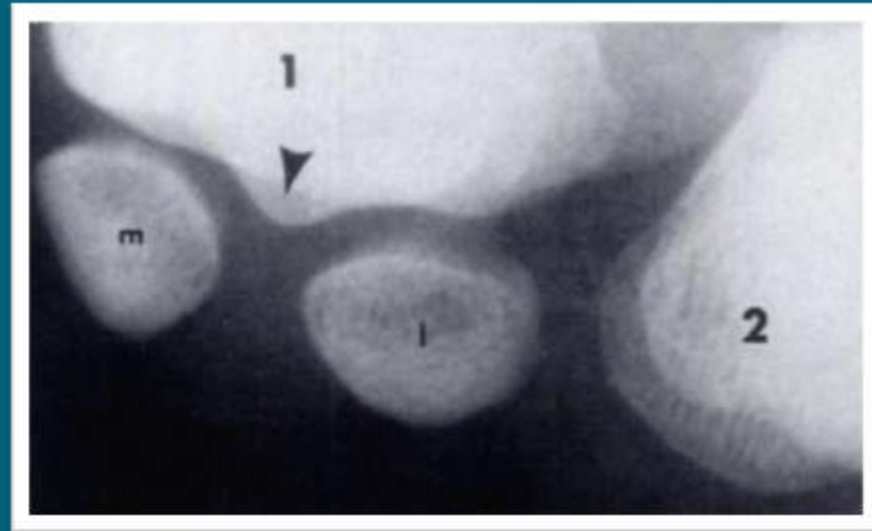


# The Metatarsophalangeal Joints (MR Anatomy and Pathology)



# ANATOMY OF THE GREAT TOE MTP JOINT

# Articular anatomy



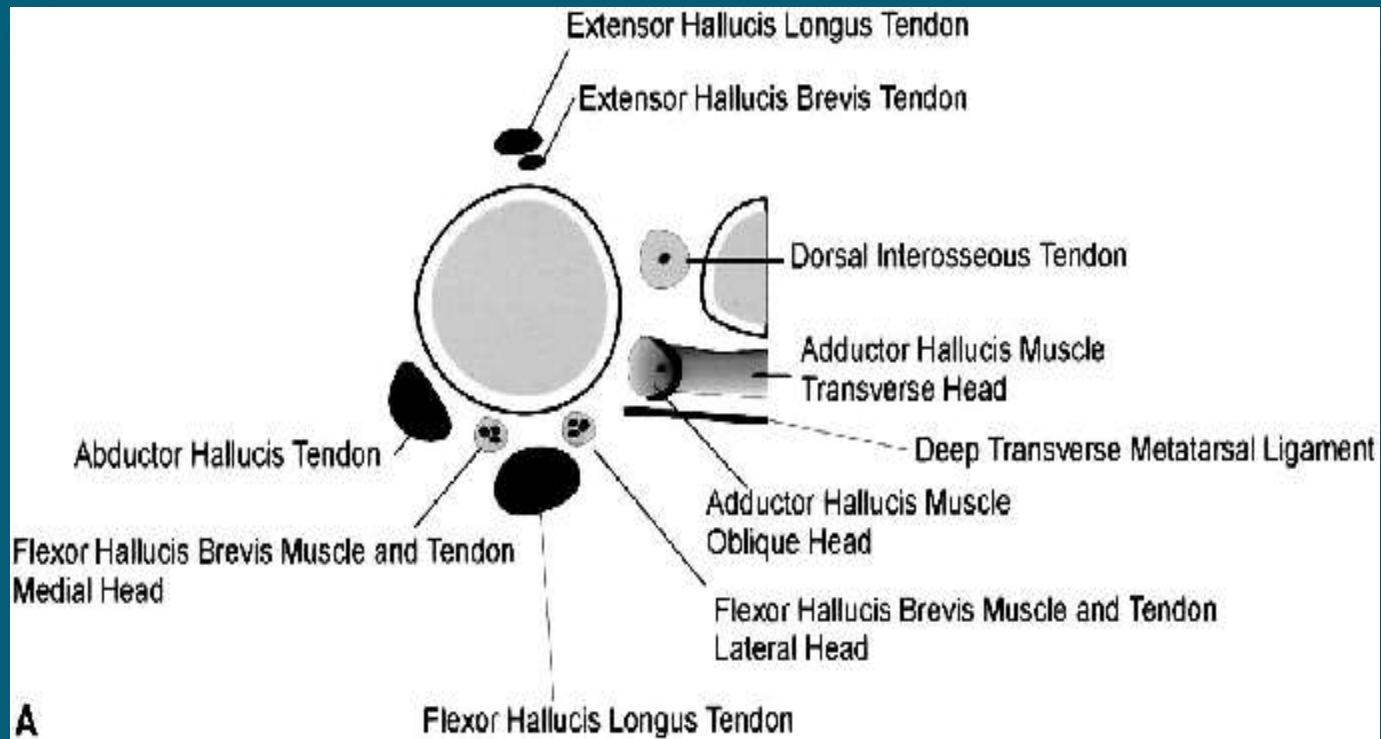
- Metatarsophalangeal
- Metatarsosesamoid (tibial, fibular)

# Capsuloligamentous complex

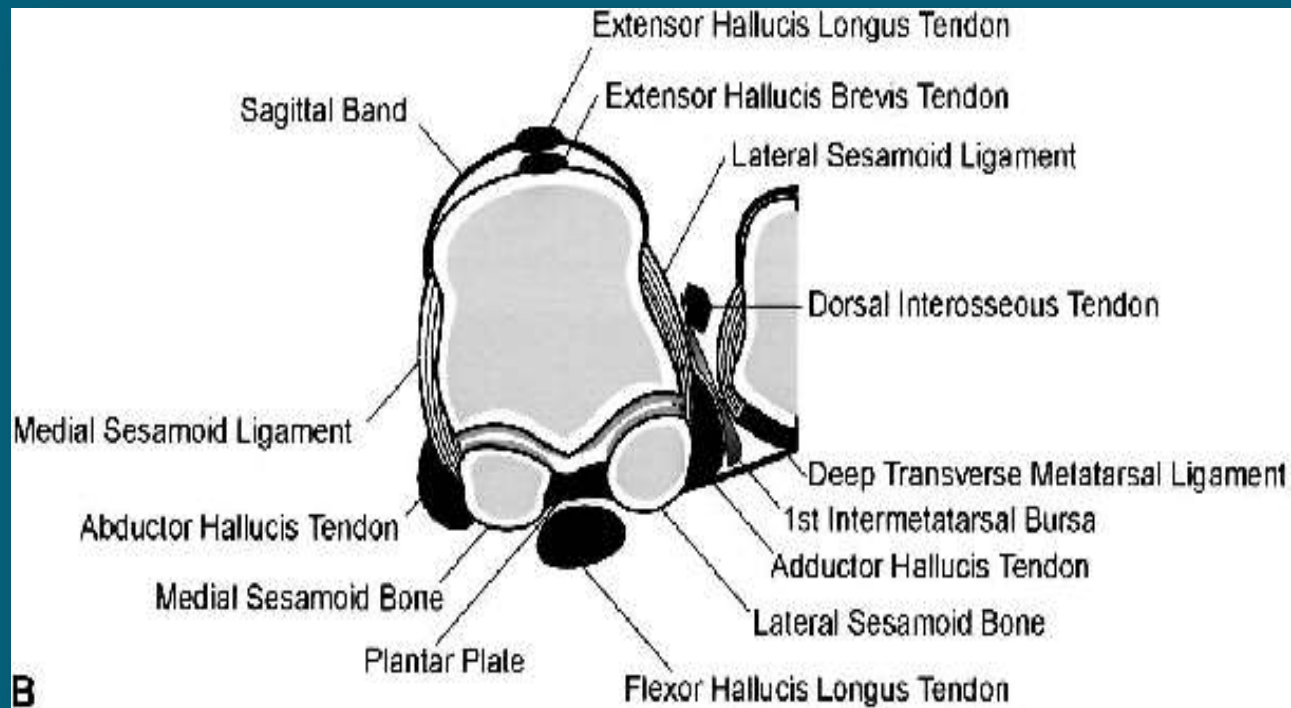
- **Fibrous capsule**
  - Redundant; attachments to MT head/neck junction, proximal phalangeal base
- **Collateral ligamentous complex (CLC)**
  - Main collateral ligaments (medial, lateral): MT head -> base proximal phalanx
  - Sesamoid-metatarsal ligaments (medial, lateral); aka “sesamoid ligaments”
  - 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 1<sup>st</sup> 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

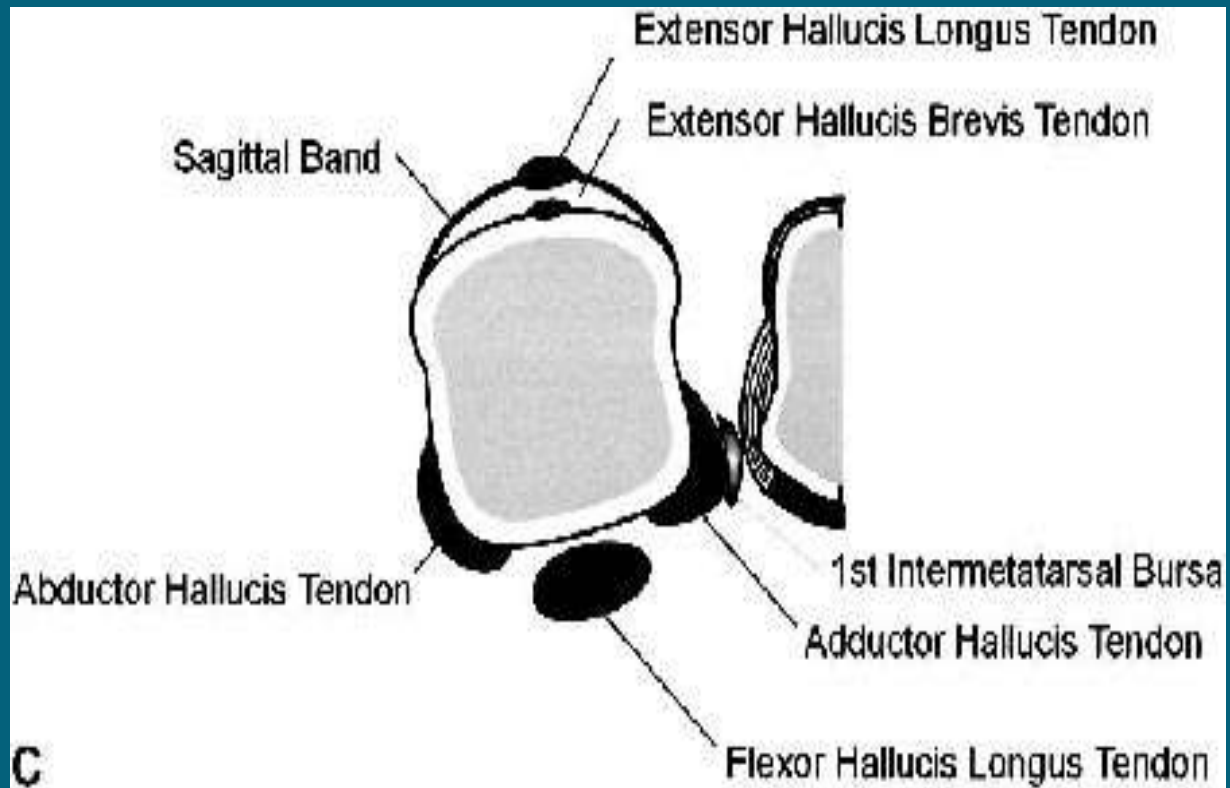
- **Flexor hallucis brevis tendons** (medial, lateral heads)
  - Origin: cuboid, lateral cuneiform
  - Insertion: medial, lateral sesamoids
- **Adductor hallucis tendon** (transverse, oblique heads)
  - Transverse head originates from capsules of 2<sup>nd</sup>-5<sup>th</sup> MTP joints, deep transverse lig
  - Oblique head originates from 2<sup>nd</sup>-4<sup>th</sup> 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

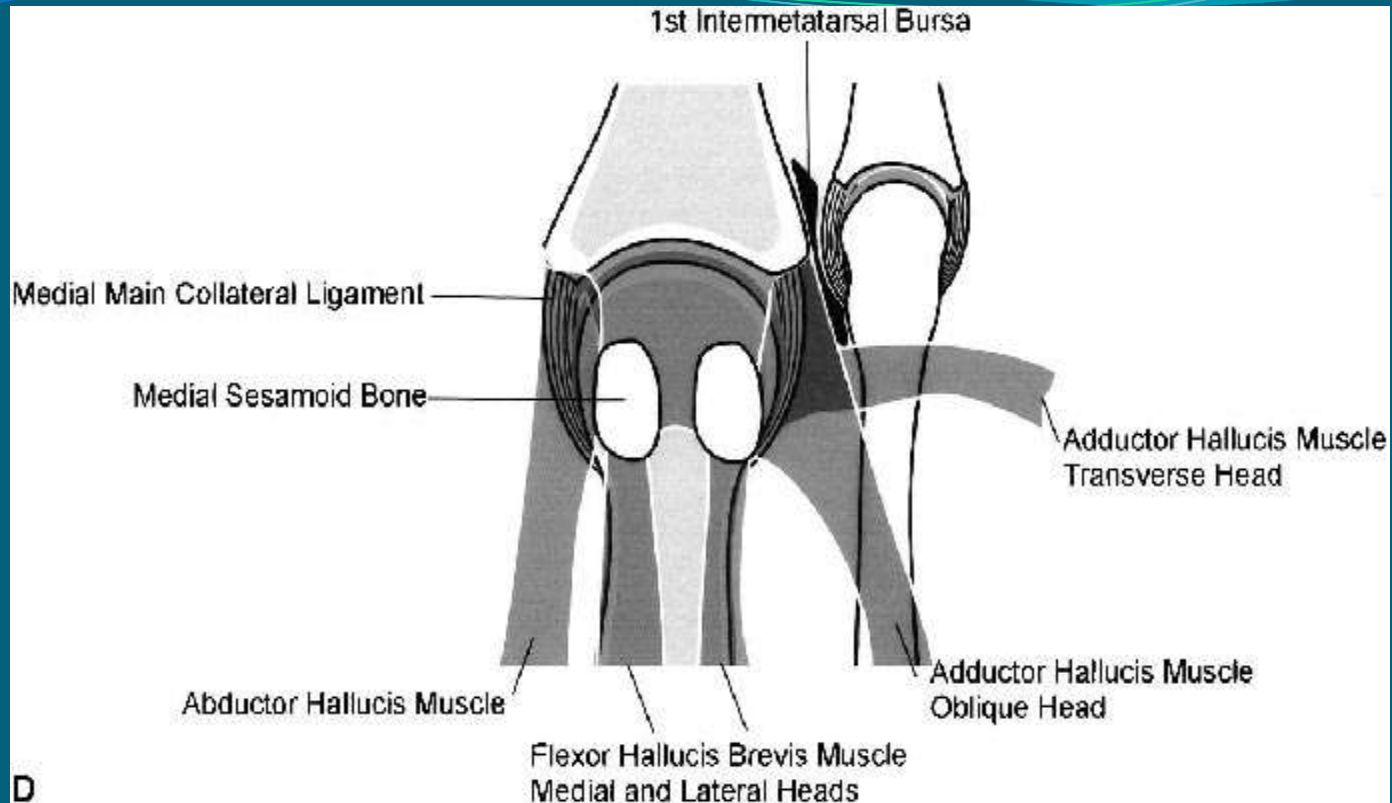


First MTP joint structures at the level of the sesamoid bones

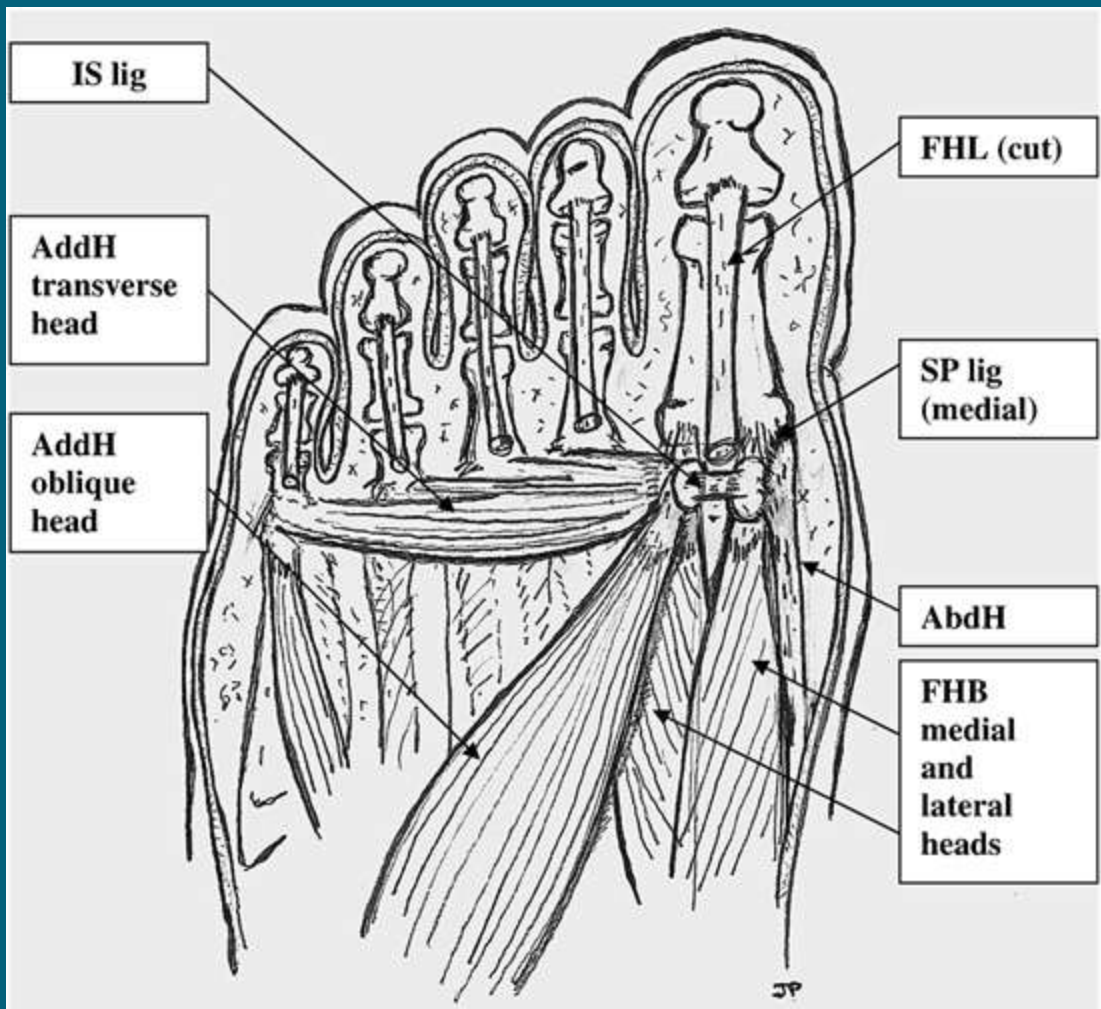


First MTP joint at the level of the proximal phalangeal base



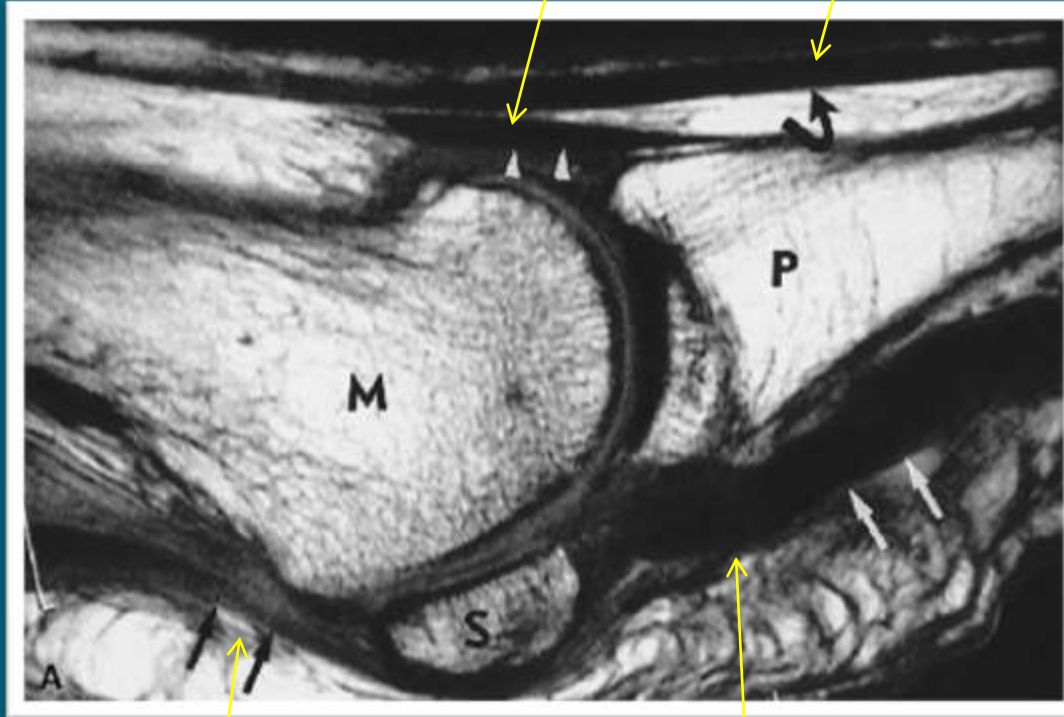


First MTP joint structures in the transverse plane at the level of the sesamoid bones



