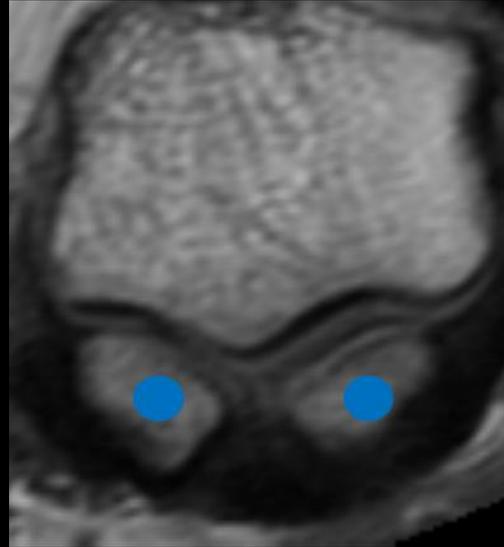


Toes: Anatomy, Pathology and Common Surgical Procedures



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Learning Objectives

1. Osseous and soft tissue toe anatomy

- a. The great toe
- b. The lesser toes

2. Pathophysiology and clinical presentation of injury to great and lesser toes

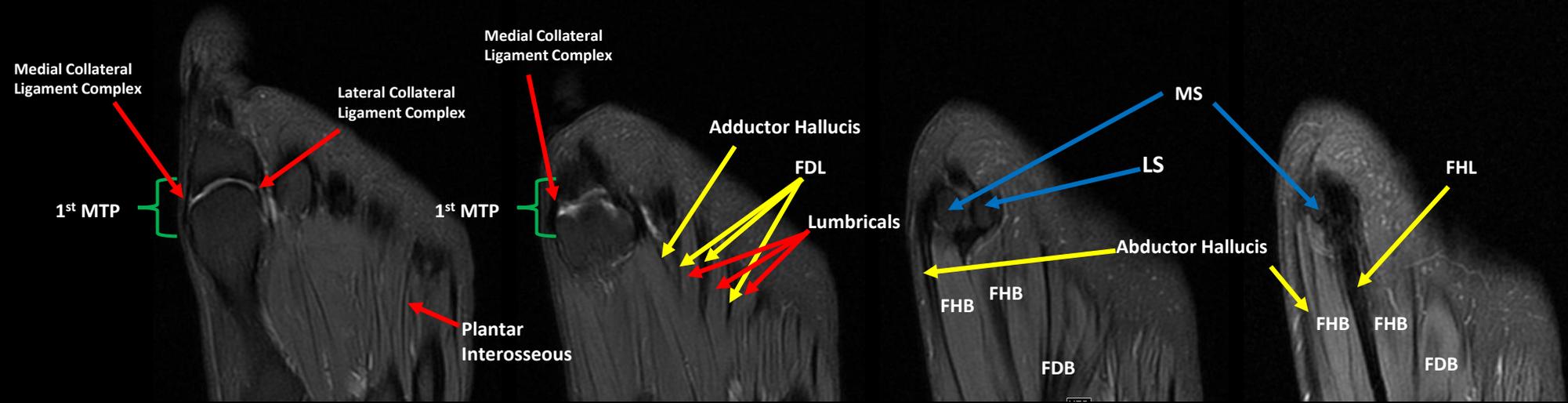
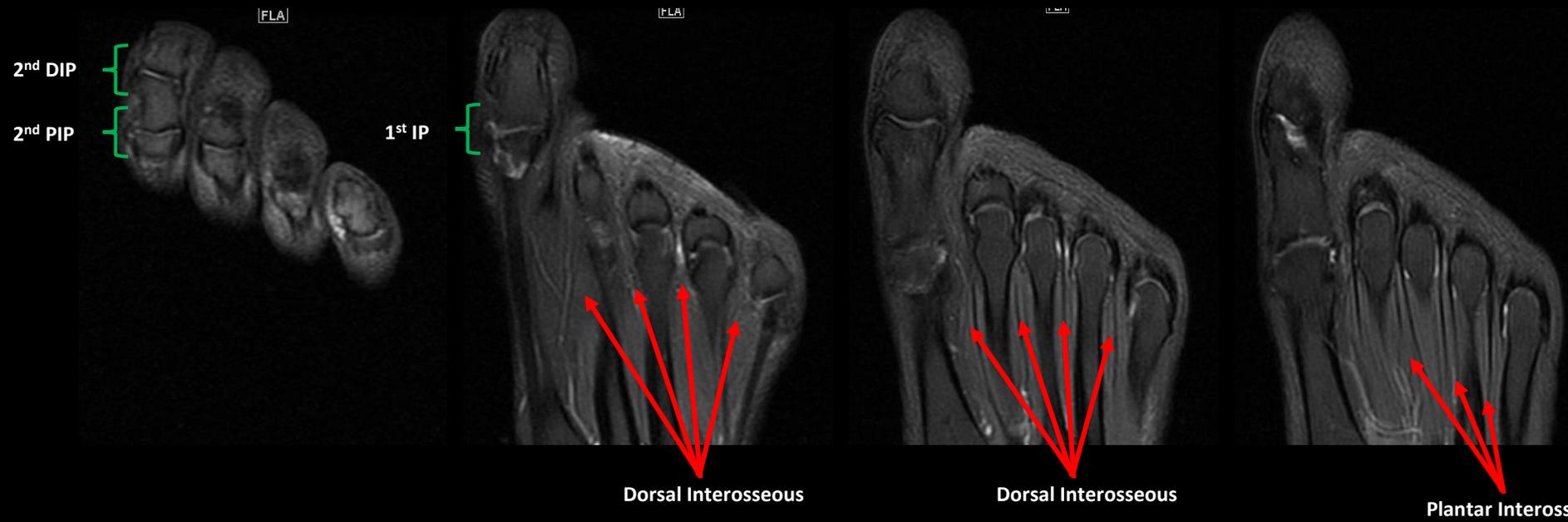
- a. Hallux valgus, varus and rigidus
- b. Bunion and bunionette
- c. Hallux sesamoid complex injury and turf toe
- d. Hammer , claw and mallet toe
- e. Freiberg infraction
- f. Neuroma
- g. Benign masses
 - a. Subungal exostosis
 - b. Plantar fibroma

3. Commonly encountered surgical procedures

Osseous and Soft Tissue Anatomy Overview

Dorsal

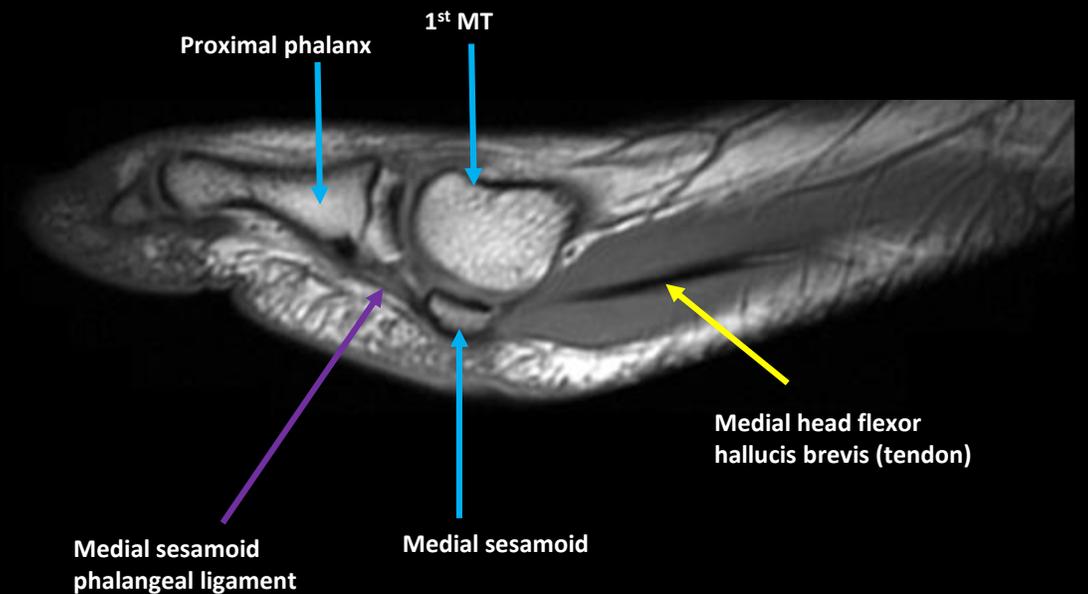
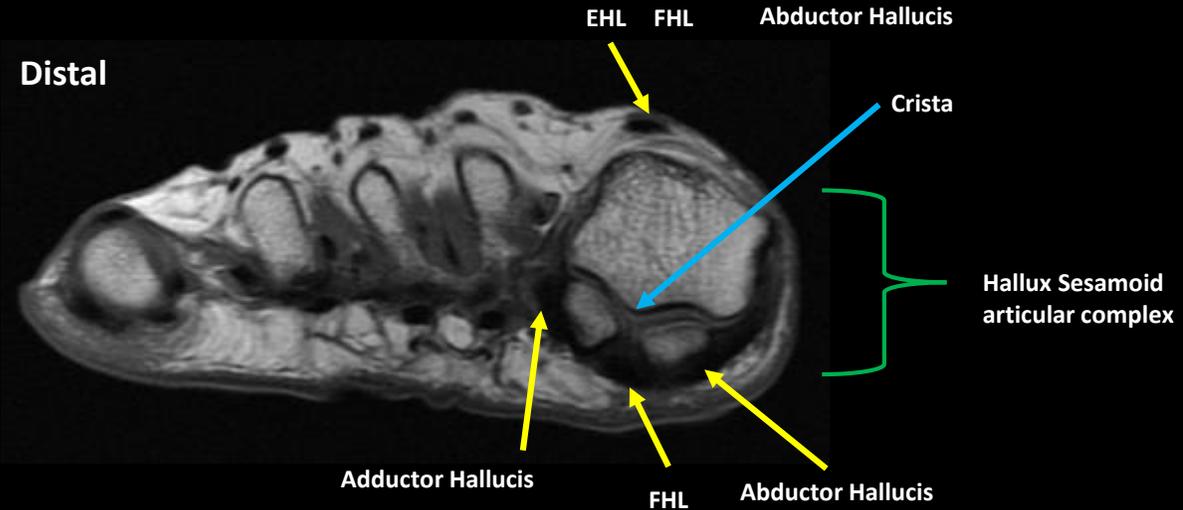
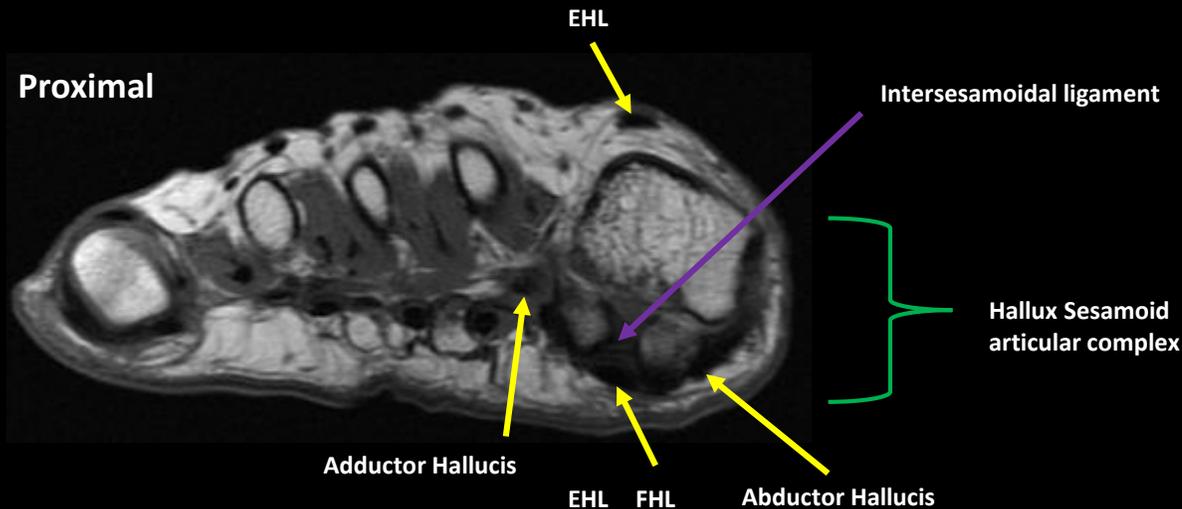
	Joint
	Muscle belly
	Tendon
	Osseous structure



