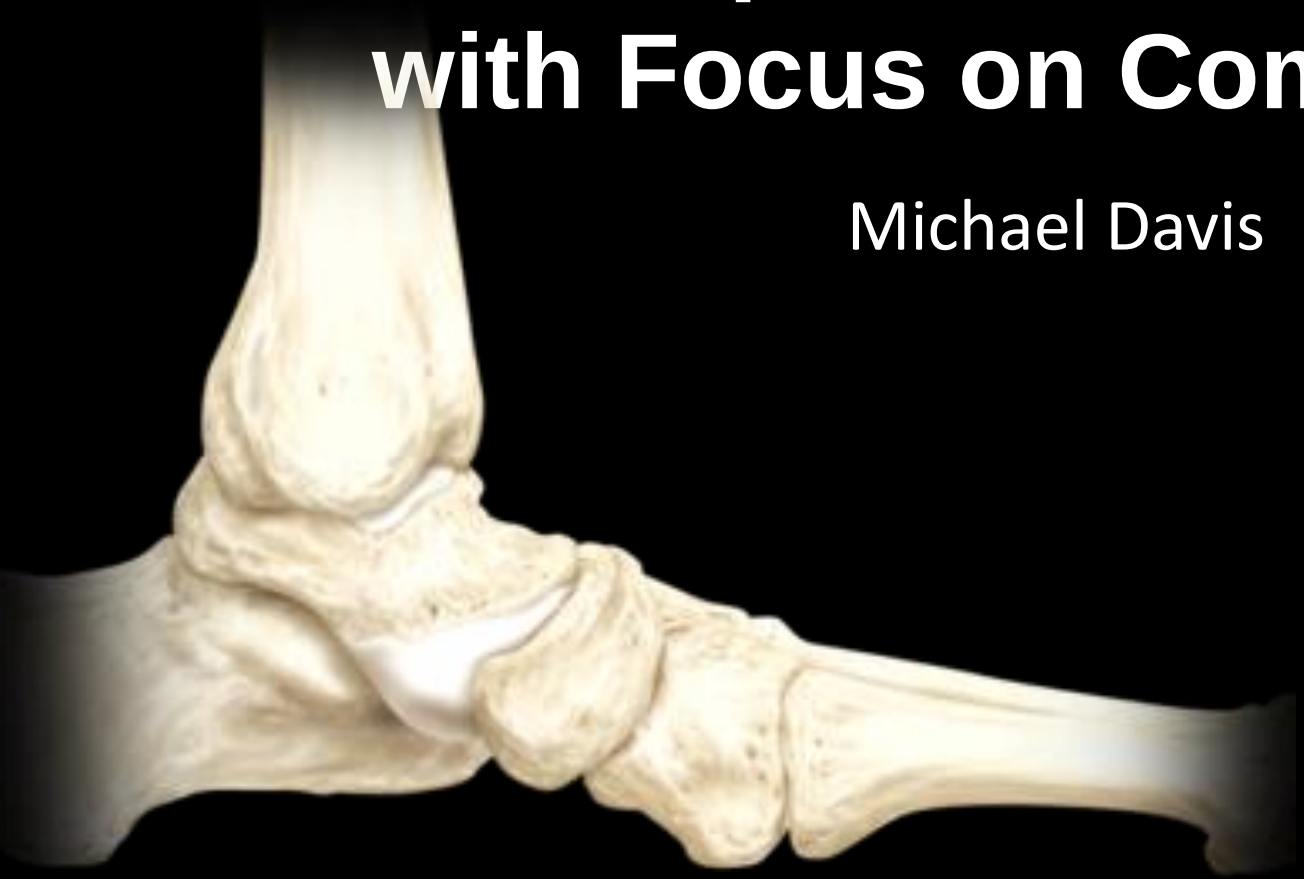
Adult Flatfoot Deformity: Preoperative Imaging and Postoperative Assessment with Focus on Complications

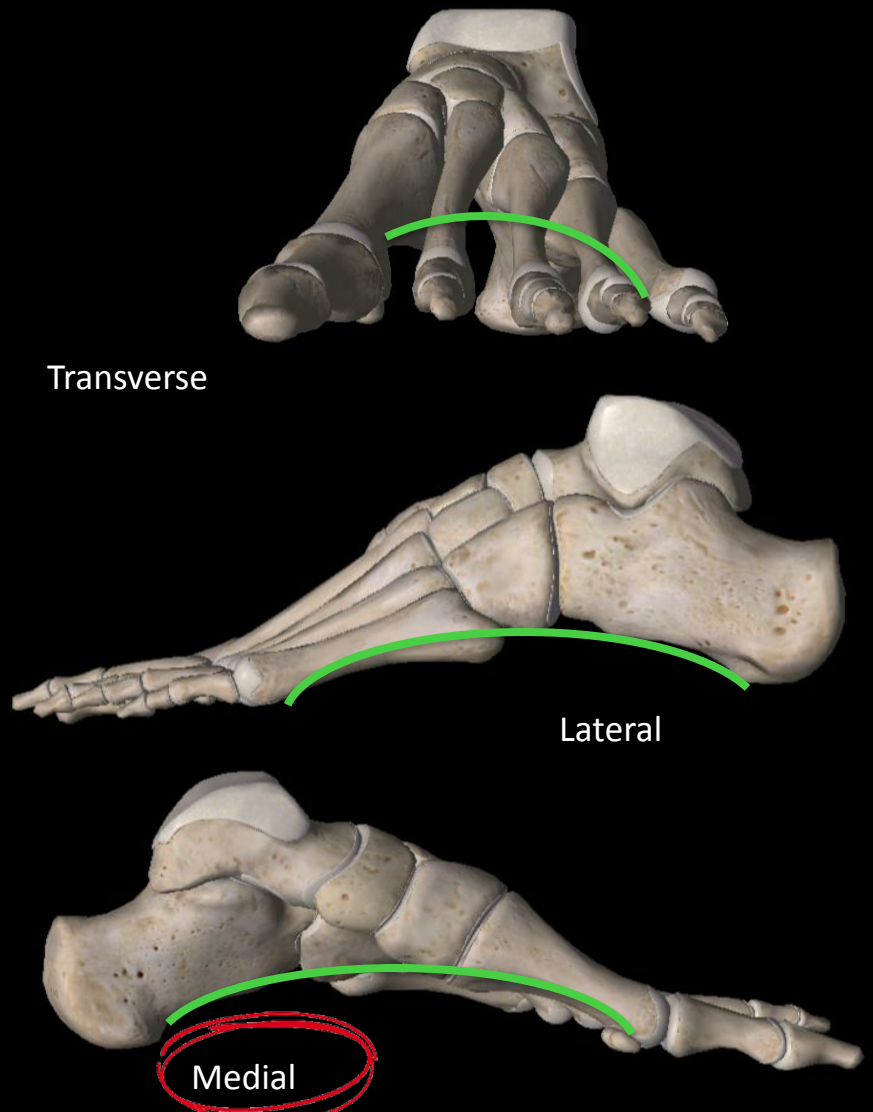
Michael Davis



Objectives

- Review the anatomy and pathophysiology of adult flatfoot deformity and the relevant preoperative imaging findings
- Review the basics of procedure selection and typical postoperative imaging appearances
- Discuss important postoperative complications

Anatomy

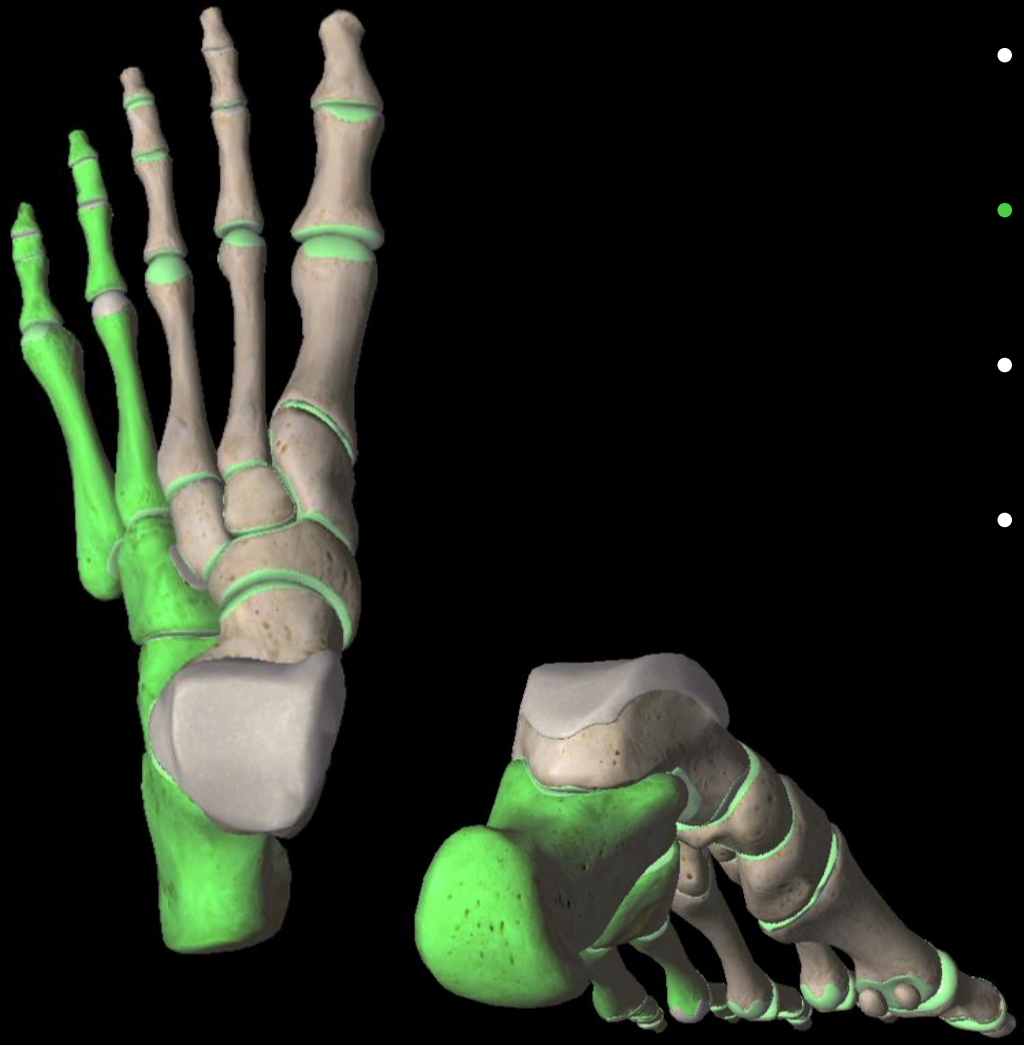


- Bones of the foot form longitudinal and transverse arches relative to the ground which distribute and absorb forces during standing and locomotion

Anatomy

- Medial column-Talus, navicular, cuneiforms and first three rays
- Lateral column-Calcaneus, cuboid and lateral 2 rays
- Lateral column intrinsically stable
- Medial column has an adaptive function during weight-bearing -Abnormal repetitive loading on the medial column leads to dysfunction of the dynamic and static stabilizers

Anatomy



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http://uwmsk.org/footalignment

Anatomy

- Dynamic stabilizers-short muscles of the foot, PTT, FHL, PL
- Static Stabilizers-Spring ligament, deltoid ligament, long plantar ligament and plantar fascia

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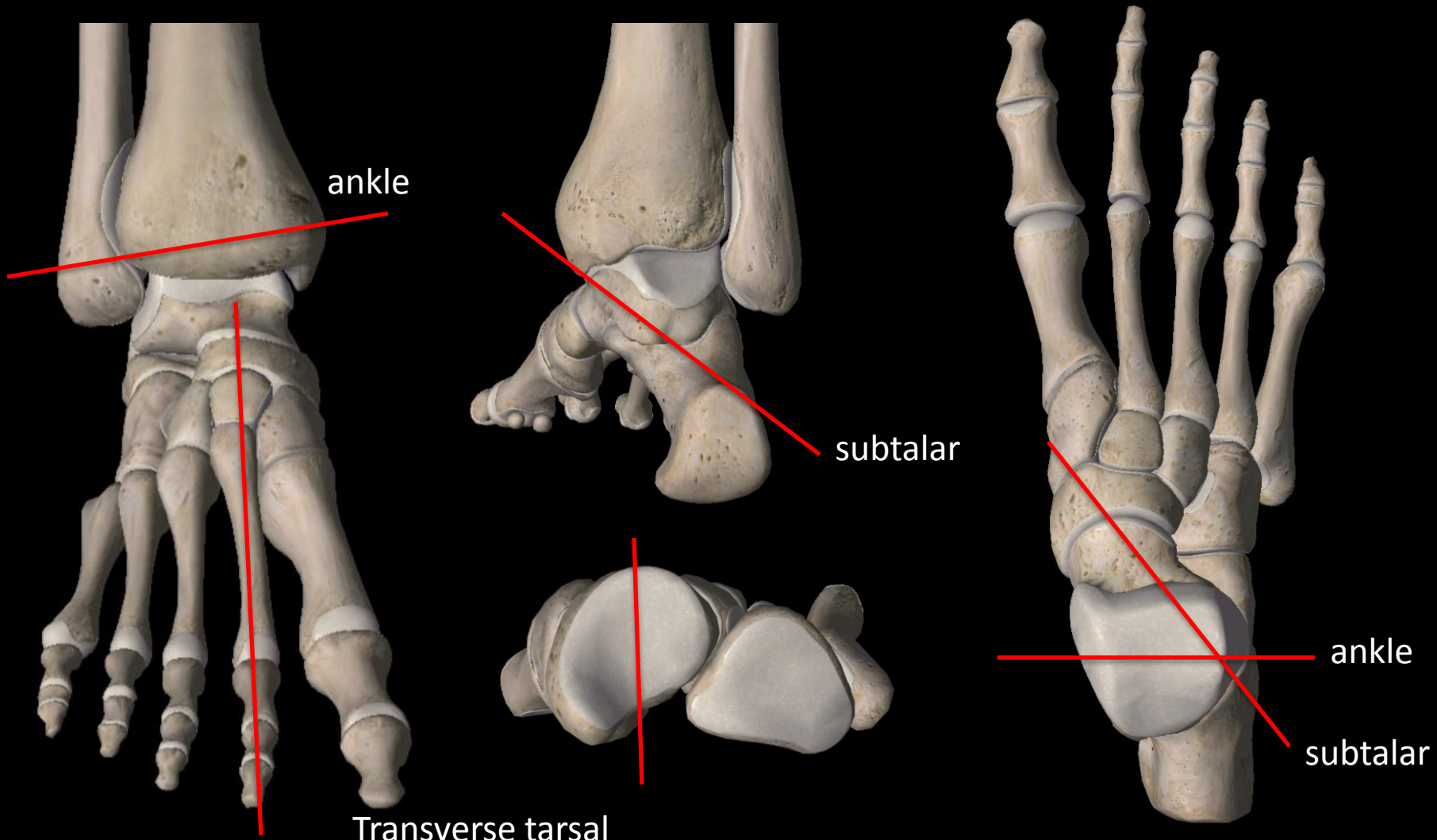