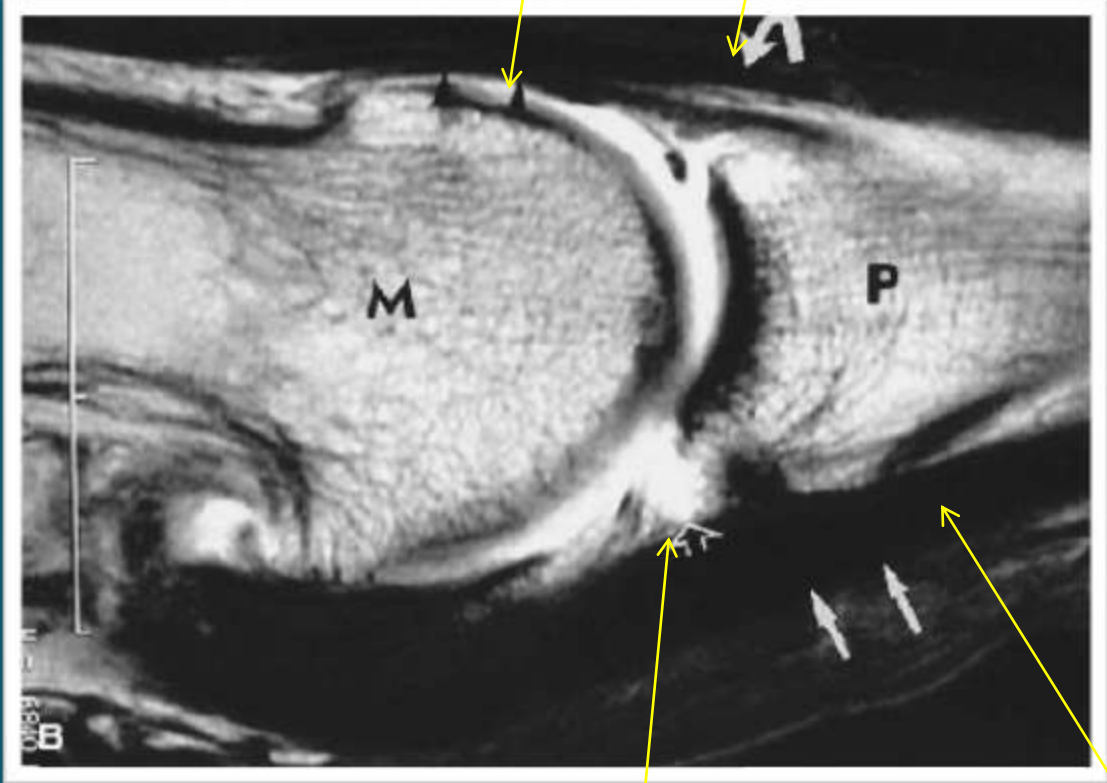
Extensor Hallucis Brevis

Extensor Hallucis Longus



Flexor Hallucis Brevis

Flexor Hallucis Longus

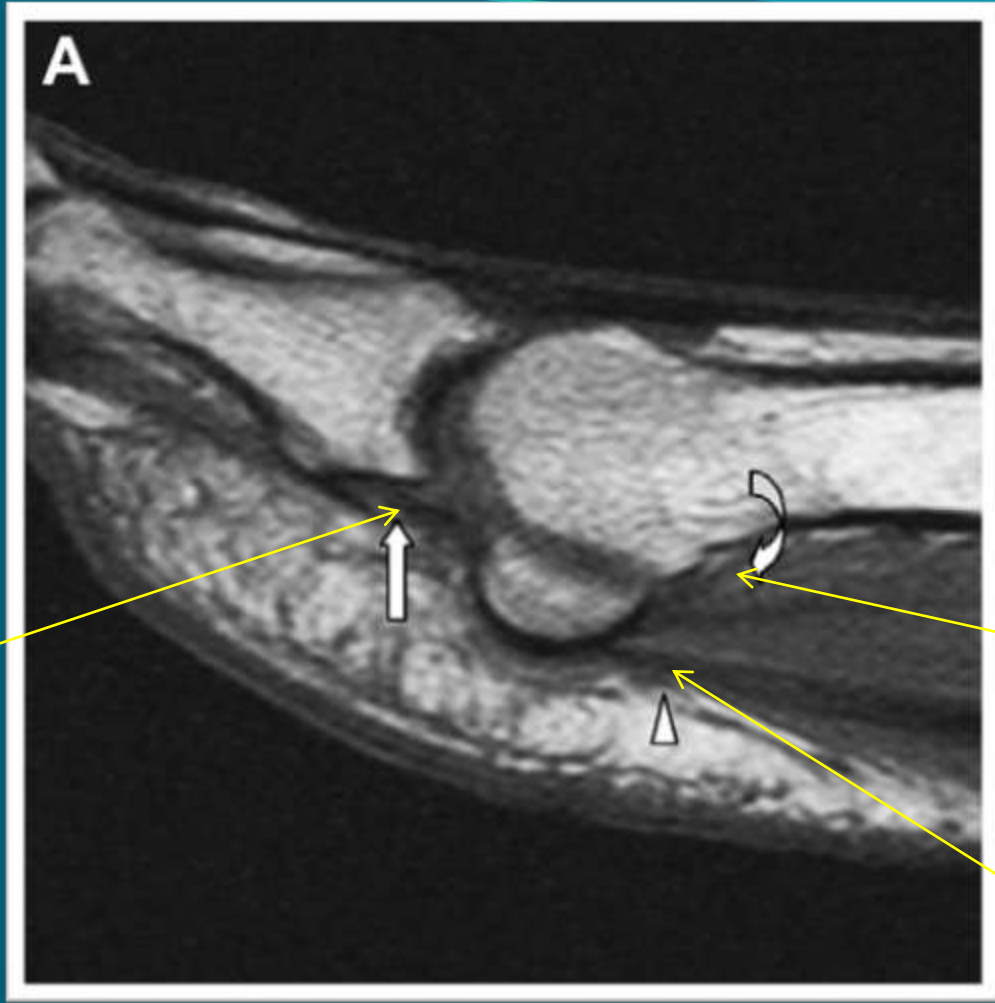


Joint capsule

EHL

Distal recess of plantar plate

FHL

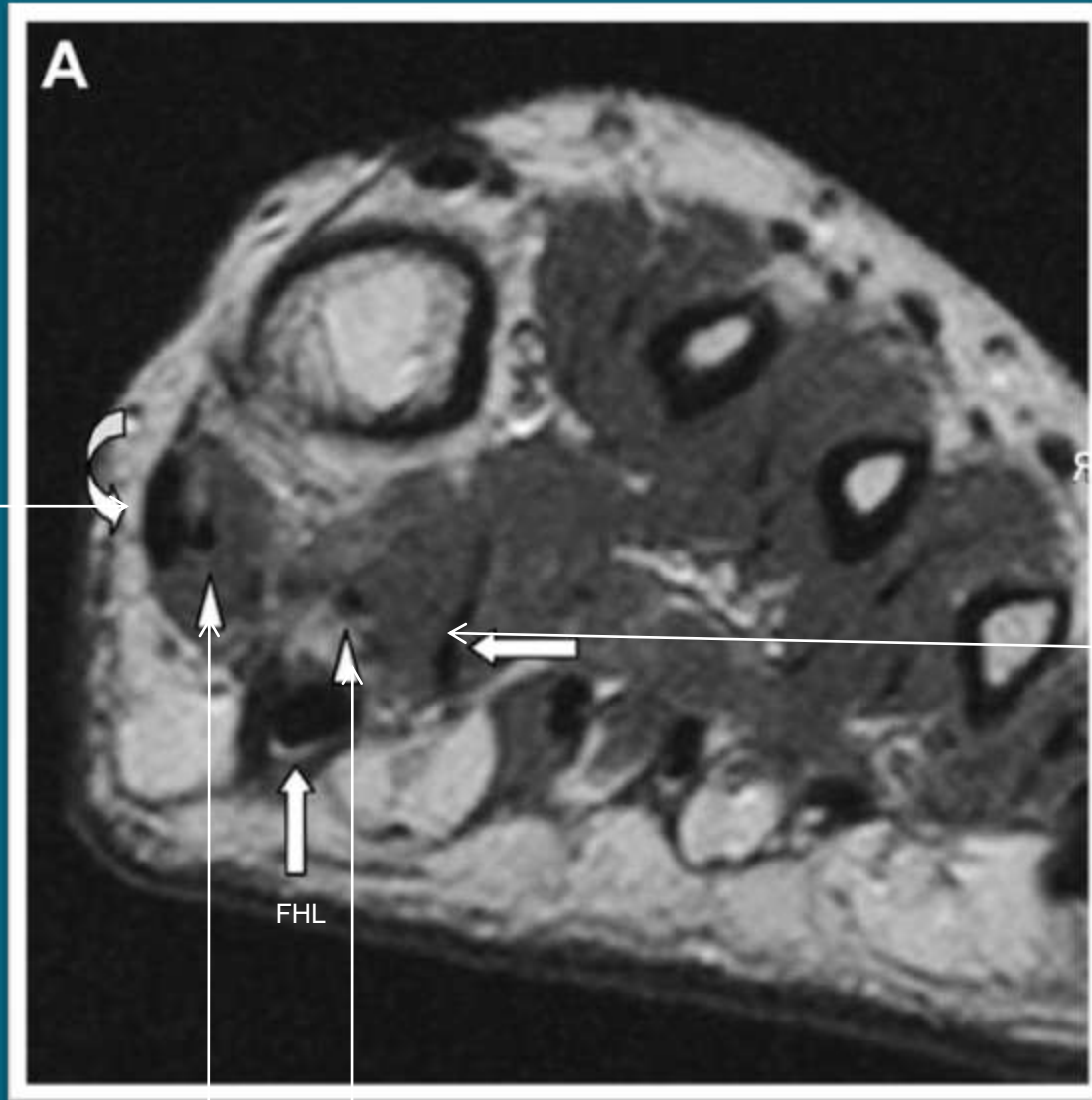


Sesamoid-phalangeal ligament

MT-sesamoid ligament

FHB insertion

A

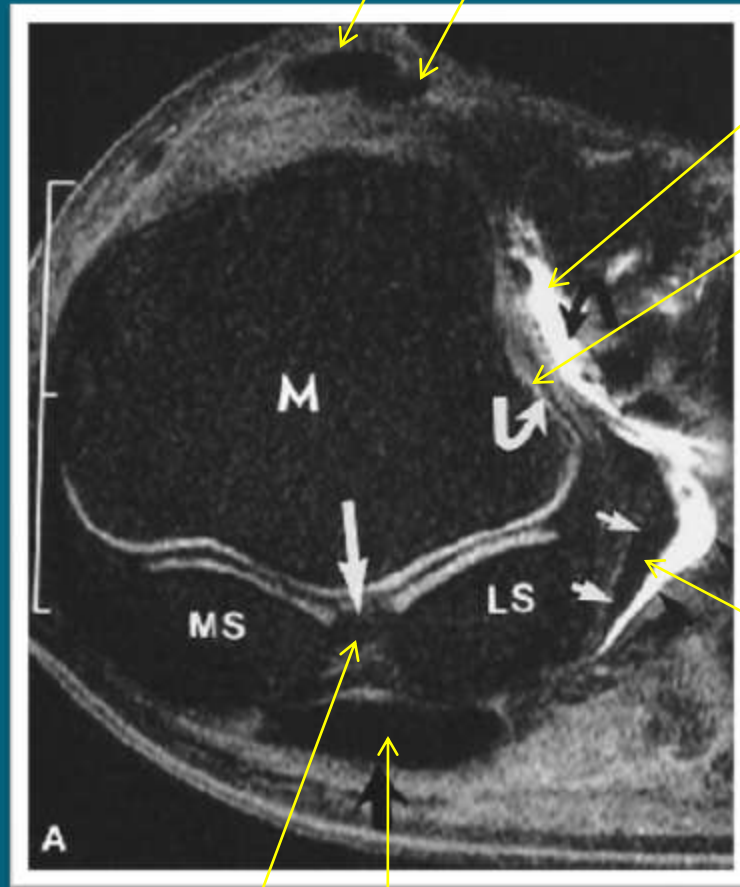


Abductor  
hallucis

Adductor  
hallucis

FHL

Flexor hallucis brevis (medial & lateral heads)



EHL EHB

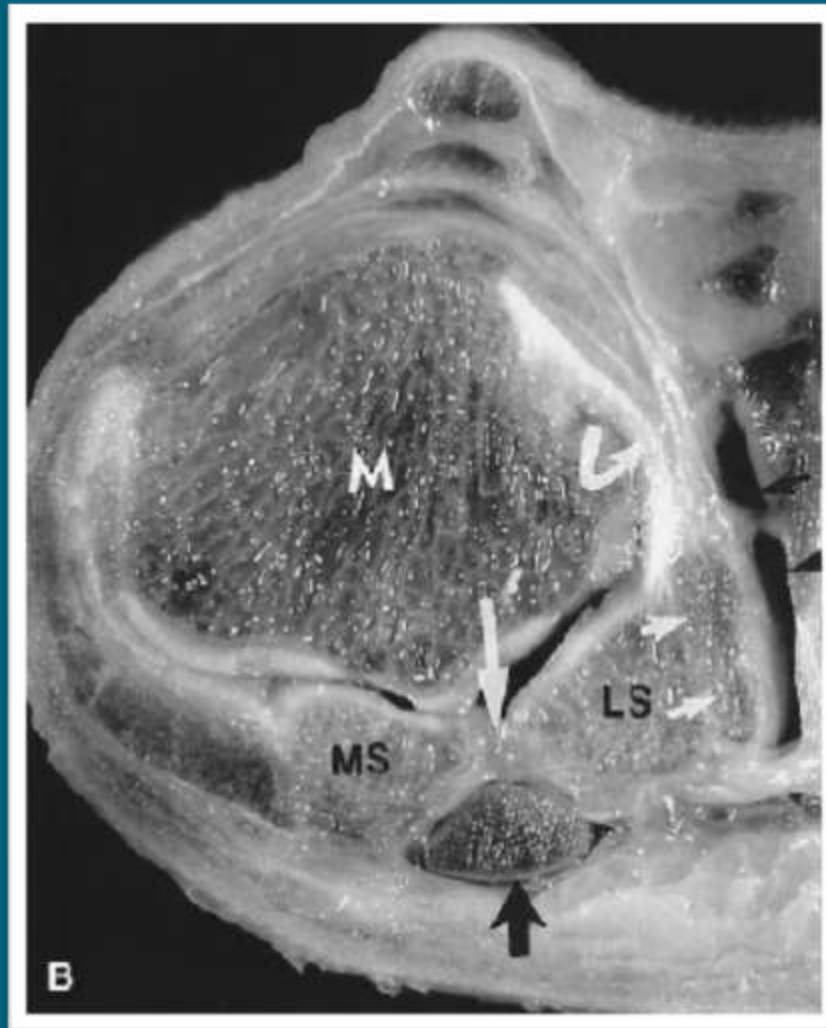
Inter-MT bursa

Lateral sesamoid-MT ligament

Adductor hallucis

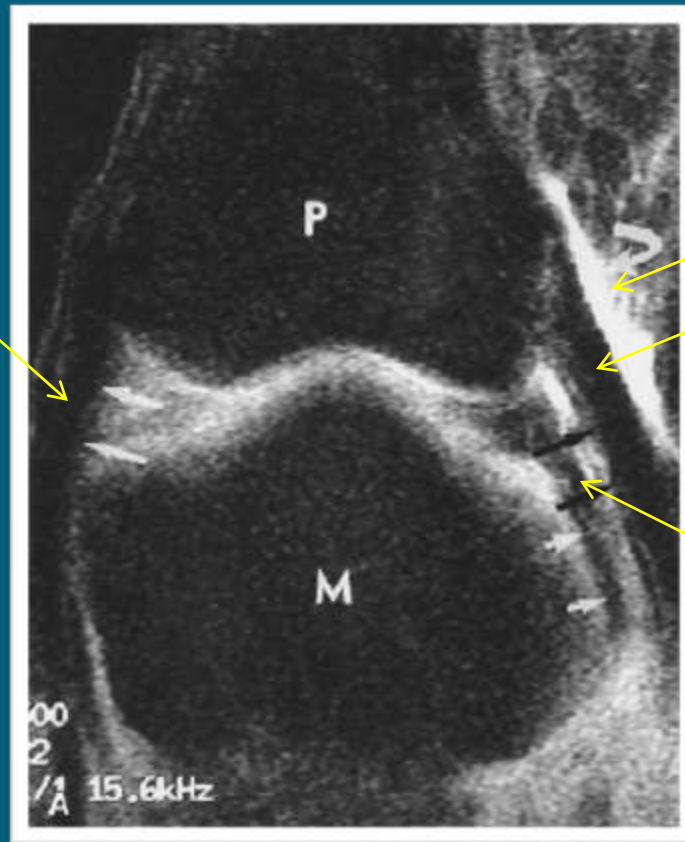
Intersesamoid Ligament/plantar plate

FHL





Abductor  
Hallucis



Bursa

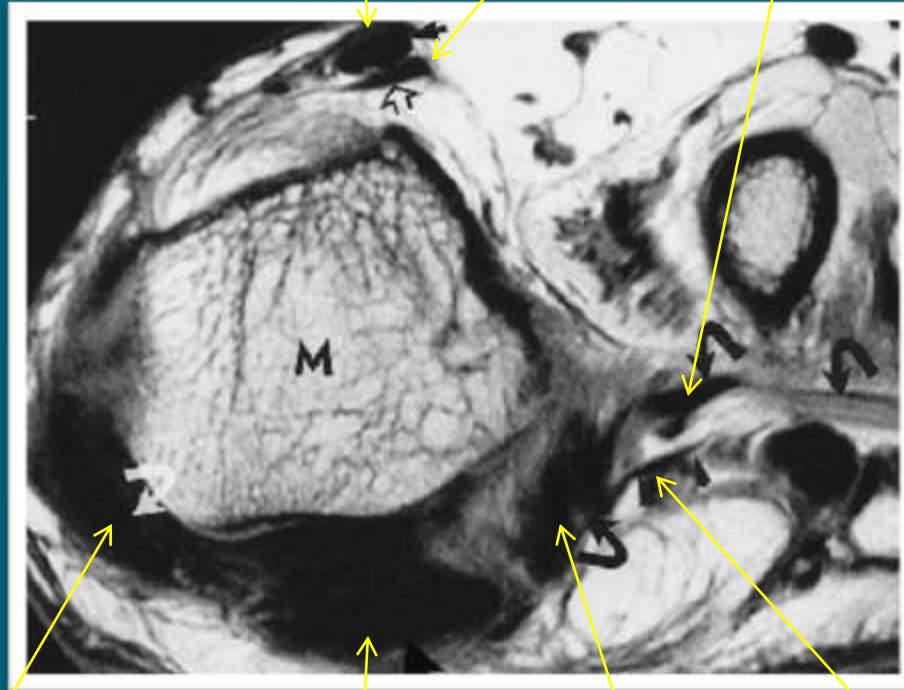
Adductor Hallucis

Lateral main  
collateral  
ligament

EHL

EHB

Adductor Hallucis  
(transverse head)



Abductor  
Hallucis

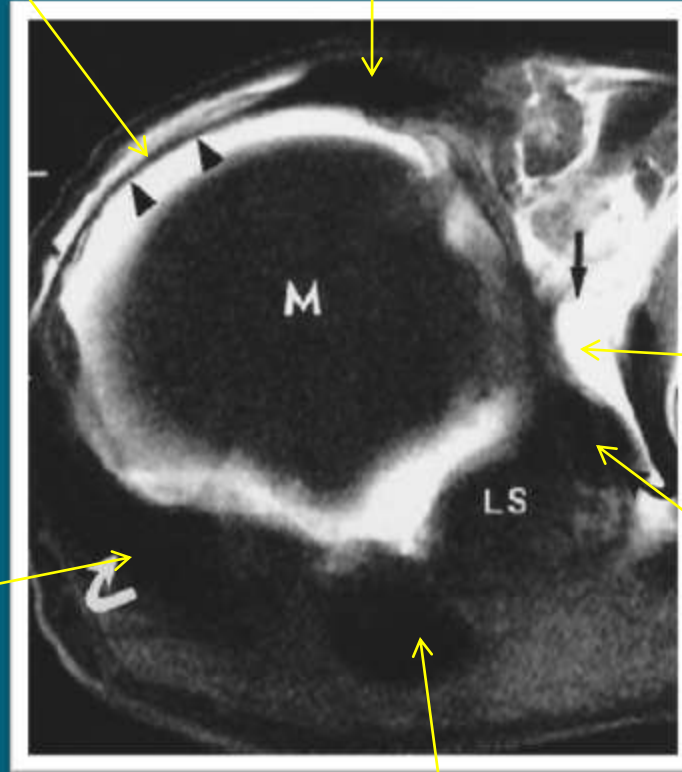
FHL

Adductor  
Hallucis

Deep transverse  
metatarsal  
ligament

Extensor hood  
(sagittal band)

EHL, EHB



bursa

Abductor  
hallucis

Adductor  
hallucis

FHL



Lateral sesamoid  
MT ligament

Adductor  
hallucis

Abductor  
hallucis

Intersesamoid  
ligament/  
plantar plate

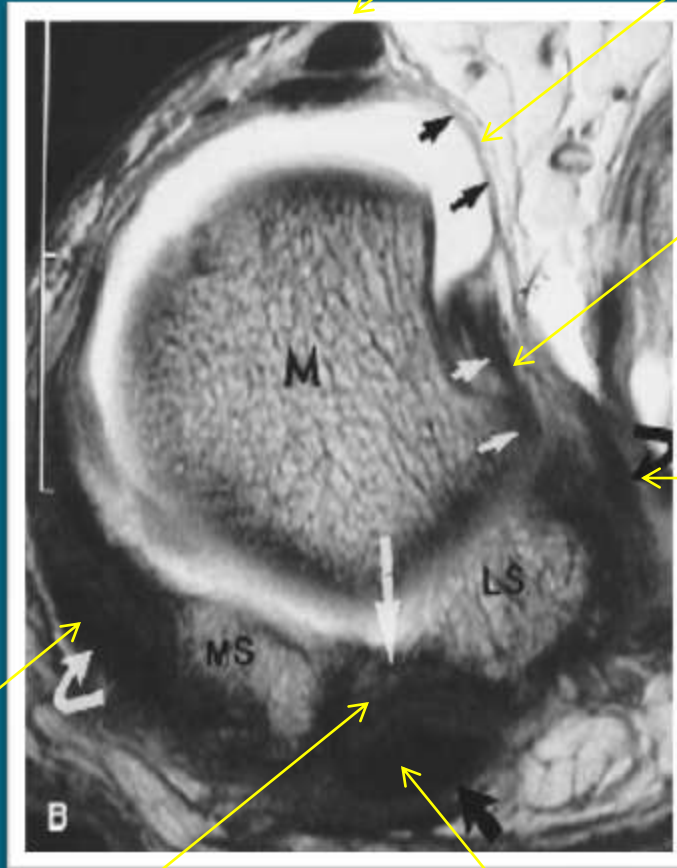
FHL

EHL

Sagittal band

Lateral  
sesamoid-MT  
ligament

Add  
hallucis

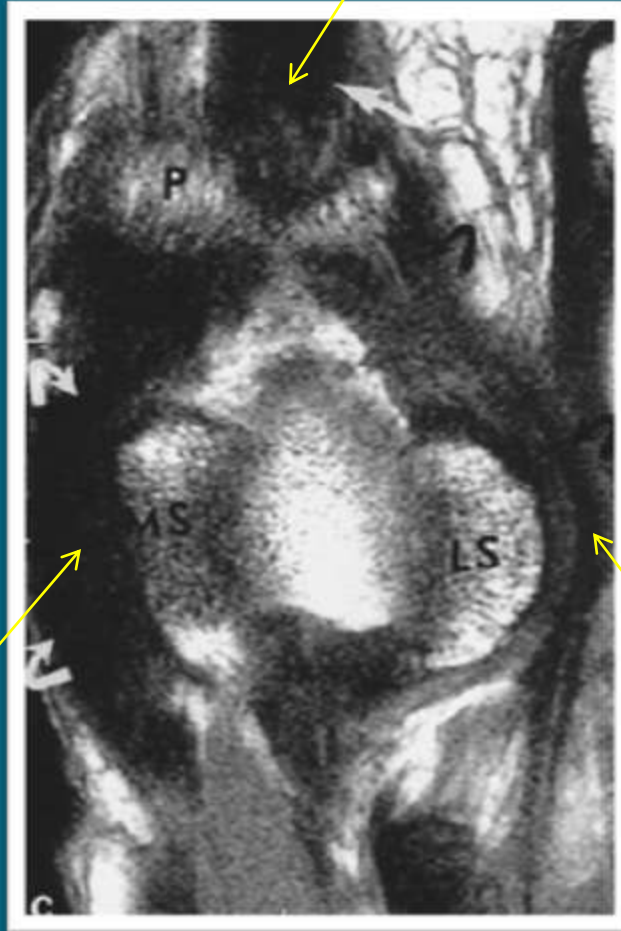


Abd  
hallucis

IS ligament/  
plantar plate

FHL

FHL



Abductor hallucis

Adductor hallucis

# ANATOMY OF THE LESSER MTP JOINTS

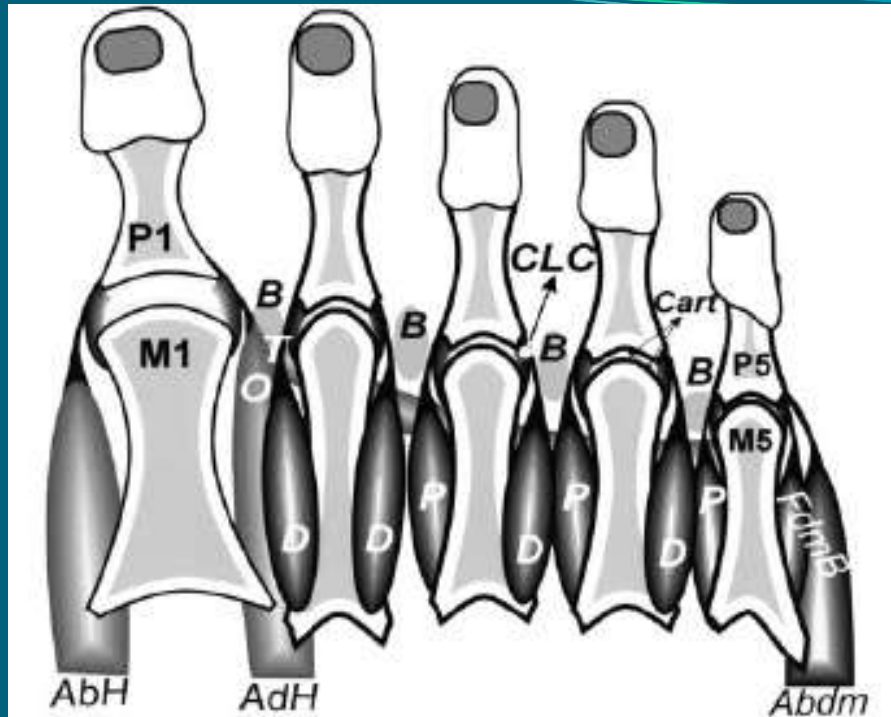
# Capsuloligamentous complex

- 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
- Lumbricals
- Deep transverse metatarsal ligament
- Superficial transverse metatarsal ligament
- Neurovascular bundles



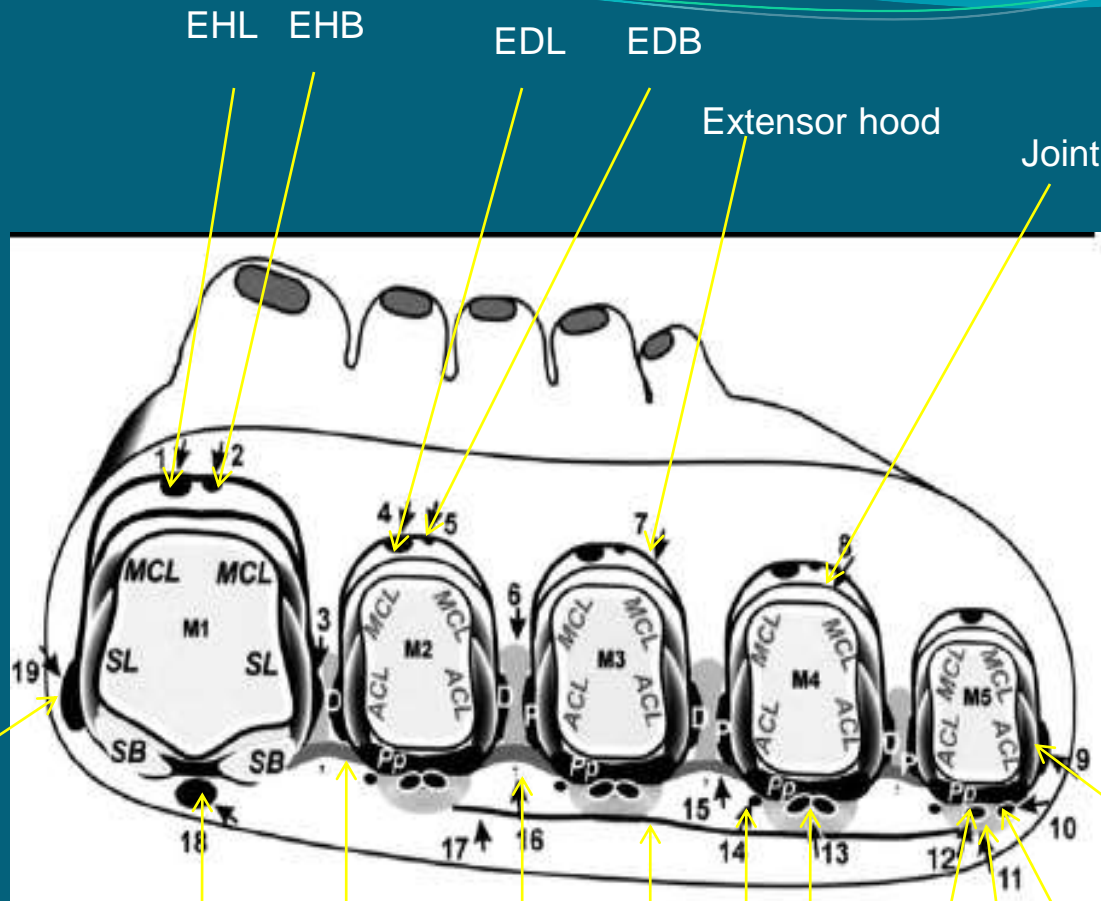
CLC = collateral ligamentous complex

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

NV bundle

L

FDL, FDB

FDL

PI fascia

Abductor digiti minimi

Flexor digiti minimi brevis

Deep transverse MT ligament (connects plantar plates)