Plantar

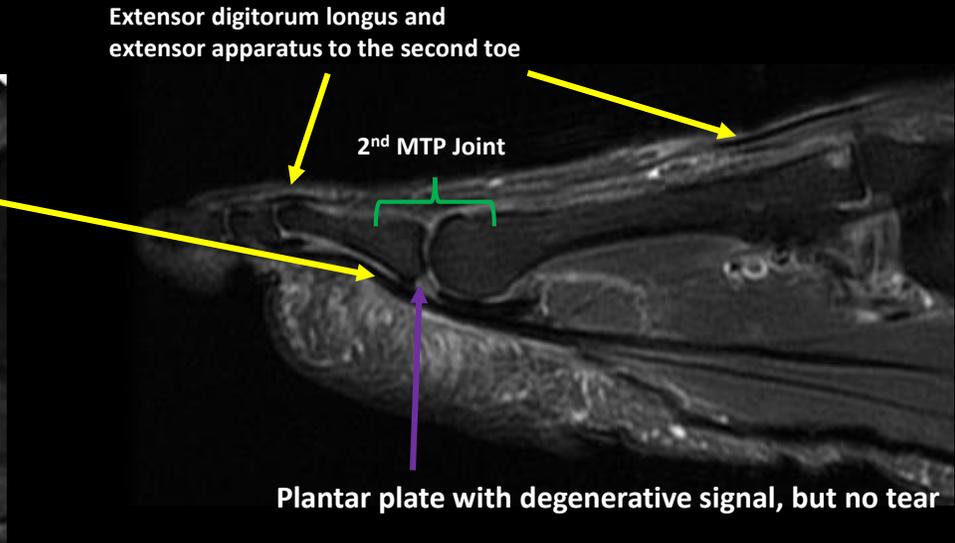
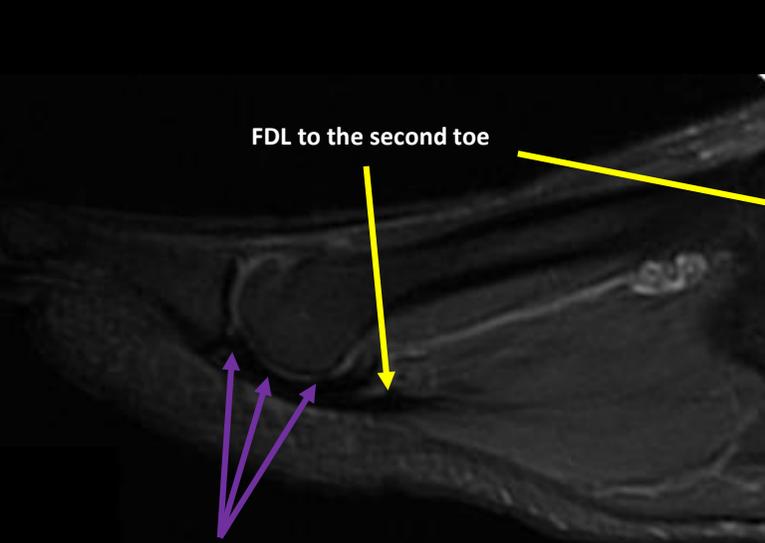
Osseous and Soft Tissue Anatomy: The Great Toe

	Joint
	Ligament
	Tendon
	Osseous structure



Osseous and Soft Tissue Anatomy: The Lesser Toes

	Joint
	Ligament
	Tendon
	Osseous structure



Flexor digitorum brevis (yellow) originates in plantar foot and tendon splits at the proximal phalanx to then insert on the middle phalanx allowing for PIP flexion. The **flexor digitorum profundus** tendon passes between the FDB slips and continues to insert into the distal phalanx to allow for DIP flexion.



Extensor digitorum brevis (yellow) originates in lateral foot and tendon joins extensor apparatus. **Central slip** inserts into middle phalanx to allow for PIP extension while **terminal tendon** passes around central slip to insert on distal phalanx and allow for DIP extension. There is no EDB to 5th toe.

Pathophysiology: Hallux Valgus, Varus and Rigidus

Common hallux radiographic measurements

Hallux valgus interphalangeus angle

- Angle between long axes of distal and proximal phalanges
- Angle at IP joint
- Normal < 8 degrees

Hallux valgus angle

- Angle between long axes of proximal phalanx and 1st MT
- Angle at MTP joint
- Normal < 15 degrees

Metatarsus primus varus angle

- Angle between 1st MT and 1st cuneiform
- Angle at 1st TMT joint
- Normal 10 - 25 degrees

1st intermetatarsal angle

- Angle between 1st MT and 2nd MT
- Normal < 10 degrees

Distal metatarsal articular angle (DMAA)

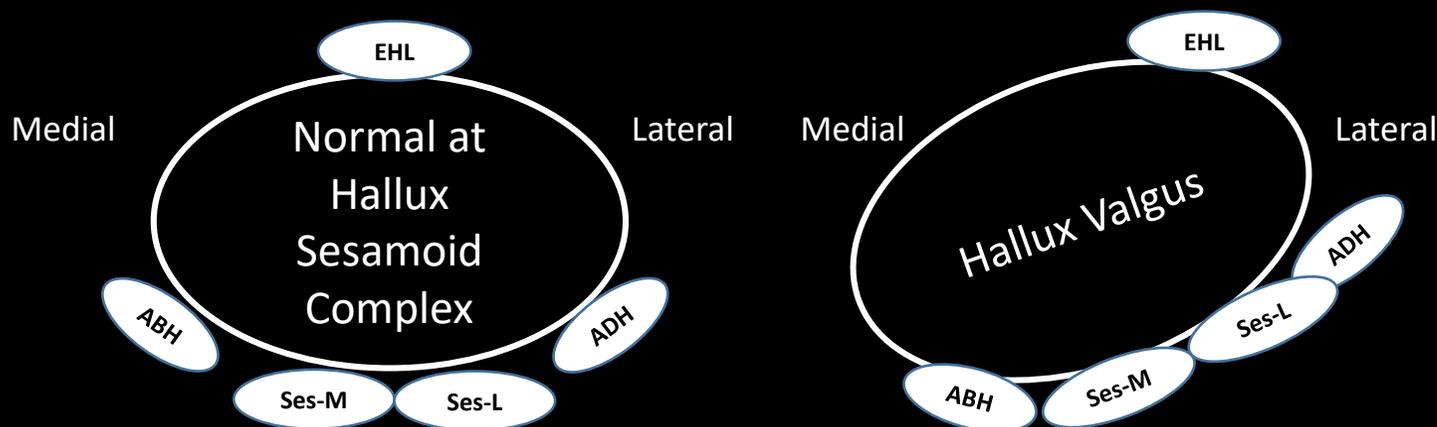
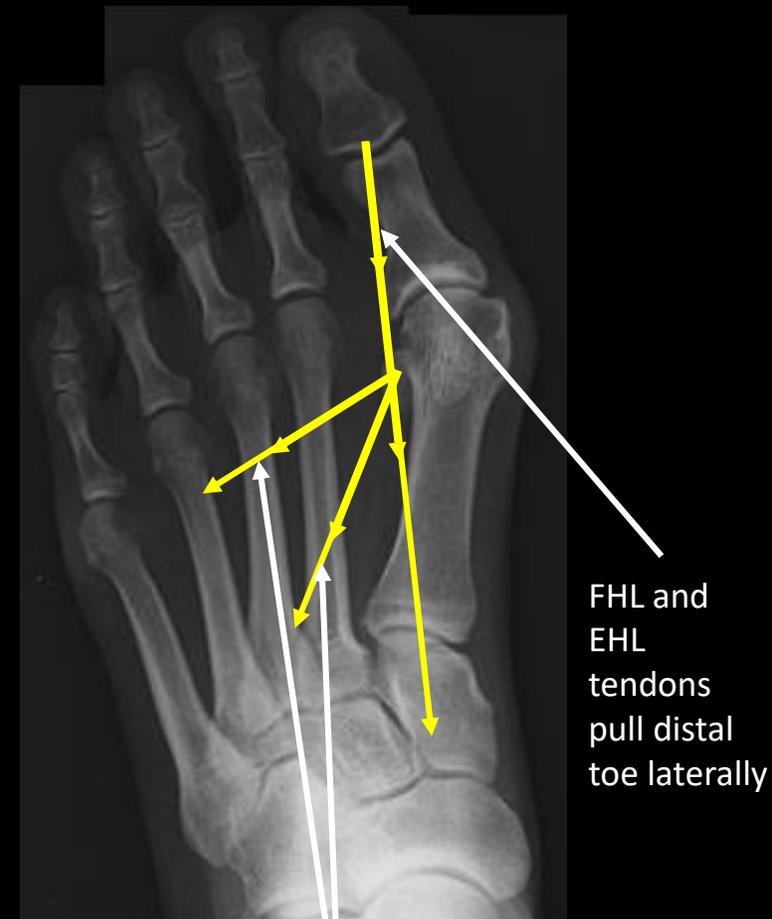
- Angle between 1st MT shaft and line through base of articular cap
- Normal < 10 degrees
- Tells if there is incongruity of joint



Pathophysiology: Hallux Valgus, Varus and Rigidus

Hallux valgus (lateral deviation of toe relative to 1st MT)

