is outlined by edema and hemorrhage deep to FHL.
NORMAL ANATOMY
Football injury: Distal metatarsosesamoid ligament tear, FHB strain; intact sesamoid phalangeal ligament
Intersesamoid ligament rupture with sesamoid diastasis
Complete tear of MCL and partial tear of LCL
Normal MCL, LCL (main collateral ligaments)
FHB medial head strain
Abductor hallucis

Adductor hallucis

Flexor hallucis brevis (medial & lateral heads)
Capsular and tendinous avulsion from the medial margin of the medial sesamoid with periosteal stripping (subacute injury)
51-year-old man with recent injury of left great toe
Turf toe with diastasis of fractured sesamoids
Bipartitie sesamoid diastasis
Turf toe injury in a 24-year-old professional football player: disruption of plantar plate with associated edema and osteochondral injury.

Normal plantar plate for comparison.
Disrupted plantar plate at the 2nd MTP joint in a 48-year-old woman who presented with foot pain (no history of injury)
Classification of injury

- Grade I: sprain of the plantar capsular complex with pain, tenderness, swelling
- Grade II: capsular disruption with bruising, decreased ROM
- Grade III: Chronic injury; results in decreased ROM, OA
Treatment

- Low grade injury usually treated conservatively
- High consideration for surgery if:
  - Extensive capsular tearing with instability
  - Sesamoid fx
  - Significant sesamoid retraction
  - Sesamoid diastasis
  - Osteochondral lesions
  - Intra-articular bodies
  - High level athletes
- Goal of surgery = repair and restore anatomy
Preoperative exam: proximal rupture of the sesamoid phalangeal ligament
Post-operative examination showing primary repair of the sesamoid phalangeal ligament
Complications/sequelae

- Chondromalacia of 1\textsuperscript{st} MT head
- Osteoarthritis 1\textsuperscript{st} MTP
- Hallux valgus
- Hallux rigidus (dorsal osteophytosis)
Skimboarding is a beachside sport in which the athlete stands on the shore, drops the board on the ground, and jumps on it in very shallow water.

Skimboardeer’s toe = hyperdorsiflexion injury of the MTP joints.

Unlike in turf toe, the injured capsuloligamentous structures are dorsal, rather than plantar.
MECHANISM:

- Skimboarder uses toes to grip board; if board slips posteriorly in relation to skimboarder, hyperdorsiflexion at the MTP joints may occur.

- If the toe is violently hyperextended, forces apply to the EHL/EDL in a dorsal direction, potentially disrupting the extensor expansion.

- May be a/w avulsion fx proximal phalanx.

- Theory as to why anatomic distribution of injury differs from turf toe despite similar mechanism: skimboarding is done barefoot, rendering extensor longus tendons more apt to dorsiflex and tear the extensor expansion.
39-year-old skimboarder s/p hyperextension injury of 1\textsuperscript{st} MTP joint:

- dorsal soft tissue swelling
- disruption of dorsal aspect of extensor expansion
- intact extensor tendons
- intact plantar plate
Hyperextension injury of the 2\textsuperscript{nd} MTP:

- dorsal soft tissue swelling
- lax/wavy, discontinuous extensor hood
- marrow edema proximal phalanx
- normal plantar plate
Metatarsal fracture

- Acute fx
- Stress fx
  - Fatigue
    - Runners, military recruits, gymnasts
    - Especially mid-distal 2nd-4th MTs
  - Insufficiency
Metatarsal stress fracture
Insufficiency fracture of 2\textsuperscript{nd} MT head
Insufficiency fracture of 2\textsuperscript{nd} MT head
Insufficiency fracture of 2\textsuperscript{nd} MT head
Freiberg’s infraction

- MC in adolescents, young women
- MC in 2nd MT head
- Cause is controversial, likely multifactorial
  - Popular theory: traumatic insult (acute or repetitive) leading to vascular compromise
- Radiographs show flattening, increased density, cystic lucent areas; ultimately leading to deformity and enlargement, secondary degenerative changes
Freiberg’s infraction
Hallux valgus/Bunion