Superficial transverse MT ligament

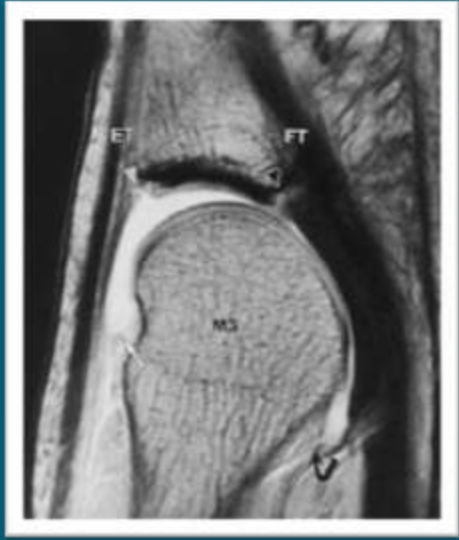


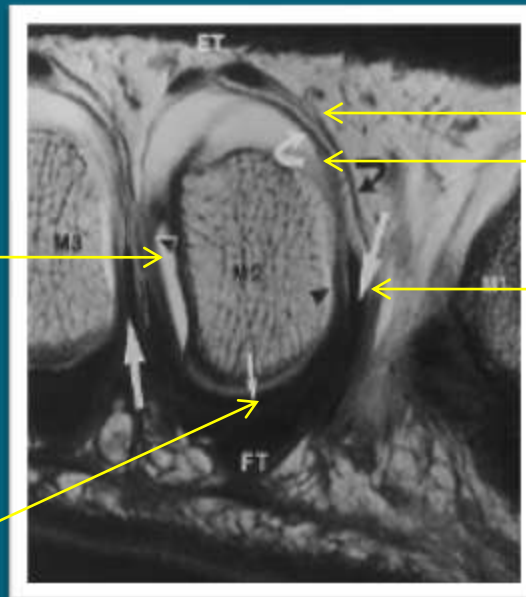
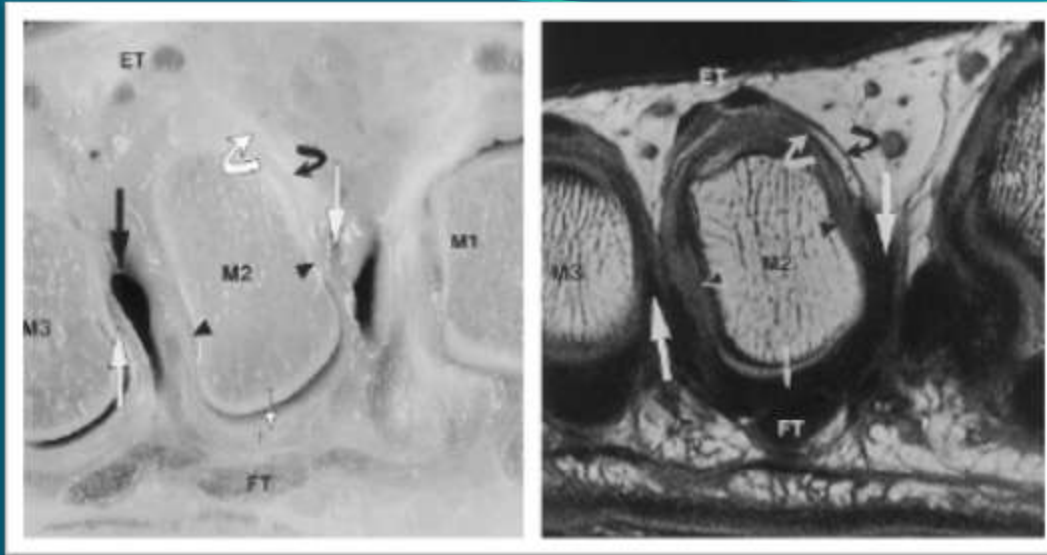
Plantar plate recess

Plantar plate

Capsular attachment

Capsular-plantar plate attachment





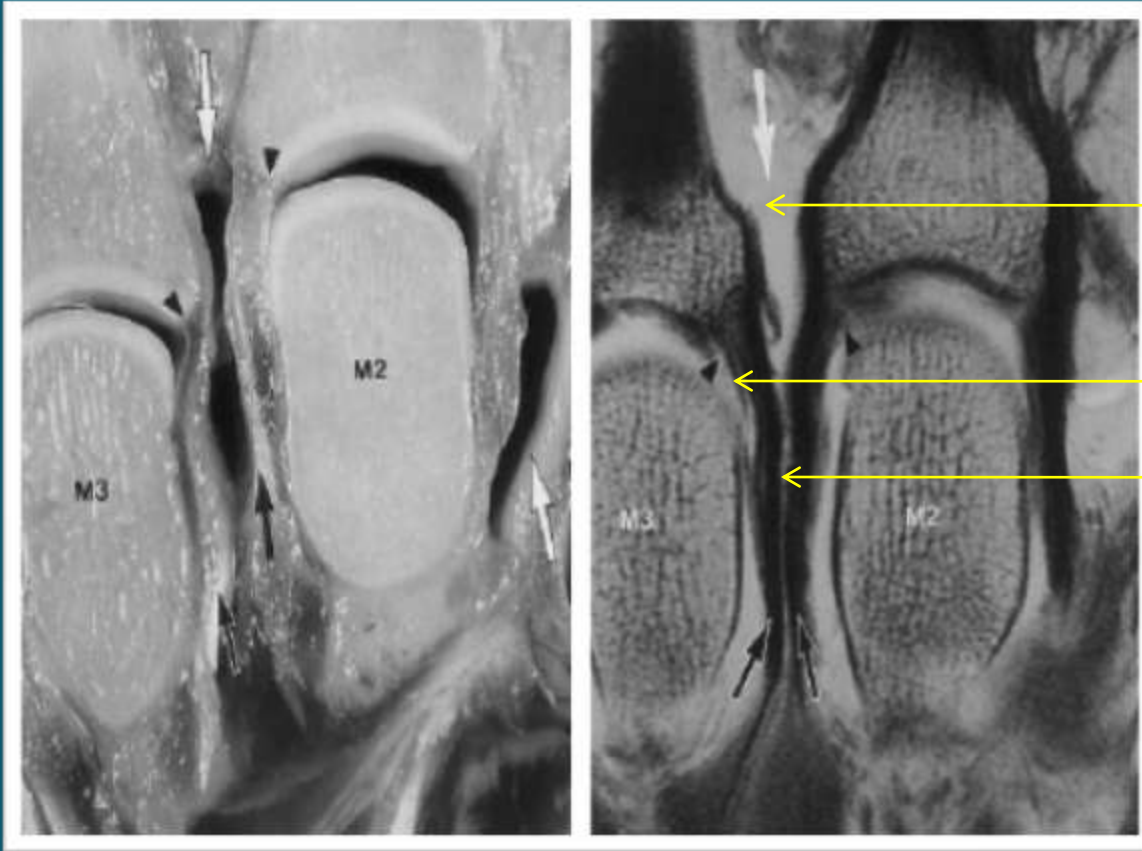
CLC

Extensor hood

Fibrous capsule

Interosseous tendon

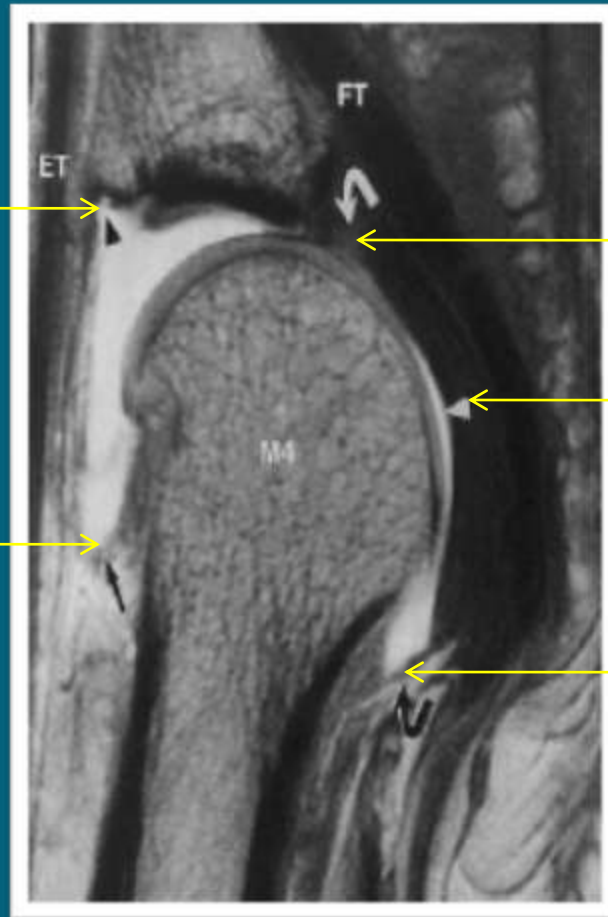
Plantar plate



bursa

Main collateral ligament

Interosseous tendon



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

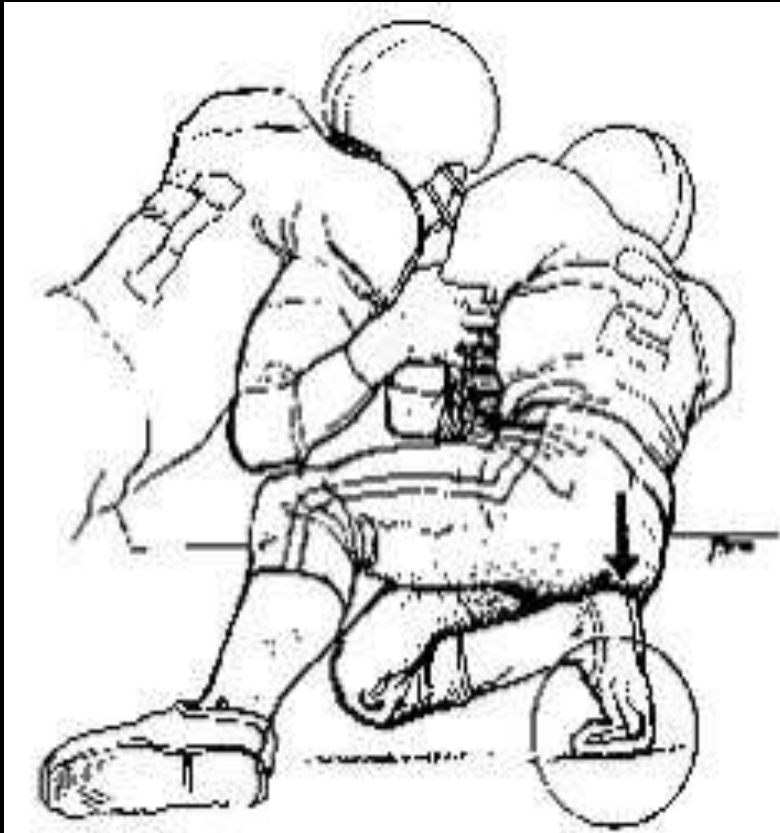
# Painful conditions affecting the MTP joints

- 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



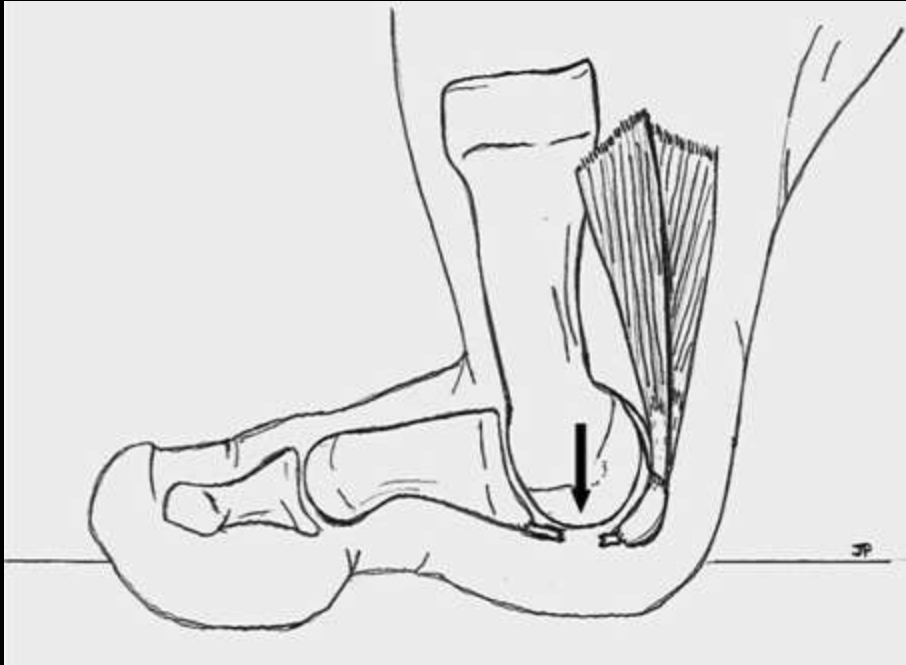
- ❖ Sprain of the plantar capsuloligamentous complex of the great toe MTP joint
- ❖ #1 mechanism is hyperextension
- ❖ Called “turf toe” after advent of artificial playing surfaces in late 1960’s led to increased use of flexible footwear with less plantar support
- ❖ MC in athletes who participate in cutting or pivoting sports, especially football

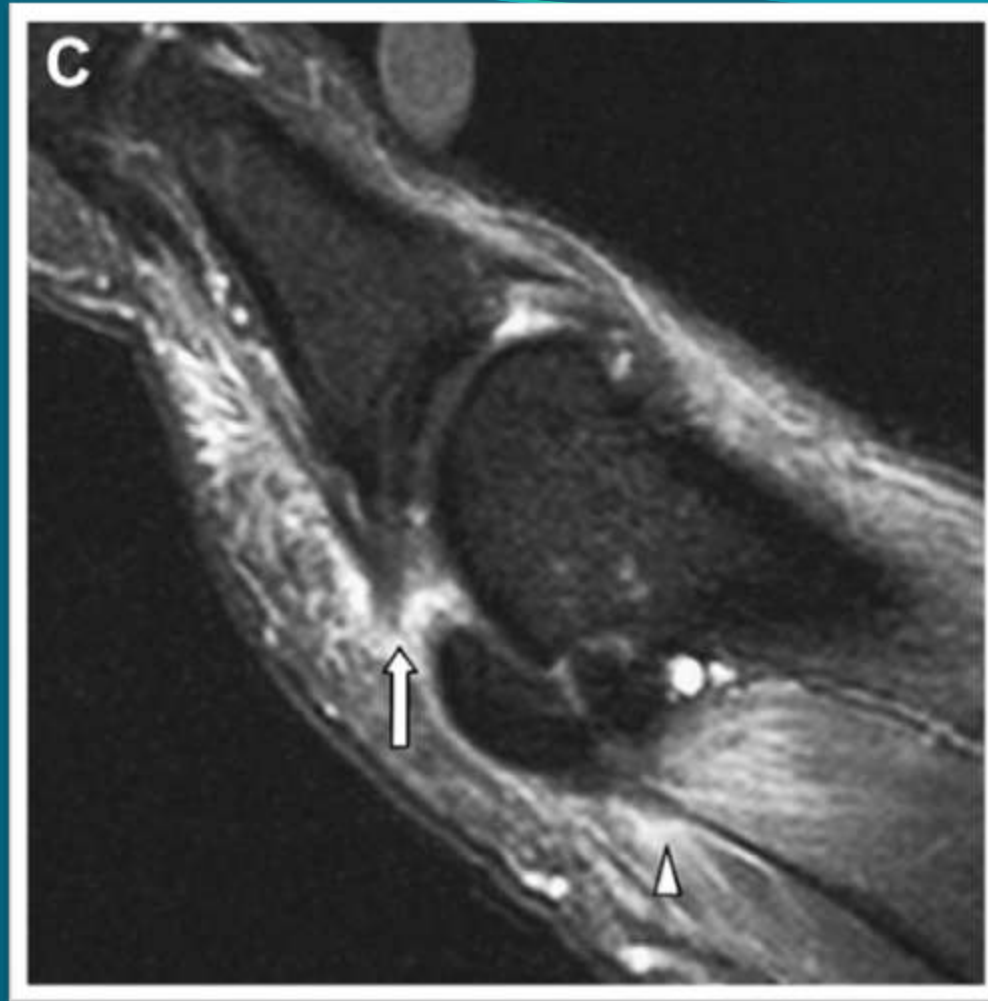
## Capsuloligamentous complex:

- ❖ Plantar plate
- ❖ fibrous capsule
- ❖ collateral ligamentous complex
  - main collateral ligaments
  - sesamoid-MT ligaments
- ❖ sesamoid-phalangeal ligaments
- ❖ intersesamoid ligament

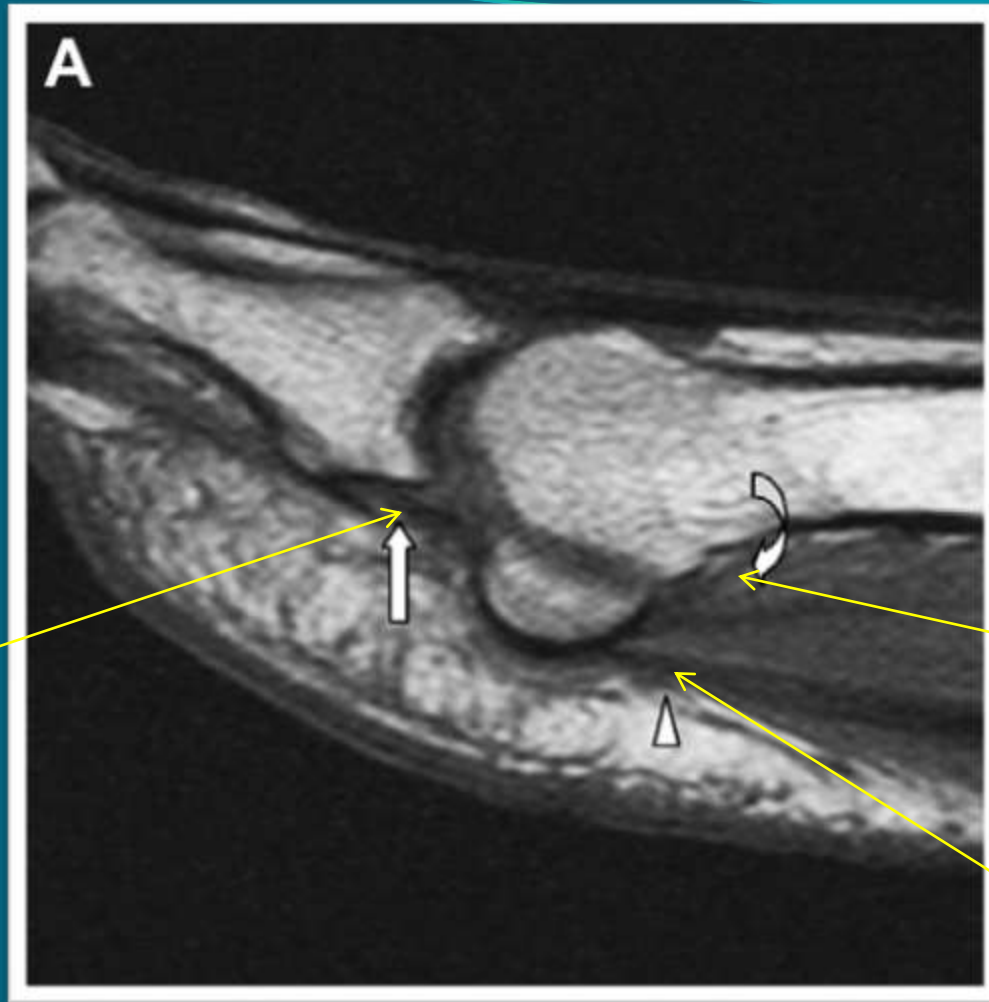
## Spectrum of injury also encompasses:

- ❖ Osseous/osteochondral injury:
  - sesamoid injury (fx, diastasis, diastasis of bipartite sesamoid)
  - 1<sup>st</sup> 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

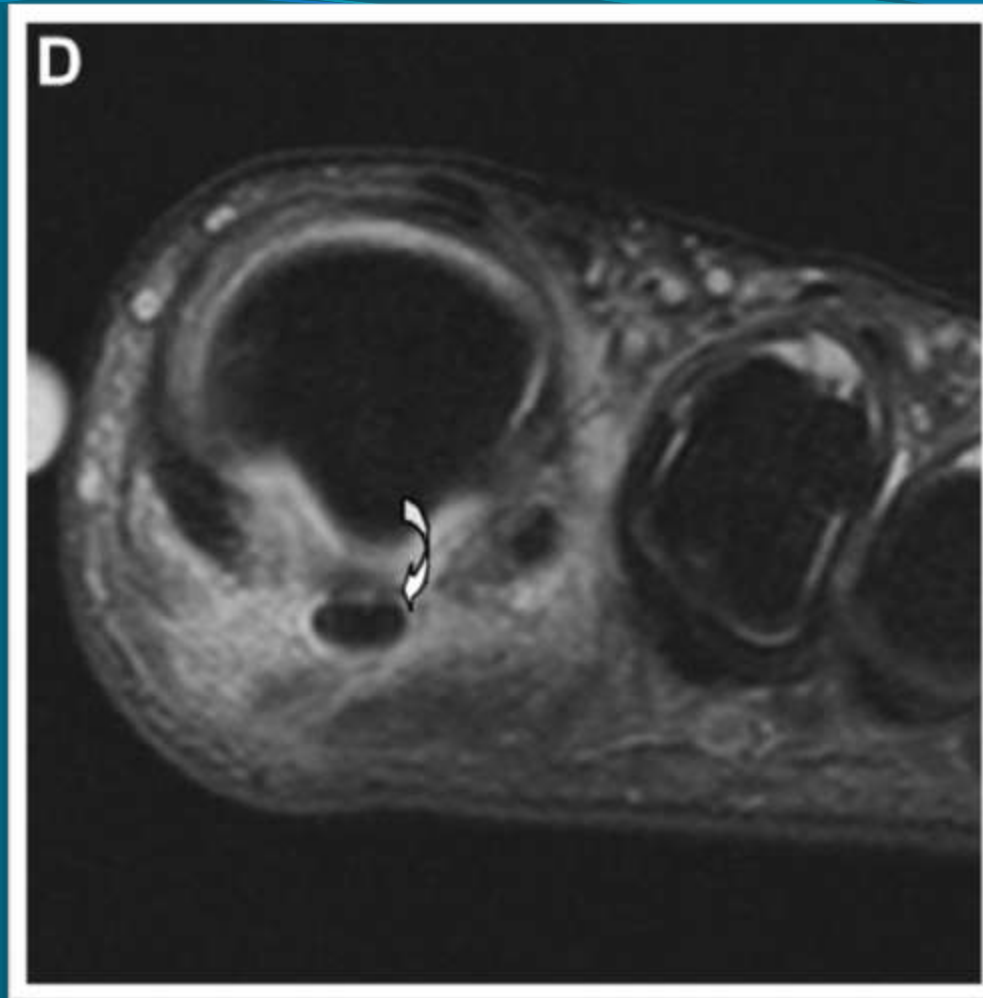


Sesamoid-phalangeal ligament

MT-sesamoid ligament

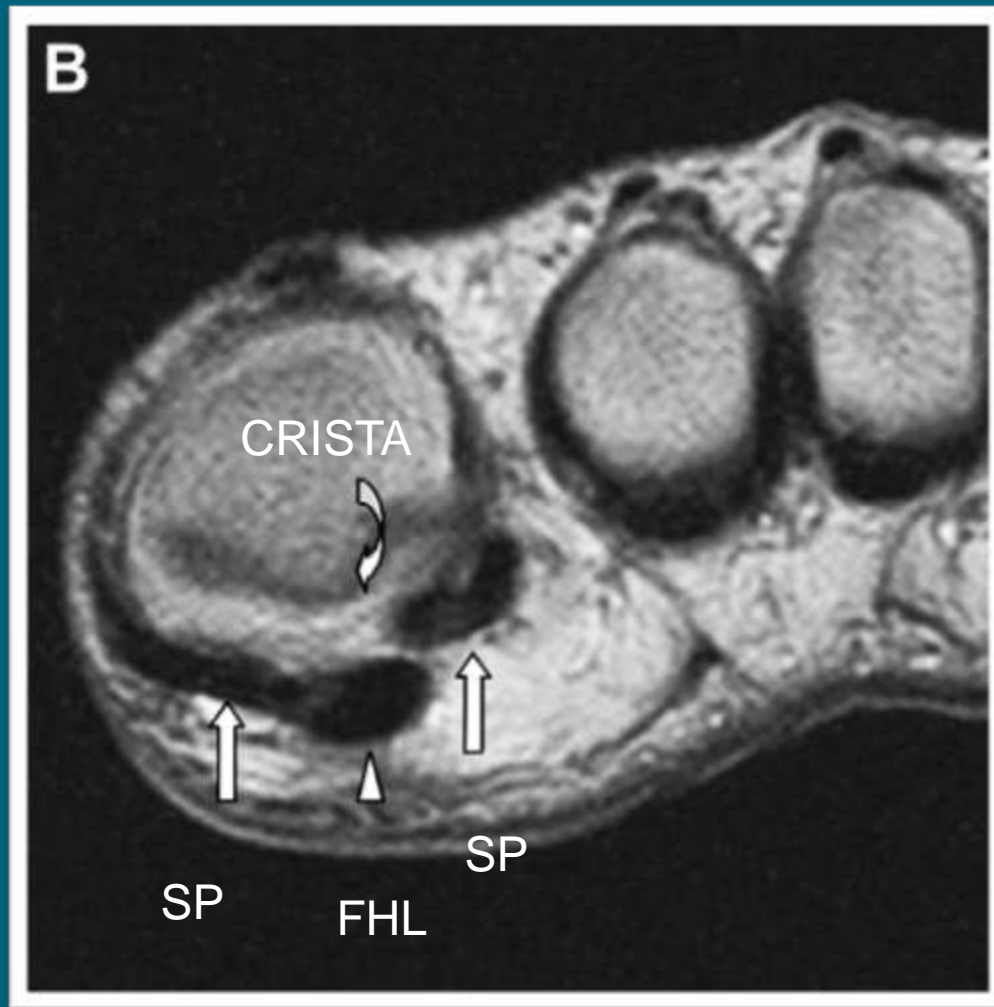
FHB insertion

NORMAL ANATOMY



Football injury: Bilateral sesamoid phalangeal ligament tears with edema, hemorrhage; plantar plate is outlined by edema and hemorrhage deep to FHL.