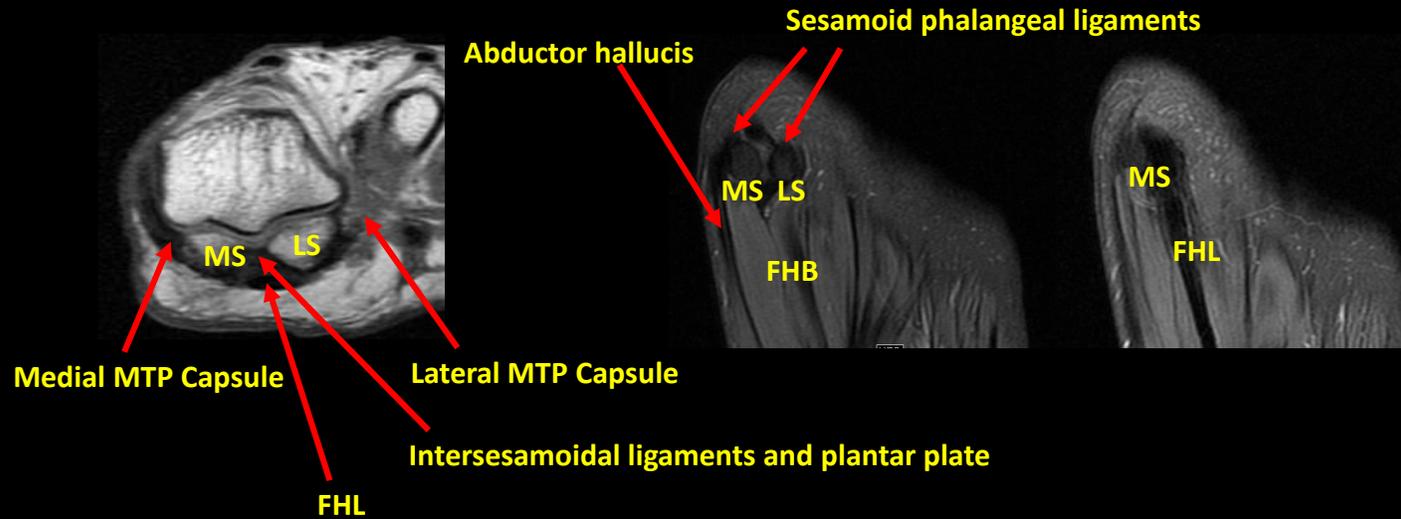
- May be associated with RA, cerebral palsy, following a second toe amputation, family history, with pes planus or, more commonly when chronically wearing high heeled shoes with a narrow toe box
- Complex pathophysiology:
 - Proximal phalanx moves in valgus direction while 1st metatarsal moves in a varus direction
 - Adductor hallucis attaches to lateral sesamoid and pulls the sesamoids laterally. Also, sesamoids attached to deep transverse intermetatarsal ligament which keeps sesamoids stable relative to medially deviating 1st MT.
 - EHL and FHL shifts laterally which pulls the distal toe in a lateral direction, worsening deformity
 - Medial capsule side of the 1st MTP joint is stretched while lateral side is scarred/contracted
 - Further varus positioning of the 1st MT head brings it closer to inside of narrow toe box resulting in increased pressure on the medial 1st MT head and superficial soft tissues
 - Valgus movement of toe may result in first and second toe cross over
 - Abductor hallucis rotates in a plantar and lateral direction resulting in great toe pronation
 - Remodeling of the medial eminence of the 1st MT results in bunion with or without adventitial bursitis



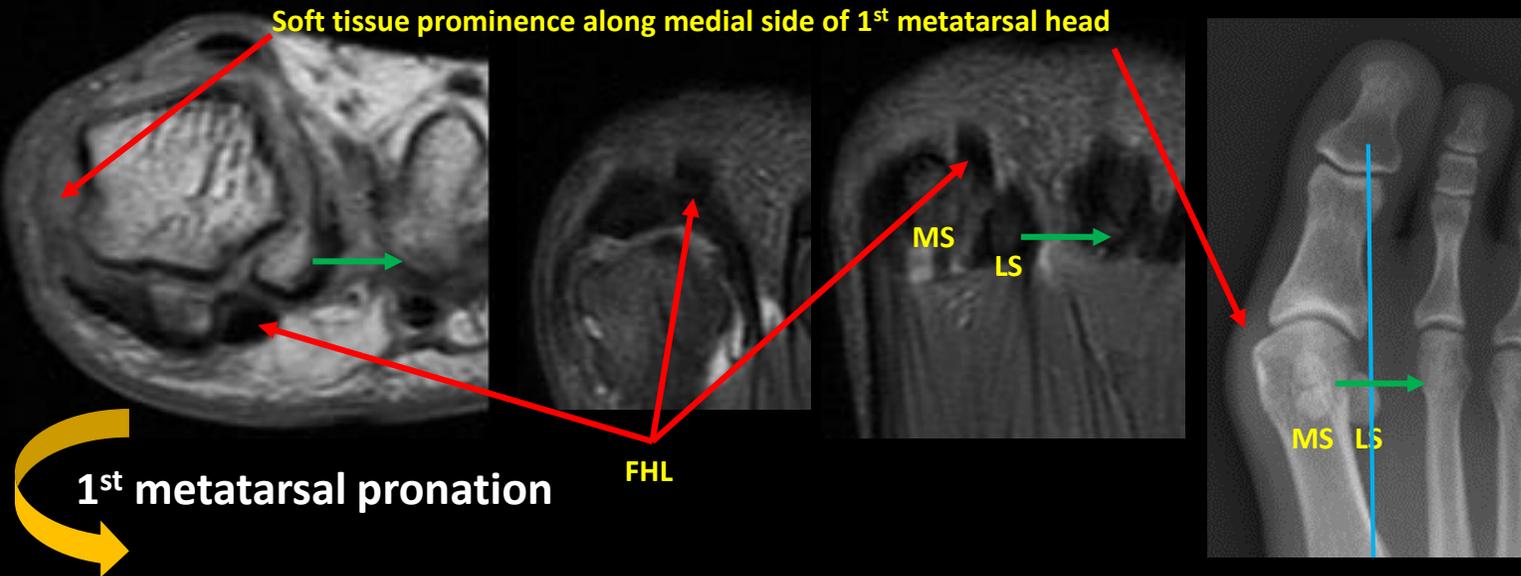
Transverse and oblique heads of adductor hallucis along with deep intermetatarsal ligament allow for medial subluxation of the 1st MT head from the sesamoids resulting in their progressive uncovering (lateral sesamoid uncovered first)

Pathophysiology: Hallux Valgus, Varus and Rigidus

Normal



Hallux Valgus



- Phalanges deviate laterally
- Stretching of the medial 1st MTP joint capsule
- Adductor hallucis and IML holds sesamoids lateral with respect to 1st MT (green arrows)
- FHL (blue line) deviates laterally contributing to further valgus deviation of the phalanges
- 1st metatarsal head deviates medially
- Soft tissue prominence at bone remodeling result at the medial 1st metatarsal head (bunion)
- Pull of the abductor hallucis results in great toe pronation (curved orange arrow)

Pathophysiology: Hallux Valgus, Varus and Rigidus

Hallux varus (medial deviation of the toe relative to the 1st MT)

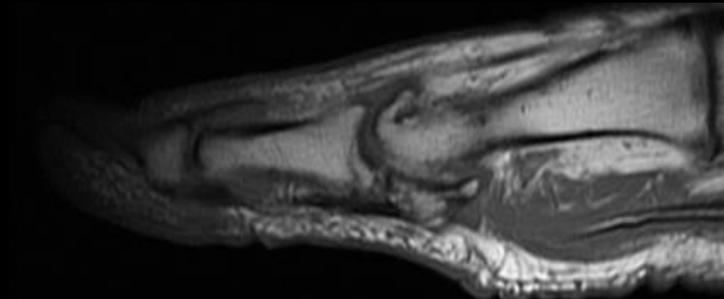
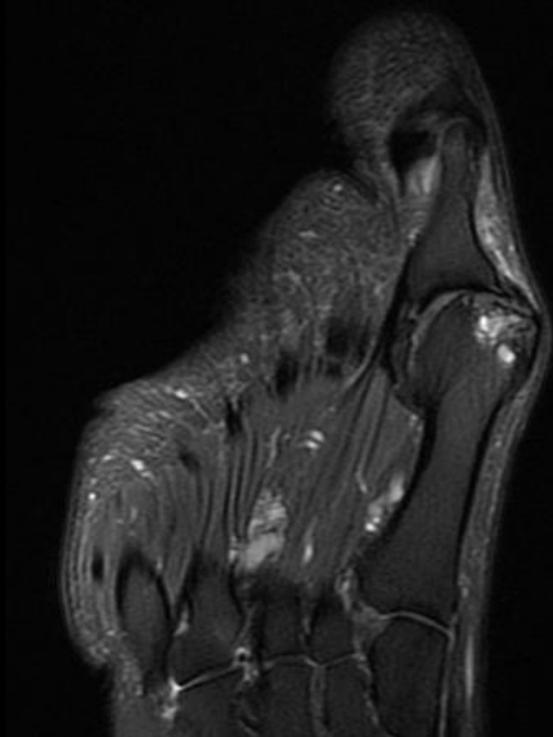
- Often associated with overcorrection of hallux valgus, but can be seen in inflammatory and neuropathic arthritis
- Pathophysiology related to excessive surgical correction of hallux valgus:
 - Excessive medial eminence resection with overtightening of the medial capsule with release of medial capsule pulls the proximal phalanx medial with respect to the 1st MT
 - May have overcorrection with osteotomies
- Although can be determined without measuring, a hallux valgus angle of less than 0 degrees is diagnostic of hallux varus. If the angle opens medially, it is considered negative. In bottom right, hallux valgus angle was - 14 degrees.



Pathophysiology: Hallux Valgus, Varus and Rigidus

Hallux rigidus

- Thought to be related to repetitive microtrauma
- Pathophysiology related to progressive 1st MTP joint osteoarthritis
 - Dorsal osteophytes form reducing range of motion (dorsiflexion at MTP joint)
 - Spurs may also irritate dorsal cutaneous nerves with dorsiflexion at the joint



1st MTP OA with dorsal osteophytes in this patient with limited painful dorsiflexion. There is also hallux valgus and bunion.