- Static subluxation of 1st MTP joint characterized by valgus deviation of the great toe and varus deviation of the 1st metatarsal
- Etiology is multifactorial; higher frequency in women (constrictive footwear); other predisposing factors include metatarsus primus varus, pronation of the foot, rheumatoid arthritis, neuromuscular disease
- Sesamoids maintain their relation with the other metatarsal bones; therefore they become laterally located with respect to 1st MT head
- Overgrowth of median eminence of 1st MT head, which has an irregular appearance; may contain prominent cystic areas simulating the appearance of gout
- Adjacent soft tissue swelling
- Complications:
  - OA (1st MTP and sesamoid-MT), dorsal osteophytosis
  - Stress fx sesamoids, medial margin of proximal phalangeal base
- Rx = medianl eminence shaving, 1st MT osteotomy
- Hallux valgus: > 15 degrees between 1\textsuperscript{st} MT head and proximal phalanx

- Metatarsus primus varus: >10 degrees between 1\textsuperscript{st}, 2\textsuperscript{nd} metatarsals
HALLUX VALGUS, BUNION
TAILOR’S BUNION (BUNIONETTE)

- Bony overgrowth, soft tissue swelling 5\textsuperscript{th} MTP
- Exacerbated by tight footwear, excess pressure on lateral aspect of foot
- fifth toe often deviated in medial direction at MTP
- a/w hallux valgus
Arthritis

- OA
- RA
- Gout
- CPPD
- Reactive arthritis
- Neuropathic arthropathy
OSTEOPATHRITIS
Severe OA, bulky dorsal osteophytosis

HALLUX RIGIDUS
GOUT

- 1st MTP joint is MC location
- well-defined erosions with overhanging edge
- soft tissue tophi
- normal bone mineralization
- late joint space narrowing
Tophaceous gout in a 56-year-old man with hyperuricemia, presenting with foot pain and swelling

- low signal intensity tophi, with post contrast enhancement

- adjacent periarticular erosions with characteristic overhanging edges

- Non-specific MR features; correlate with lab values to distinguish from RA, septic arthritis, neoplasm
Rheumatoid arthritis: hallux valgus, erosions, soft tissue swelling, joint space narrowing, lateral subluxation of sesamoids
Rheumatoid arthritis
Rheumatoid arthritis: marginal erosions, joint space narrowing, synovitis
Reiter's disease: enthesopathy or whiskering of the sesamoids, MTP
Osteomyelitis

- MC in diabetics
- Usually from transcutaneous spread of infection
- Cutaneous ulcers develop at pressure points; esp under 1st, 5th MT heads
- MR non-specific: T1 hypointensity, T2 hyperintensity, enhancement (ddx = neuropathic arthropahty)
- +/- abscess, sinus tract, bony destruction
- Distinguishing factors: location, ulcer, abscess/phlegmon, sinus tract
- Septic arthritis: joint effusion, synovitis, marrow edema
Osteomyelitis of 1st MT head, septic arthritis of 1st MTP joint
Morton’s neuroma

- Fibrotic response in and about plantar digital nerves (digital branches of medial, lateral plantar nerves)
- Likely on the basis of mechanical impingement
- MC in women, repetitive stress such as in ballet or running, etc
- #1 location is between the 3rd & 4th MT heads (3rd interspace), #2 location is 2nd interspace
- Clinical:
  - Pain at level of MTP joint that may radiate into toes
  - May be asx
- MR: T1 - hypo, T2 SE – iso to hypo, T2 FSE FS hyperintense; ++ enhancement
- Appear larger when foot imaged prone
- Often associated with intermetatarsal bursitis
- 1st interspace = Joplin’s neuroma
Morton’s neuroma
Bursitis

- Intermetatarsal or adventitial (beneath MT heads)
- May be mechanical, post-traumatic, infections, inflammatory
- NOTE: small fluid collections within first 3 inter-metatarsal bursae with transverse diameter <3mm are common and of doubtful clinical significance
Adventitial bursal formation (submetatarsal)
Sub-metatarsal Fibrosis
Benign soft tissue masses

- Ganglion cyst (#1)
- Plantar fibromatosis
- Hemangioma
- Lipoma
- Giant cell tumor tendon sheath
- Nerve sheath tumor
- Foreign body granuloma
- Inflammatory mass (i.e. gouty tophus)
Ganglion cyst
Plantar fibromatosis

- Common condition associated with fibrous proliferation and replacement of portions of the plantar aponeurosis
- All age groups
- MC central cord > medial cord
- May be solitary or multiple, can enlarge
- Usually asx, nodules usually found on palpation
- Patterns of abnormality
  - Focal nodule/soft tissue mass
  - Small fusiform and tapered thickenings, usually involging the central cord, often in its distal portions
- MR: low signal on T1 (similar to muscle), low to intermediate on T2 (though can also be T2/STIR hyperintense), variable enhancement
Plantar fibromatosis
Plantar fascia