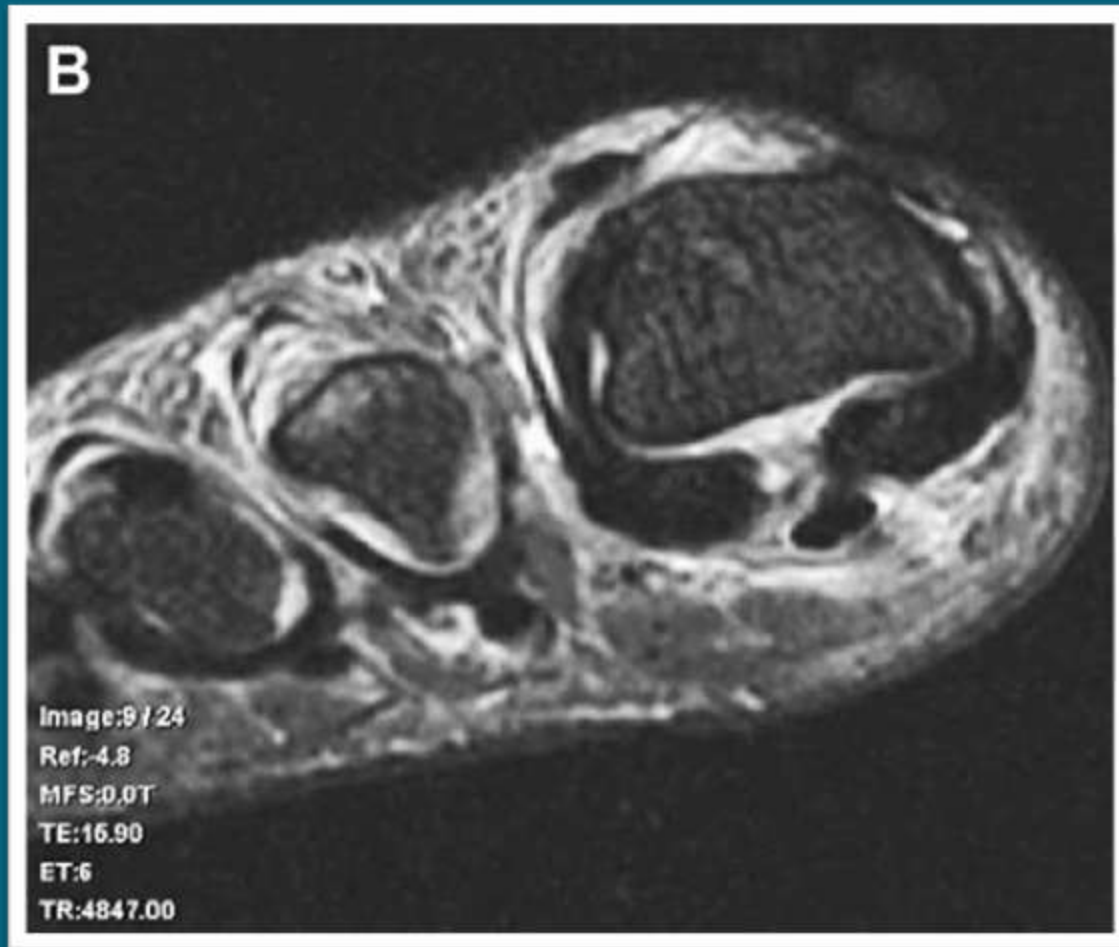




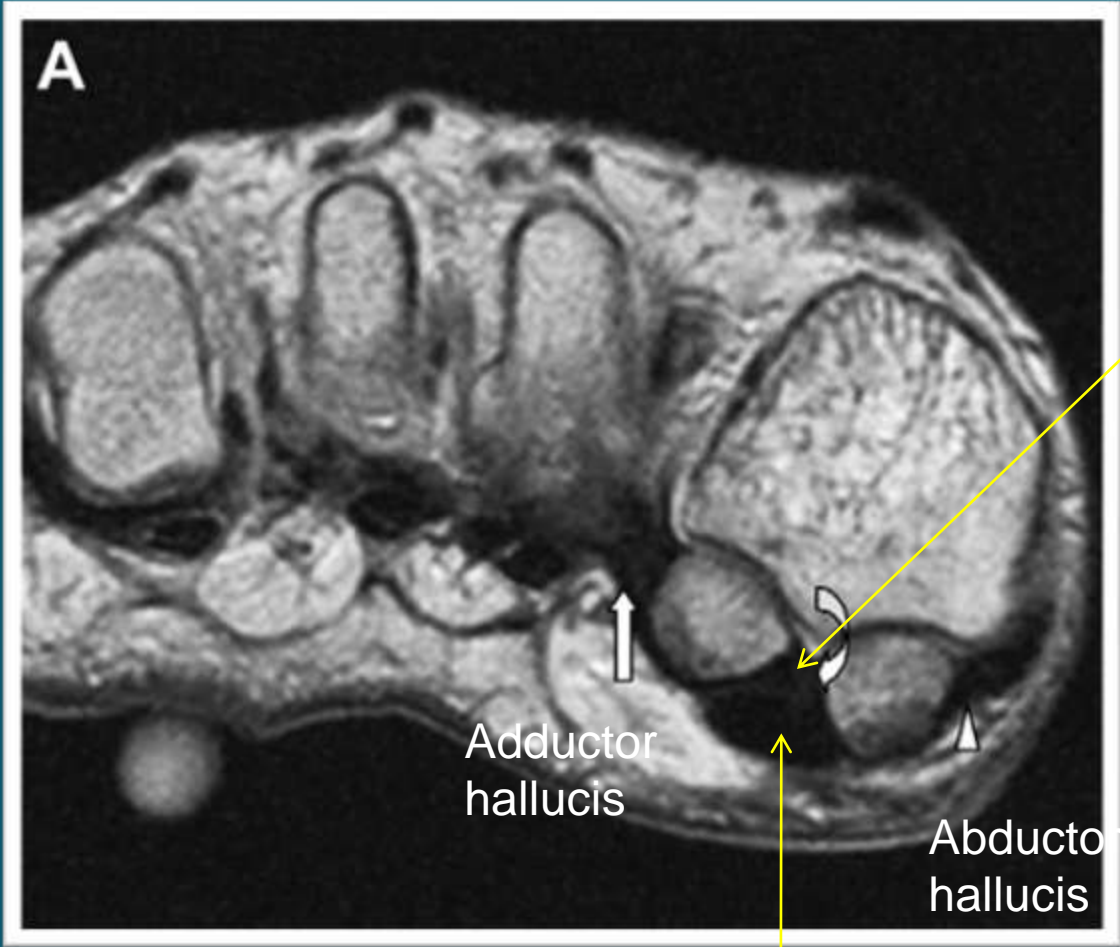
NORMAL ANATOMY



Football injury: Distal metatarsosesamoid ligament tear, FHB strain; intact sesamoid phalangeal ligament



Intersesamoid ligament rupture with sesamoid diastasis



Intersesamoid  
ligament

Adductor  
hallucis

Abductor  
hallucis

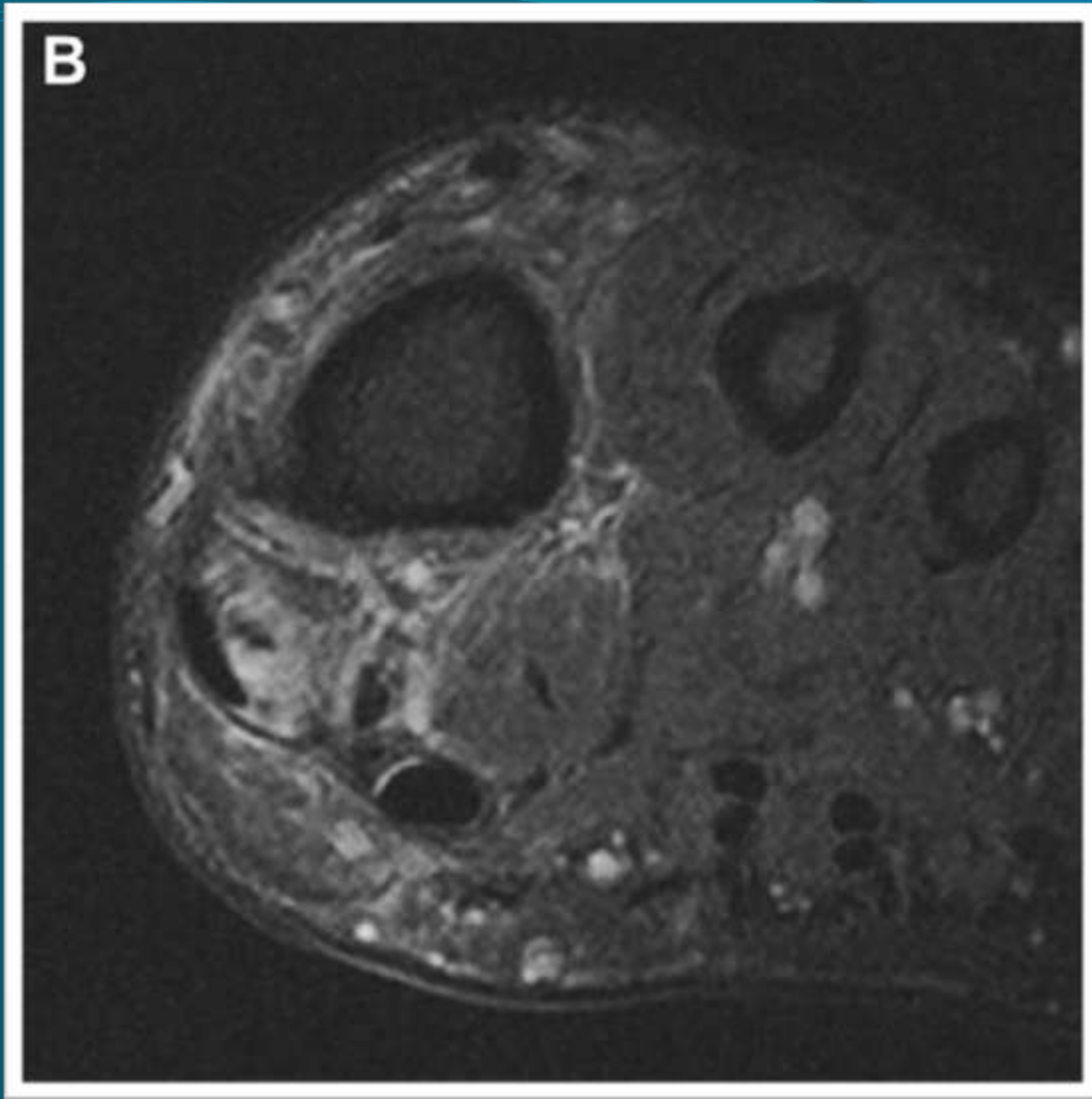
FHL



Complete tear of MCL and partial tear of LCL

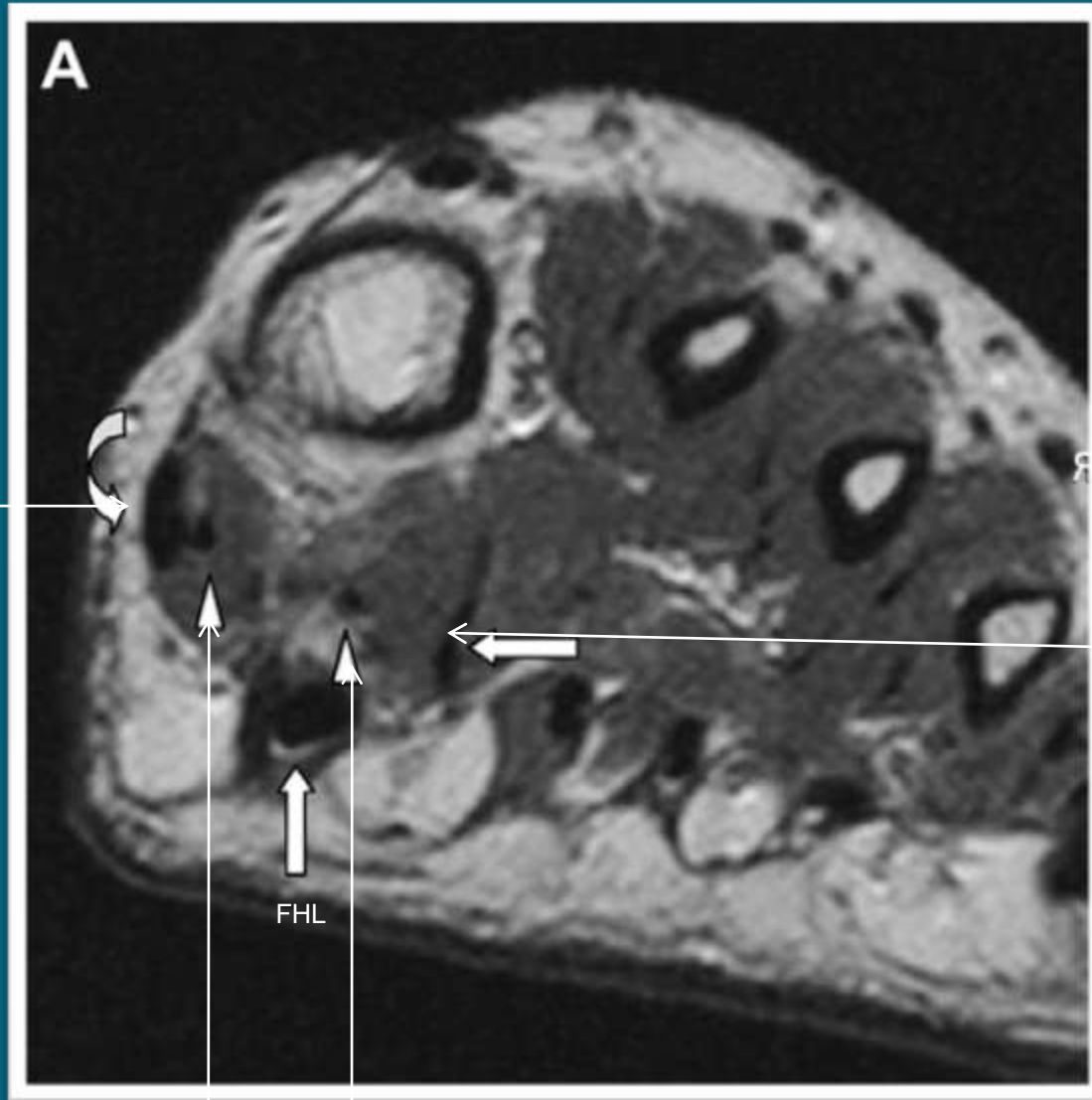


Normal MCL, LCL (main collateral ligaments)



FHB medial head strain

A



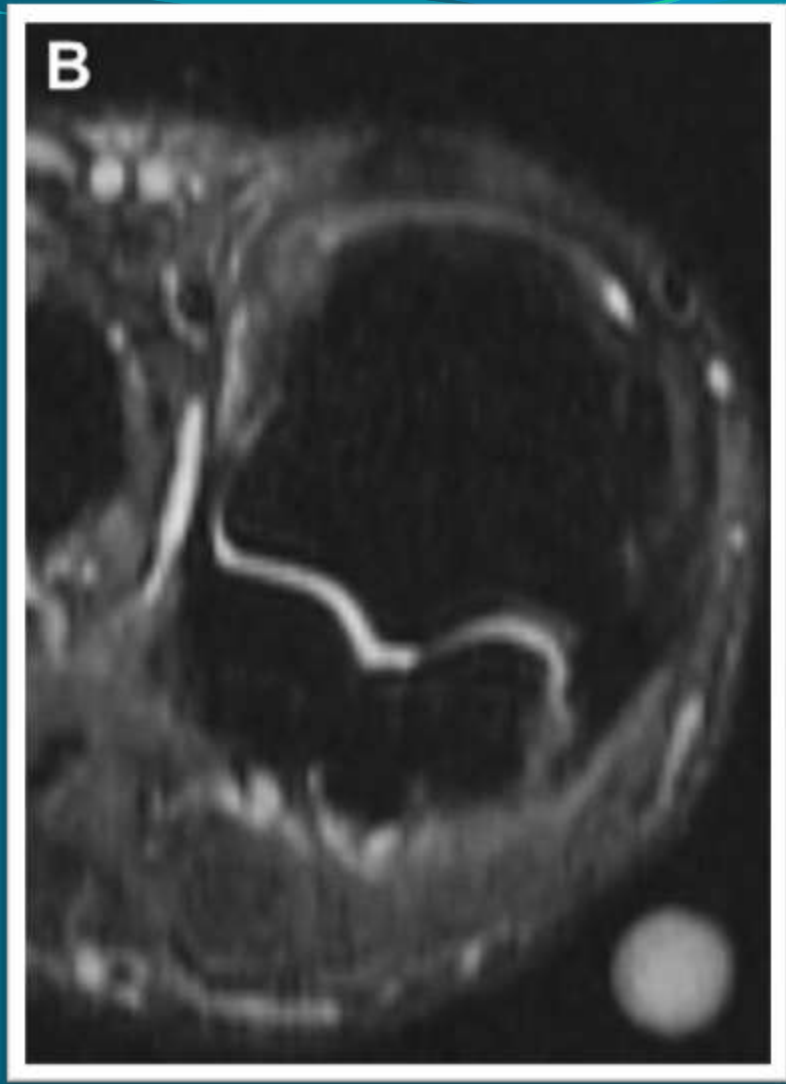
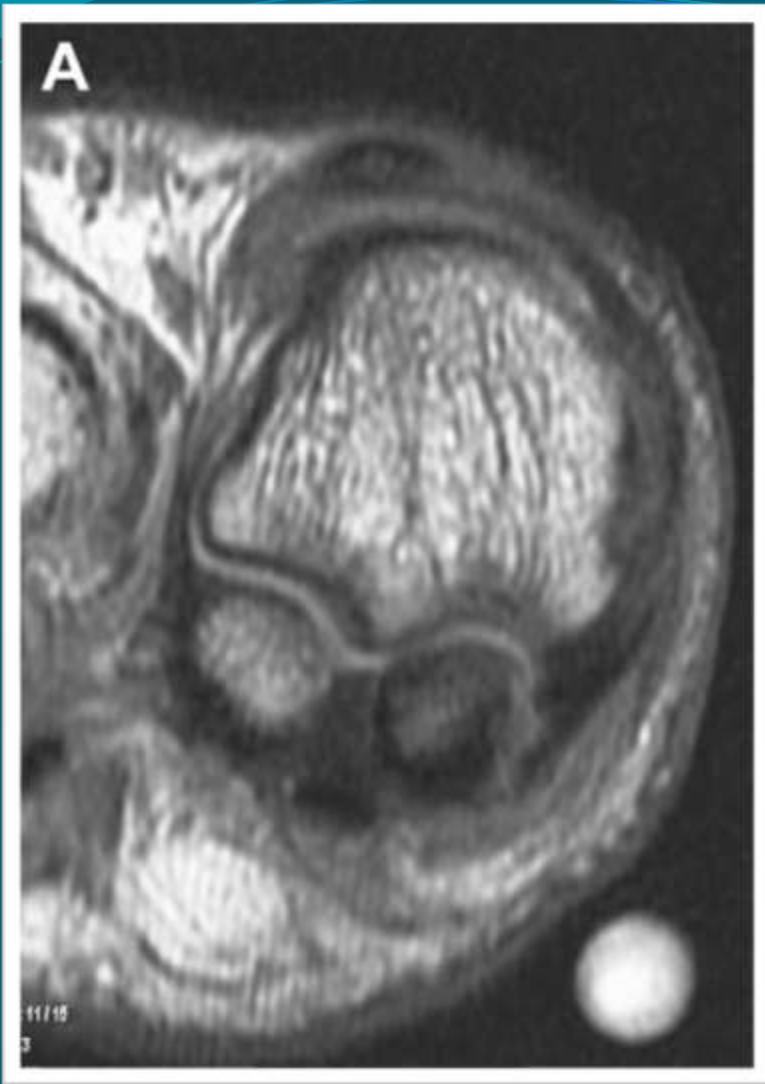
Abductor  
hallucis

Adductor  
hallucis

FHL

Flexor hallucis brevis (medial & lateral heads)



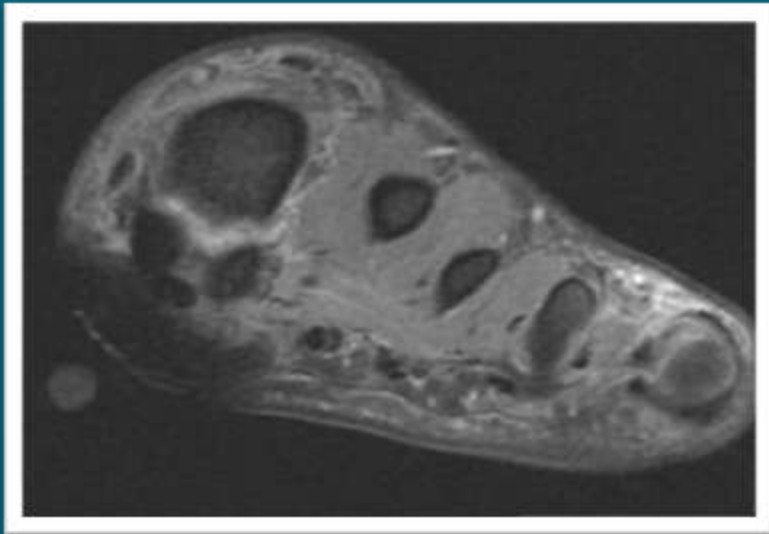
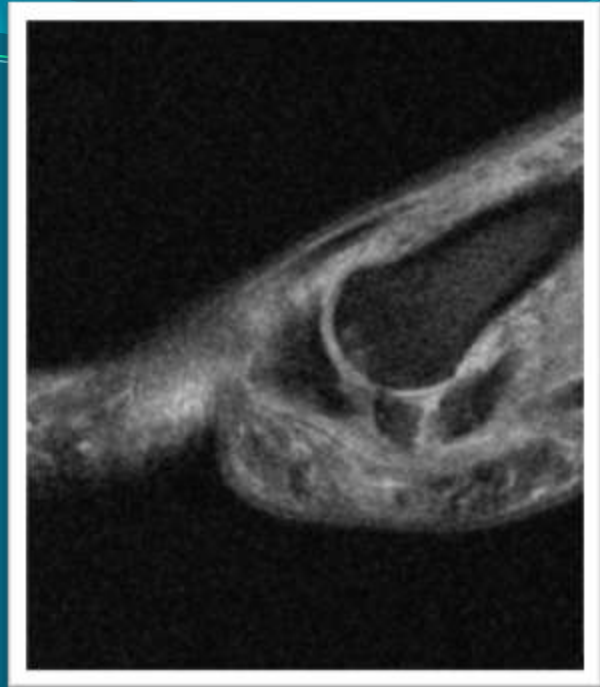
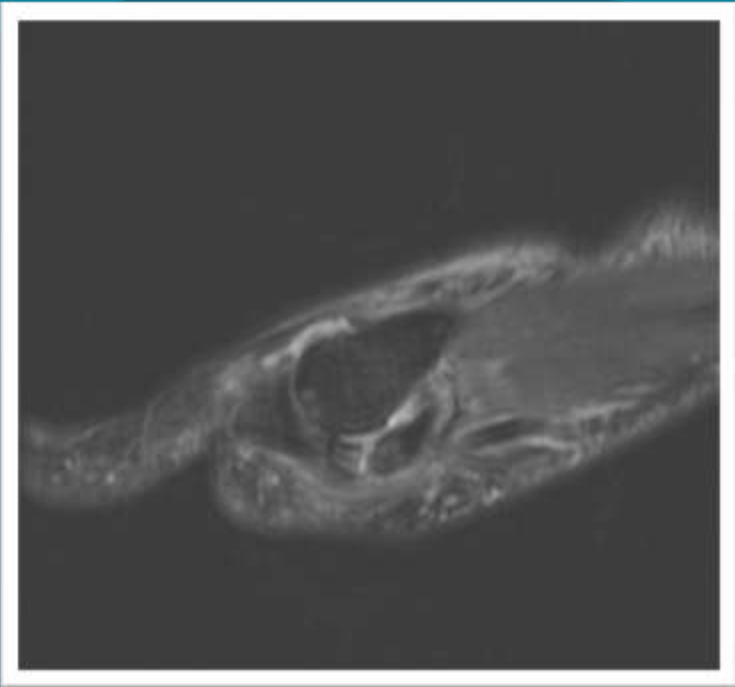


Capsular and tendinous avulsion from the medial margin of the medial sesamoid with periosteal stripping (subacute injury)