Surgical Correction: Hallux Valgus

Preoperative



1st MTP Angle / Hallux Valgus Angle = 26.2°
1st Intermetatarsal Angle = 13.7°

Postoperative



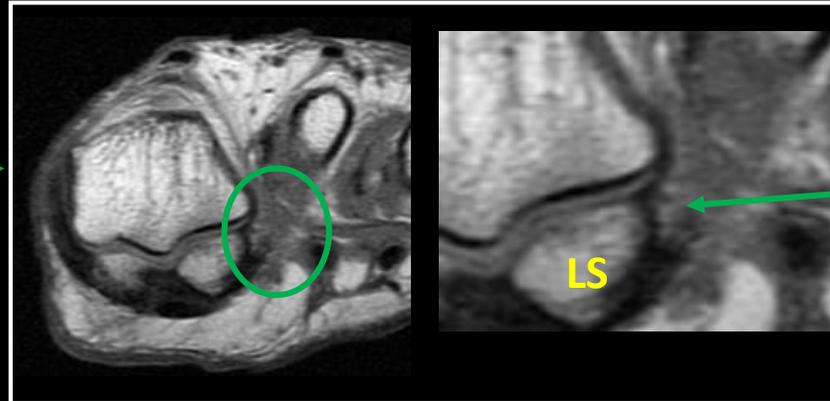
1st MTP Angle / Hallux Valgus Angle = 15.8°
1st Intermetatarsal Angle = 10.6°

Surgical Correction: Hallux Valgus



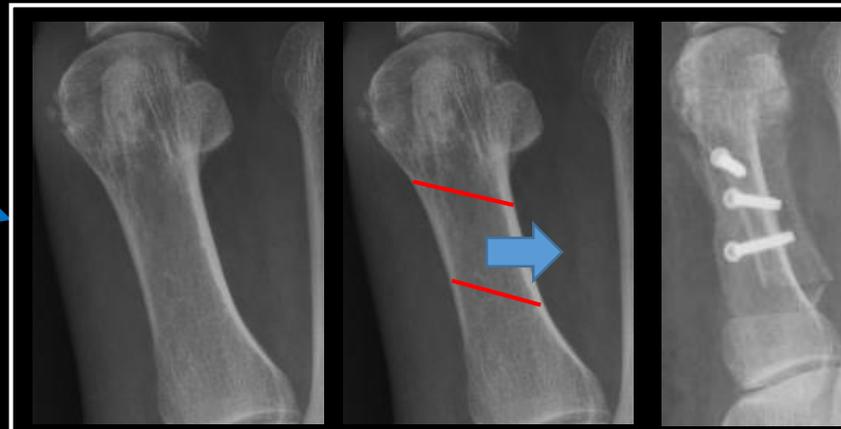
Akin Osteotomy

- Medial opening wedge osteotomy of the 1st proximal phalanx
- Pin or plate to fix osteotomy and add compression to help healing



Modified McBride

- Release of the adductor hallucis
- Release of the **lateral capsule** 1st MTP
- Medial MTP capsular tightening
- Original McBride included **lateral sesamoid** removal which is no longer done and has been replaced by the above modified McBride



1st Metatarsal Osteotomy (Scarf)

- Dorsal distal to proximal plantar Z shaped osteotomy with a lateral shift of the distal fragment
- Pinned in place and add compression to help healing

Surgical Correction: Hallux Varus

Preoperative



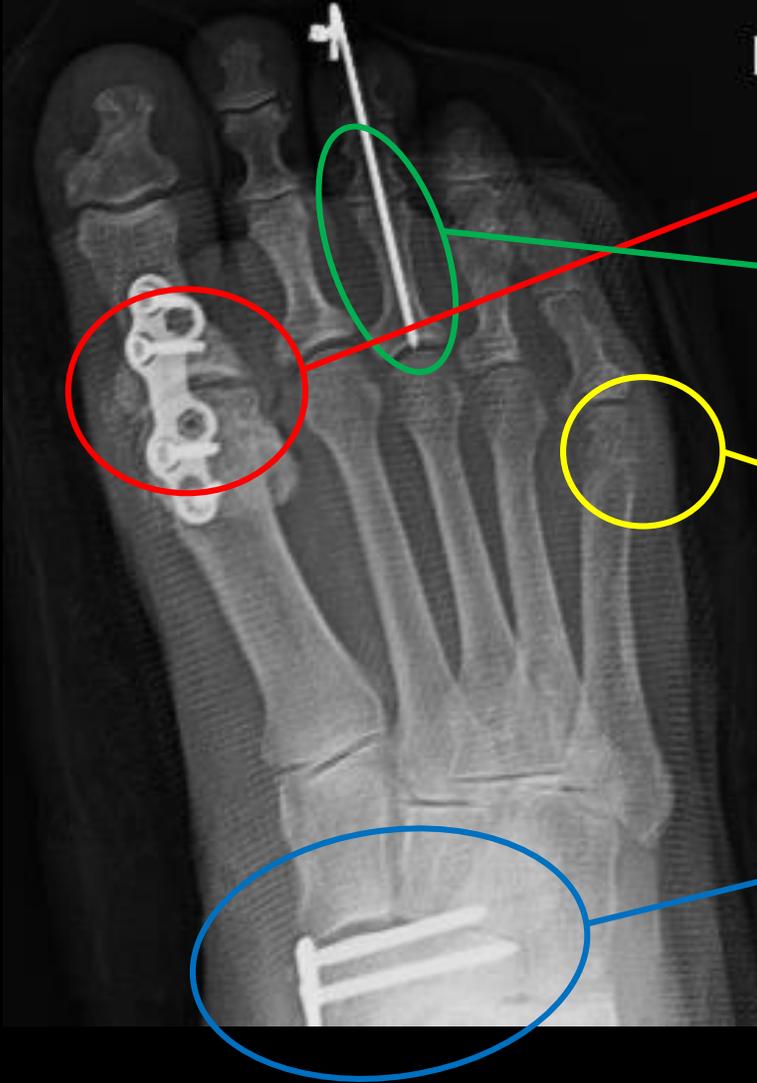
1st MTP Angle / Hallux Valgus Angle = -14°

Postoperative



1st MTP Angle / Hallux Valgus Angle = 0°

Surgical Correction: Hallux Varus



1st MTP Joint arthrodesis and medial capsular release

- Release/incise the medial 1st MTP joint capsule which is scarred and contracted
- Scrape the cartilage out and debride down to bleeding bone
- Correct hallux varus, compress and then place the plate. Secure plate with screws.

Hammer toe correction

- To be discussed in another slide

Bunionette removal

- To be discussed in another slide

Talonavicular joint arthrodesis

- Patient also had severe TN joint osteoarthritis

Surgical Correction: Hallux rigidus

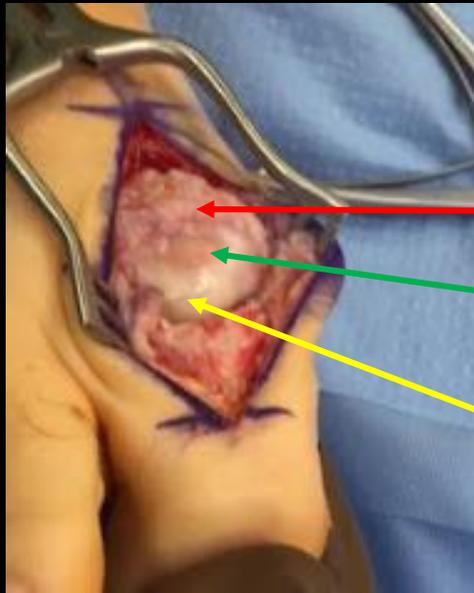
Preoperative



Postoperative



Intra-operative



MTP in flexion to expose the first MT head

Red arrow = large dorsal bone spur

Green arrow = denuded cartilage on dorsal 1st MT head

Yellow arrow = normal appearing cartilage for comparison

1st MTP Cheilectomy

-Removal of dorsal spurs

-May include some cartilage debridement / chondroplasty

-May include removal of osteochondral debris / broken spurs (blue arrow)

Pathophysiology and Surgical Correction: Bunion

Bunion

- **Bony prominence along the medial aspect of the first MTP, usually due to excessive varus movement of the 1st MT with the medial side of the head pushing on skin when foot in narrow toe box shoe. Usually just the 1st MT head uncovered at the MTP joint due to capsular/ligamentous failure**
- Sometimes can result in hypertrophic changes of the medial eminence of the 1st MT head
- Typically associated with hallux valgus
- In case of bunion to right, patient had painful swelling along lateral 1st MTP joint and bony spur along the medial eminence was removed
- **** Term bunionectomy bit of a misnomer because although may remove bone from medial 1st MT head, need to correct hallux valgus to remove bunion (notice hallux valgus corrective changes)**

Preoperative



Postoperative



Pathophysiology and Surgical Correction: Bunionette

Bunionette / AKA Tailor's bunion

Bony prominence with or without hypertrophic changes/remodeling of the lateral eminence of the 5th MT and pressure on adjacent soft tissues when foot in narrow toe box shoe

Typically associated with hallux valgus

In case of bunionette to right, patient had painful swelling along lateral 5th MTP joint and bony spur along the lateral eminence was removed

Preoperative



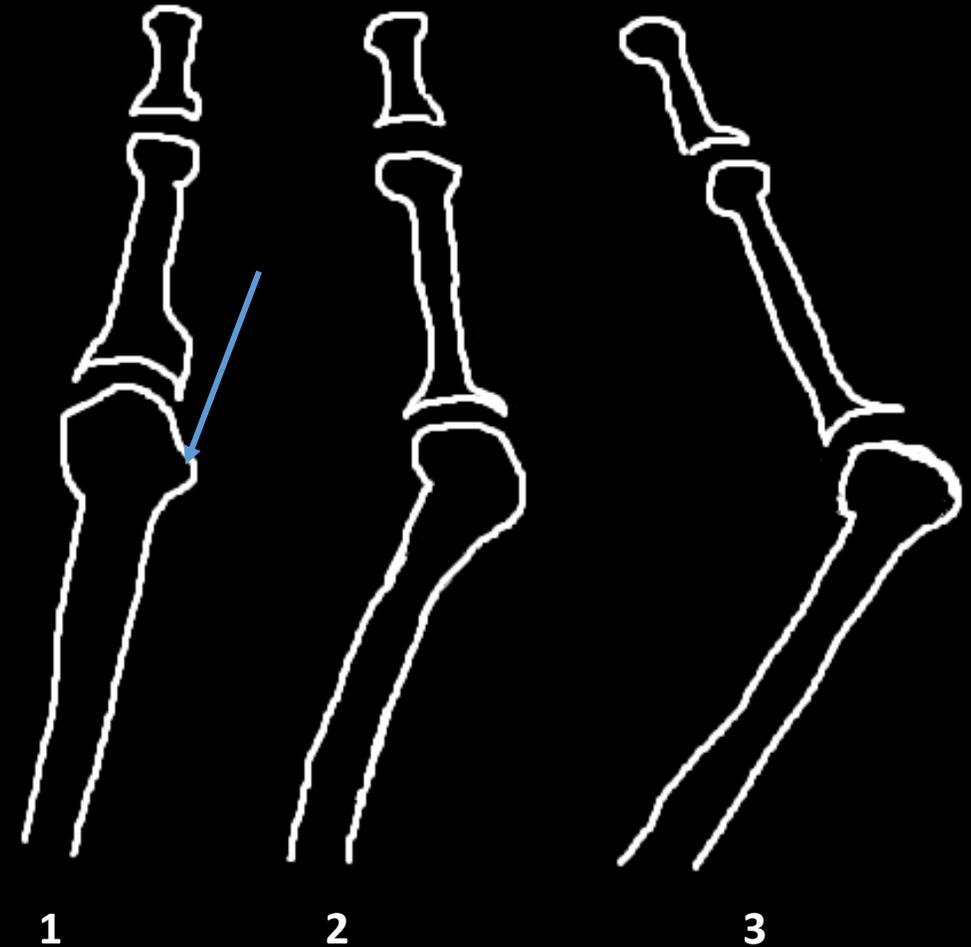
Postoperative



Pathophysiology and Surgical Correction: Bunionette

Bunionette Classification

- 3 types with type 3 being more common
- Type 1: bony spur along lateral side of MT head (blue arrow)
- Type 2: lateral bowing of the 5th MT shaft with a normal intermetatarsal angle between 4th and 5th MT (normal range is between 6.5 – 8 degrees)
- Type 3: lateral deviation of the 5th MT (opposite appearance of the 1st MT head in hallux valgus) with increased angle between 4th and 5th MT
- Treatment (if surgery is to be done)
 - Symptomatic type 1: may do either a lateral condyle / spur resection with or without a lateral capsule plication and/or distal metatarsal osteotomy
 - Symptomatic types 2 and 3: distal metatarsal osteotomy or rotational diaphyseal osteotomy