Adult Acquired Flatfoot

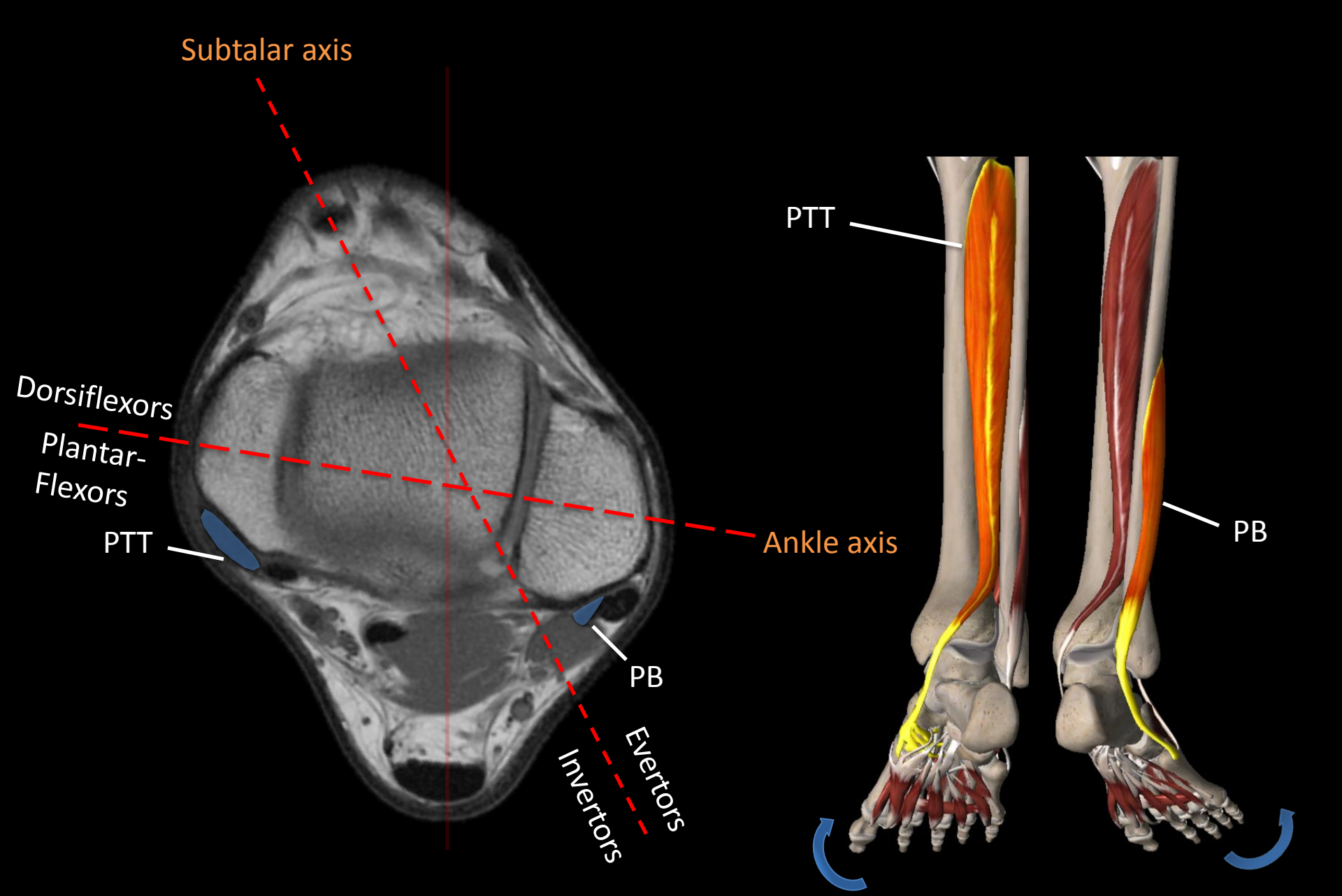
- Progressive abnormality characterized by collapse of the medial longitudinal arch and development of hindfoot valgus
- Caused by mechanical uncoupling of the bones of the tarsus due to failure of the dynamic and static stabilizers of the medial longitudinal arch

Causes of Adult Flatfoot

- Posterior tibial tendon dysfunction
  - Degeneration
  - Tenosynovitis
  - Tears
- Ligamentous injury
  - Deltoid ligament
  - Spring ligament
  - Lisfranc ligament
- Plantar fascia rupture
- Arthritis in hindfoot/midfoot
  - Degenerative
  - Inflammatory
  - Neuropathic arthropathy
- Malunited fracture
  - Calcaneal fracture
  - Fibular fracture with shortening and syndesmotic injury
- Hypermobility leading to plastic deformation/elongation of medial tendon, ligament, and capsular supports
- Tight triceps surae or isolated gastrocnemius tightness
- Spastic flatfoot
- Neuromuscular imbalance
  - Polio
  - Cerebral palsy
  - Closed head injury
  - Stroke

Posterior Tibial Tendon

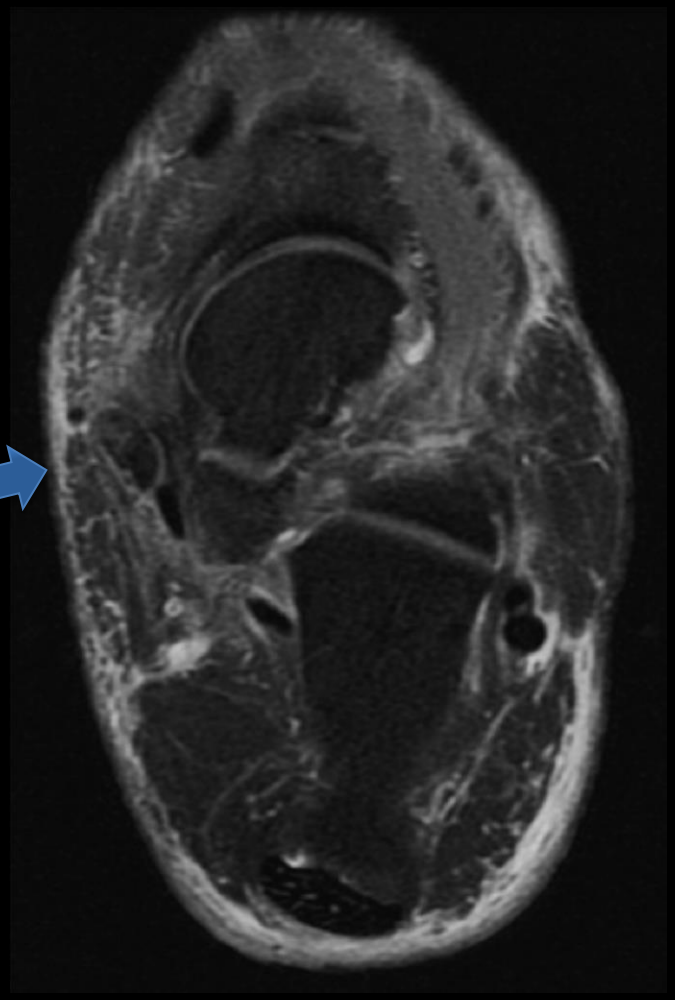
- Key dynamic stabilizer of the medial longitudinal arch
- Inverts the hindfoot and midfoot
- Assists in plantar flexion of the foot and ankle
- Adducts the transverse tarsal joint
- Stabilizes the hindfoot and midfoot during the toe-off stage of gait by locking the calcaneocuboid and talonavicular joints



Hartog Foot and Ankle Clinics 2001

PTT Dysfunction

- Most commonly due to degenerative tendinopathy at the submalleolar (watershed) level
- Less common due to inflammatory arthropathy
- Insertional tendinopathy (may be associated with type II accessory navicular) less common than noninseritonal
- If PTTD is not treated, there is progressive failure of the static stabilizers of the medial longitudinal arch.



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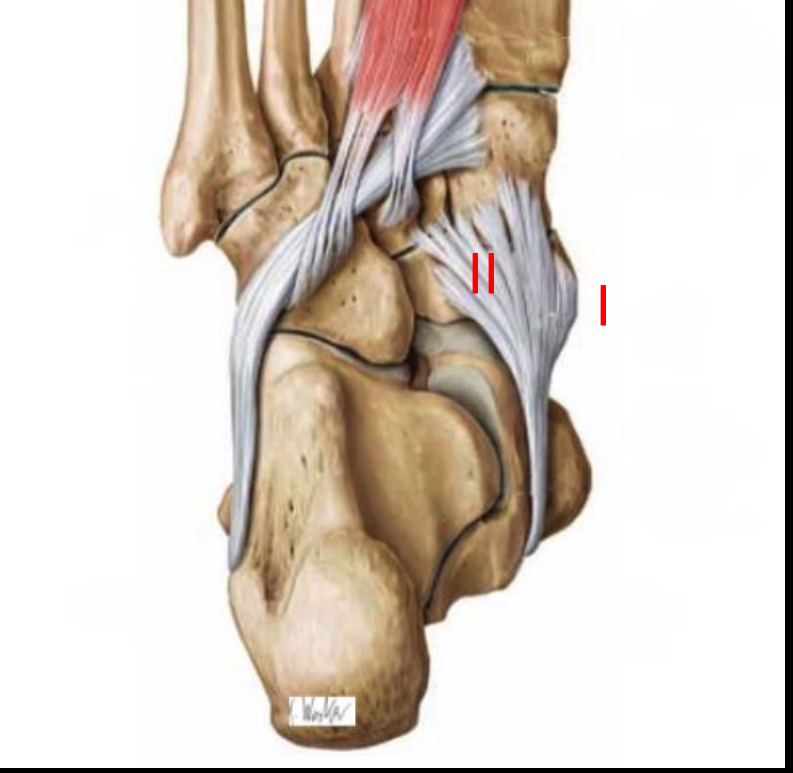