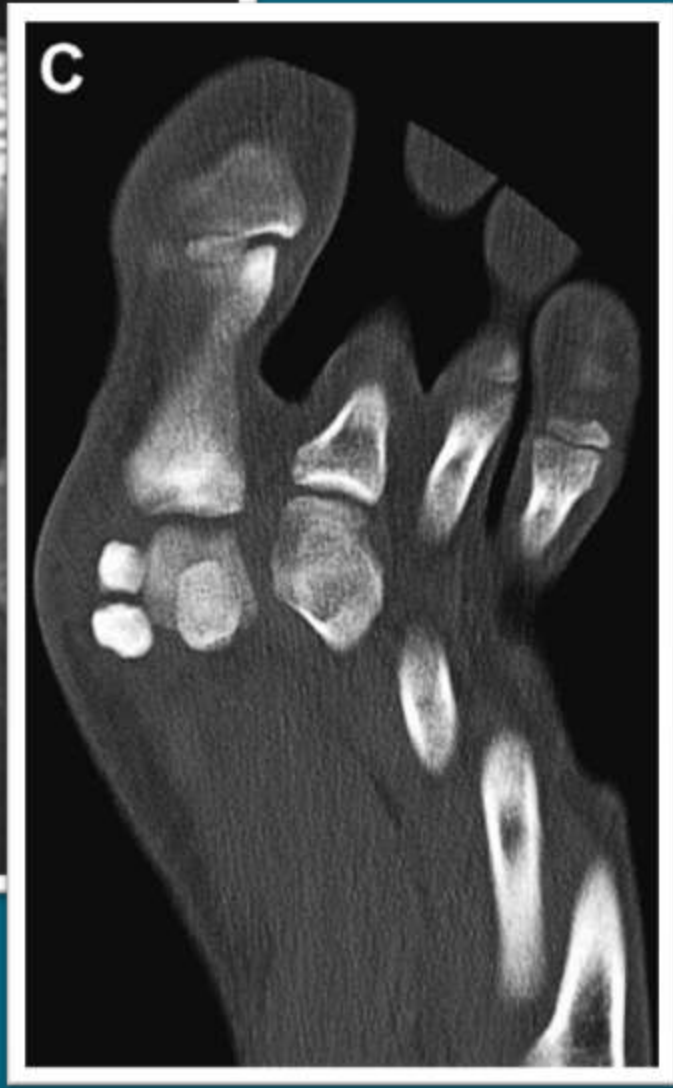
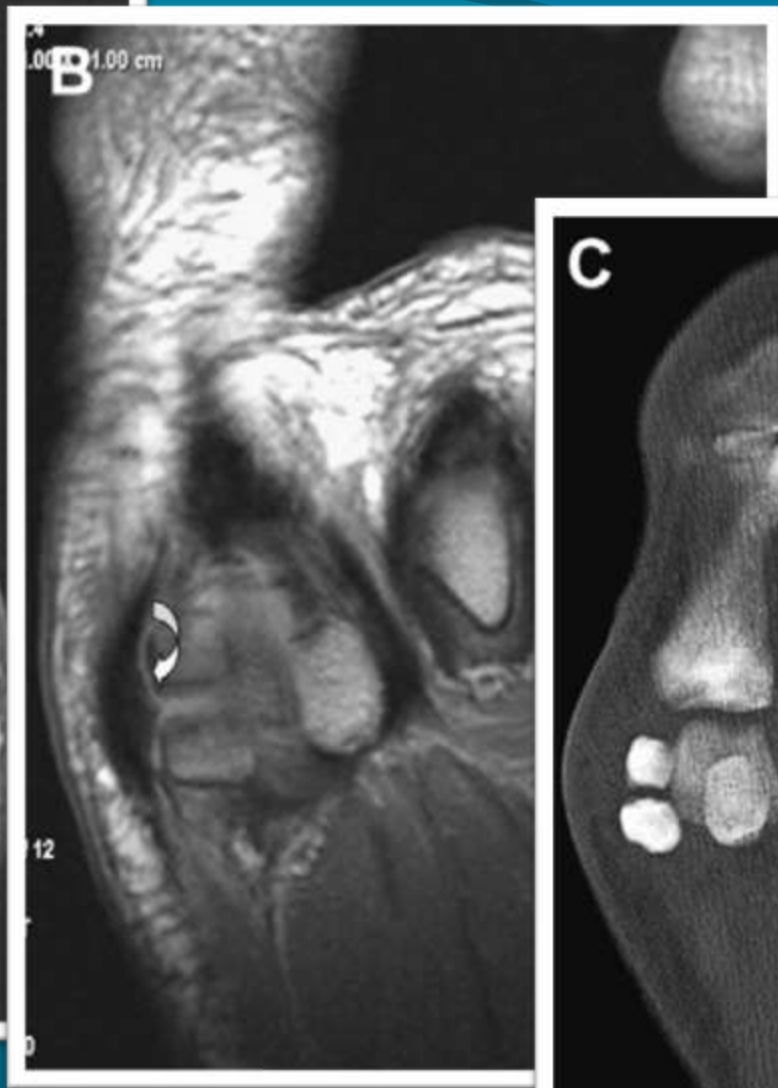
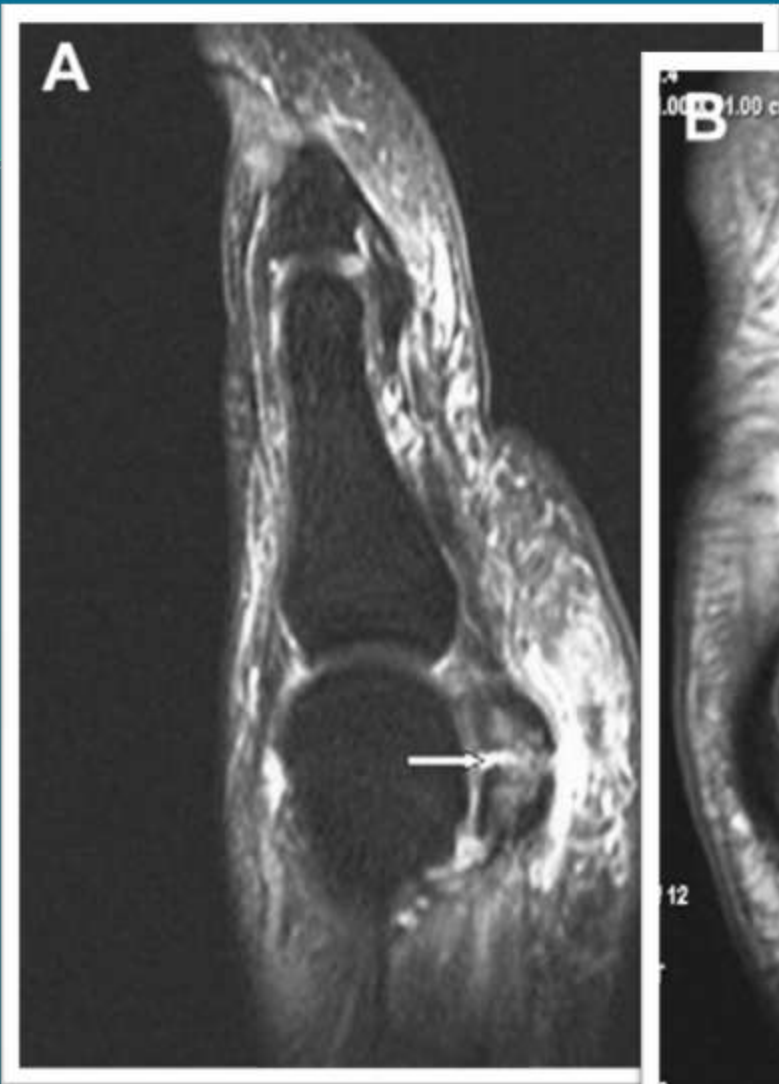
51-year-old man with recent injury of left great toe



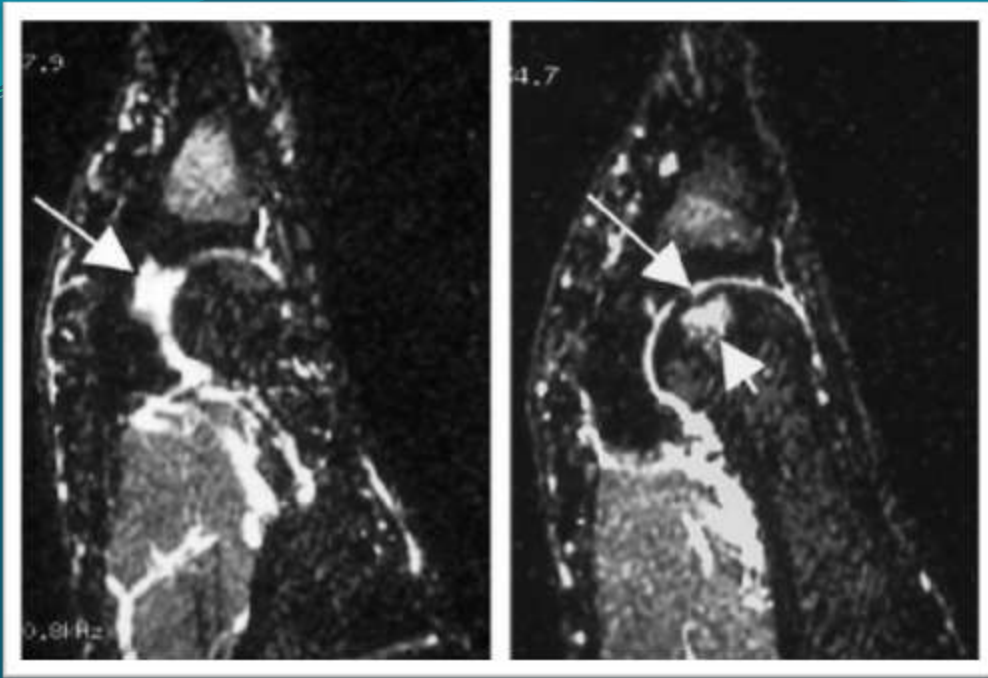




Turf toe with diastasis of fractured sesamoids



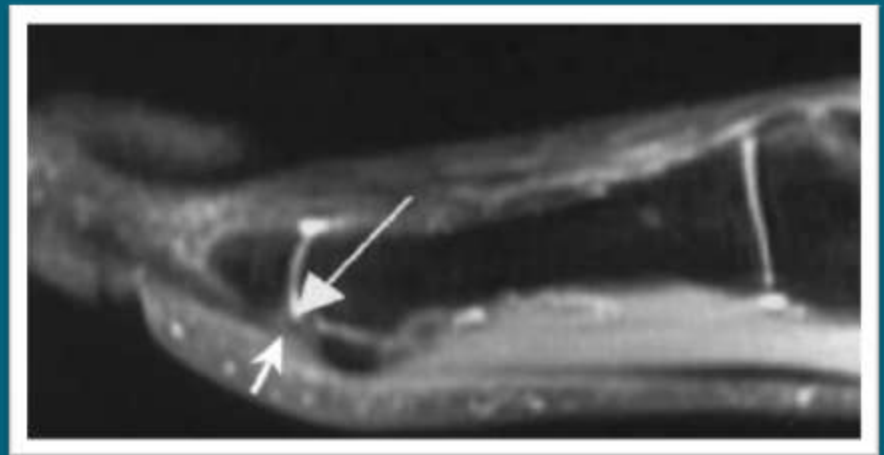
Bipartite sesamoid diastasis

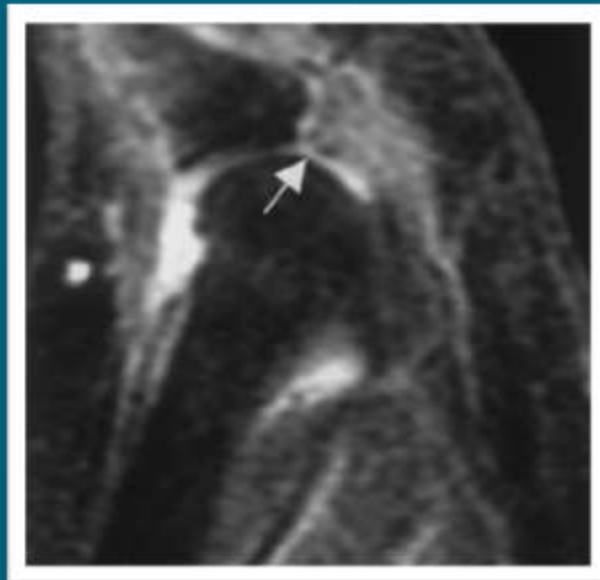
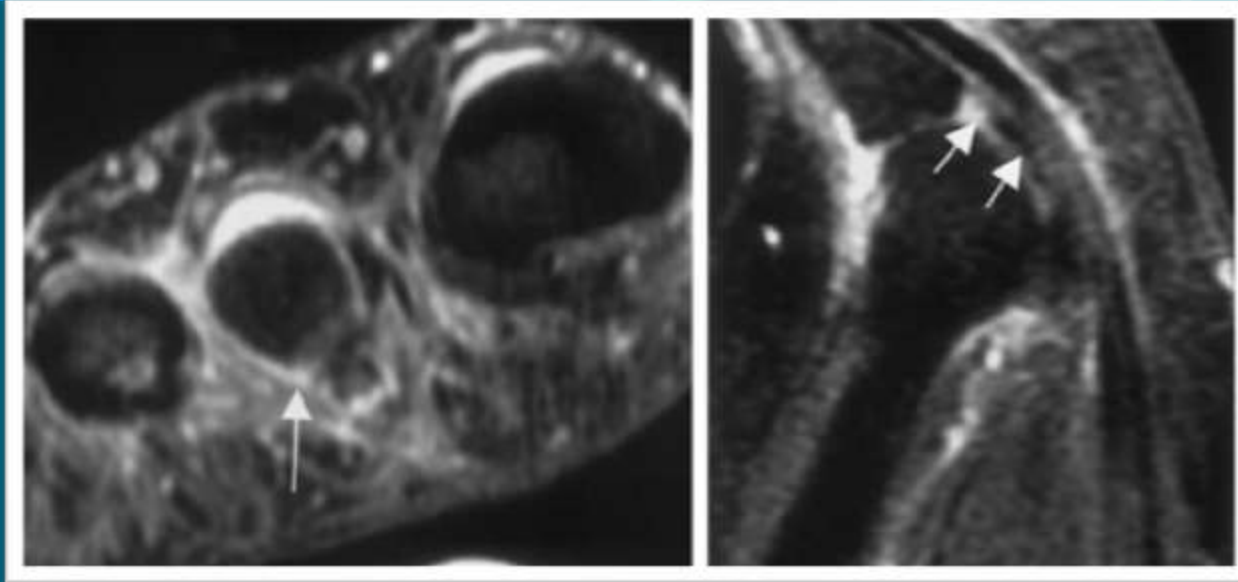


Turf toe injury in a 24-year-old professional football player: disruption of plantar plate with associated edema and osteochondral injury 1<sup>st</sup> MT head



Normal plantar plate for comparison





Disrupted plantar plate at the 2<sup>nd</sup> MTP joint in a 48-year-old woman who presented with foot pain (no history of injury)

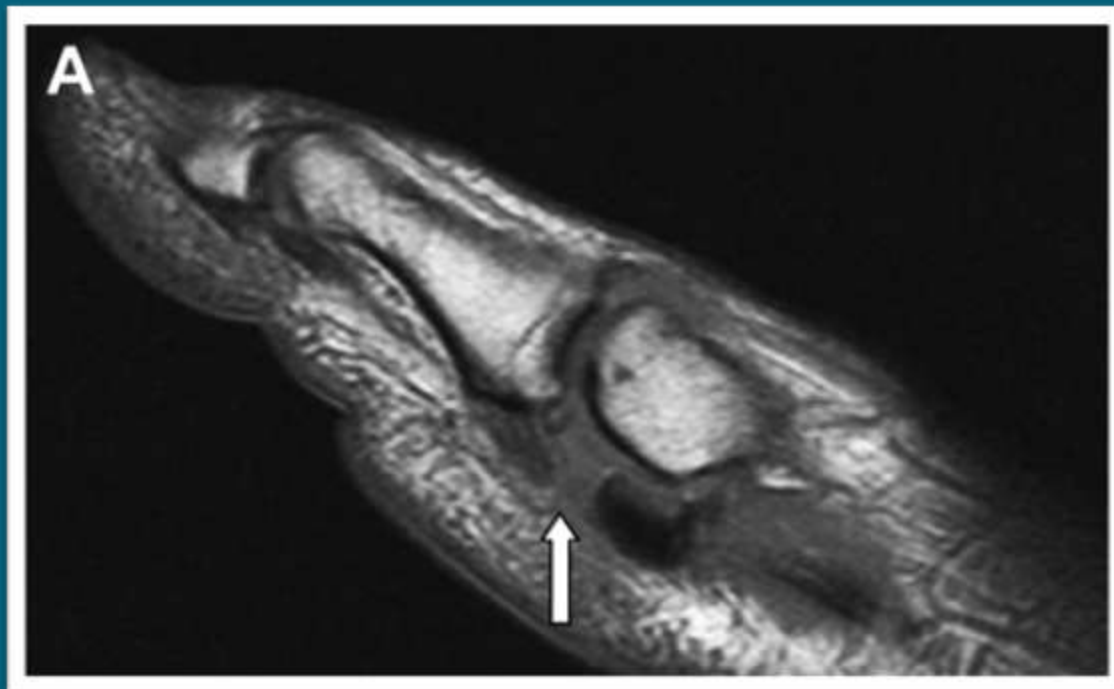


# Classification of injury

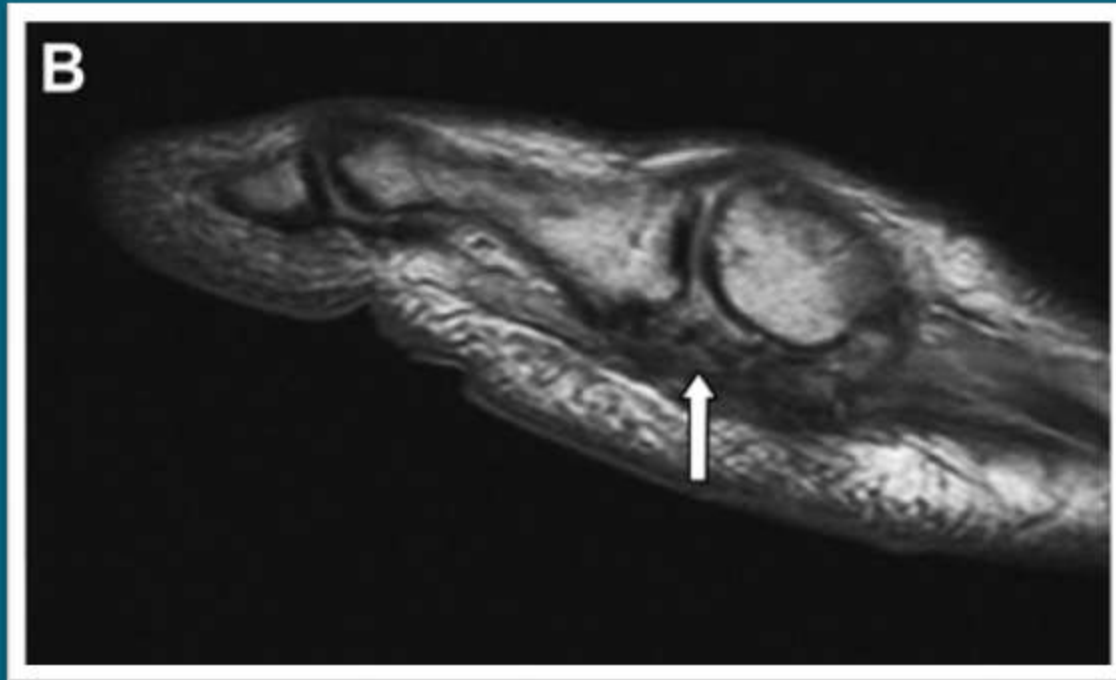
- Grade I: sprain of the plantar capsular complex with pain, tenderness, swelling
- Grade II: capsular disruption with bruising, decreased ROM
- Grade III: Chronic injury; results in decreased ROM, OA

# 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

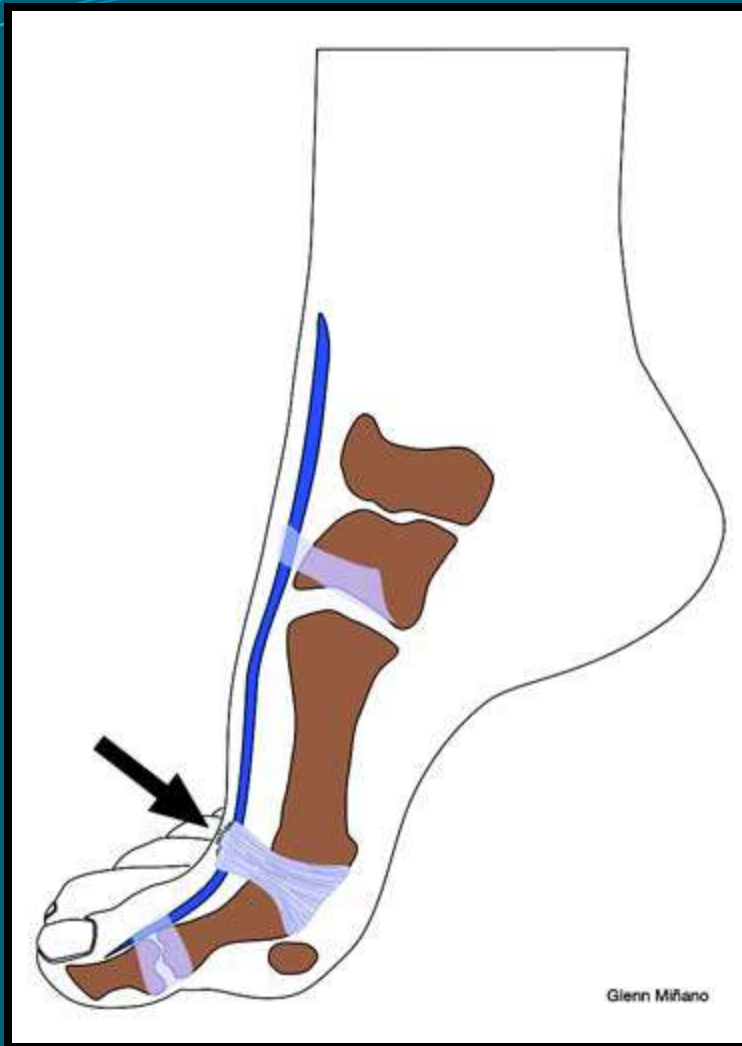
- Chondromalacia of 1<sup>st</sup> MT head
- Osteoarthritis 1<sup>st</sup> MTP
- Hallux valgus
- Hallux rigidus (dorsal osteophytosis)

# SKIMBOARDER'S TOE

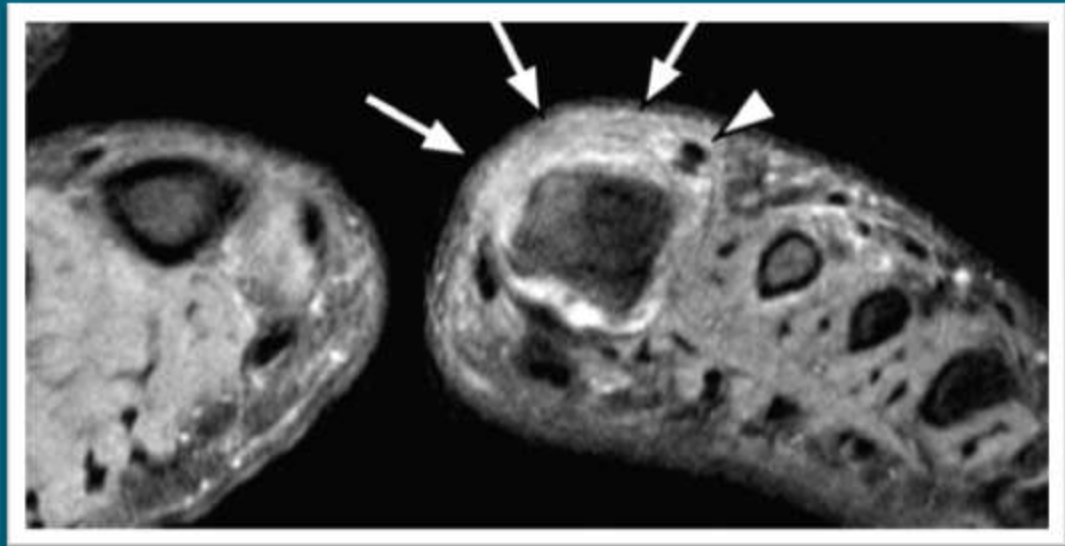


- ❖ Skimboarding is a beachside sport in which the athlete stands on the shore, drops the board on the ground, and jumps on it in very shallow water
- ❖ Skimboarder's toe = hyperdorsiflexion injury of the MTP joints
- ❖ Unlike in turf toe, the injured capsuloligamentous structures are dorsal, rather than plantar

# MECHANISM:



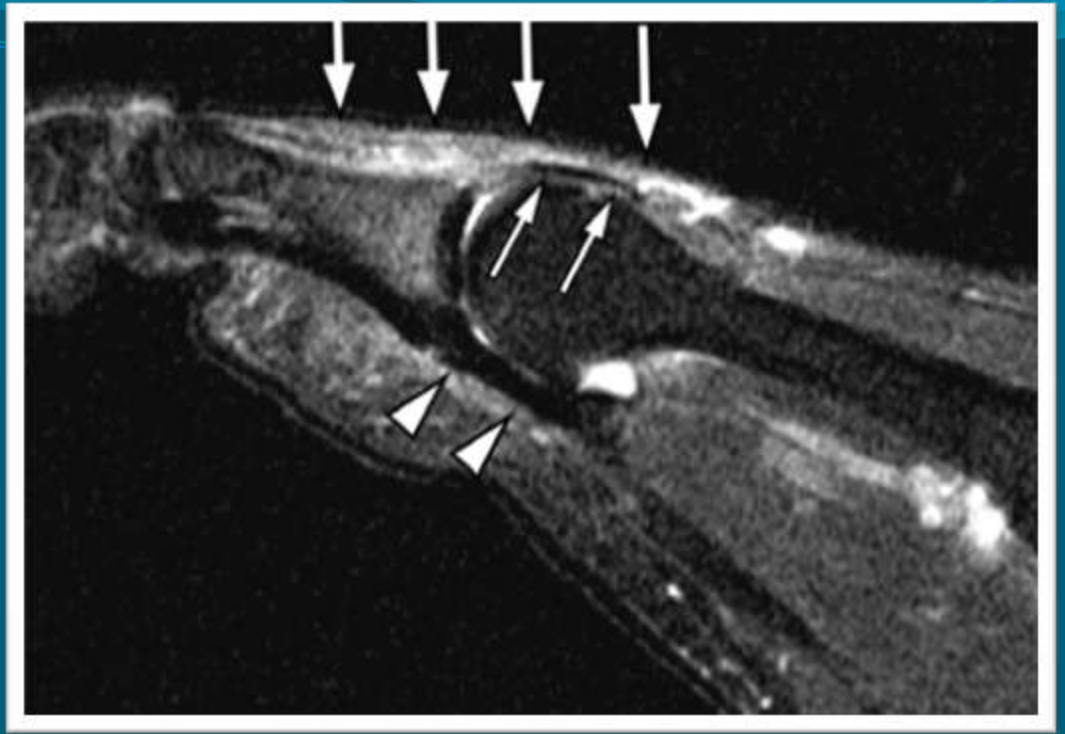
- ❖ Skimboarder uses toes to grip board; if board slips posteriorly in relation to skimboarder, hyperdorsiflexion at the MTP joints may occur
- ❖ If the toe is violently hyperextended, forces apply to the EHL/EDL in a dorsal direction, potentially disrupting the extensor expansion
- ❖ May be a/w avulsion 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<sup>st</sup> MTP joint:

- dorsal soft tissue swelling
- disruption of dorsal aspect of extensor expansion
- intact extensor tendons
- intact plantar plate