Pathophysiology: Hallux sesamoid articular complex pathology and turf toe

Hallux sesamoidal pathology and variation

- Sesamoiditis

- pain at the sesamoid(s) usually due to chronic stress reaction from weight bearing and repetitive microtrauma
- Can see chronic remodeling with sclerosis on the undersurface (usually the medial sesamoid) with or without subjacent cutaneous tissue scar (low signal on T1 and T2)

- Sesamoid osteonecrosis

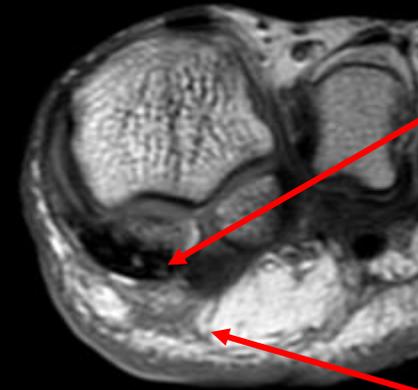
- Looks similar to osteonecrosis elsewhere, may see bone marrow edema pattern and geographic serpentine sclerosis
- Thought to be related to acute or chronic trauma with interrupted blood supply and could result in complete sclerosis of the sesamoid

- Sesamoid fracture

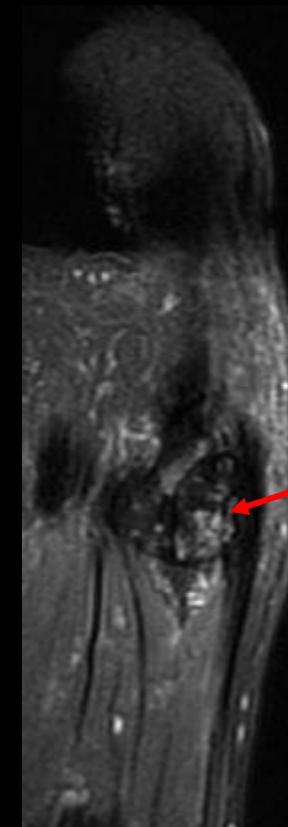
- Could be due to direct impaction or hyperextension injury as part of a case of turf toe

- Bipartite sesamoid

- Not a true pathology, but a normal anatomic variant
- Typically involves the medial sesamoid with lateral much more rarely
- May mimic a fracture
- Typical findings suggesting bipartite rather than fracture include a medial sesamoid that is much larger than the lateral (when combining both pieces), appropriately positioned pieces (not distracted proximally), no diastasis between pieces, lack of appropriate history (no recent trauma) and no soft tissue swelling



Minimal sclerosis on undersurface of sesamoid due to chronic remodeling / stress reaction



Just deep to the area of remodeling, focal scarring of the subjacent subcutaneous adipose

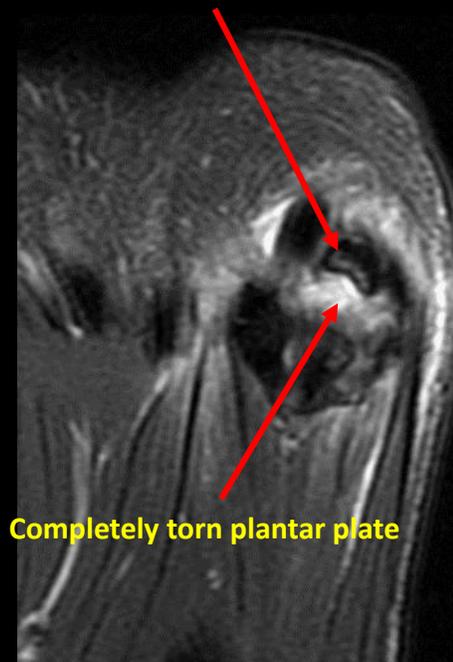
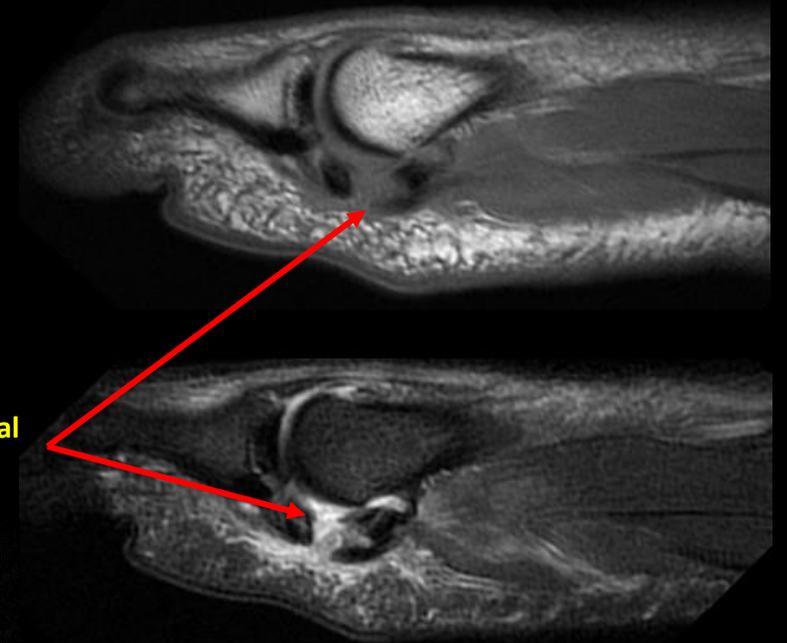
Bone marrow edema pattern in the medial sesamoid in absence of known trauma and with chronic medial plantar 1st MTP pain (same patient as above) compatible with diagnosis of sesamoiditis

Pathophysiology: Hallux sesamoid articular complex pathology and turf toe

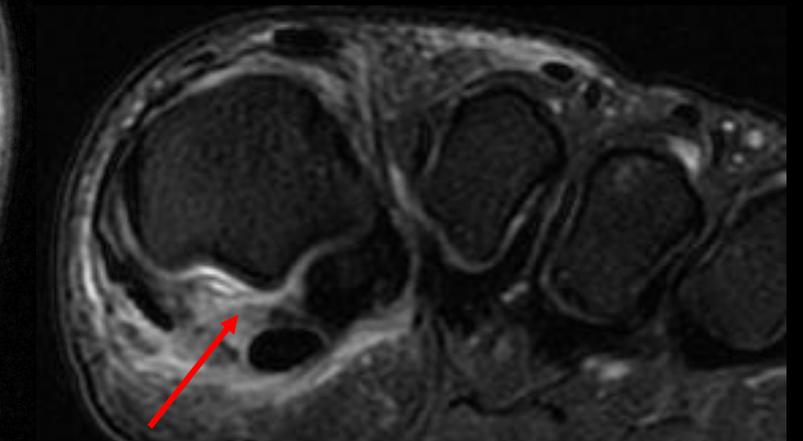
- Pathophysiology: hyperextension of the 1st MTP results in injury to the joint capsule and plantar plate
- Common scenarios of injury: competitive American football and soccer players
- Turf toe may result from injury to various structures associated with the 1st MTP hallux sesamoid articular complex (plantar capsular disruption)
- Grading of Turf Toe:
 - 1: Plantar plate sprain (increased T2 signal without disruption)
 - 2: Plantar plate partial tear
 - 3: Plantar plate complete tear
- Management:
 - Grade 1 and 2: Tends to be initial conservative management, especially in non-elite athletes
 - Grade 3: Surgery: primary repair of plantar plate
 - Retracted/Diastatic sesamoids: surgical repair/excision
 - Failed conservative management: surgical repair of plantar plate