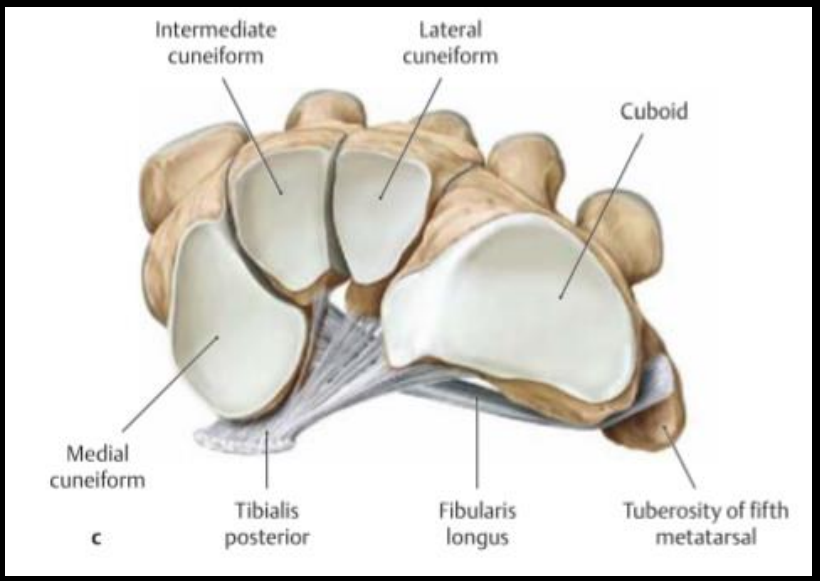

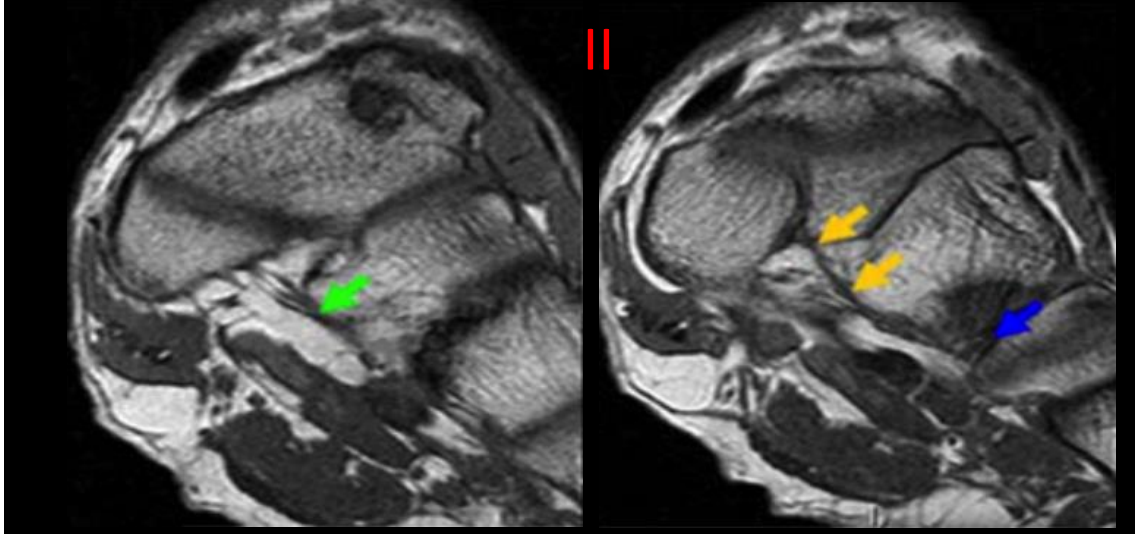

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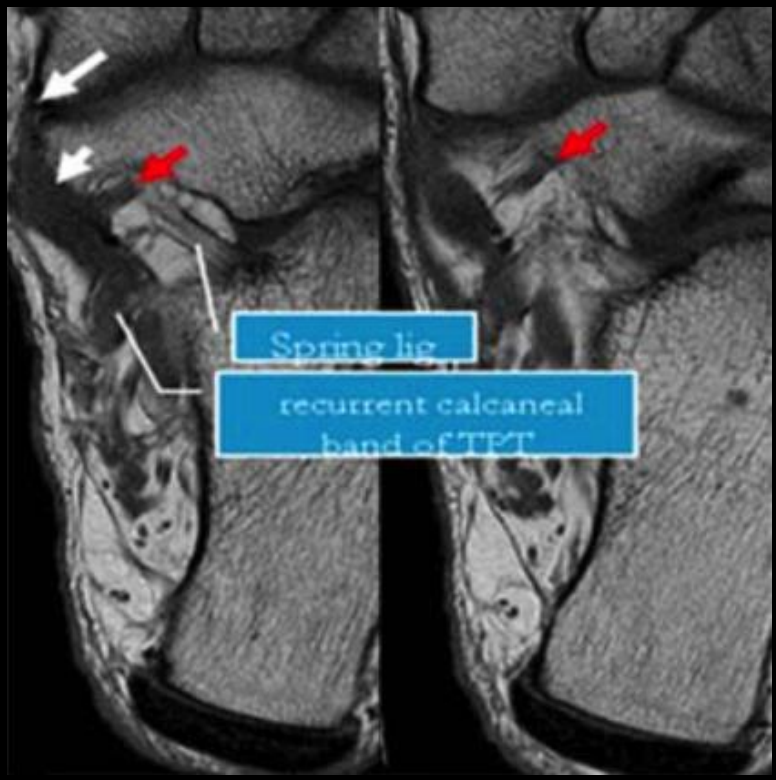
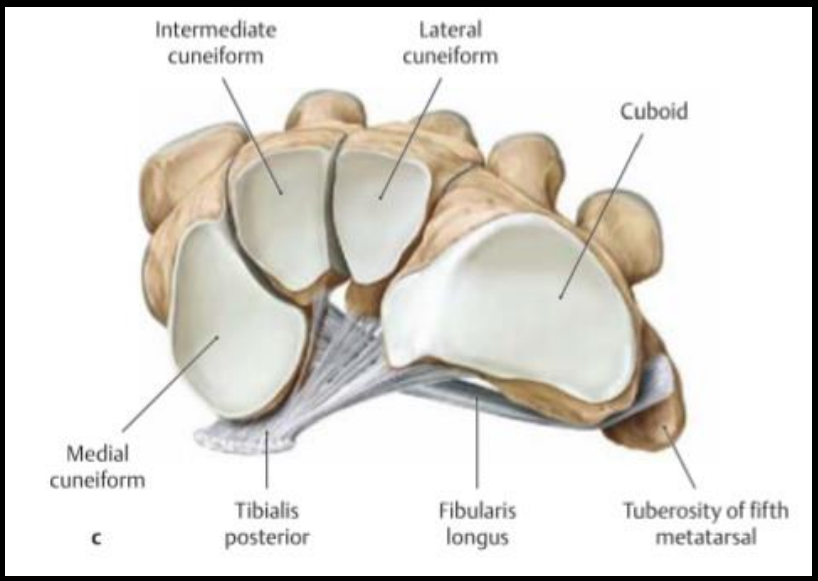


Pastore et al. Skel Radiol 2008

Table 1: Insertion sites of the posterior tibialis tendon

Number	Side	Navicular	Cuneiform/Cuboid	MT	FHB	PL	ST	Spring	Other
1	R	Y	Y	2,3,4,5	Y	Y	Y		
2	R	Y	Y	2,3,4	N	Y	Y		
3	L	Y	Y	2,3,4	Y	N	Y		
4	R	Y	Y	2,3,4,5	Y	N	Y		
5	L	Y	Y	2,3,4,5	Y	N	Y		Abductor hallucis
6[a]	R	Y	Y	2,3,4,5	Y	N	Y	Y	Abductor hallucis
7[a]	L	Y	Y	2,3,4,5	Y	N	Y	Y	Abductor hallucis
8	L	Y	Y	2,3,4	N	Y	Y		Abductor hallucis
9	R	Y	Y	2,3,4,5	Y	N	Y	Y	
10	L	Y	Y	2,3,4	Y	N	Y	Y	Abductor hallucis
11	R	Y	Y	2,3,4,5	Y	Y	Y		

Navicular, tuberosity and naviculocuneiform capsule; Cuneiform/Cuboid, medial, middle, lateral cuneiform, and cuboid; MT, metatarsal — metatarsal bases; FHB, flexor hallucis brevis — medial limb; PL, peroneus longus — near insertion at base of first metatarsal; ST, sustentaculum tali; Spring, spring ligament.
[a]Same subject.



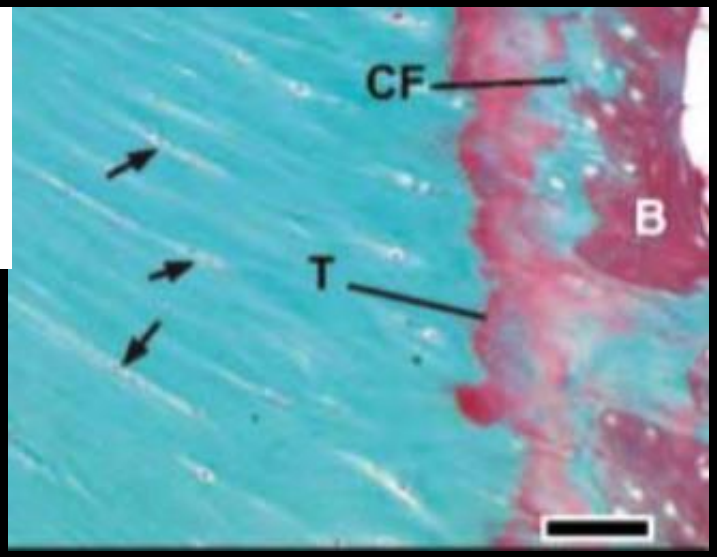
*Most patients who had an accessory navicular showed a direct insertion of the posterior tibial tendon into the accessory navicular, with absence of the multiple insertions into the midfoot seen in normal specimens.

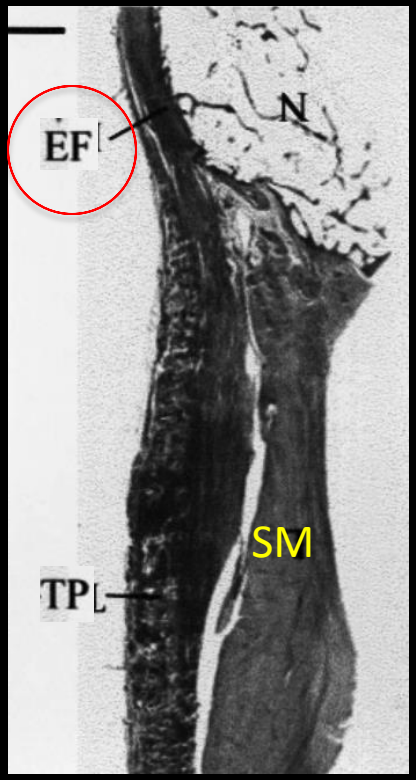
Bloome Foot and Ankle International October 2003

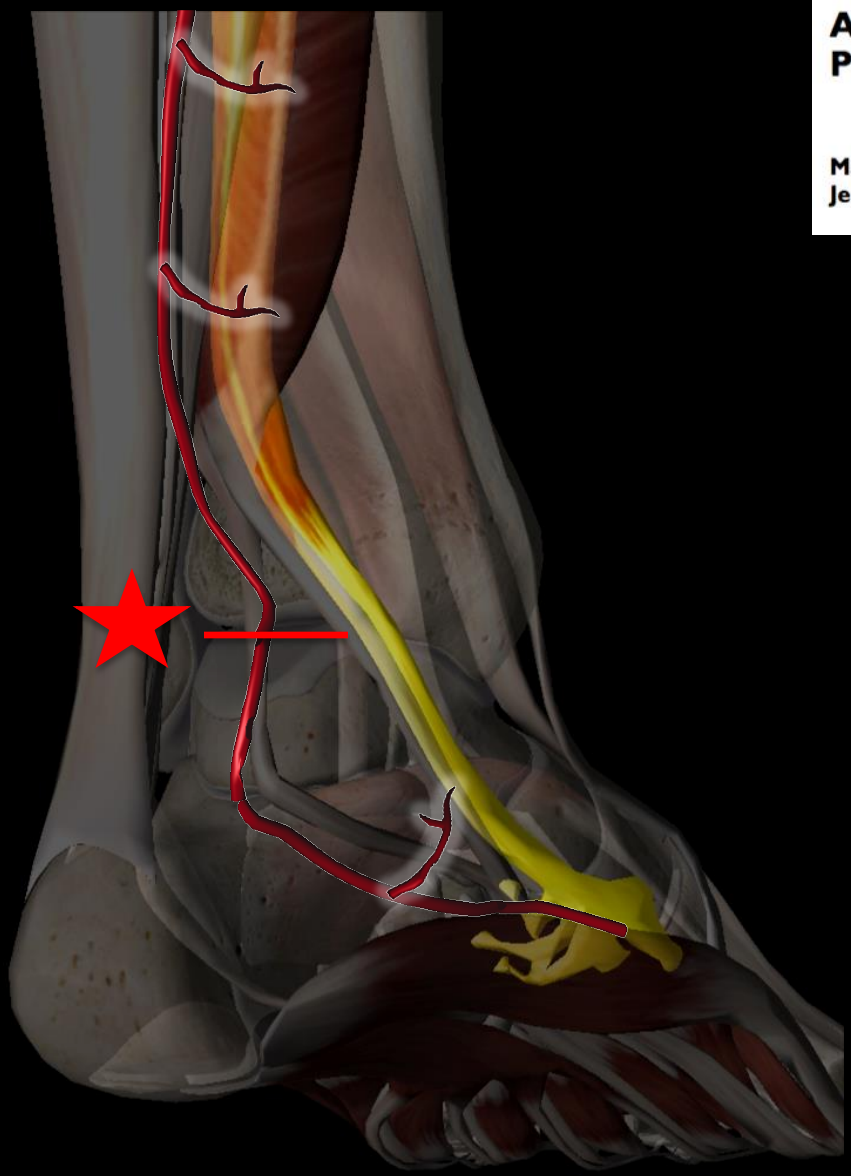
The Journal of Rheumatology Volume 30, no. 3

The structure and histopathology of the "enthesis organ" at the navicular insertion of the tendon of tibialis posterior.

Bernhard Moriggl, Tsukasa Kumai, Stefan Milz and Michael Benjamin







Arterial Anatomy of the Tibialis Posterior Tendon

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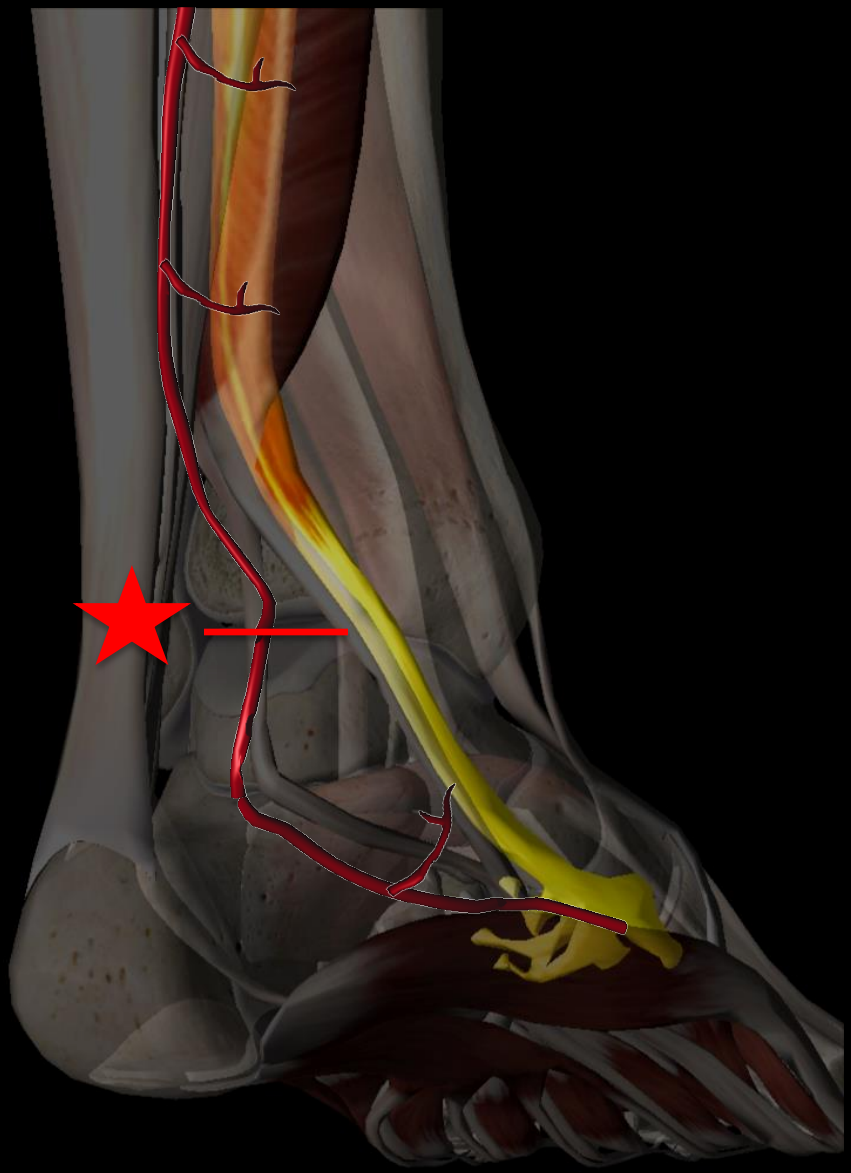
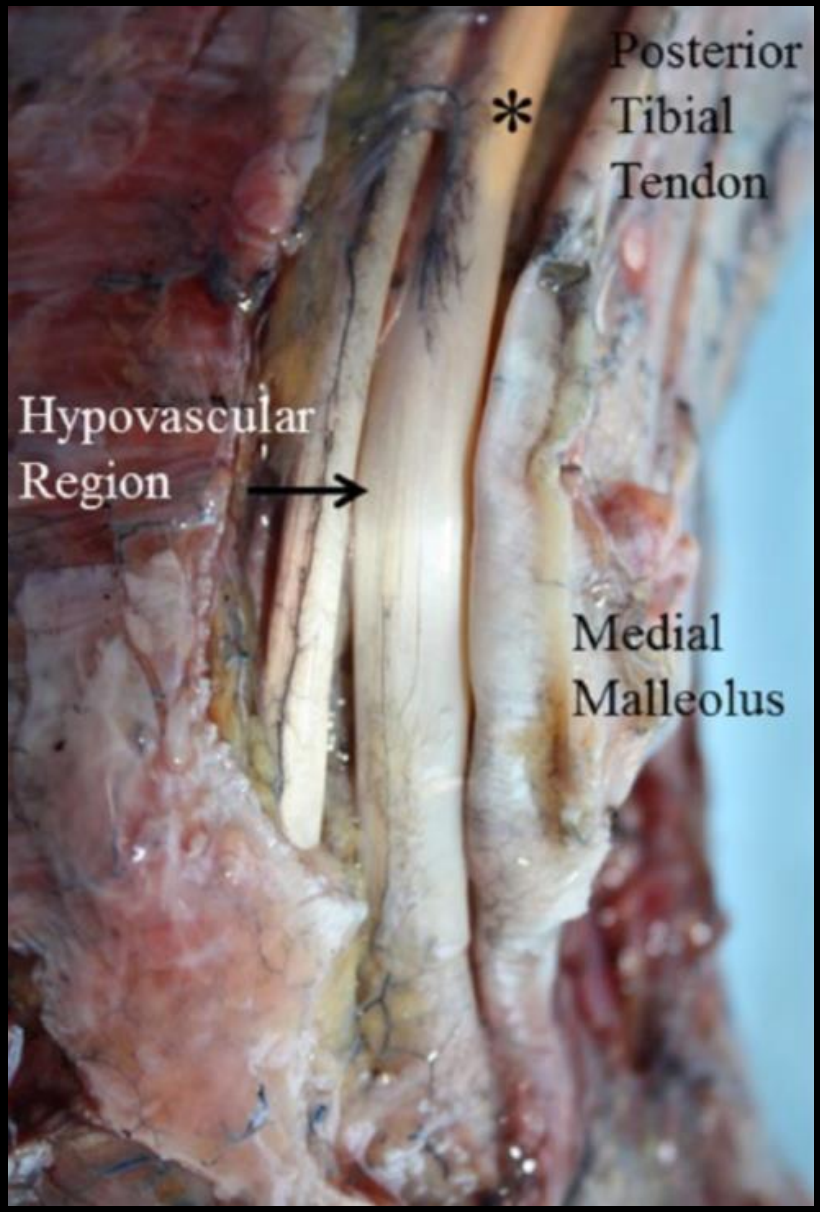
fai.sagepub.com