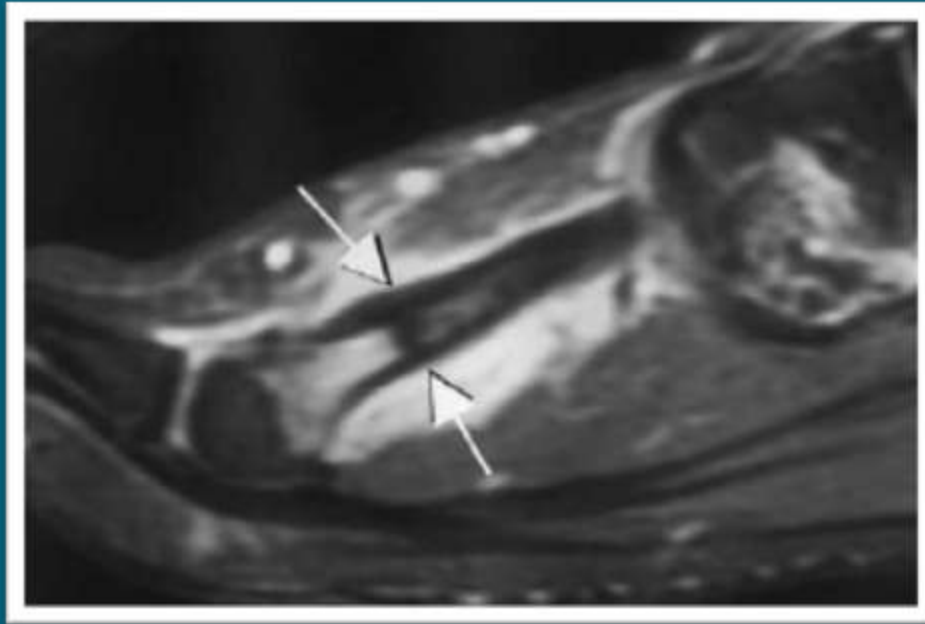


### Hyperextension injury of the 2<sup>nd</sup> MTP:

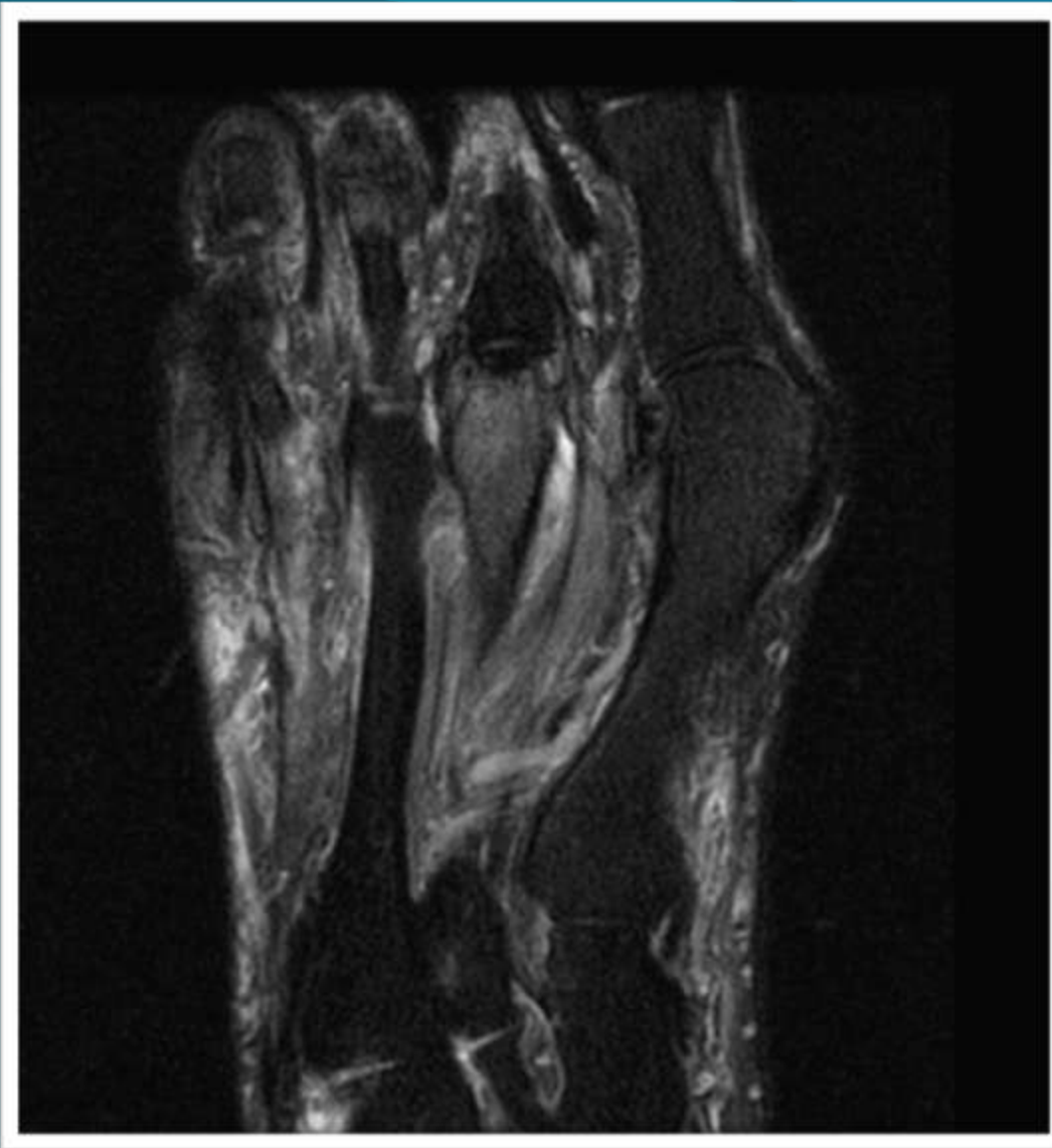
- dorsal soft tissue swelling
- lax/wavy, discontinuous extensor hood
- marrow edema proximal phalanx
- normal plantar plate

# Metatarsal fracture

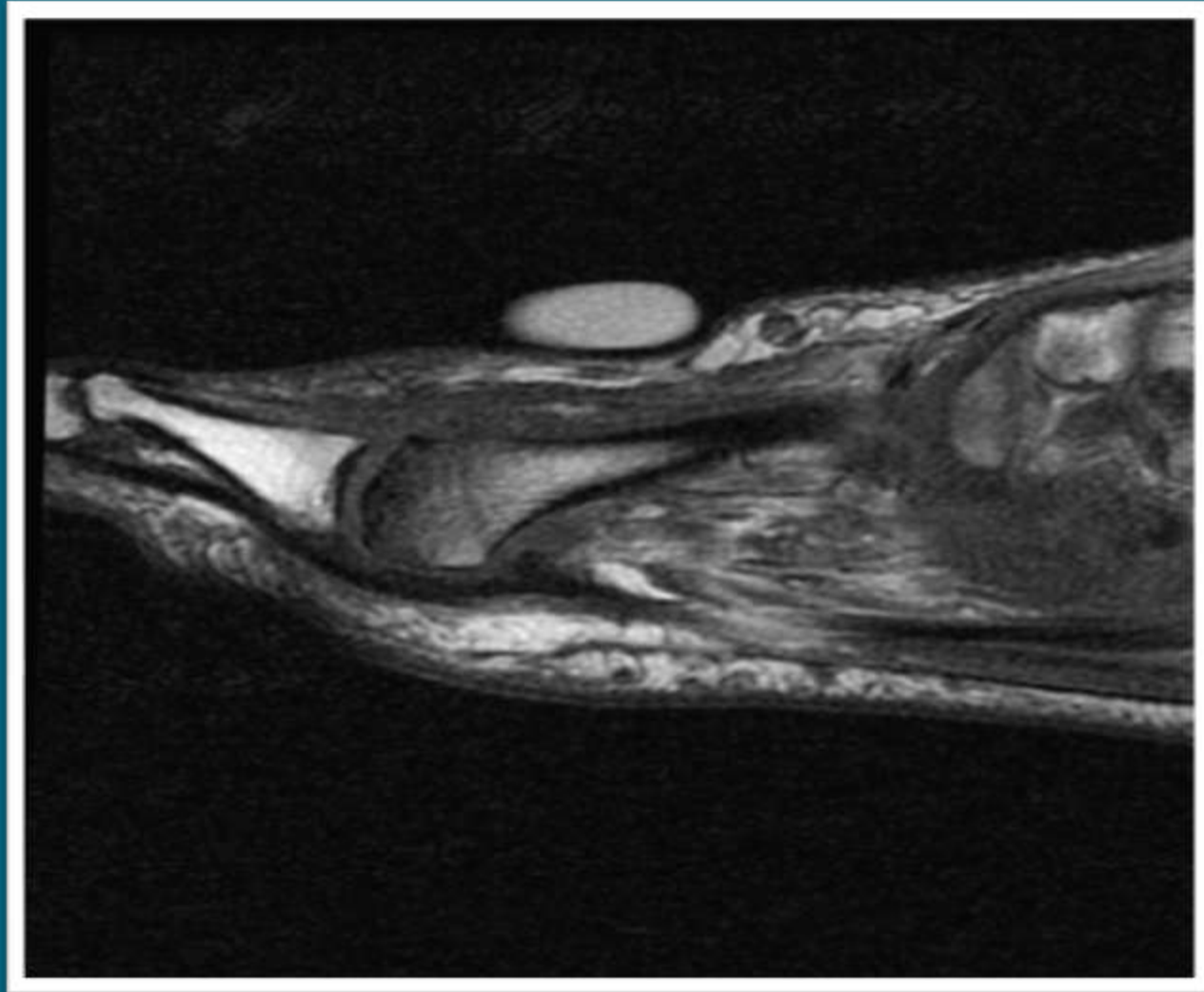
- Acute fx
- Stress fx
  - Fatigue
    - Runners, military recruits, gymnasts
    - Especially mid-distal 2<sup>nd</sup>-4<sup>th</sup> MTs
  - Insufficiency



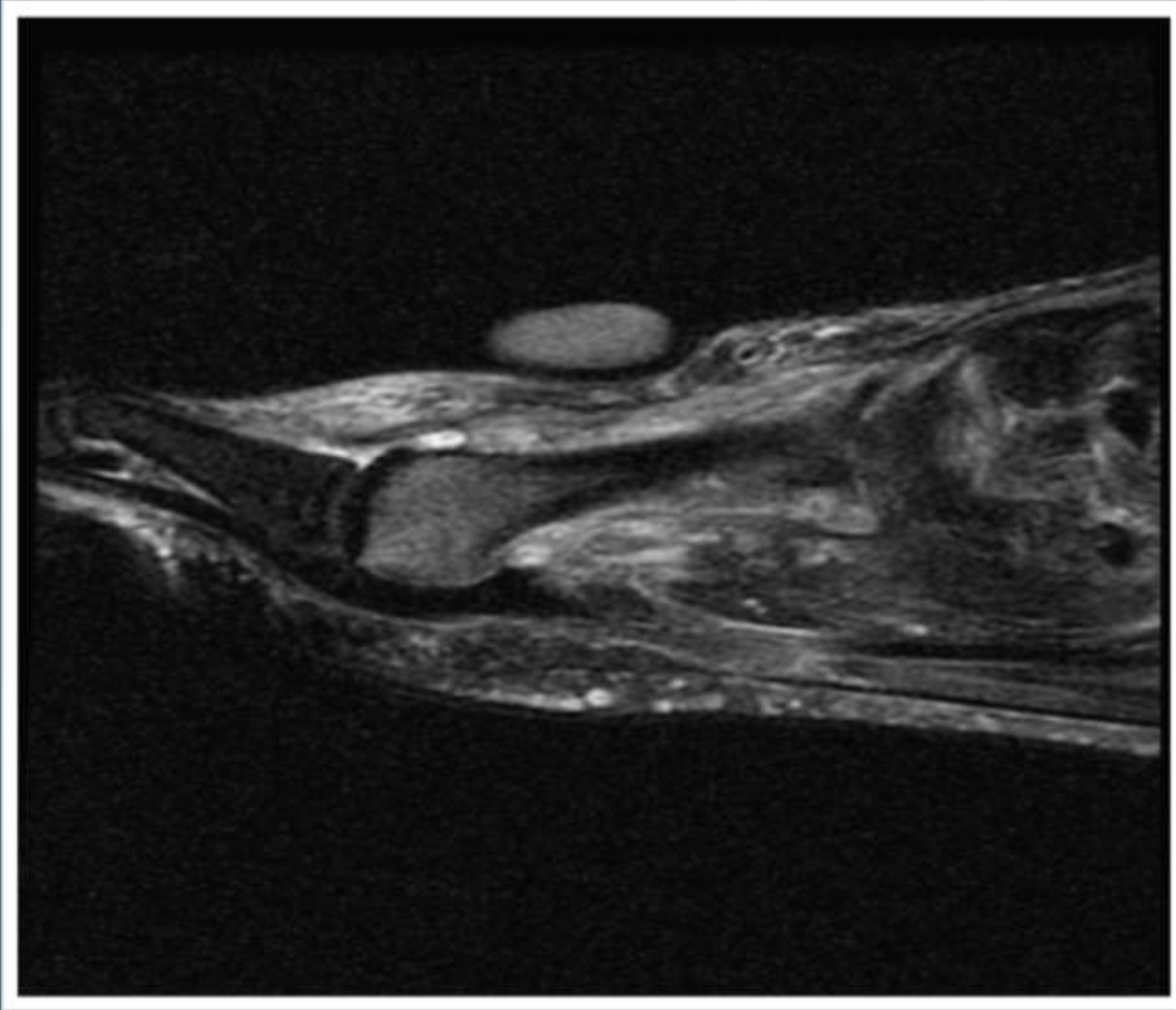
Metatarsal stress fracture



Insufficiency fracture of 2<sup>nd</sup> MT head



Insufficiency fracture of 2<sup>nd</sup> MT head



Insufficiency fracture of 2<sup>nd</sup> MT head

# Freiberg's infraction

- MC in adolescents, young women
- MC in 2<sup>nd</sup> 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 1<sup>st</sup> MTP joint characterized by valgus deviation of the great toe and varus deviation of the 1<sup>st</sup> 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 1<sup>st</sup> MT head
- Overgrowth of median eminence of 1<sup>st</sup> MT head, which has an irregular appearance; may contain prominent cystic areas simulating the appearance of gout
- Adjacent soft tissue swelling
- Complications:
  - OA (1<sup>st</sup> MTP and sesamoid-MT), dorsal osteophytosis
  - Stress fx sesamoids, medial margin of proximal phalangeal base
- Rx = median eminence shaving, 1<sup>st</sup> MT osteotomy



❖ Hallux valgus: > 15 degrees between 1<sup>st</sup> MT head and proximal phalanx

❖ Metatarsus primus varus: >10 degrees between 1<sup>st</sup>, 2<sup>nd</sup> metatarsals

# HALLUX VALGUS, BUNION





# TAILOR'S BUNION (BUNIONETTE)

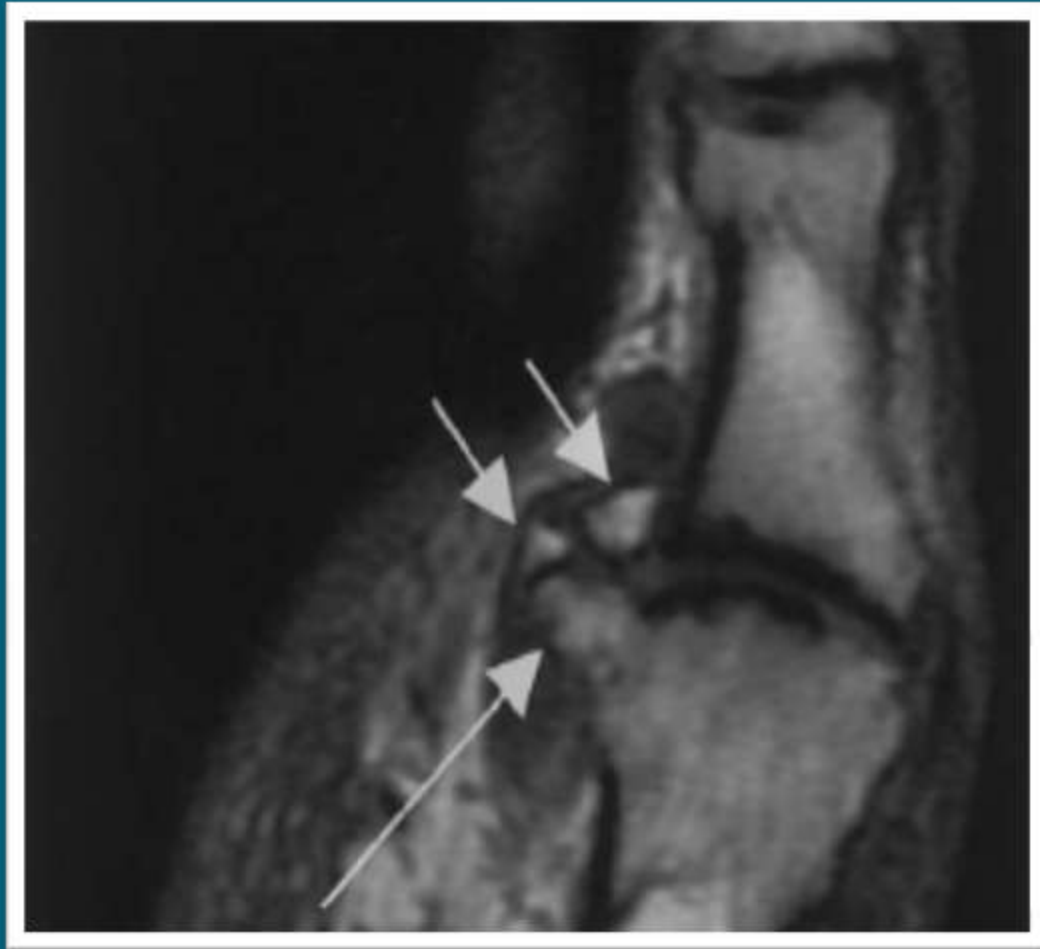


- Bony overgrowth, soft tissue swelling 5<sup>th</sup> MTP
- Exacerbated by tight footwear, excess pressure on lateral aspect of foot
- fifth toe often deviated in medial direction at MTP
- a/w hallux valgus

# Arthritis

- OA
- RA
- Gout
- CPPD
- Reactive arthritis
- Neuropathic arthropathy

# OSTEOARTHRITIS



Severe OA, bulky dorsal osteophytosis



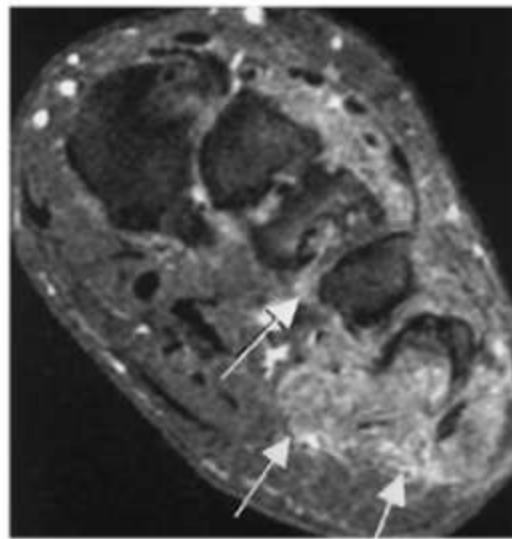
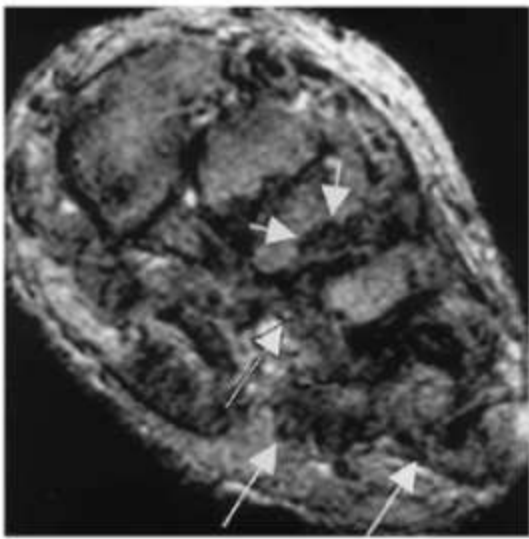
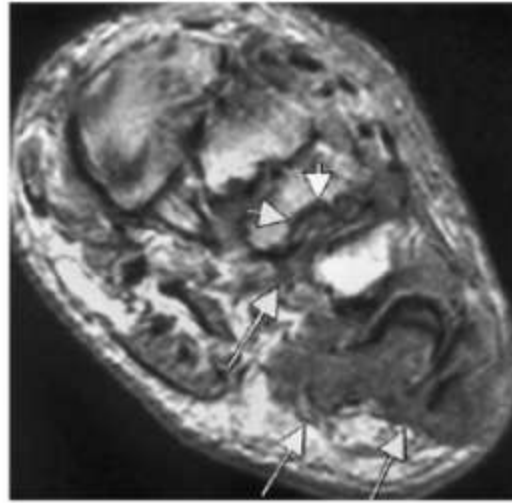
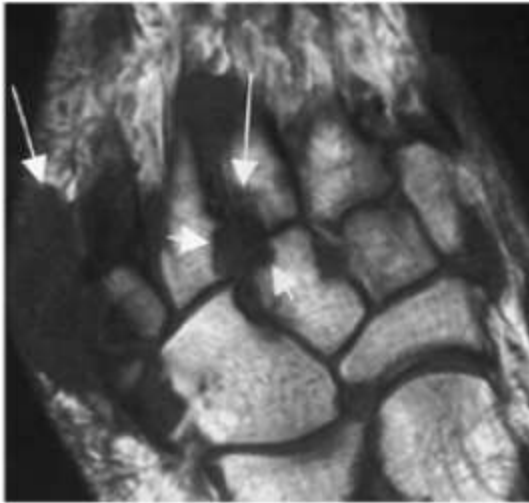
HALLUX RIGIDUS



# GOUT



- 1<sup>st</sup> 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

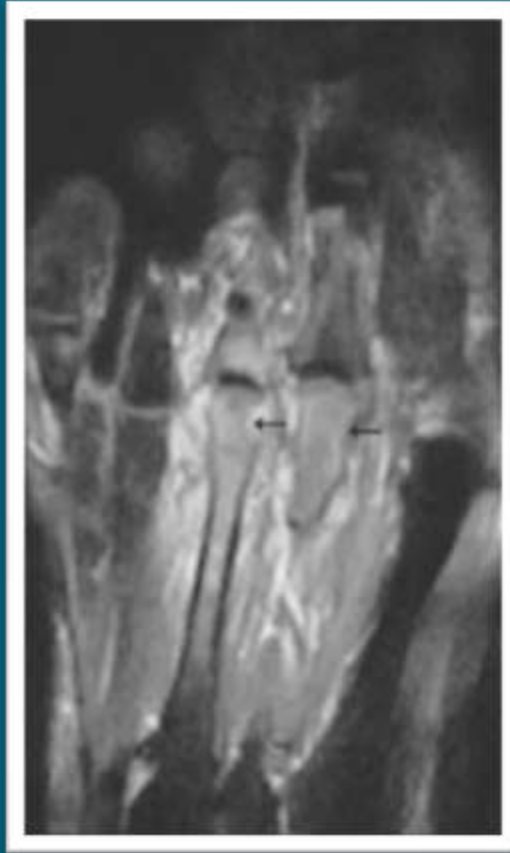
-low signal intensity tophi , with post contrast enhancement

- adjacent periarticular erosions with characteristic overhanging edges

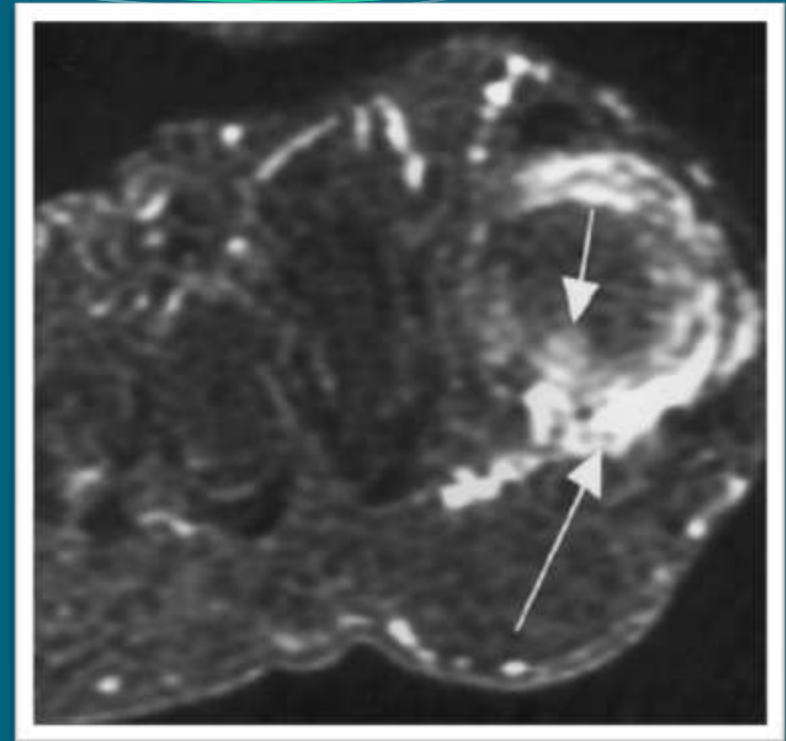
- Non-specific MR features; correlate with lab values to distinguish from RA, septic arthritis, neoplasm



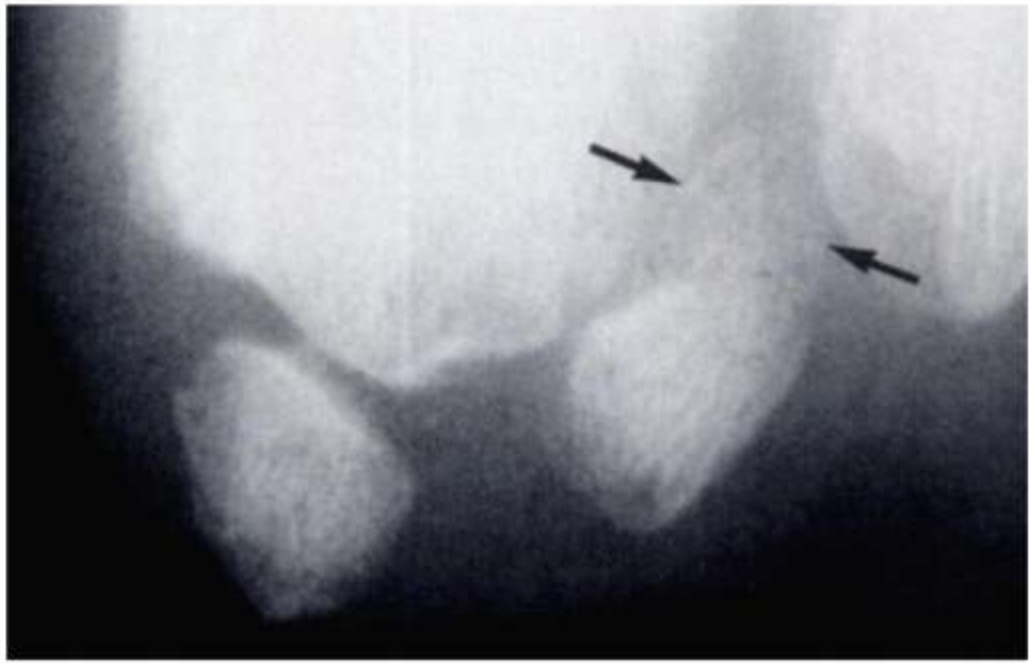
Rheumatoid arthritis: hallux valgus, erosions, soft tissue swelling, joint space narrowing, lateral subluxation of sesamoids