Diastatic medial sesamoid with proximal retraction of proximal fragment

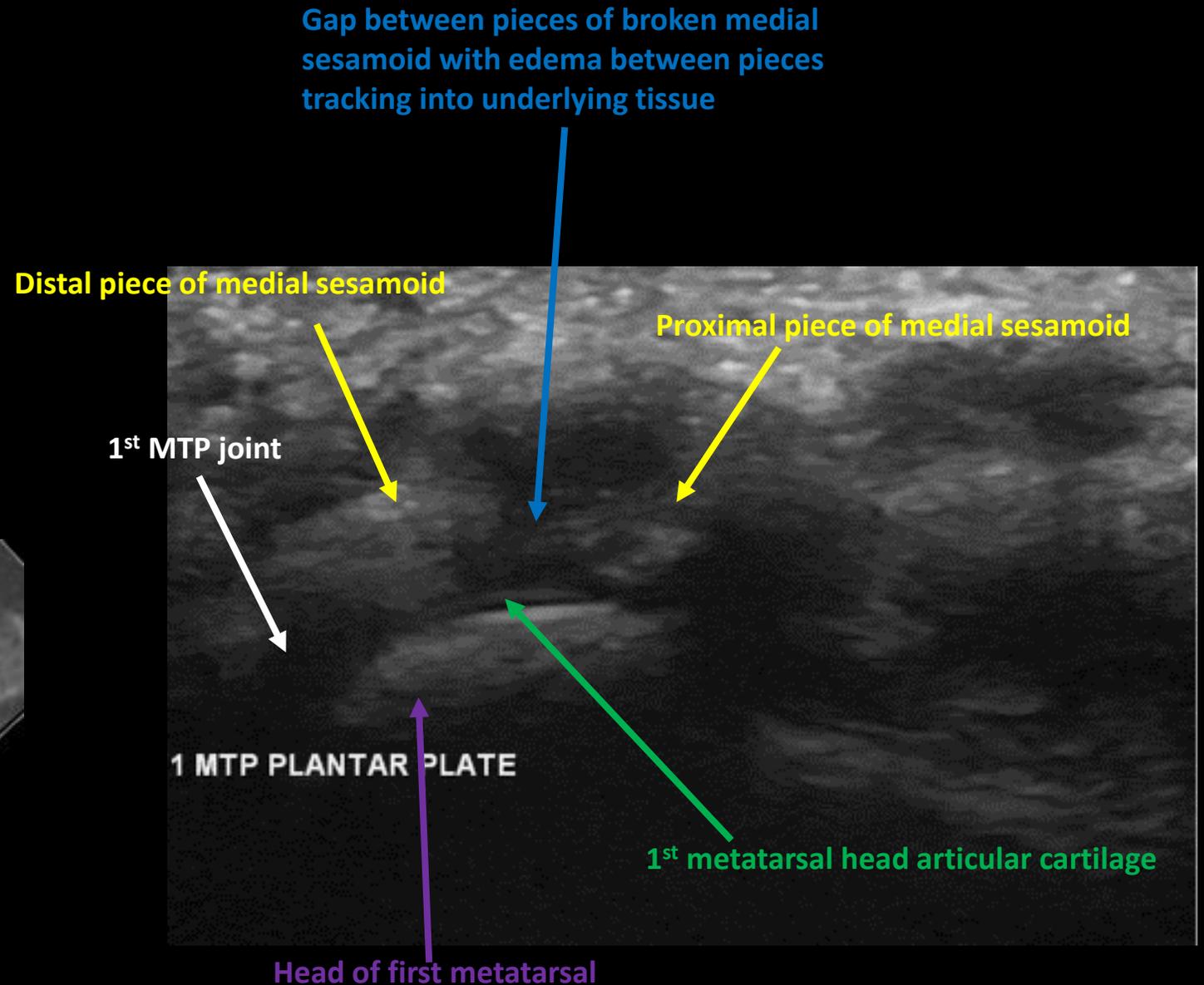
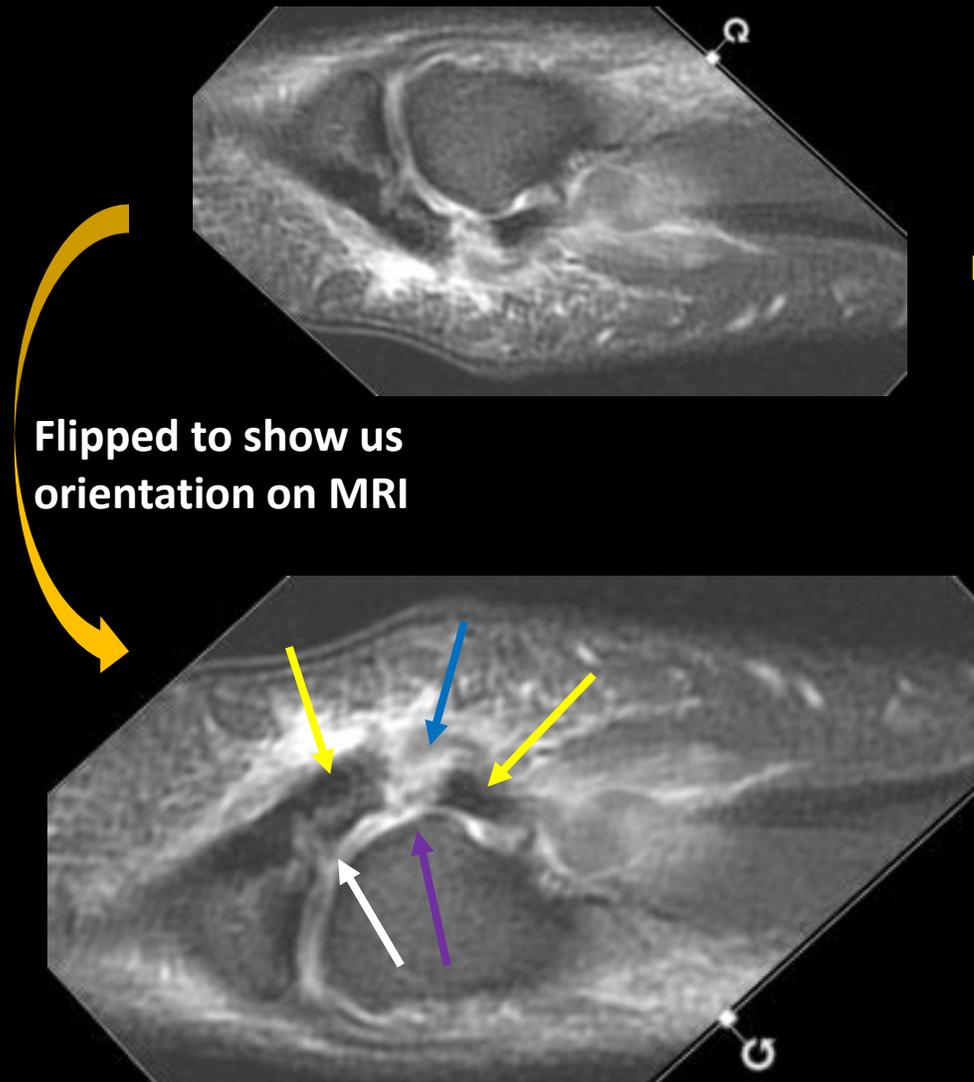


Completely torn plantar plate



Completely torn plantar plate predominantly involving medial side of plate, but extends through intersesamoidal ligament

Pathophysiology: Hallux sesamoid articular complex pathology and turf toe



Pathophysiology: Hammer, mallet and claw toes

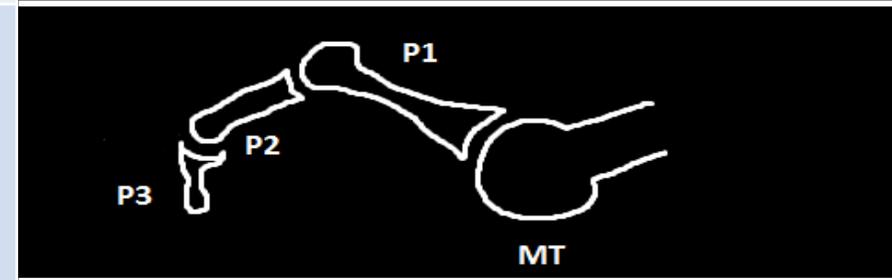
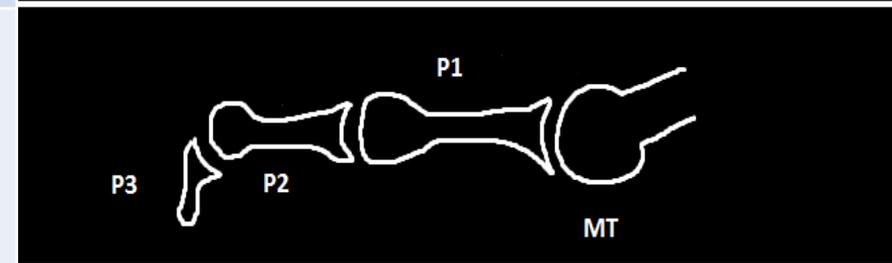
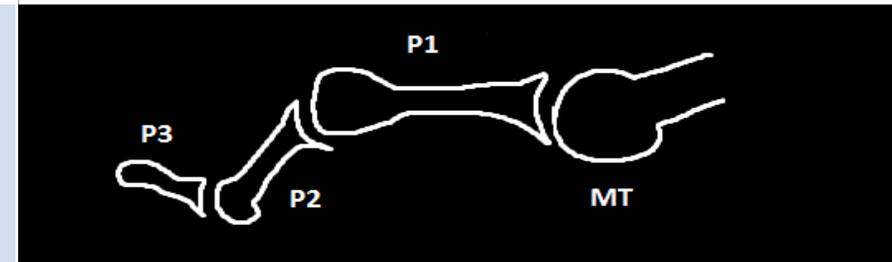
A word of caution with terminology

- There is considerable variation in the definition of claw vs hammer toes
- Sometimes, the term curly toe is also used
- Mallet toe is rare, but is agreed upon to be a flexion deformity of the DIP due to extensor tendon injury
- In a 2009 review of the literature, Schrier and colleagues found 42 studies with clear definitions of claw or hammer toes (J Am Podiatr Med Assoc. 2009 May-Jun;99(3):194-7).

Hammer toe 35 / 42 defined	<ul style="list-style-type: none">- 49 % defined as MTP extension and PIP flexion- 37 % defined as PIP flexion alone	Authors conclude that definition of hammer toe centers on PIP flexion, but claw and hammer likely continuum of same process
Claw toe 23 / 42 defined	<ul style="list-style-type: none">- 91% included MTP extension as part of definition- 52% defined as MTP extension, PIP flexion AND DIP flexion- 30% defined as MTP extension and PIP flexion	Authors conclude that definition of claw toe centers on MTP extension, but claw and hammer likely continuum of same process

Pathophysiology: Hammer, mallet and claw toes

	MTP joint	PIP joint	DIP joint
Hammer toe	Neutral or slight extension	Flexion	Neutral or Extension
Mallet toe	Neutral	Neutral	Flexion
Claw toe	Hyperextension	Flexion	Flexion



Pathophysiology: Hammer, mallet and claw toes

Hammer toe

Pathophysiology:

- Complex mechanism
- Thought that a long second toe is a predisposing factor (especially when longer than great toe)
- When in narrow shoes and with a longer second toe, the toe is forced down which causes flexion first at PIP and some extension at MTP
- Over time, plantar plate stretches and is weakened and tears allowing for MTP extension
- Leads to laxity and eventual imbalance of the extrinsic and intrinsic tendons
- EDL weakens, becomes a flexor
- Lumbricals fail and change action from flexion at MTP and extension at PIP to extension at MTP
- End result is hyperflexion of PIP, extension at MTP and neutral or slight extension at the DIP
- Rubbing of the dorsal skin at PIP causes formation of painful “corns”
- Most common to involve second toe

Common scenarios associated with a hammer toe:

- Long second toes
- Tight toe box
- Diabetes
- Inflammatory arthritis (synovitis weakens plantar plate)
- Hallux valgus