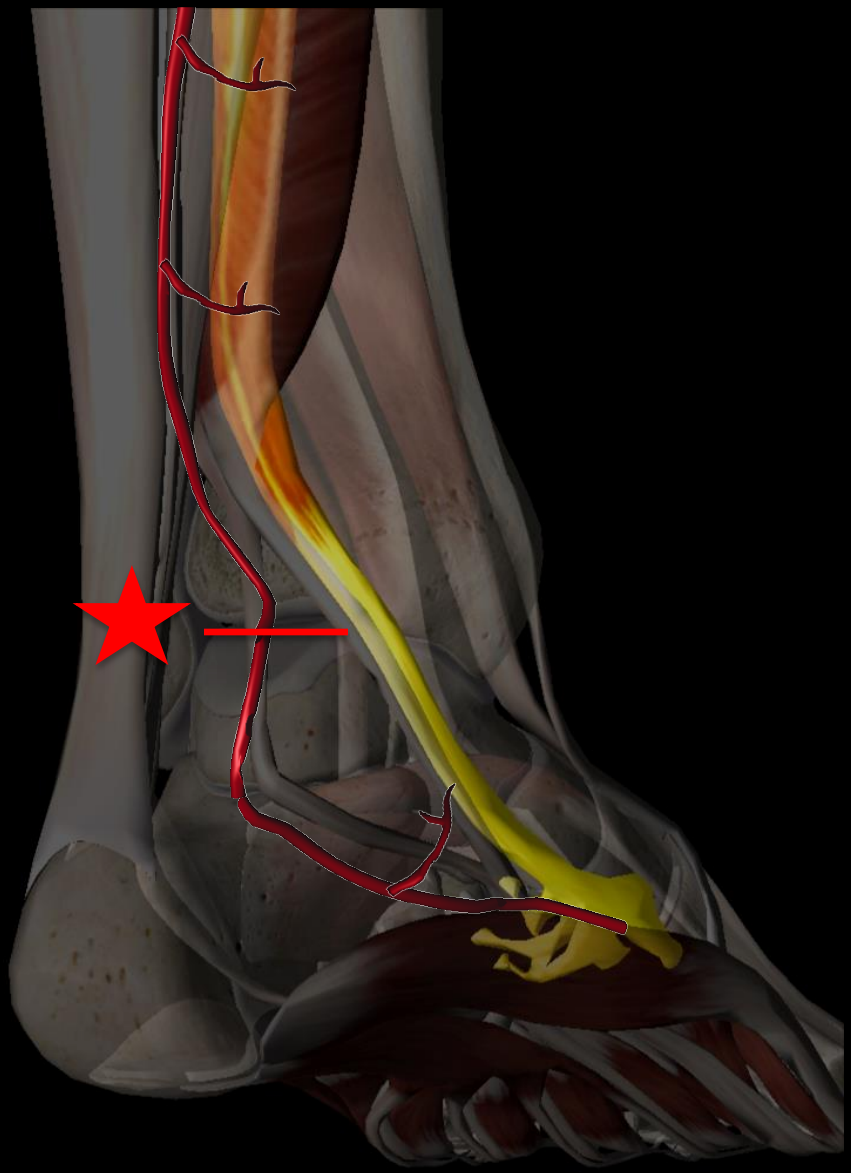
Mary Claire Manske, MD[1], Kathleen E. McKeon, MD[2], Jeffrey E. Johnson, MD[1], Jeremy J. McCormick, MD[1], and Sandra E. Klein, MD[1]

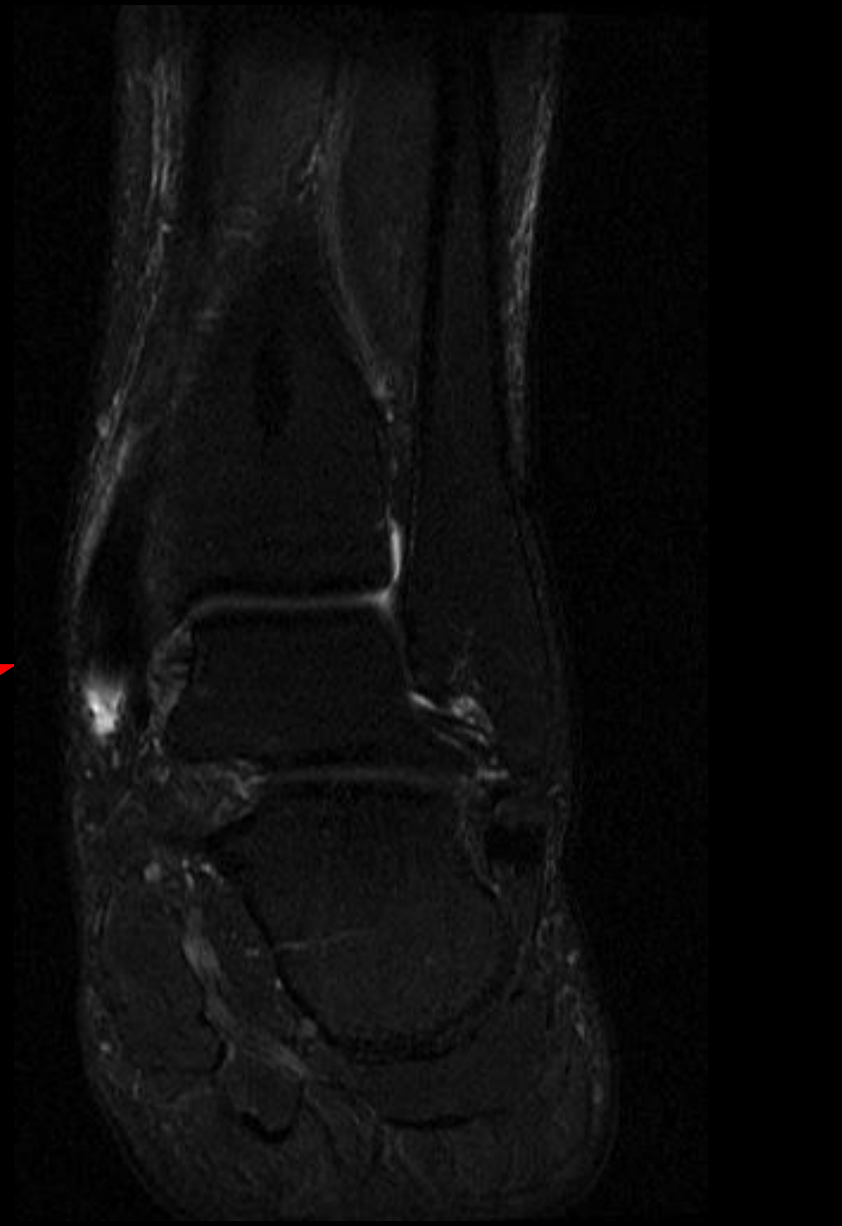
- Two entry vessels supply the PTT, entering approx 4.5cm proximal and 2cm distal to the malleolus
- A hypovascular, retromalleolar region was observed in 100% of specimens microscopically
- Concomitant hypovascularity and mechanical traction in the retromalleolar tendon may render the PTT susceptible to injury





Manske Foot and Ankle International 2015





What Other Structures Are Important?

Pertinent anatomy of the acquired flatfoot involves more than simply failure of the PTT.

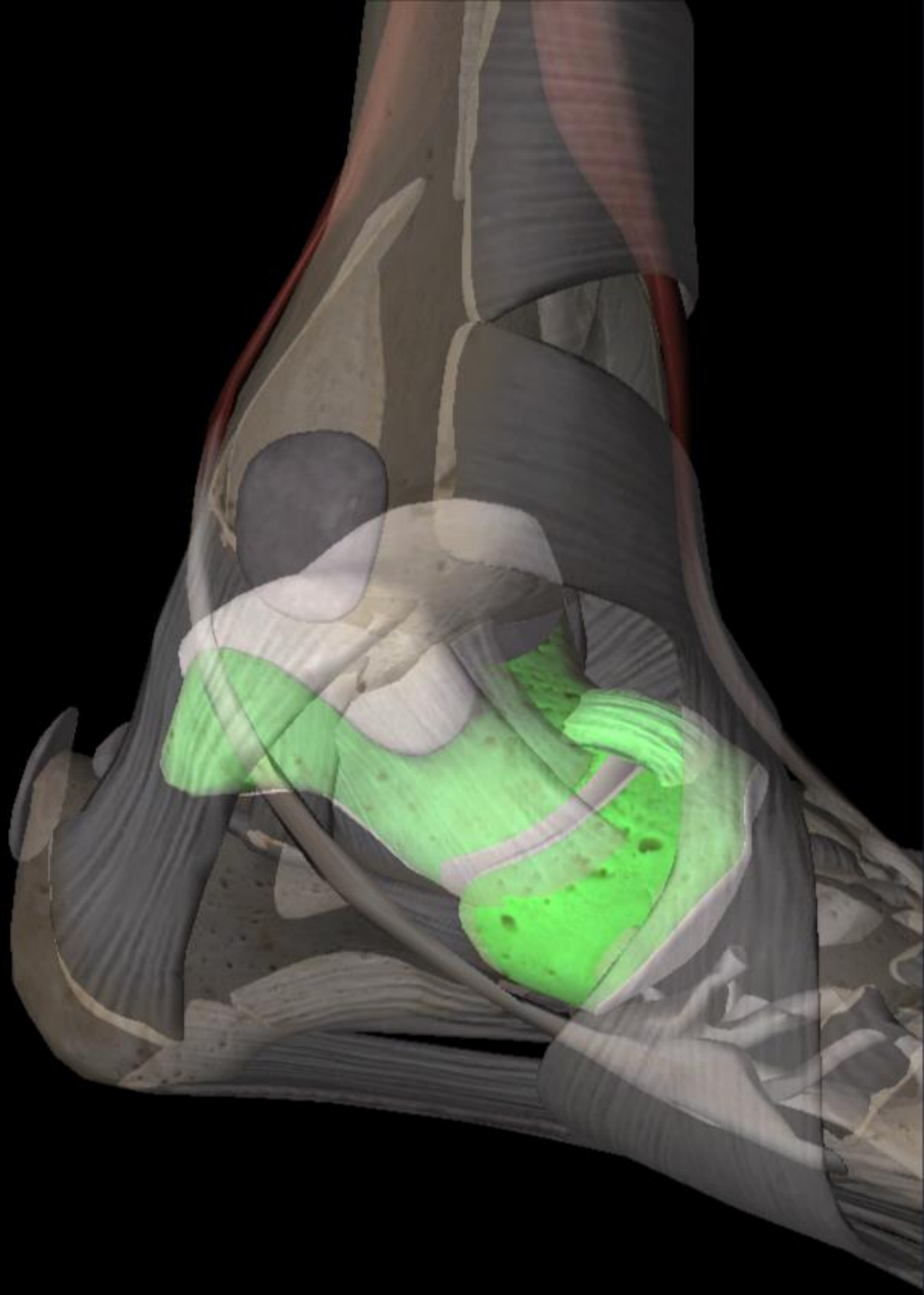
- Talonavicular joint (TNJ)
- Calcaneonavicular (spring) ligament
- Deltoid complex
- Plantar Fascia