Rheumatoid arthritis



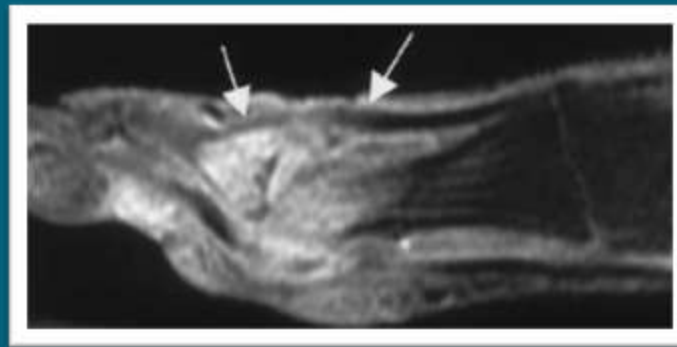
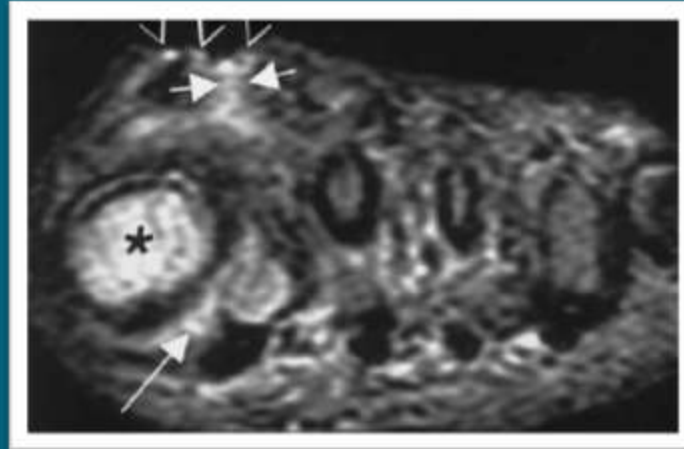
Rheumatoid arthritis: marginal erosions, joint space narrowing, synovitis



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 1<sup>st</sup>, 5<sup>th</sup> MT heads
- MR non-specific: T1 hypointensity, T2 hyperintensity, enhancement (ddx = neuropathic arthropathy)
- +/- abscess, sinus tract, bony destruction
- Distinguishing factors: location, ulcer, abscess/phlegmon, sinus tract
- Septic arthritis: joint effusion, synovitis, marrow edema

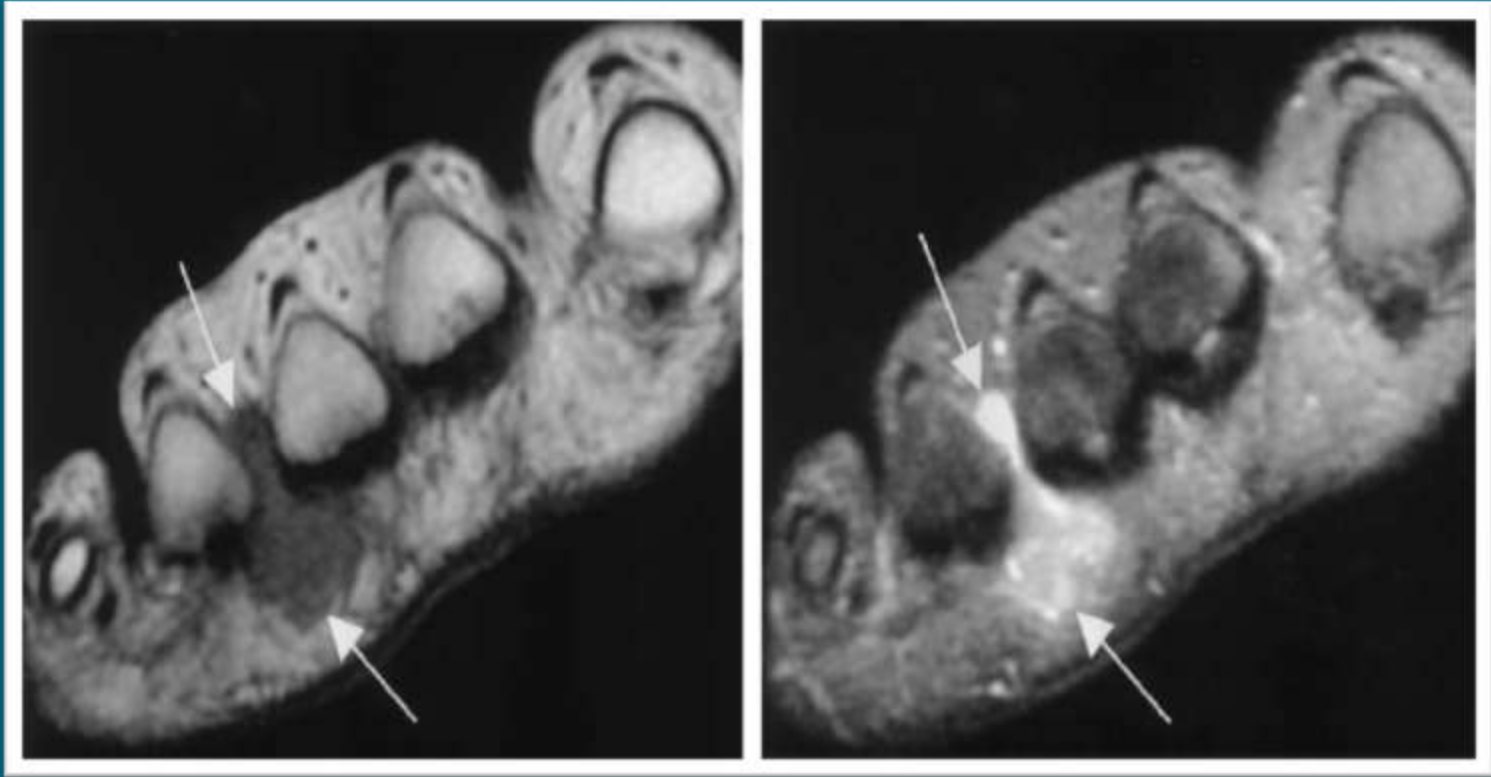


Osteomyelitis of 1<sup>st</sup> MT head, septic arthritis of 1<sup>st</sup> MTP joint



# Morton's neuroma

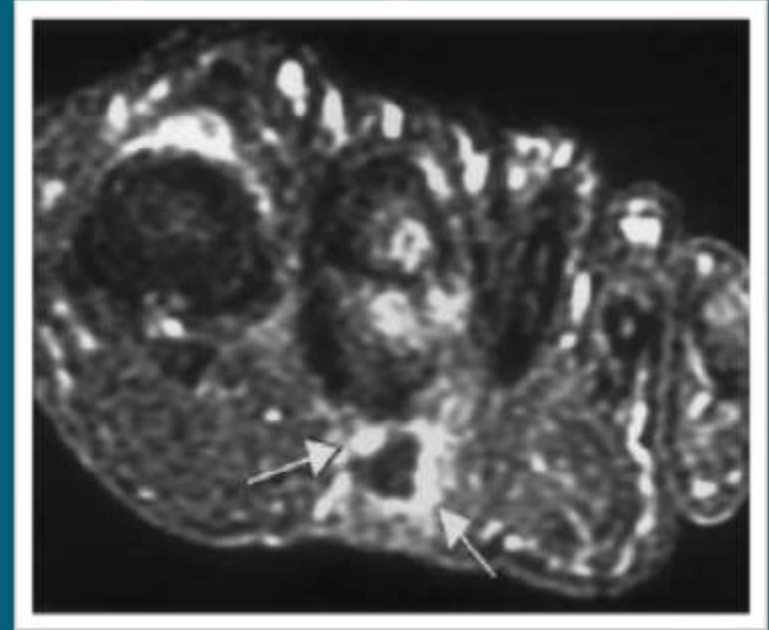
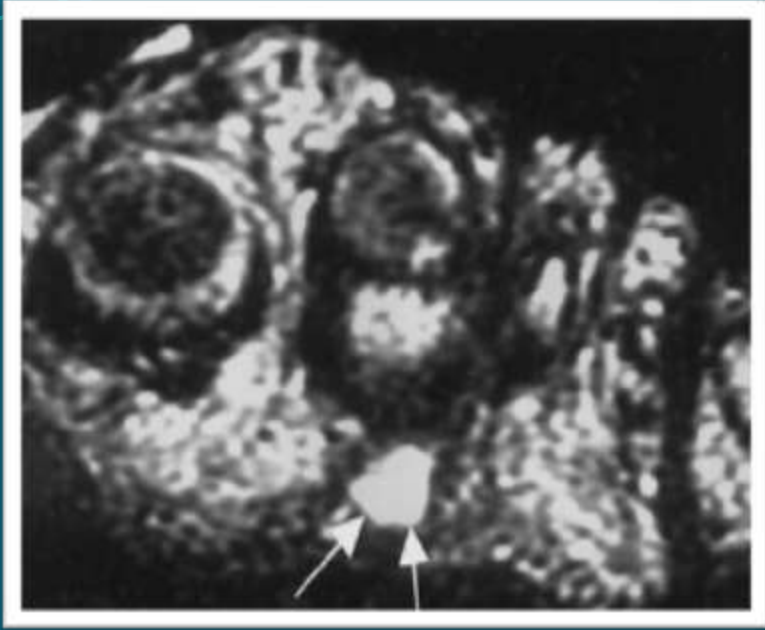
- Fibrotic response in and about plantar digital nerves (digital branches of medial, lateral plantar nerves)
- Likely on the basis of mechanical impingement
- MC in women, repetitive stress such as in ballet or running, etc
- # 1 location is between the 3<sup>rd</sup> & 4<sup>th</sup> MT heads (3<sup>rd</sup> interspace), #2 location is 2<sup>nd</sup> 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
- 1<sup>st</sup> interspace = Joplin's neuroma



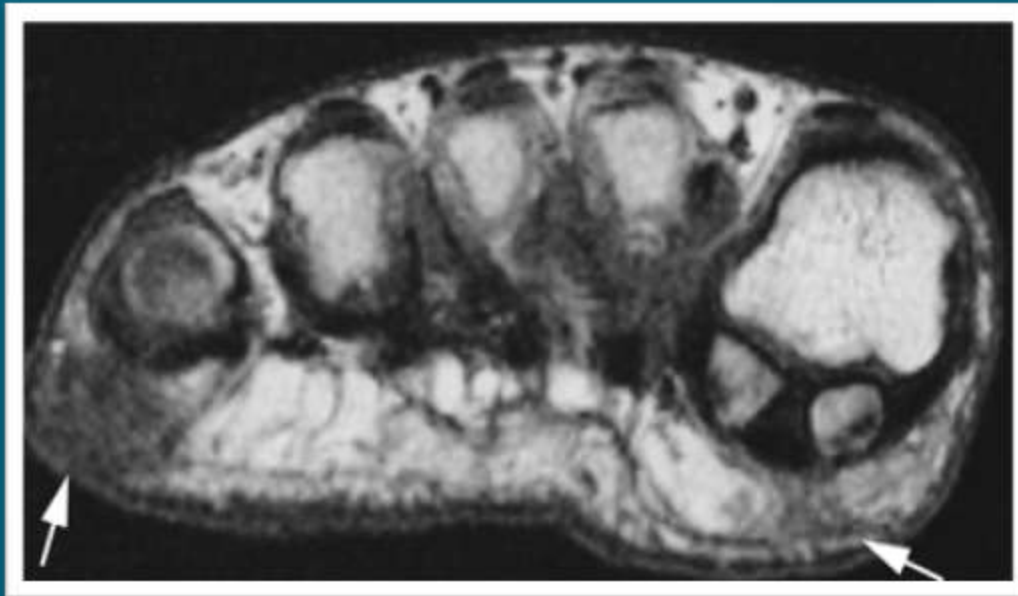
Morton's neuroma

# Bursitis

- Intermetatarsal or adventitial (beneath MT heads)
- May be mechanical, post-traumatic, infections, inflammatory
- NOTE: small fluid collections within first 3 intermetatarsal bursae with transverse diameter  $<3\text{mm}$  are common and of doubtful clinical significance



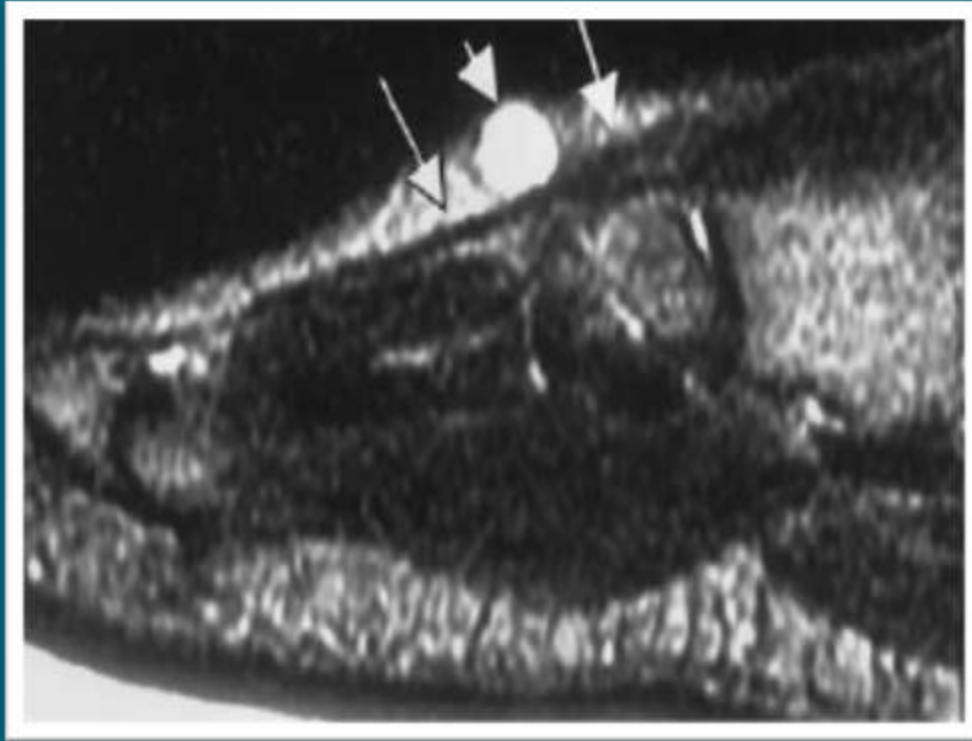
Adventitial bursal formation (submetatarsal)



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)

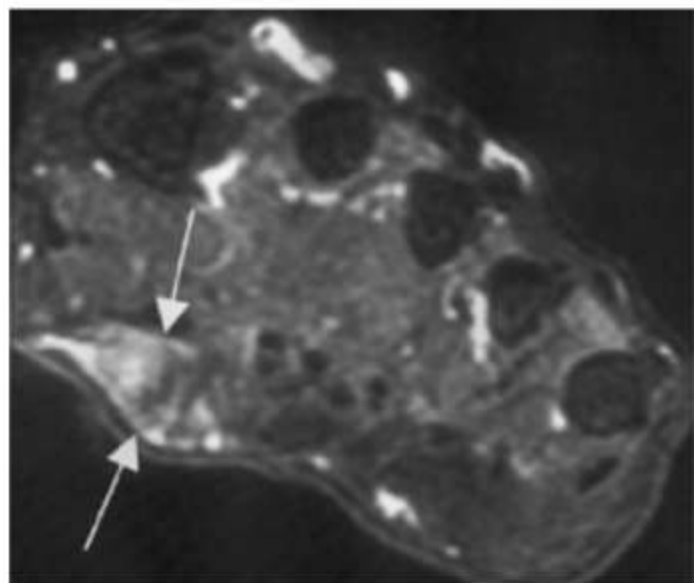
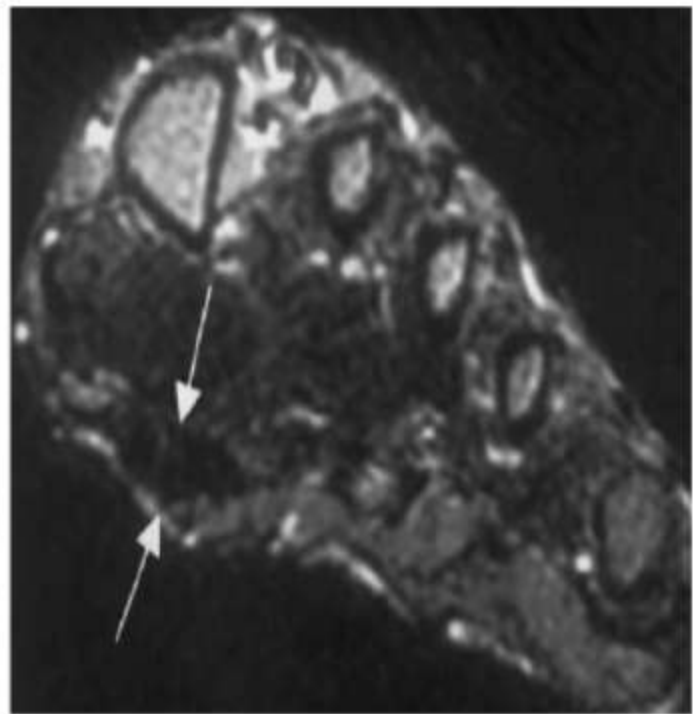
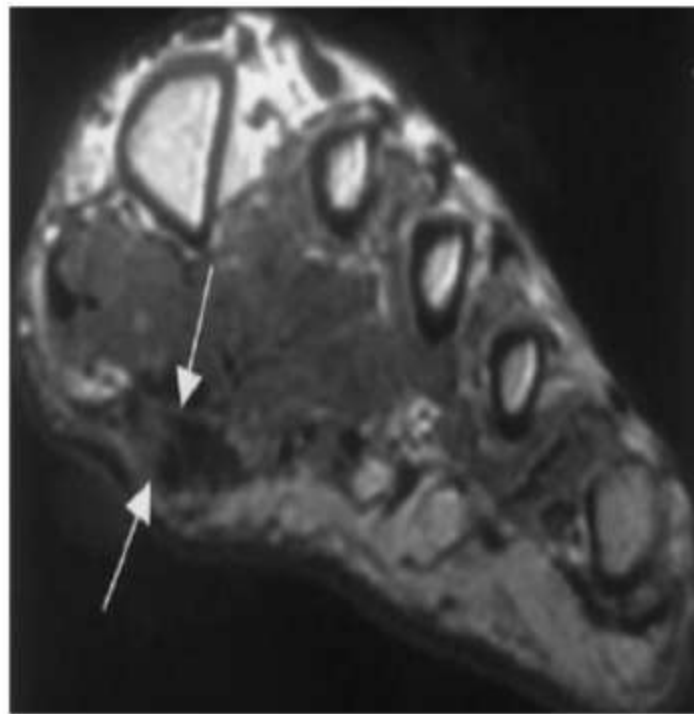


Ganglion cyst

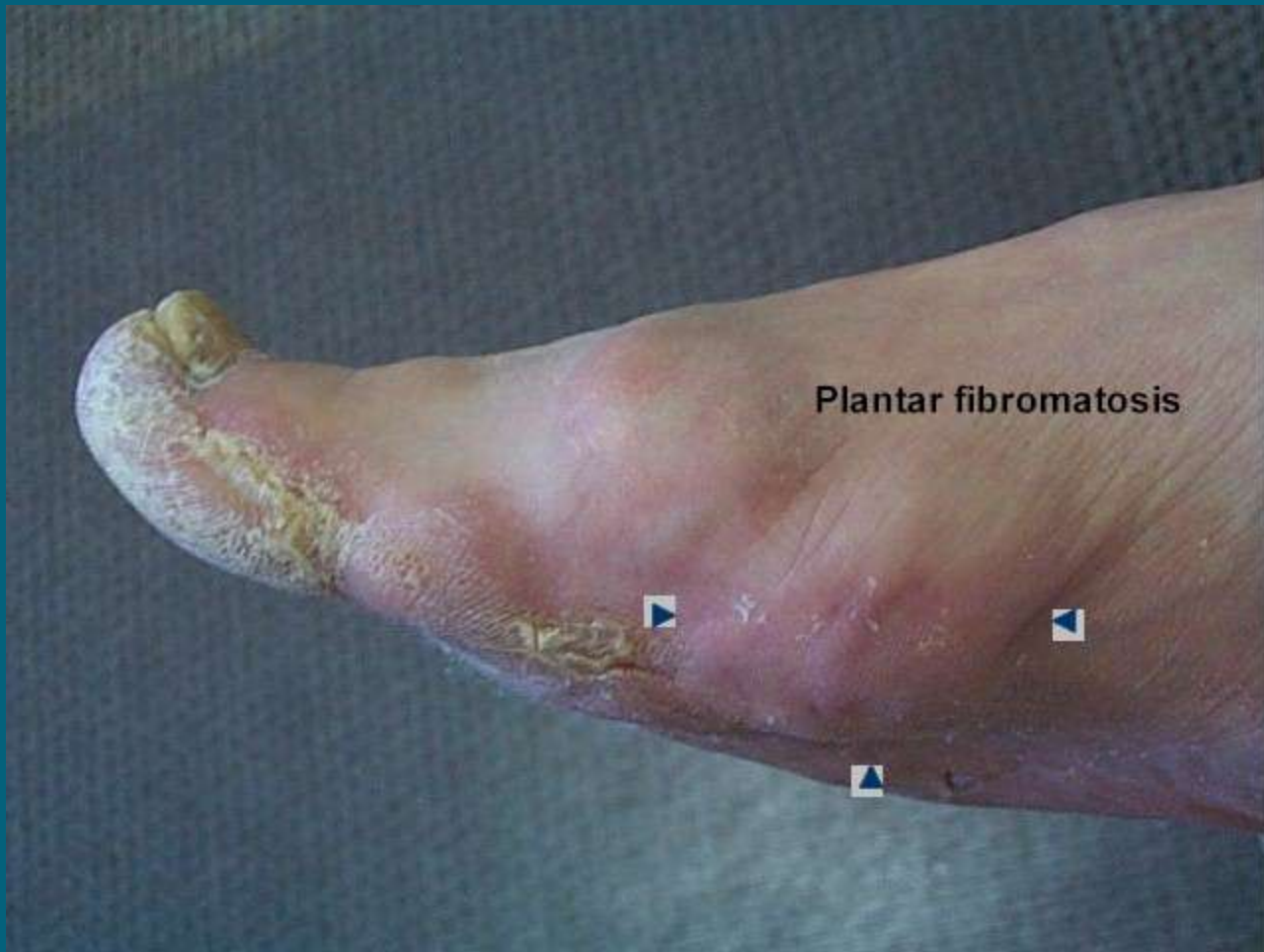
# Plantar fibromatosis

- 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 involving 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