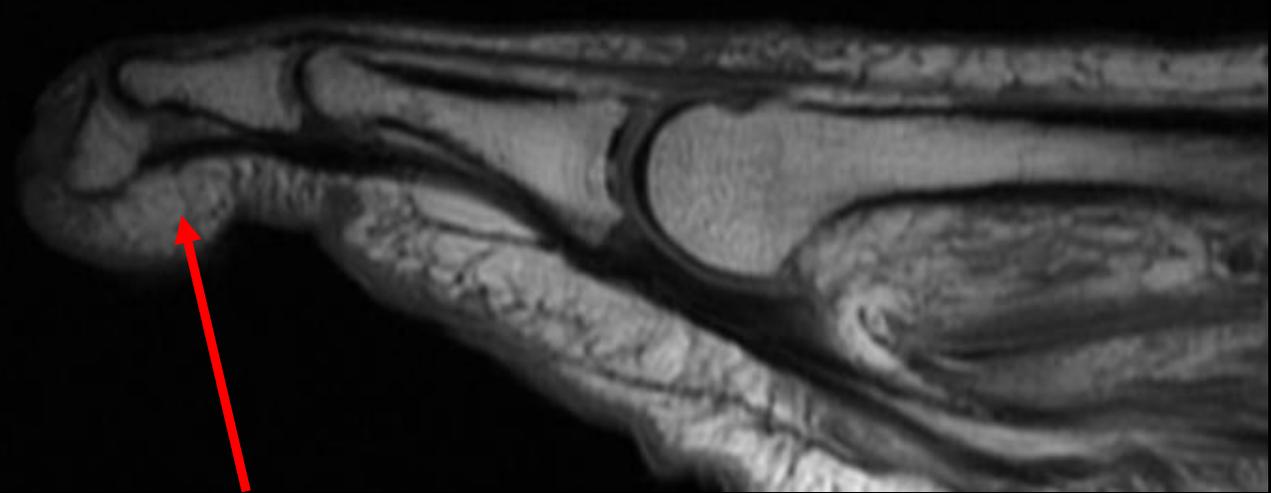


Second hammer toe – starting to look down the axis of the distal phalanx due to the PIP flexion. The big toe has moved under the second toe.

Pathophysiology: Hammer, mallet and claw toes

Mallet toe

- Pathophysiology:
 - Rupture of the terminal tendon of the extensor apparatus with now unopposed flexors at the DIP
 - May be related to contracture of the FDL
- Common scenarios associated with a mallet toe:
 - This is **an uncommon injury**
 - Associated with trauma
 - Can be congenital
 - Can be associated with long digit



Sequela of old injury, this patient did not currently have pain, but has an isolated DIP joint flexion deformity

Pathophysiology: Hammer, mallet and claw toes

Claw toe

- Pathophysiology:
 - Weakening of the plantar plate and intrinsic muscles
 - EDL and extensor hood results in MTP joint hyperextension
 - Lumbricals rotate dorsally
 - FDL and FDB flex at PIP and DIP joints
- Common scenarios associated with a claw toe:
 - Diabetes
 - Trauma (injury to undersurface of foot leads to progressive contracture of the FDP)
 - Synovitis / inflammatory arthritis
 - Charcot Marie Tooth disease

Green arrow = MTP extension
Yellow arrow = PIP flexion
Red arrow = DIP flexion

Blue arrow = tips of the toes point straight down resulting in increased pressure at the tips of his toes.

48 YOM with history of old calcaneal fracture with non-union complicated by osteomyelitis (purple arrow), there was a resulting progressive flexion deformity of all of his toes.



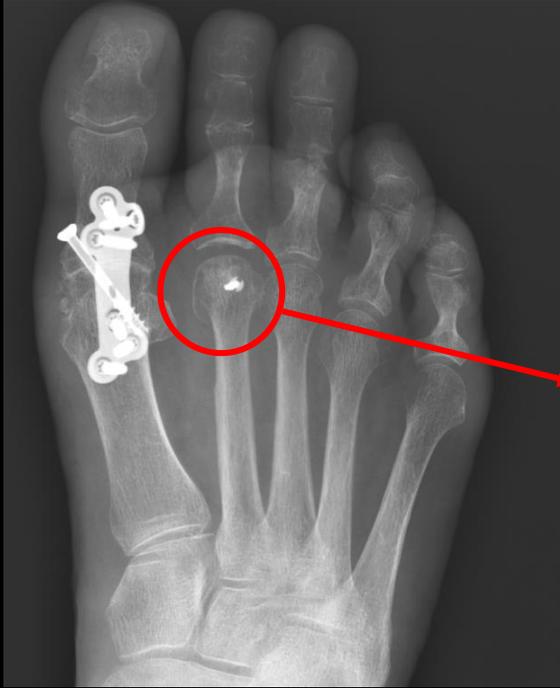
Surgical Correction: Hammer Toes



Hallux valgus correction, 1st MTP arthrodesis

Mild third hammer toe deformity - corrected

Surgical Correction: Hammer Toes



Weil Osteotomy

- Osteotomy of the distal MT made in plane parallel to sole of foot, small piece of bone removed
- Capital part of MT is slid proximally and then nail drilled in from dorsal to plantar
- This shortens MT and along with EDL tendon lengthening reduces contracture
- This shortens the toe, reduces contracture and spares the MTP joint, but allows for potential recurrence

PIP Joint Arthrodesis and resection arthroplasty

- As opposed to the Weil osteotomy, this results in fusion of the PIP joint which prevents the flexion and keeps the toe straight
- Done with soft tissue procedures
- PIP joint scraped and hammerlock anchors deployed in PIP joint for fusion
- Can also be achieved by resecting the PIP joint and putting a K-wire across the joint (as seen on prior images) – AKA resection arthroplasty



Preoperative



Postoperative



- Flexible hammer toe:
 - If hammer toe can be reduced, is not fixed
 - May treat conservatively with orthotics
 - May choose to perform soft tissue surgery only which commonly includes:
 - MTP plantar plate repair, collateral ligament release, FDL to extensor transfer and EDL lengthening (Girdlestone procedure)
- Fixed hammer toe:
 - If hammer toe cannot be reduced, is fixed
 - Means there is some tendon contracture
 - Soft tissue surgery alone likely to fail
 - Usual procedures include shortening osteotomy, PIP arthrodesis or resection arthroplasty where the PIP joint is resected and either an osseous or fibrous fusion occurs at PIP joint leading to a stiff, non-painful straight toe

Surgical Correction: Claw Toe



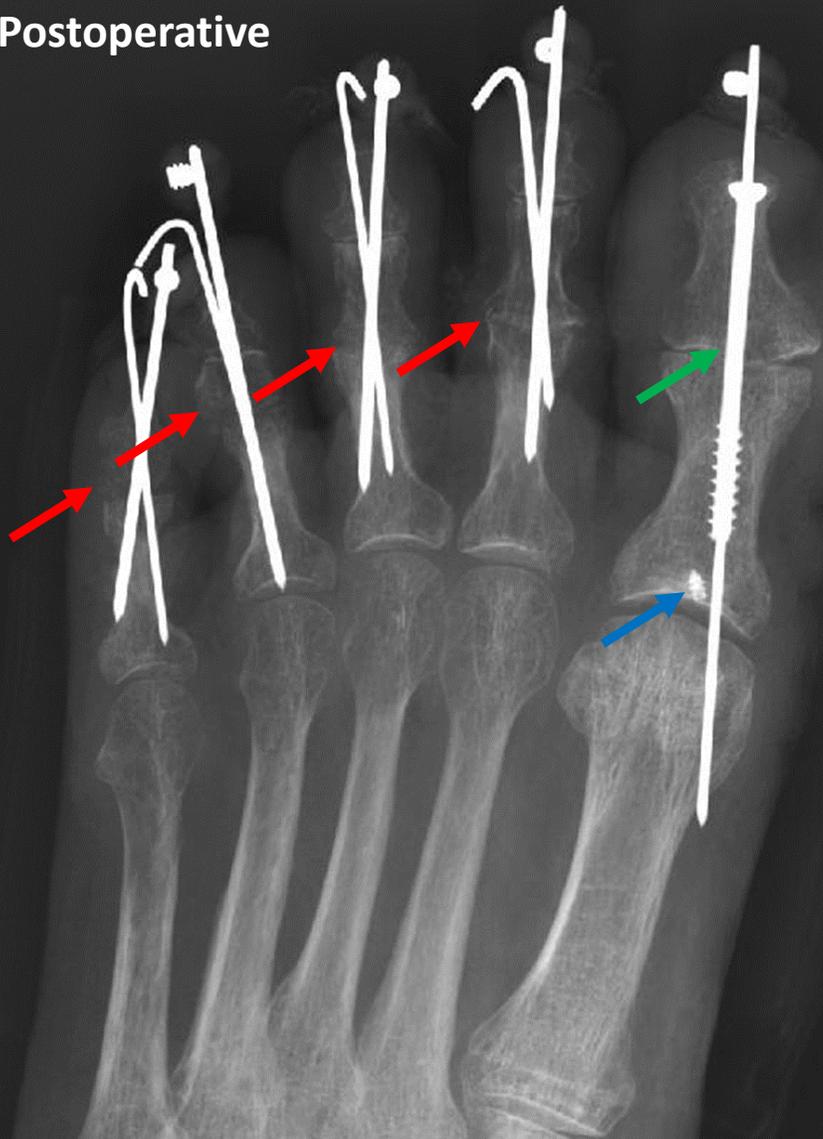
Claw toe correction

Prerop with mild extension at all MTPs with flexion at the great toe IP and PIPs + DIPs of the 2nd – 5th toes (claw toes, red arrow). The patient has pain at toe tips.

Surgical Correction: Claw Toe

Toes 2- 5

Postoperative



- Red arrows indicate PIP joint resection arthroplasties
- End of P1 and the proximal end of P2 are resected with a saw
- FDL is cut (tenotomy) as is the lateral capsule
- Using fluoroscopy, PIP is reduced until straight and K-wires driven across to stabilize
- After sufficient time, if PIP stable because of fibrous or osseous bridging, K-wires removed
- Similar to that done for hammer toe correction

Great Toe

- Resection arthroplasty at IP joint similar to the lesser toes except a permanent partially threaded cannulated screw is drilled over the K-wire which remains after K-wire removed (green arrow)
- Blue arrow indicates the suture anchor that had been placed at the medial dorsal base of P1 at surgery. The FHL had been cut and sutured into the anchor to change the FHL tendon into an extensor to reduce the flexion deformity.
- At this first post-op XR, the suture had backed out and was plantar again. It was removed and the FHL was sewn into the extensor apparatus at the MTP level.