should all be taken into consideration when evaluating the flatfoot

Walters and Mendicino Flexible adult flatfoot anatomy and pathomechanics

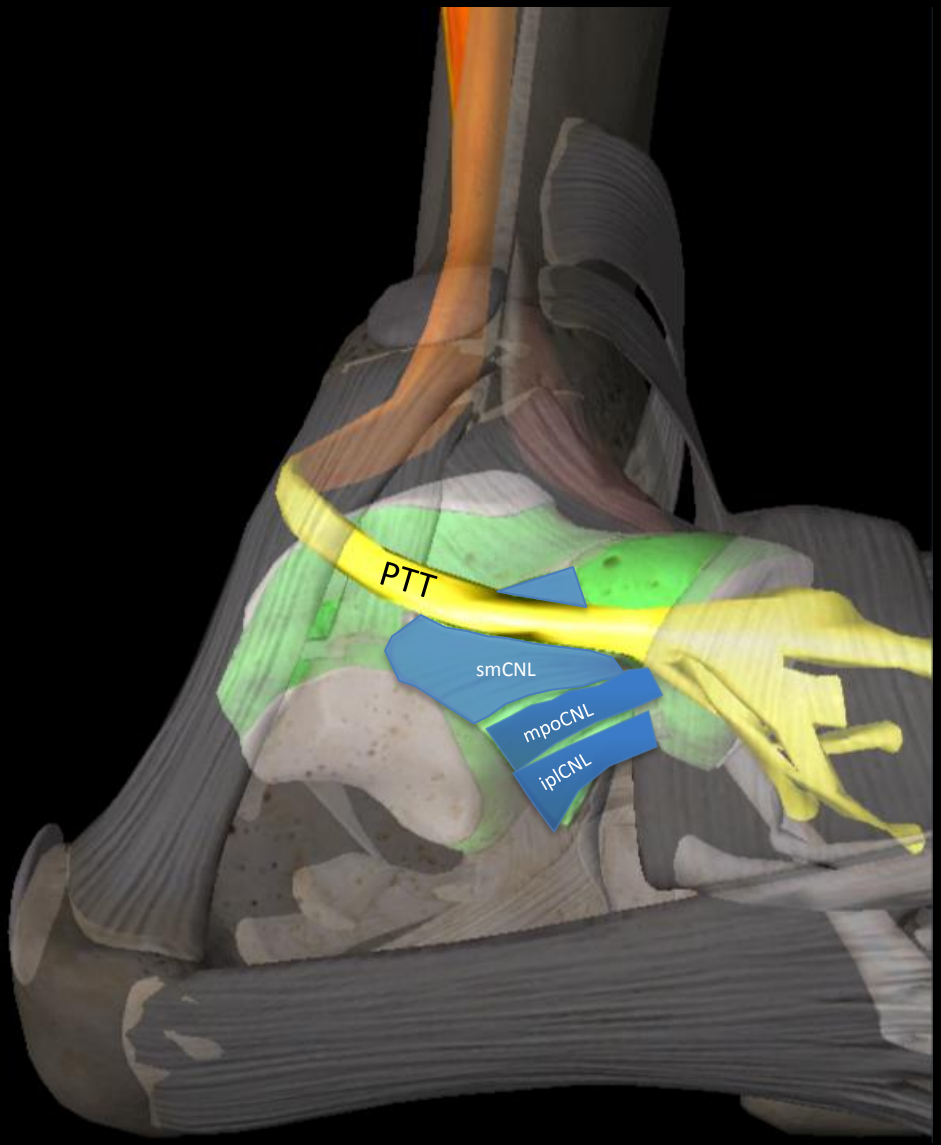
Talonavicular joint

- Keystone to motion of the hindfoot and key joint to the triple complex of the hindfoot
- Static ligamentous support and dynamic support from the PTT are critical in allowing normal talar head motion and function of the talonavicular joint
- The talonavicular joint is the primary site of deformity in AAF



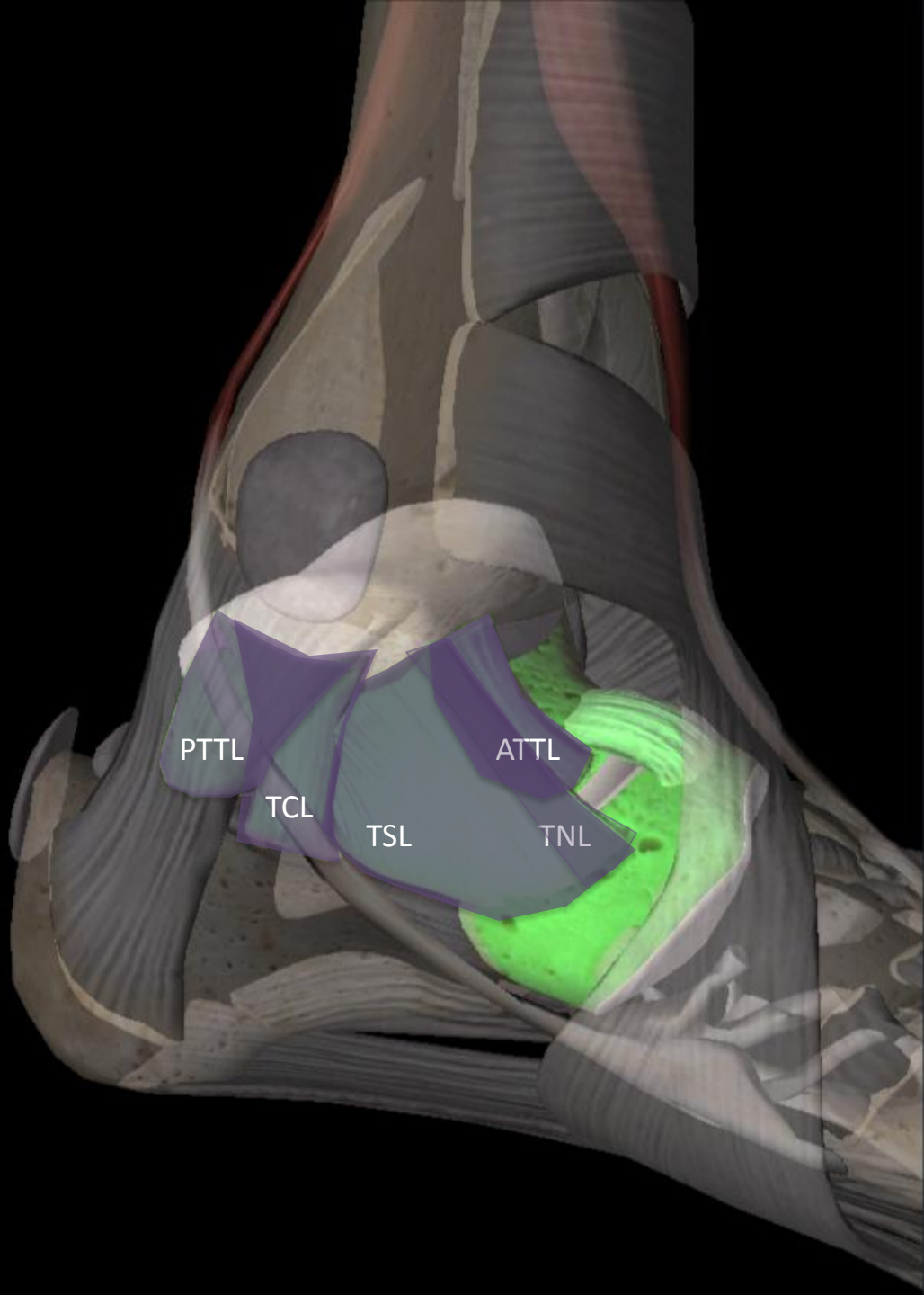
Spring Ligament

- Superomedial CNL is the broadest and most important part of the complex
- Interplays with the deltoid ligament in stabilization of the medial ankle joint
- Supplements the dynamic support of the PTT in preventing plantar and medial migration of the talar head
- “acetabulum of the talus”



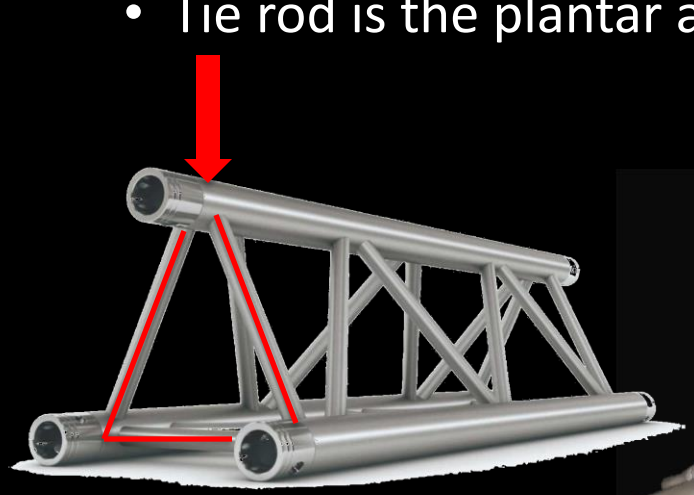
Deltoid Ligament

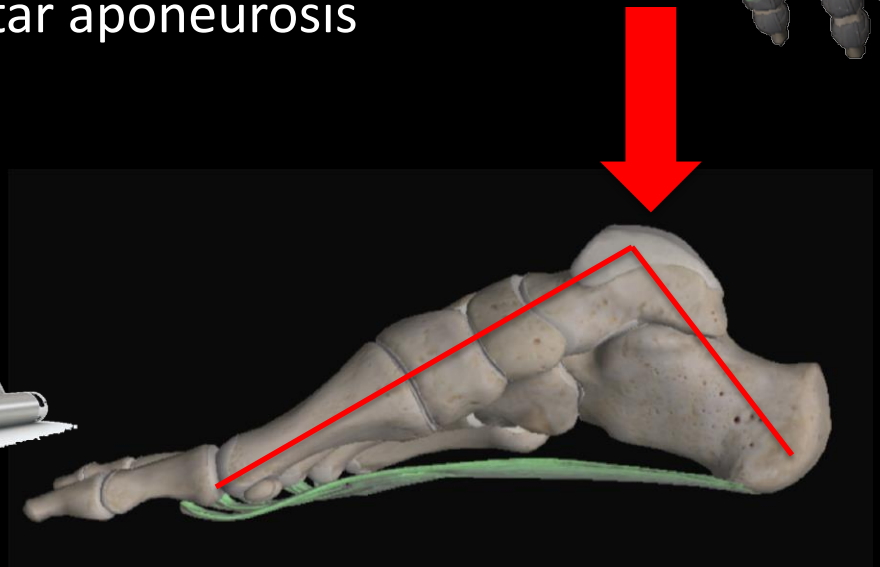
- Serves as a primary medial ankle stabilizer and prevents valgus tilting of the talus
- Failure of the deltoid ligament allows the talus to tilt into the valgus within the ankle mortise (criteria for stage IV PTTD)