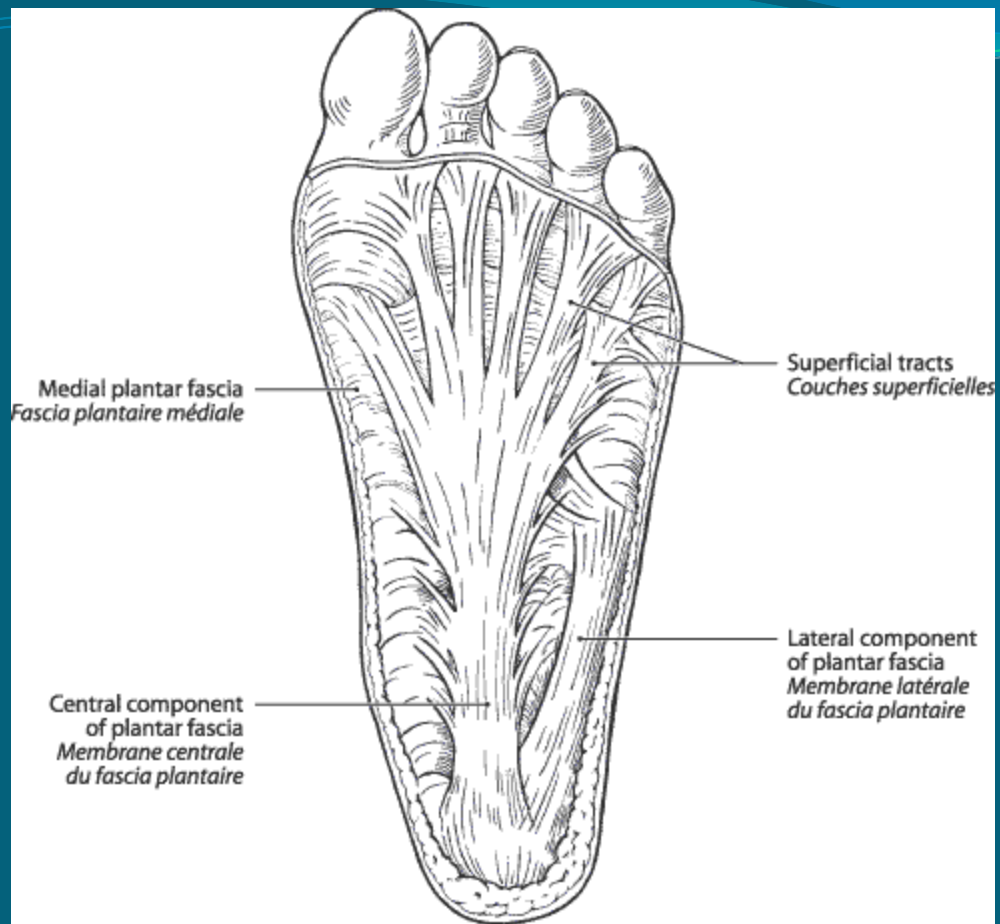
Plantar fibromatosis



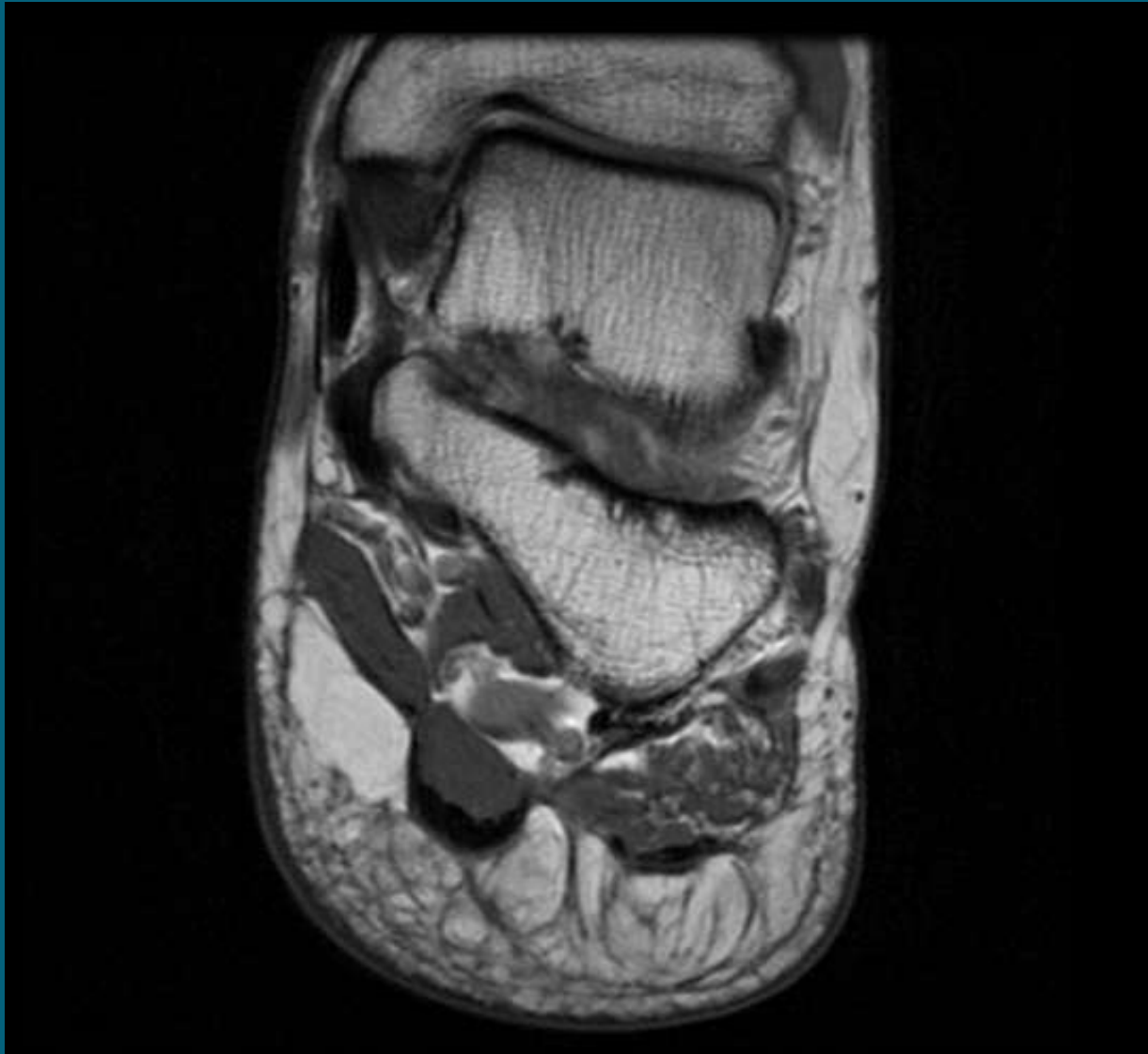
Plantar fibromatosis

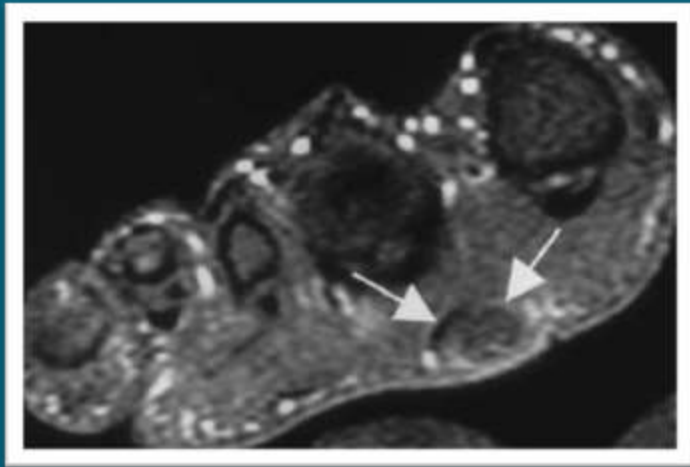
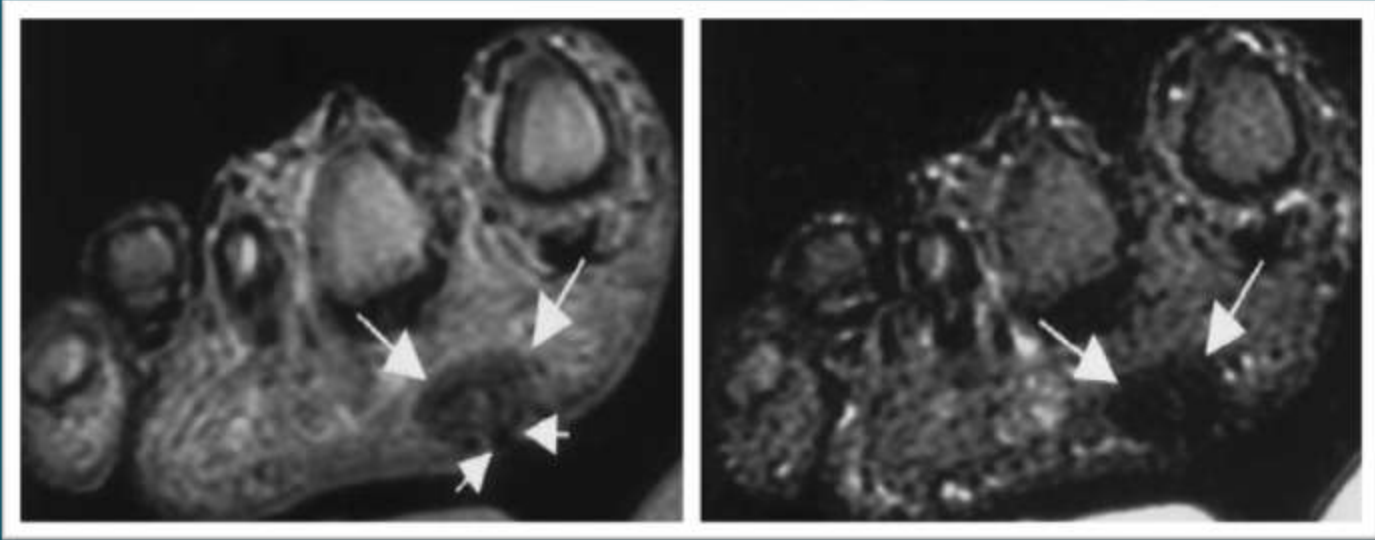
# Plantar fascia

- 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 5<sup>th</sup> 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***

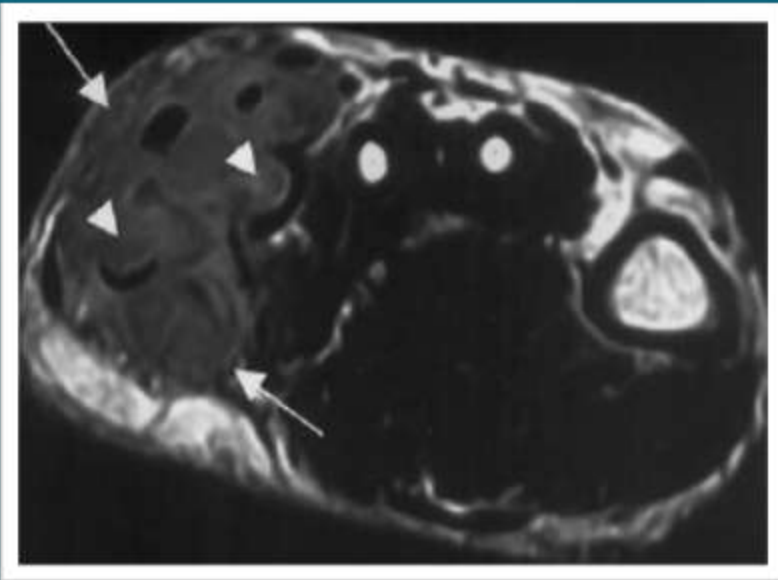
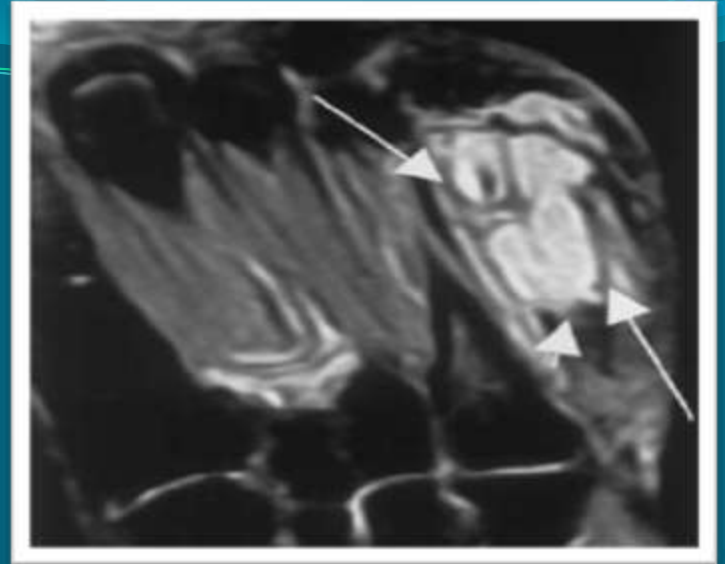
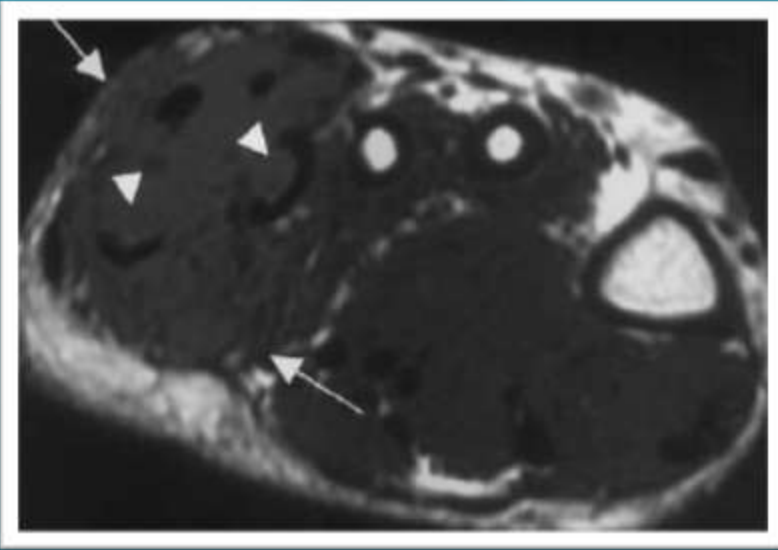




Foreign body granuloma

# Malignant soft tissue masses

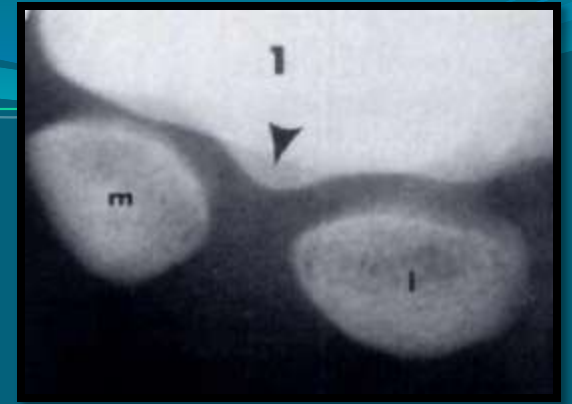
- Less common than benign tumors
- < 45 yrs
  - Synovial sarcoma (heterogeneous mass with fluid levels)
  - Rhabdomyosarcoma
- > 45 yrs
  - MFH
  - KS
  - Leiomyosarcoma
  - Liposarcoma



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

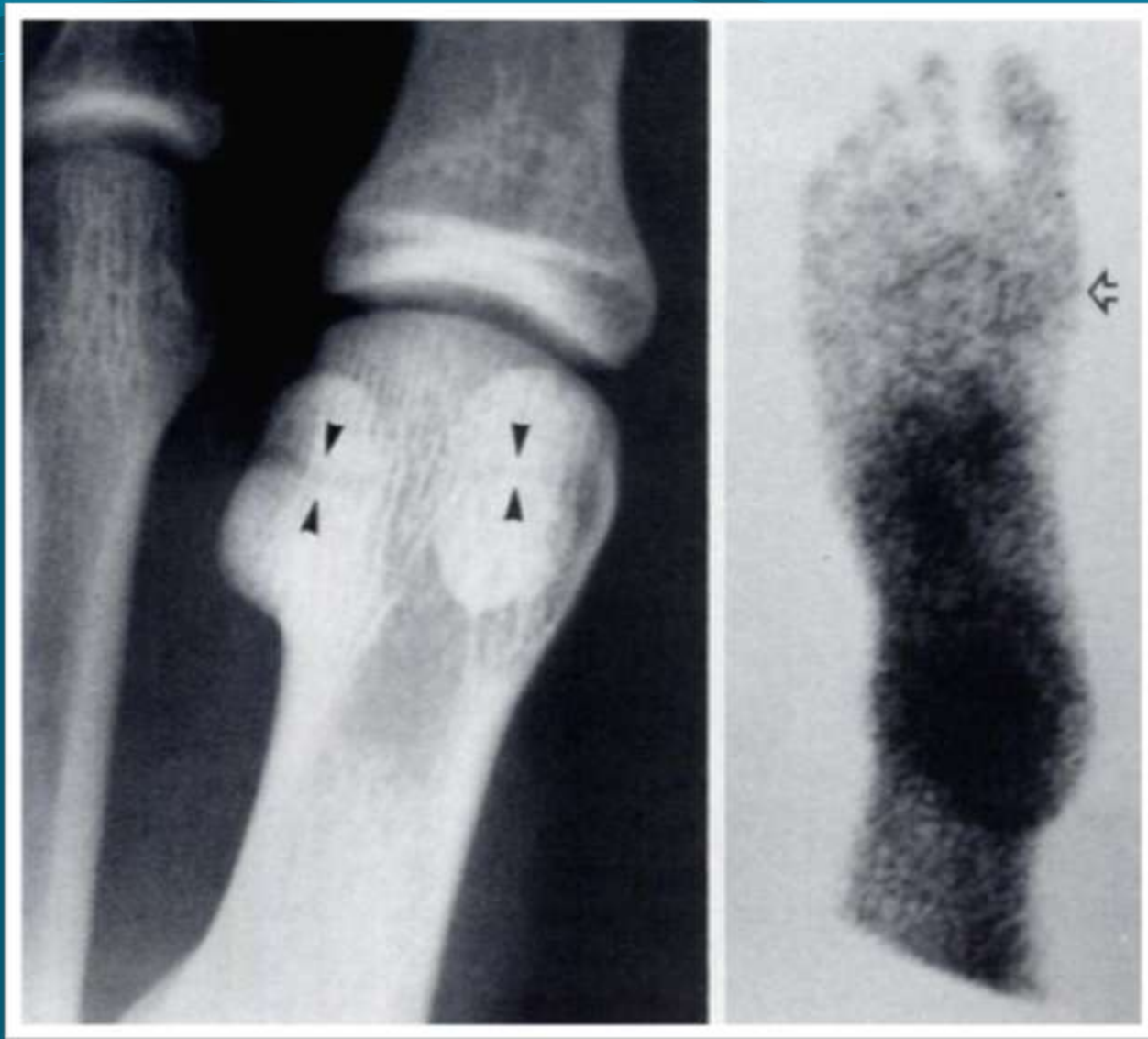
- Congenital
- Traumatic
- Articular disease
- Infection
- Osteonecrosis

# 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





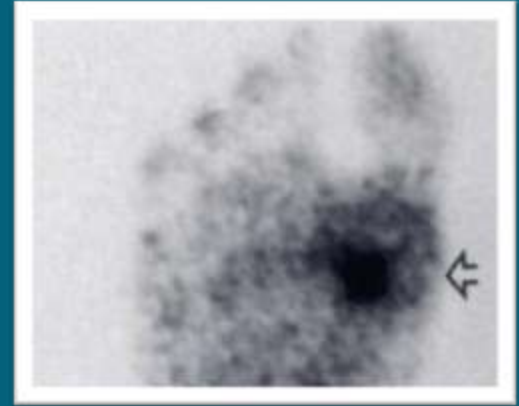
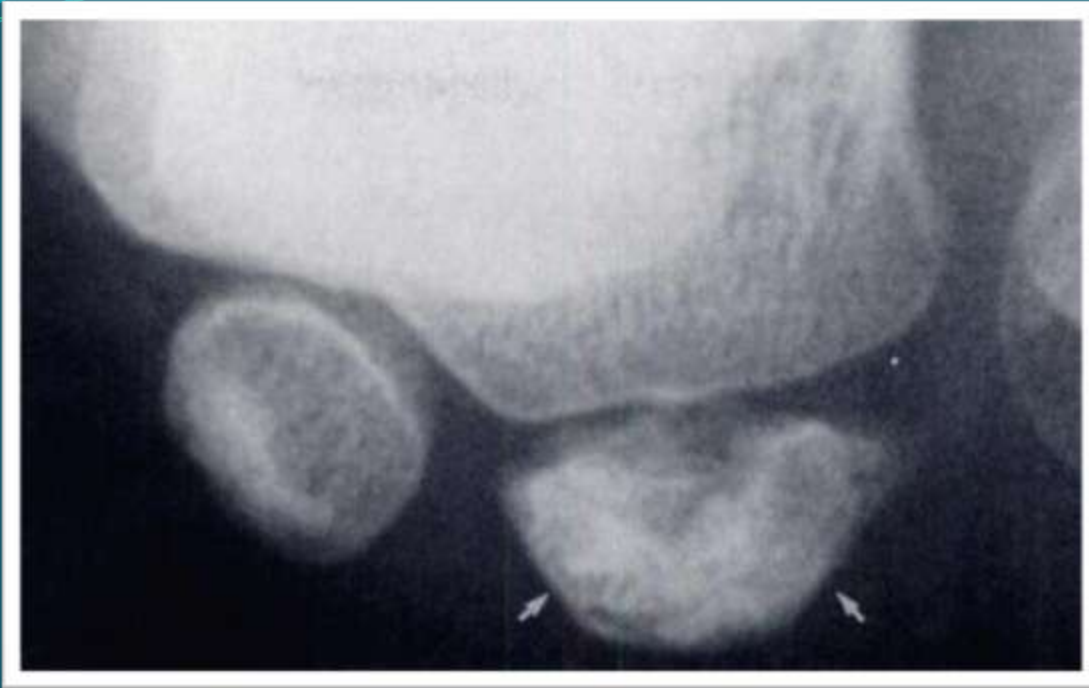
Bipartite sesamoids: well-corticated, smooth margins, no uptake on bone scan

# Sesamoid trauma

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

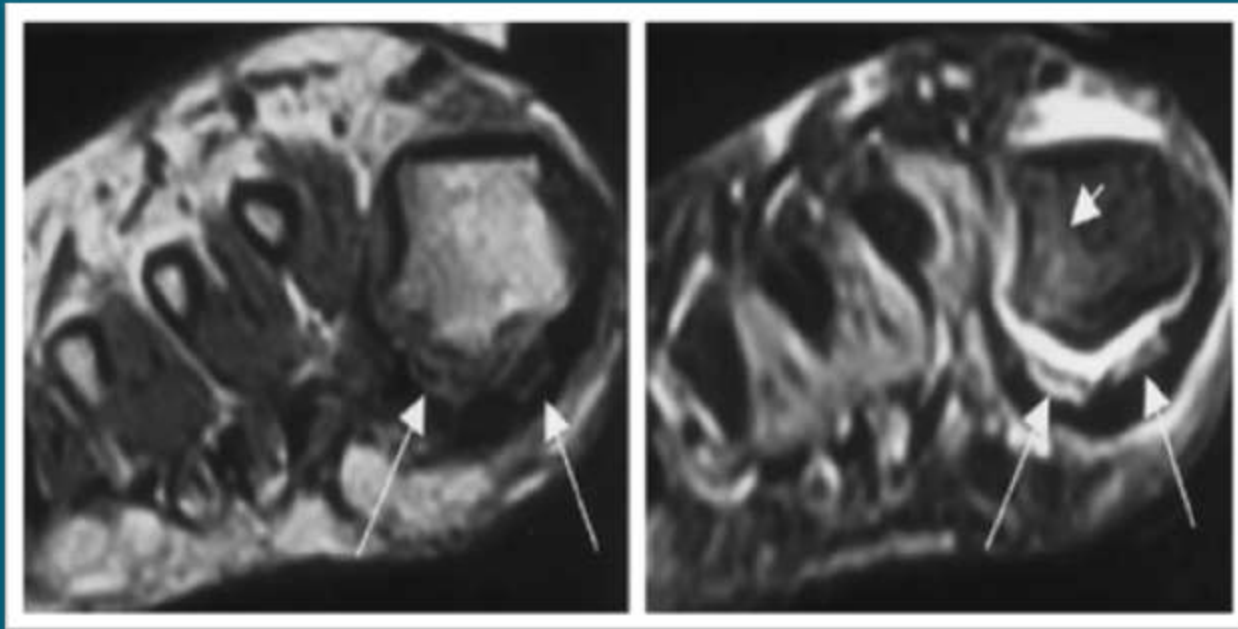
# “sesamoiditis”

- 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





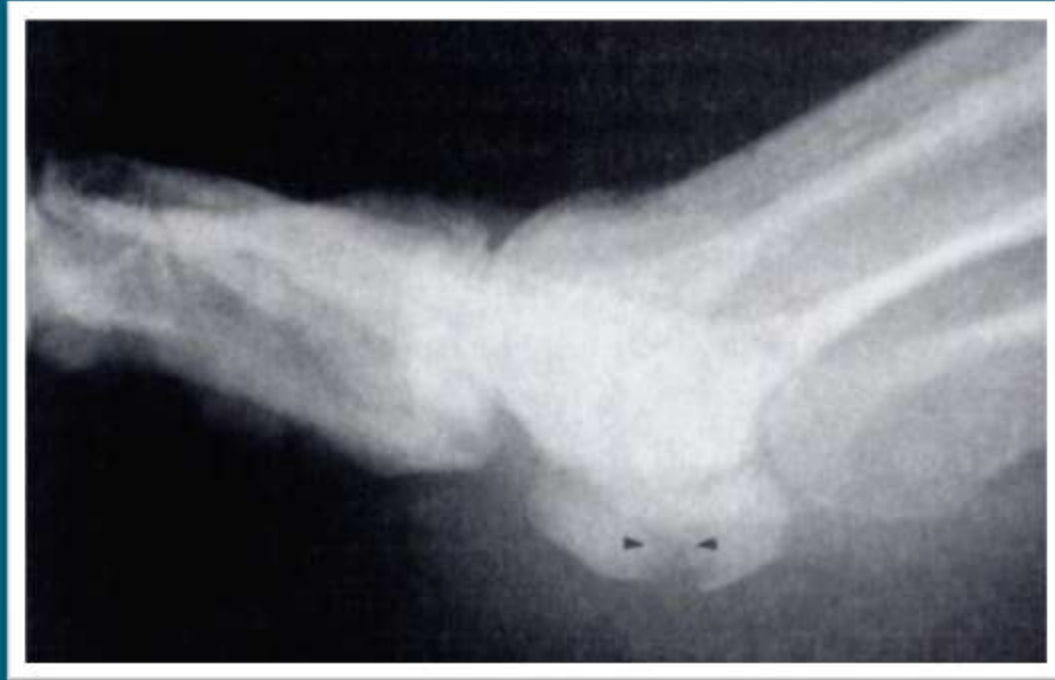
Sesamoiditis (vs stress response) in a 24-year-old female kickboxer

# 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 sx's c/w acute fracture



Sesamoid fractures



Sesamoid fracture (subacute) with resorption at the fracture site

# Sesamoid arthritis

- 1<sup>st</sup> MTP joint usually also affected
- OA
- RA
- Gout
- CPPD
- Reactive arthritis

# Sesamoid infection

- MC in diabetics
- Clinical: elevated ESR, leukocytosis, fever

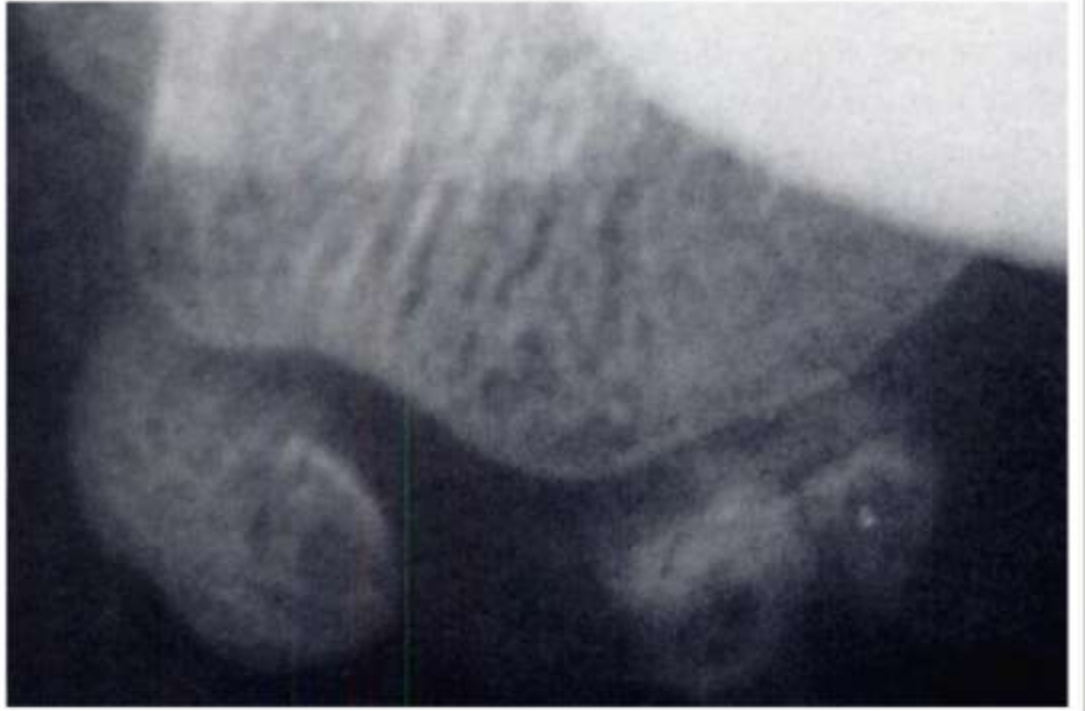


Osteomyelitis of the  
medial sesamoid

# 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

# References

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