Pathophysiology: Freiberg Infraction

- Pathophysiology:

- Thought to be related to repetitive microtrauma
- AVN at the metatarsal head
- Like in other articular surfaces, eventually leads to articular surface collapse and secondary osteoarthritis of the joint

- Common scenarios of injury:

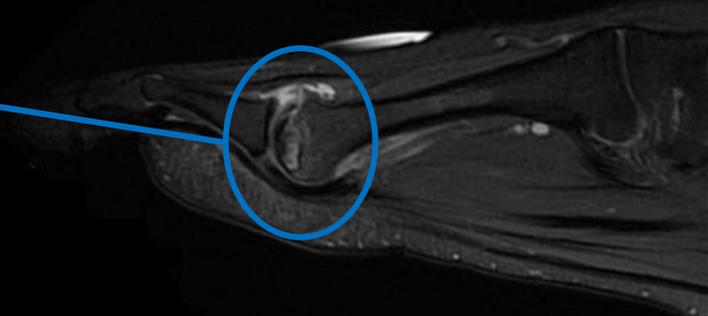
- More common in adolescents
- More common in females
- Most common in the second metatarsal head

- Treatment:

- Earlier stages may rest and use a boot
- Later, sometimes perform arthroscopy and clean out joint
- Later, arthroplasty (removal of injured area and create a more healthy articular surface or arthrodesis)

- Radiograph shows irregularity, sclerosis and collapse of the second MT head

- MR shows same thing and reactive effusion at the MTP



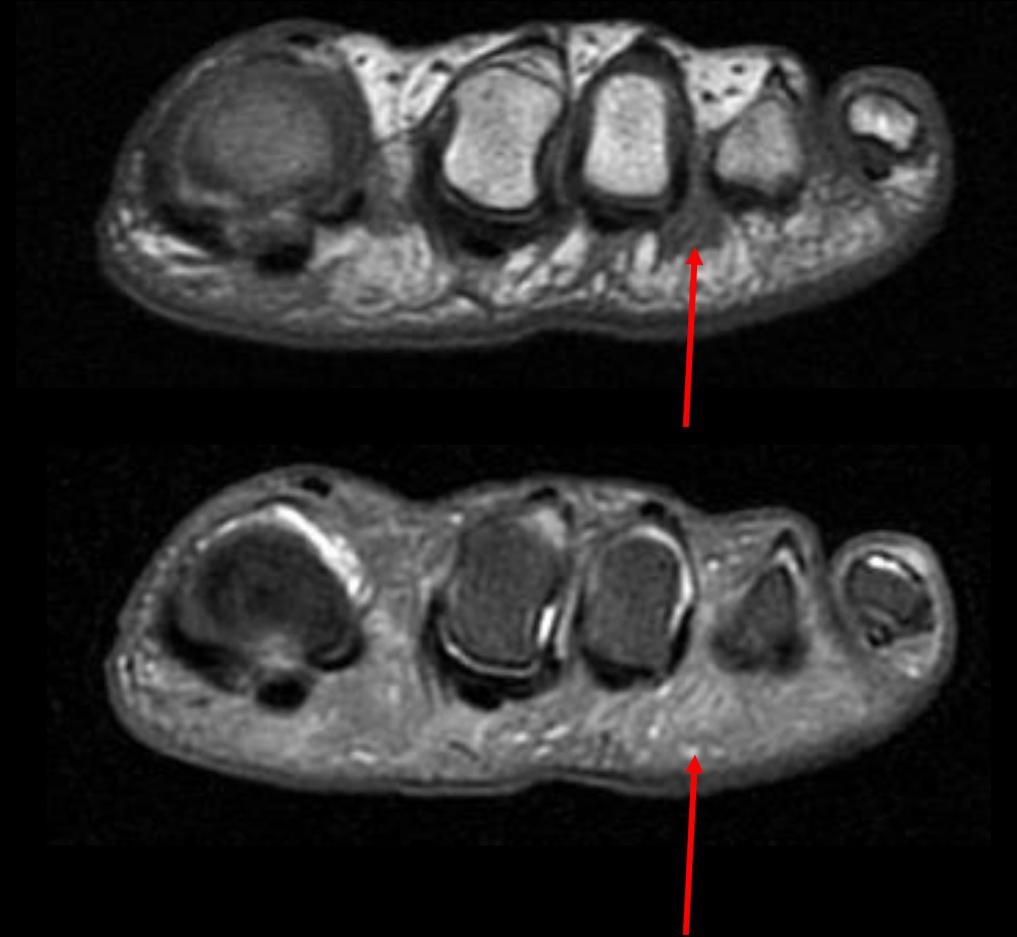
Pathophysiology: Morton's Neuroma

- Pathophysiology:

- Not entirely clear
- Female predilection
- Most commonly occurs in the 3rd intermetatarsal web space followed by the 2nd web space
- Very uncommon in the 1st and 4th web spaces
- Associated with high heel shoes and narrow toe boxes
- Thought to be a chronic inflammatory process in the more narrowed 3rd and 2nd web spaces which results in perineural fibrosis of the interdigital nerve
- Not a neoplasm

- Clinical Exam:

- Pain along the plantar aspect of the foot at the 3rd or 2nd web space
- Possible palpable mass
- Mulder's click: audible or palpable click at the site of the neuroma as it or the bursa is squeezed past the metatarsal heads



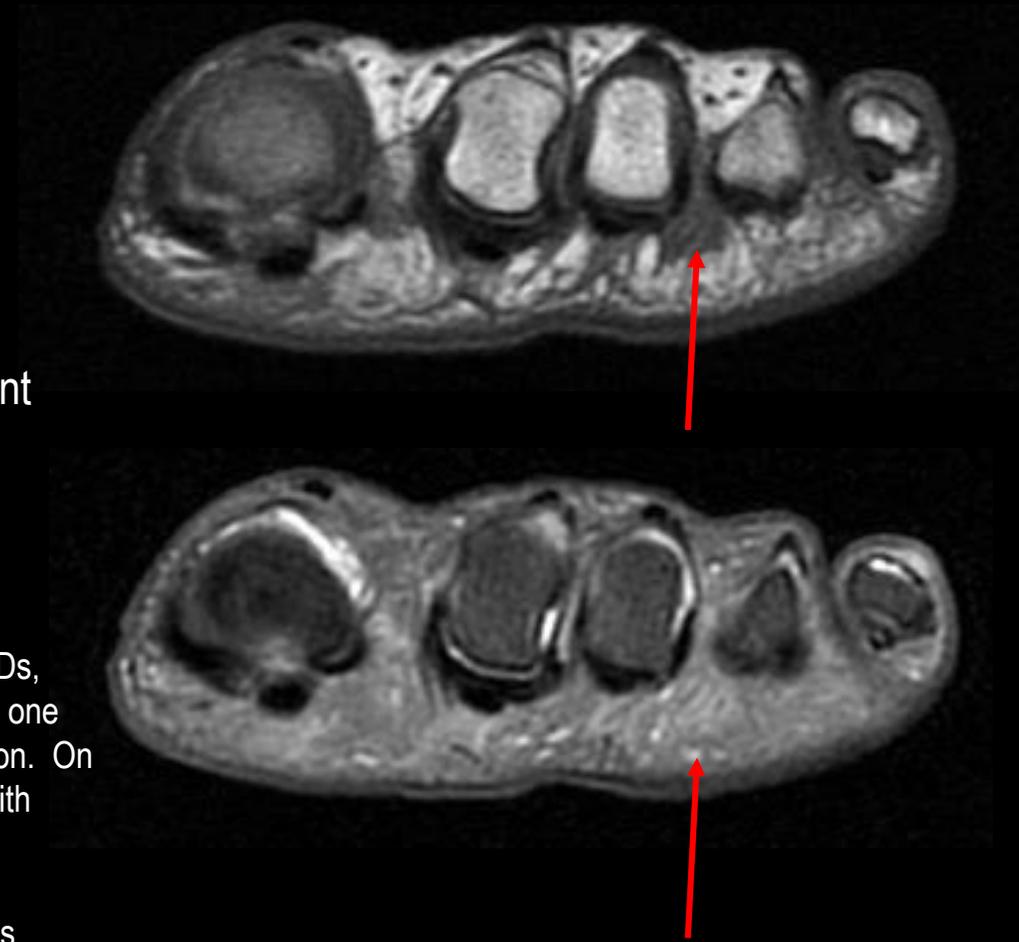
Pathophysiology: Morton's Neuroma

- Imaging:

- T1 iso to hypointense
- T2 hypointense
- Variable enhancement
- Earlier studies had suggested most enhance
- Typical location (3rd and 2nd webspace)
- Plantar position beneath the deep transverse intermetatarsal ligament
- Often not imaged and just treated based on clinical exam alone

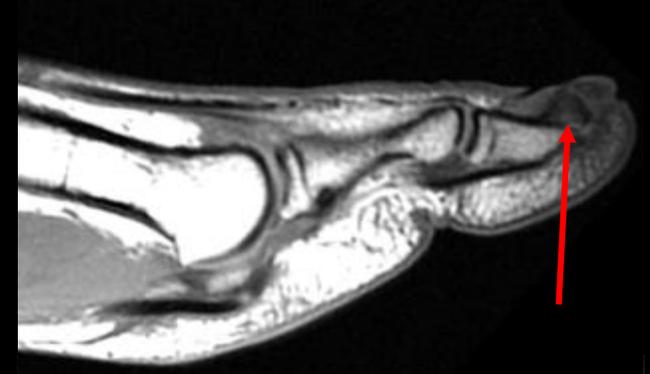
- Treatment:

- Conservative therapy is tried first and includes avoidance of high heels, orthotics, NSAIDs, steroid injections and alcohol ablations though the efficacy of injections is debatable. In one study, only 28% of patients reported complete relief 9 months after corticosteroid injection. On the other hand, there has been reported success with image guided alcohol ablations with 84% reporting being symptom free in a mean of 21 months following treatment.
- Surgical treatment includes neurectomy where the neuroma and a portion of the nerve is resected
- One of the most common complications is recurrence or formation of a stump neuroma following surgery. Neurectomy failure rates of 14- 27 % reported.



Pathophysiology: Subungual exostosis

- Pathophysiology:
 - Unknown
 - Benign tumor composed of bone and cartilage
 - Occurs most commonly in younger patients
 - Predilection for great toe
- Treatment: excision when symptomatic, curative



Potential Relatively More Frequent Post-Op Complications

Surgery	Potential relatively more frequent complications
Hallux valgus	<ul style="list-style-type: none"> - Overcorrection with development of hallux varus - AVN of 1st MT head if Chevron osteotomy performed and blood supply disrupted - Failure if 1st MTP joint incongruity not corrected - Non-union if arthrodesis attempted - Infection
Hallux varus	<ul style="list-style-type: none"> - Undercorrection - Infection
Hallux rigidus	<ul style="list-style-type: none"> - Undercorrection - Infection
Hallux sesamoid pathology	<ul style="list-style-type: none"> - Over resection of sesamoid could predispose to development of hallux valgus or varus - Infection
Turf toe	<ul style="list-style-type: none"> - Failed repair with development of 1st MTP osteoarthritis - Infection
Claw/Hammer Toe	<ul style="list-style-type: none"> - If the PIP fusion fails / destabilizes, can develop instability - Floating toe deformity - Recurrence
Morton Neuroma	<ul style="list-style-type: none"> - Recurrent neuroma / stump neuroma formation - Infection