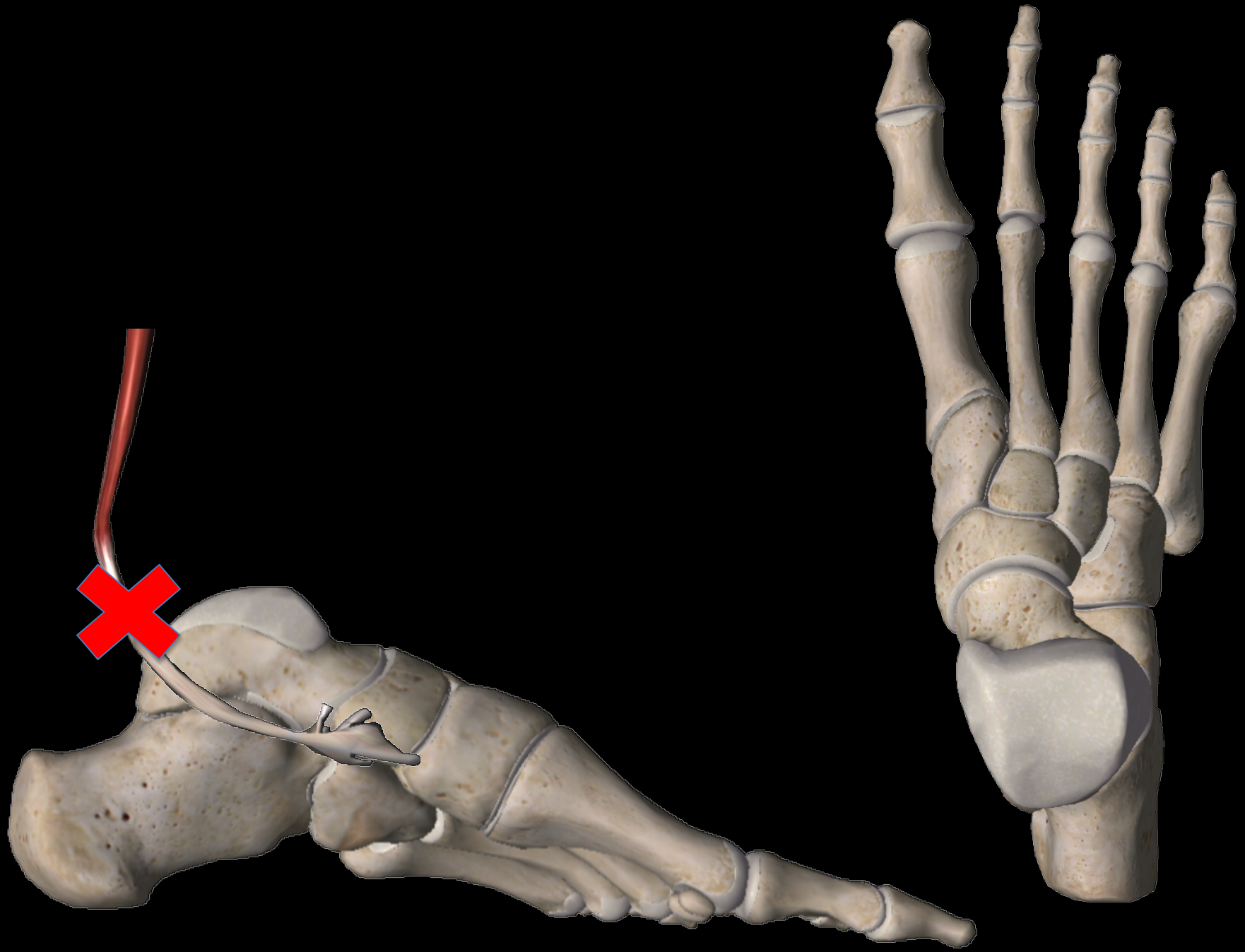


Plantar Fascia

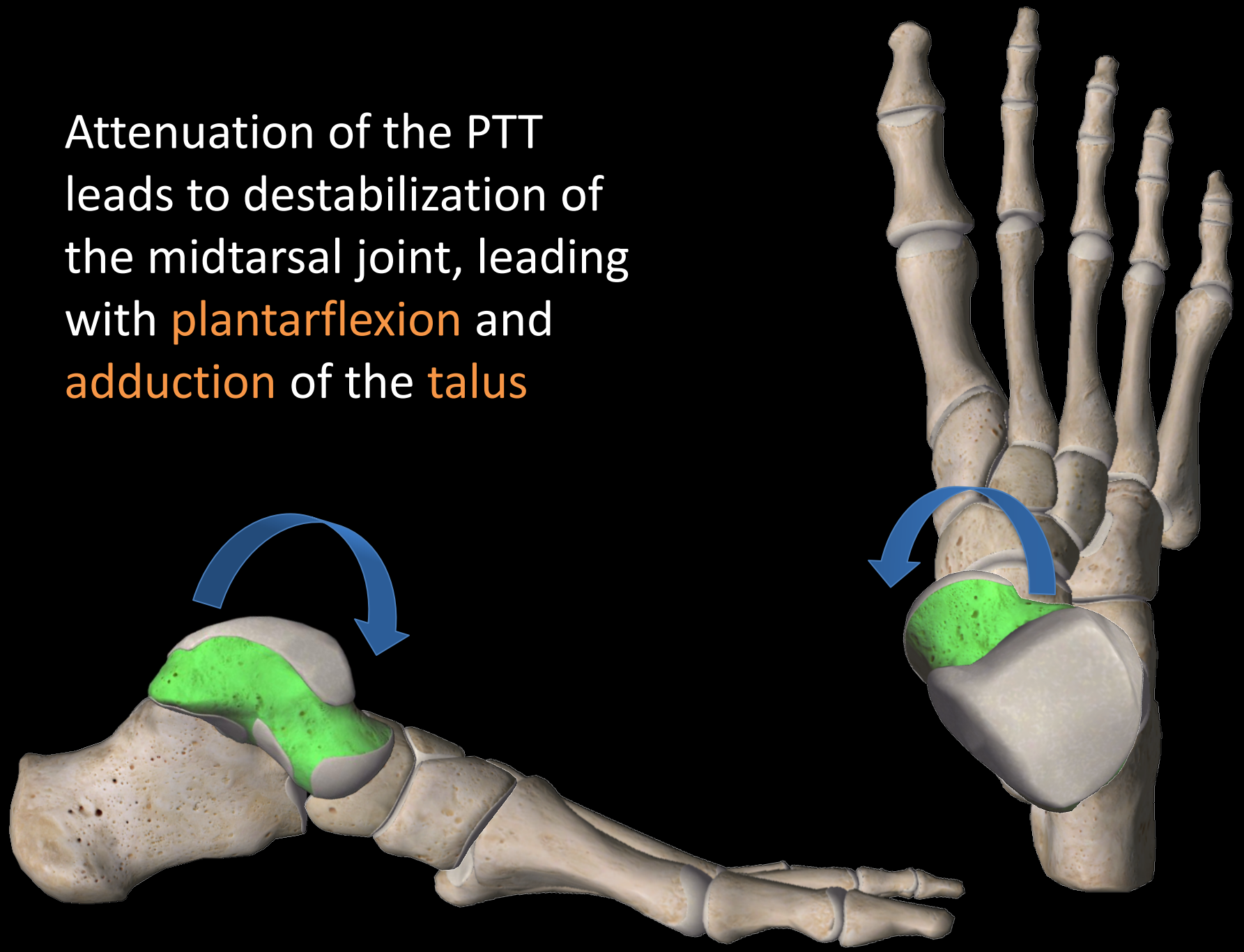
- The primary structure resisting deformity of the arch of the foot
- Lapidus described the foot as a truss
  - Proximal strut is the talus and calcaneus
  - Distal strut is the first ray
  - Tie rod is the plantar aponeurosis



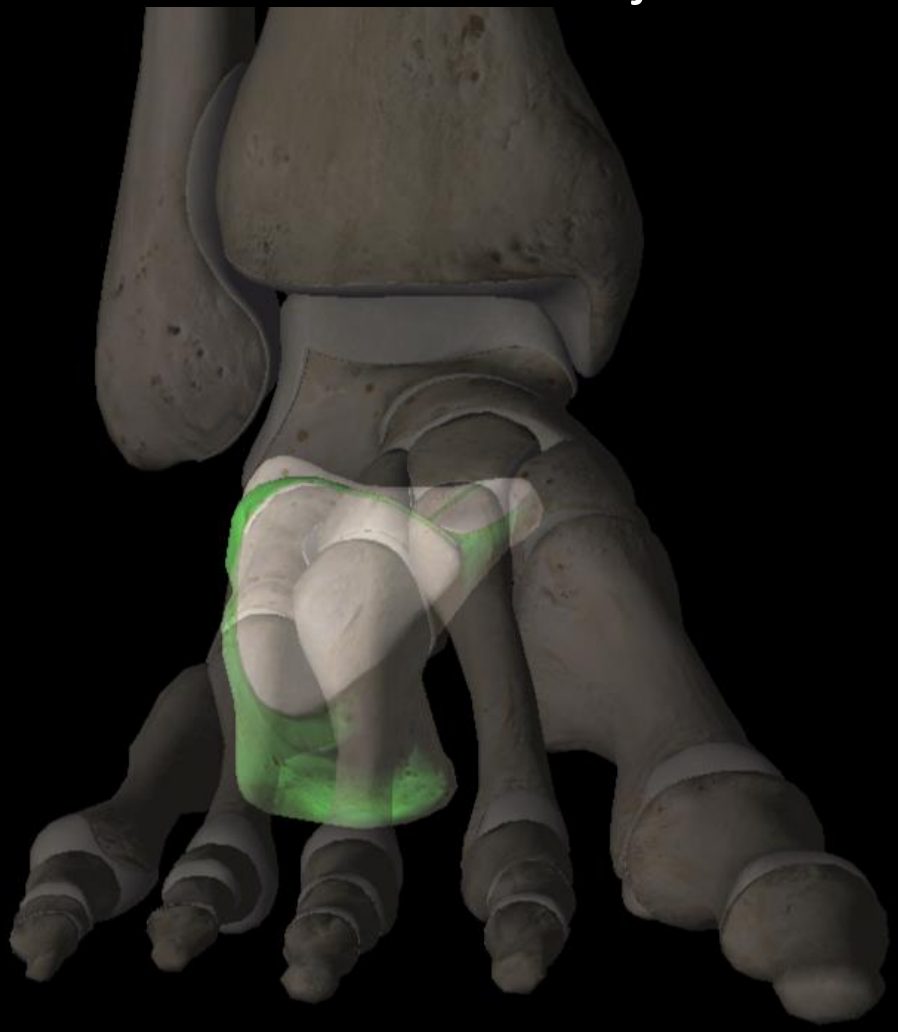


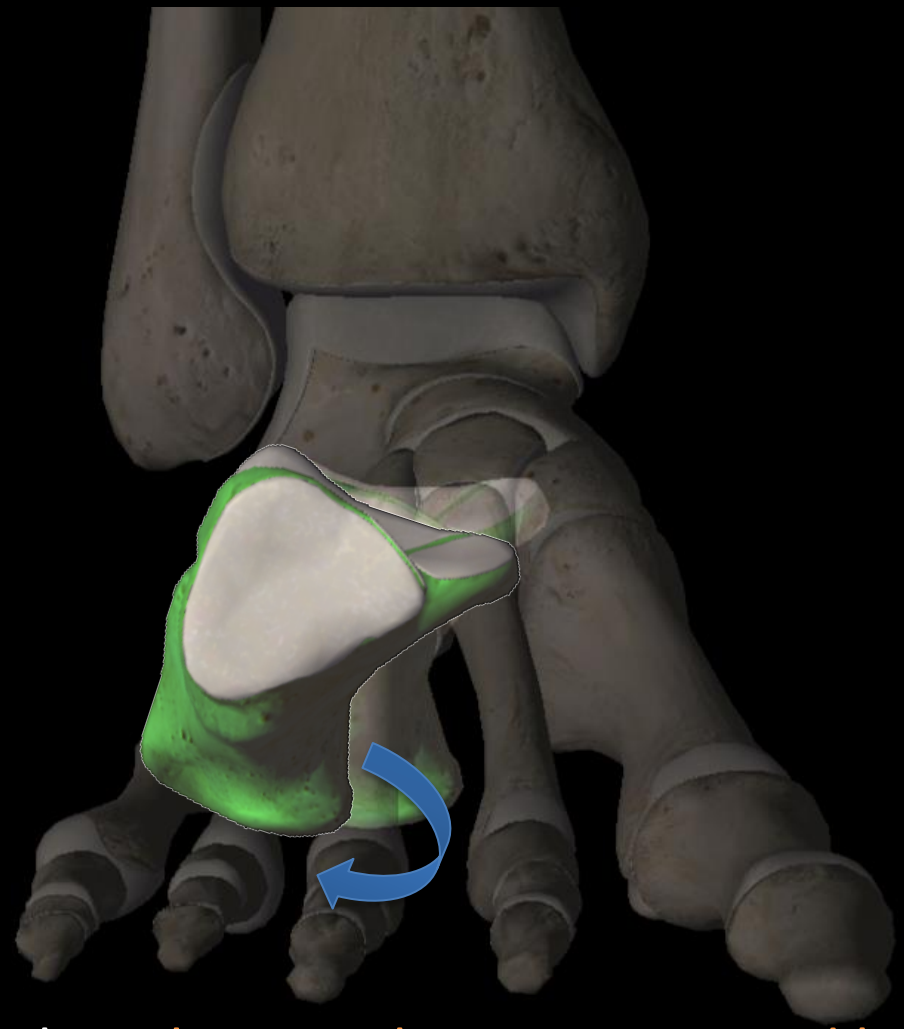


Attenuation of the PTT leads to destabilization of the midtarsal joint, leading with plantarflexion and adduction of the talus



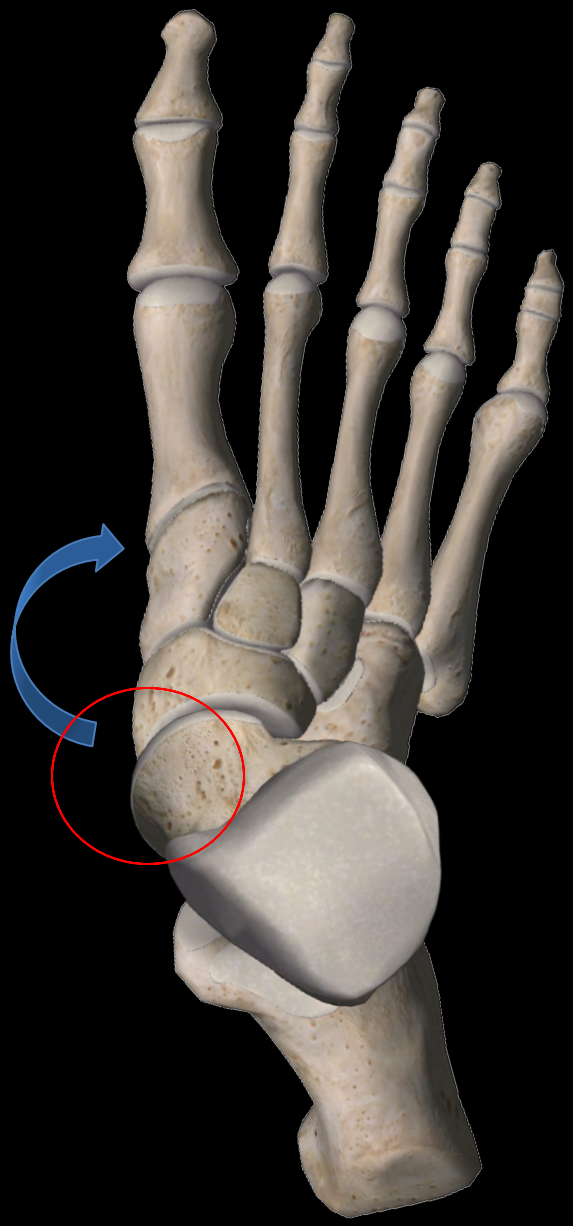
Talar migration is coupled with eversion of the calcaneus through retrograde pronation of the subtalar joint





The talus is no longer supported by the anterior and middle facets of the calcaneus and plantarflexes further

As the medial longitudinal arch flattens and elongates, the lateral longitudinal arch cannot elongate by nature of its anatomic and ligamentous attachments

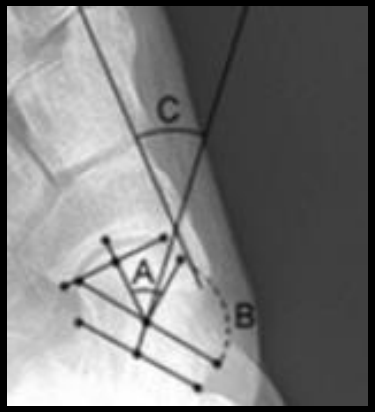


As the medial longitudinal arch flattens and elongates, the lateral longitudinal arch cannot elongate by nature of its anatomic and ligamentous attachments

The entire forefoot abducts with lengthening of the medial column and relative shortening of the lateral column

Navicular subluxes laterally with respect to the talus (talonavicular uncoverage/lateral peritalar subluxation)

Radiographic Assessment



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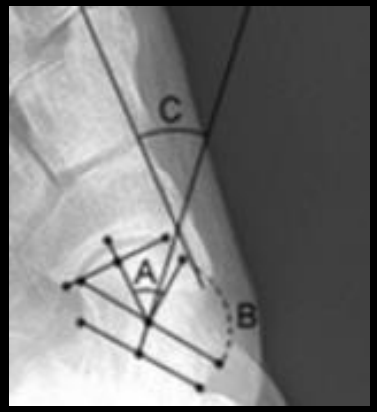