- **Central cord**
  - largest
  - originates from medial tuberosity of calcaneus
  - adheres to subjacent flexor digitorum brevis muscle
  - Broadens as it extends distally; near MT heads, divides into 5 processes, each with superficial and deep components, each extending to one toe
- **Lateral cord**
  - originates from the lateral margin of the medial tuberosity of the calcaneus
  - blends with fascia of abductor digiti minimi
  - Attaches to 5th MT base
- **Medial cord**
  - very thin, hard to identify proximally
  - forms the investing fascia of abductor hallucis muscle
  - becomes more substantial distally, passing medially and obliquely to join the dorsal fascia of the foot
The plantar fascia is a multilayered fibrous aponeurosis.

Le fascia plantaire est une aponévrose formée de plusieurs épaisseurs de membrane fibreuse.
Foreign body granuloma
Malignant soft tissue masses

- Less common than benign tumors
- < 45 yrs
  - Synovial sarcoma (heterogeneous mass with fluid levels)
  - Rhabdomyosarcoma
- > 45 yrs
  - MFH
  - KS
  - Leiomyosarcoma
  - Liposarcoma
Leiomyosarcoma
The Sesamoid bones

- Assist with weight bearing (especially tibial sesamoid)
- Improve mechanical advantage of FHL tendon
- Critical for high level athletic function
Sesamoid dysfunction

- Congenital
- Traumatic
- Articular disease
- Infection
- Osteonecrosis
Bipartite/Multipartite sesamoids

- Can simulate pathology
- 33% sesamoids are bipartite; LC multipartite
- Usually tibial (medial) sesamoid – 85%
- Often bilateral
- May be more susceptible to injury cf complete sesamoid
- Cleft is usually transverse, smooth, rounded with well-corticated margins
- Usually no uptake on bone scan or marrow edema on MR
- Usually asx, though can occasionally be a/w abnormal motion between the fragments with pain, marrow edema
BIPARTITE TIBIAL SESAMOID
Bipartite sesamoids: well-corticated, smooth margins, no uptake on bone scan
Sesamoid trauma

- “Sesamoiditis”
- Stress fracture
- Acute fracture
- Turf toe
  - Fracture
  - Diastasis
  - Diastasis of bipartitie sesamoid
- Dislocation
“sesamoiditis”

- Controversial, generic/non-specific term, usually applied when other conditions have been excluded
- Described as a painful inflammatory condition related to injury, such as pressure from football cleats, stepping on rocks, etc
- Overlap with “stress response”
- May be difficult to distinguish from osteonecrosis
- MC in medial sesamoid
- Imaging may be NL or may see marrow edema on MR, increased density, sclerosis, fragmentation; increased uptake on bone scan
- Usually self-limiting
“Sesamoiditis” in a 28-year-old with pain and swelling beneath the great toe and no h/o trauma to this area
Sesamoiditis (vs stress response) in a 24-year-old female kickboxer
Sesamoid fracture

- MC in tibial sesamoid
- Unlike bipartite sesamoid => Jagged, irregular margins w/o sclerotic edge, associated with soft tissue swelling, + bone scan, marrow edema on MR
- Stress fracture
  - Ballet dancers, sprinters
  - Forced propulsion off dorsiflexed toe
  - More gradual onset of sxs c/w acute fracture
Sesamoid fractures
Sesamoid fracture (subacute) with resorption at the fracture site
Sesamoid arthritis

- 1st MTP joint usually also affected
- OA
- RA
- Gout
- CPPD
- Reactive arthritis
Sesamoid infection

- MC in diabetics
- Clinical: elevated ESR, leukocytosis, fever
Osteomyelitis of the medial sesamoid
Osteonecrosis

- Controversial; some maintain that the changes are related to prior trauma or chronic repetitive injury
- MC in adolescents, young women
- Gradual onset of pain, worse with weightbearing
- Non-specific imaging appearance: fragmentation, irregularity, mottling, cyst formation; progressing to sclerosis, collapse, enlargement of sesamoid
Osteonecrosis of the lateral sesamoid
SUMMARY

- Pain in the region of the MTP joints is a common clinical complaint
- Causes are numerous
- Detailed knowledge of the complex anatomy is important for accurate diagnosis
2. Resnick D. Internal Derangement of Joints, 2nd ed.