Radiographic Assessment

- Adult flatfoot is a complex 3 dimensional problem
- Each radiographic measurement is a two dimensional representation
- 3 basic components
  1. Longitudinal Arch Collapse
  2. Hindfoot Valgus
  3. Forefoot Abduction

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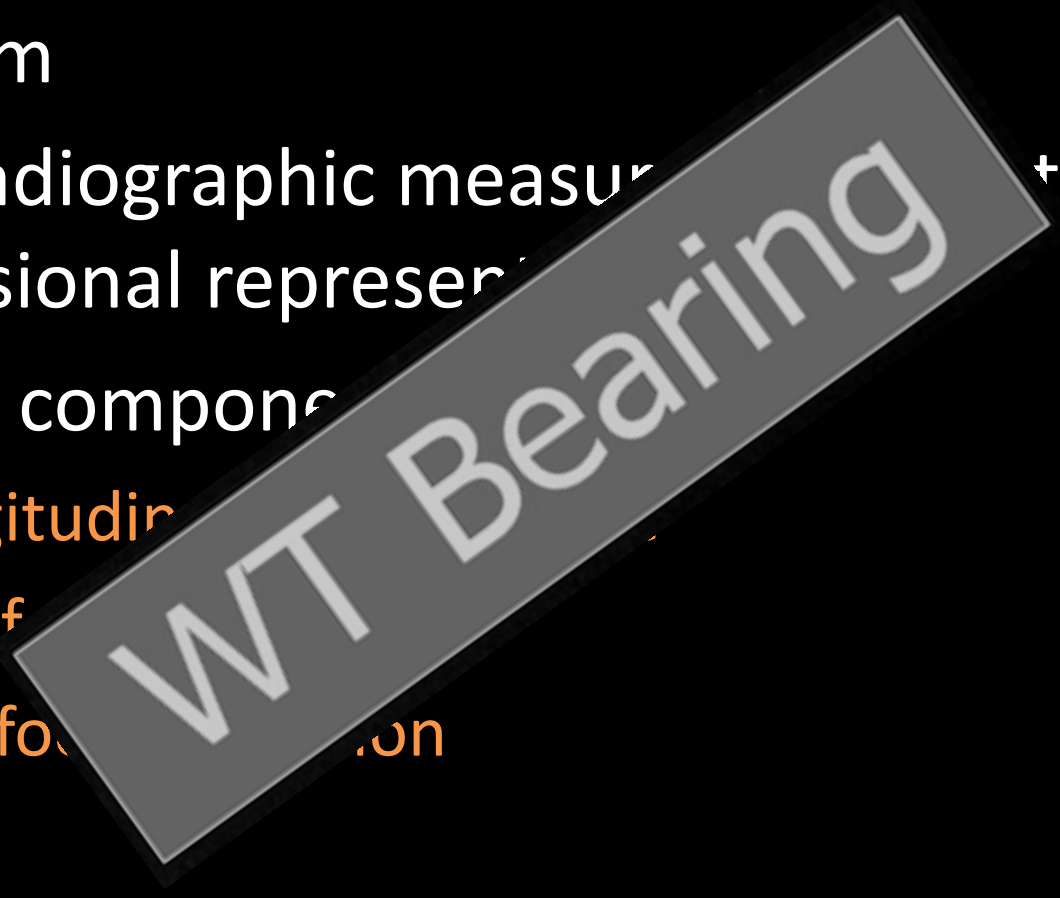
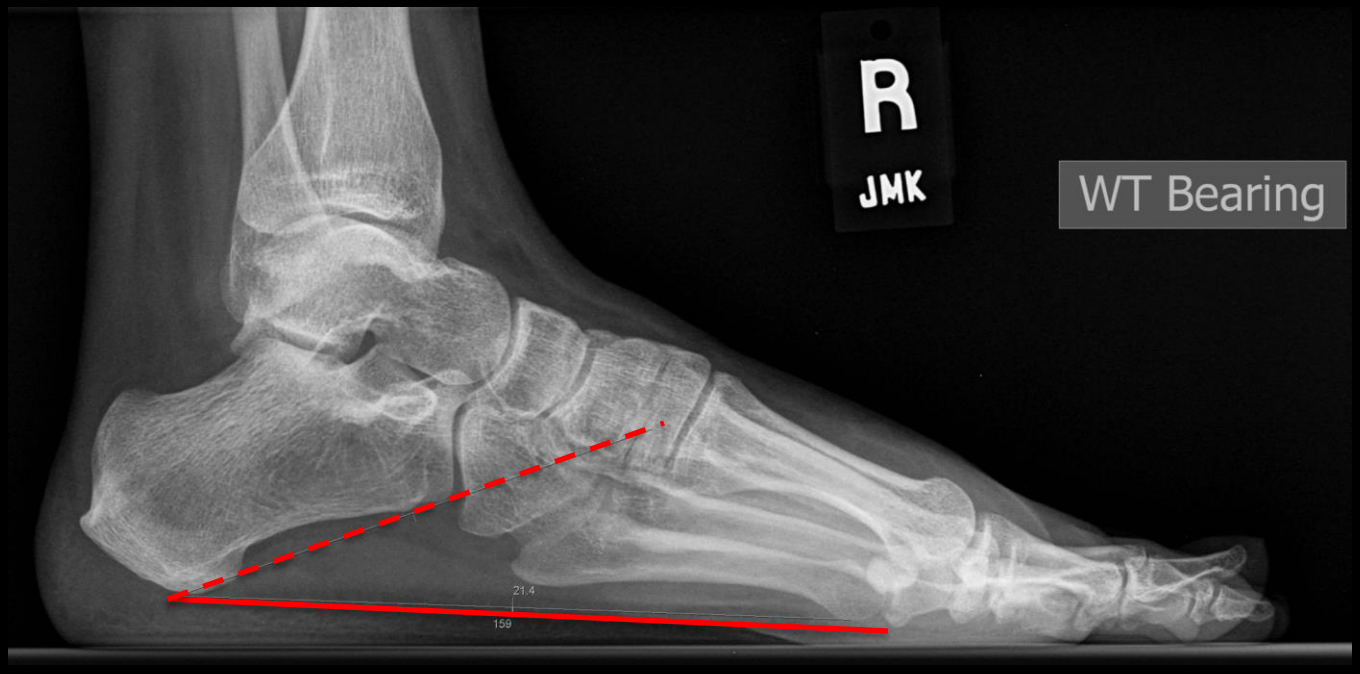


Longitudinal Arch Collapse

CALCANEAL PITCH ANGLE

-Formed by horizontal line from the base of the heel to inferior cortex of the calcaneus and a line from the base of the heel to the plantar aspect of the fifth metatarsal head

-18-20 degrees considered normal



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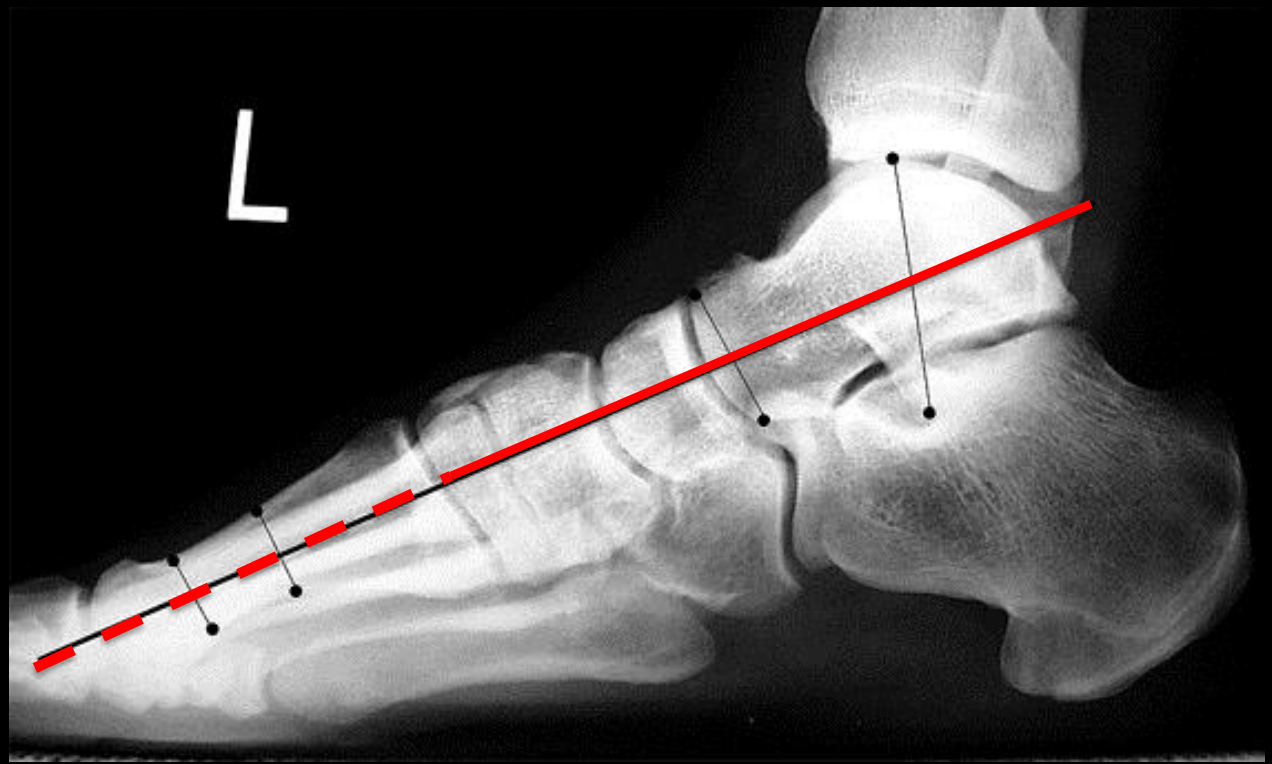
Collapse of the Longitudinal Arch

LATERAL TALAR-1ST METATARSAL (MEARY) ANGLE

-Formed by the long axis of the talus and the first metatarsal on a weight-bearing view.

-Angle greater than 4 degrees convex downward is abnormal

-15-30 degrees moderate, greater than 30 degrees severe



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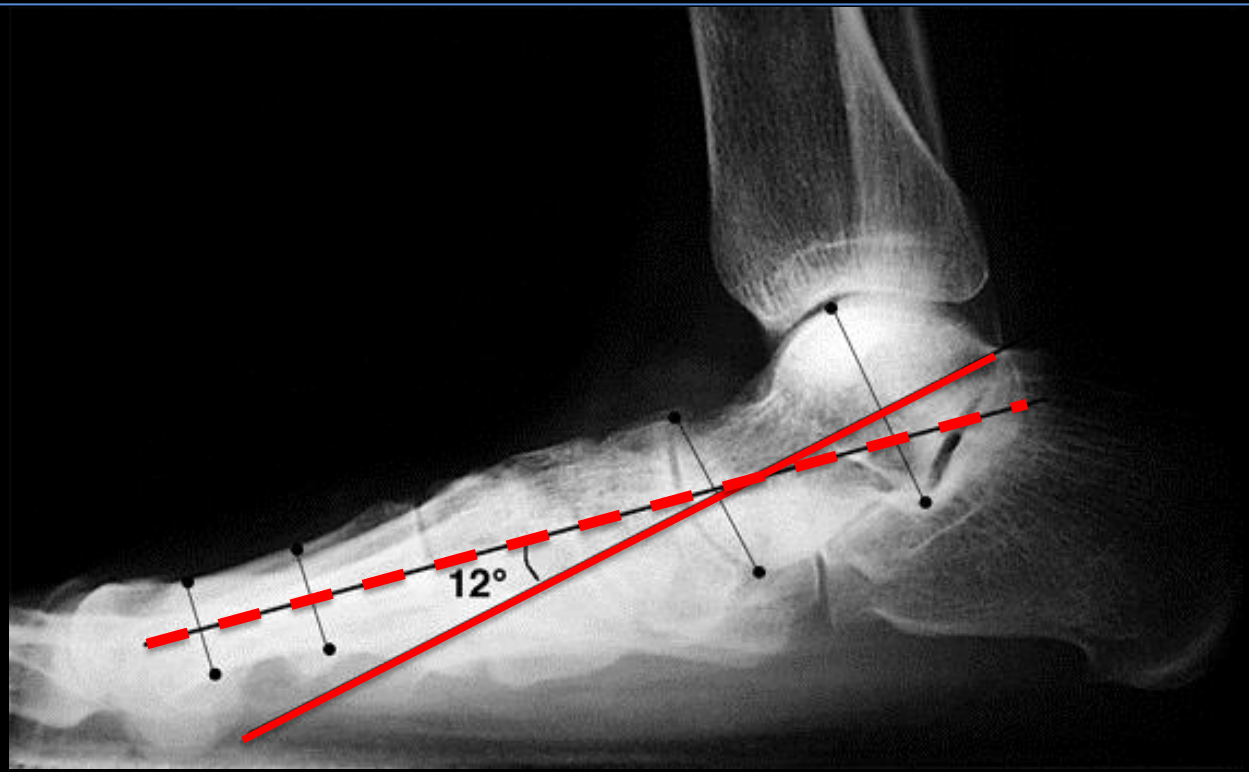
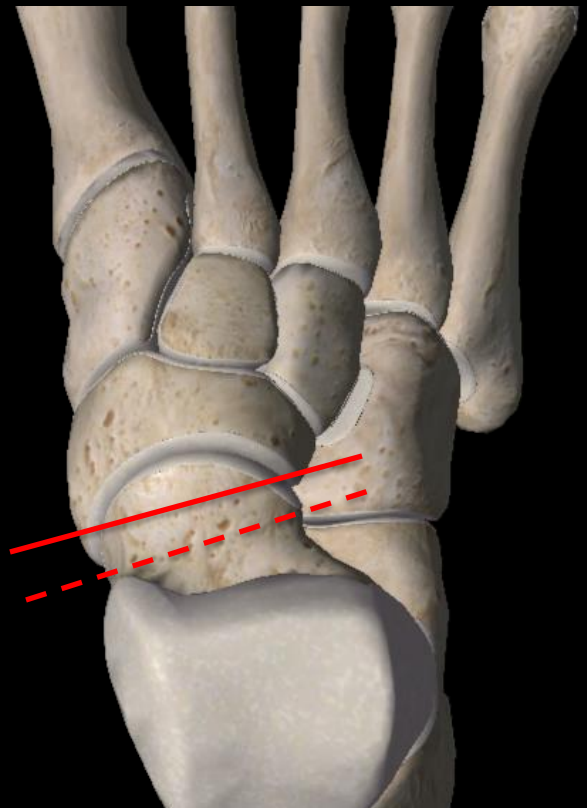
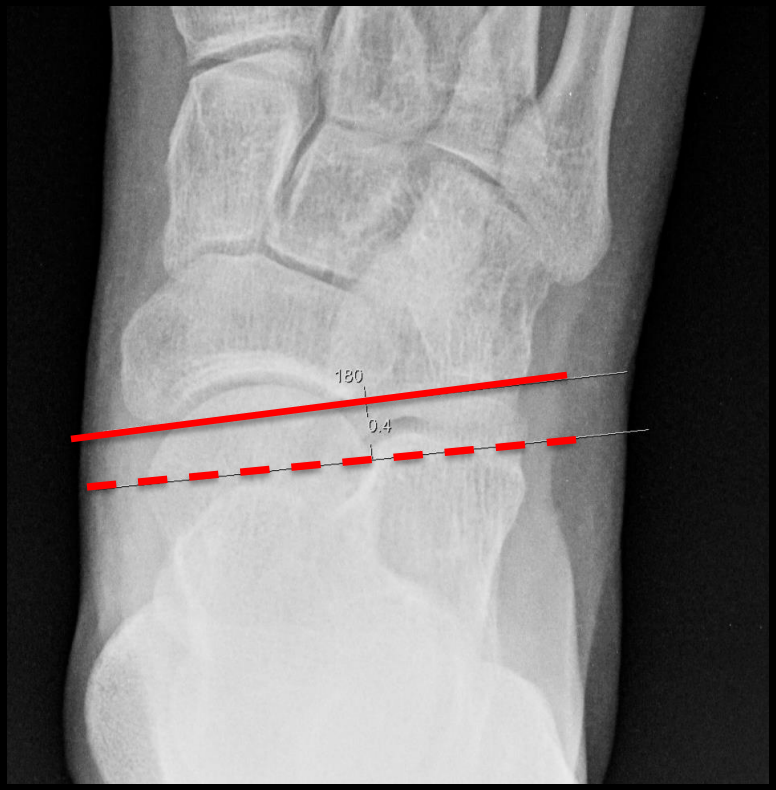


Forefoot Abduction

TALONAVICULAR COVERAGE ANGLE

-Line connecting the edges of the articular surface of the talus
-Line connecting the edges of the articular surface of the navicular
-Angle of greater than 7 degrees is abnormal





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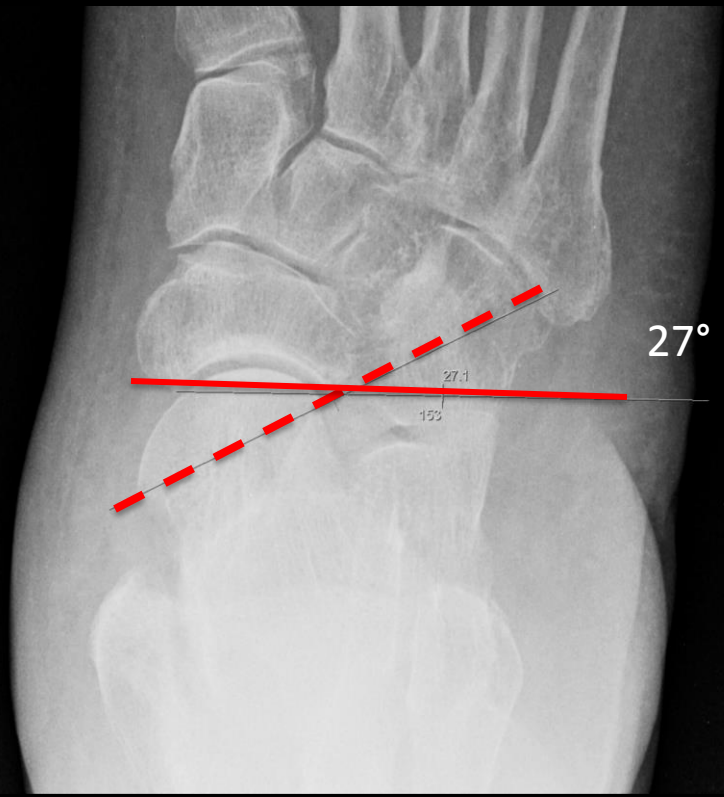

Forefoot Abduction

FIRST METATARSAL ANGLE

A line drawn through the mid-axis of the talus should be in line with the first metatarsal shaft, if it is angled medial to the first metatarsal it indicates pes planus

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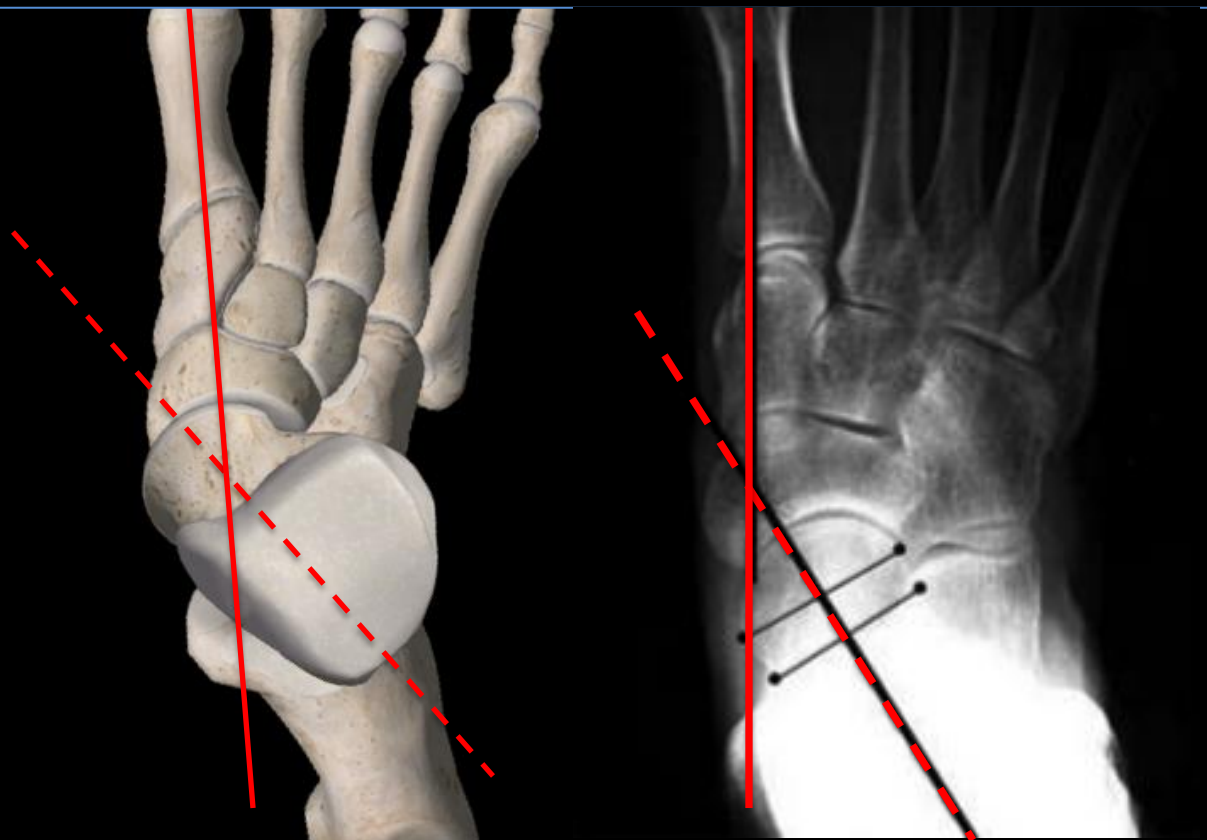
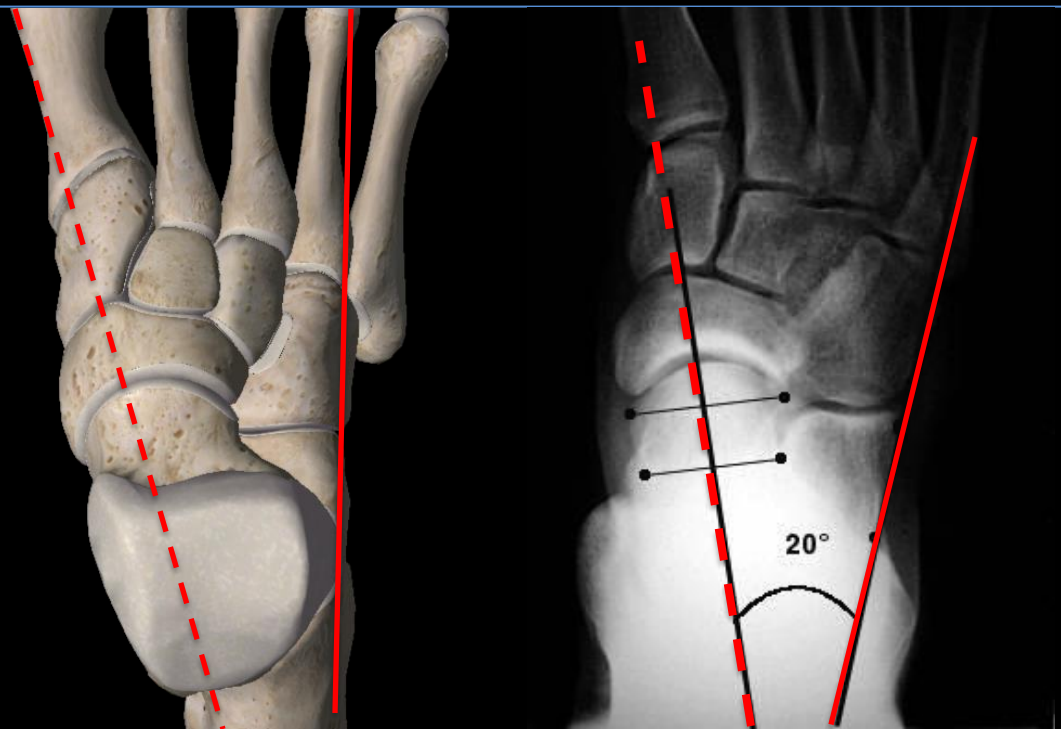


Hindfoot Valgus

AP TALO-CALCANEAL ANGLE (KITE'S ANGLE)

-Intersection of a line bisecting the head and neck of the talus and a line parallel with the lateral surface of the calcaneus.

-Normal is 15-30 degrees. Angle greater than 30 degrees indicates hindfoot valgus.

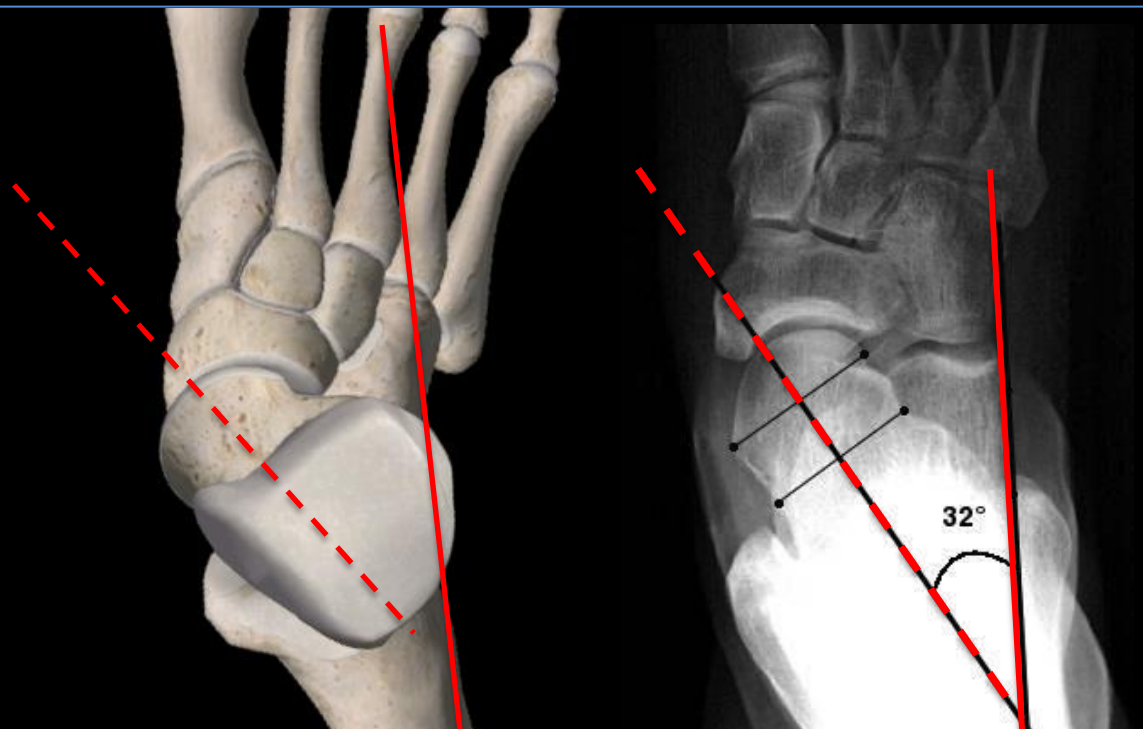


Hindfoot Valgus

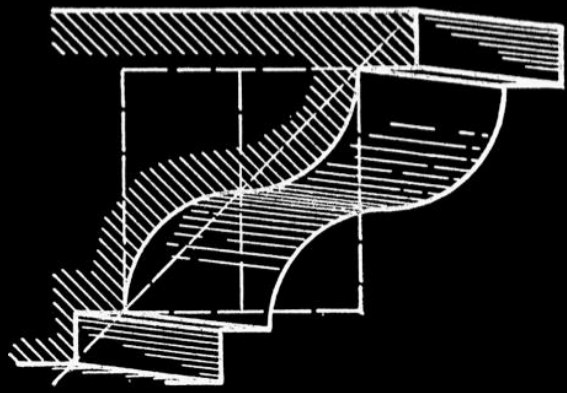
AP TALO-CALCANEAL ANGLE (KITE'S ANGLE)

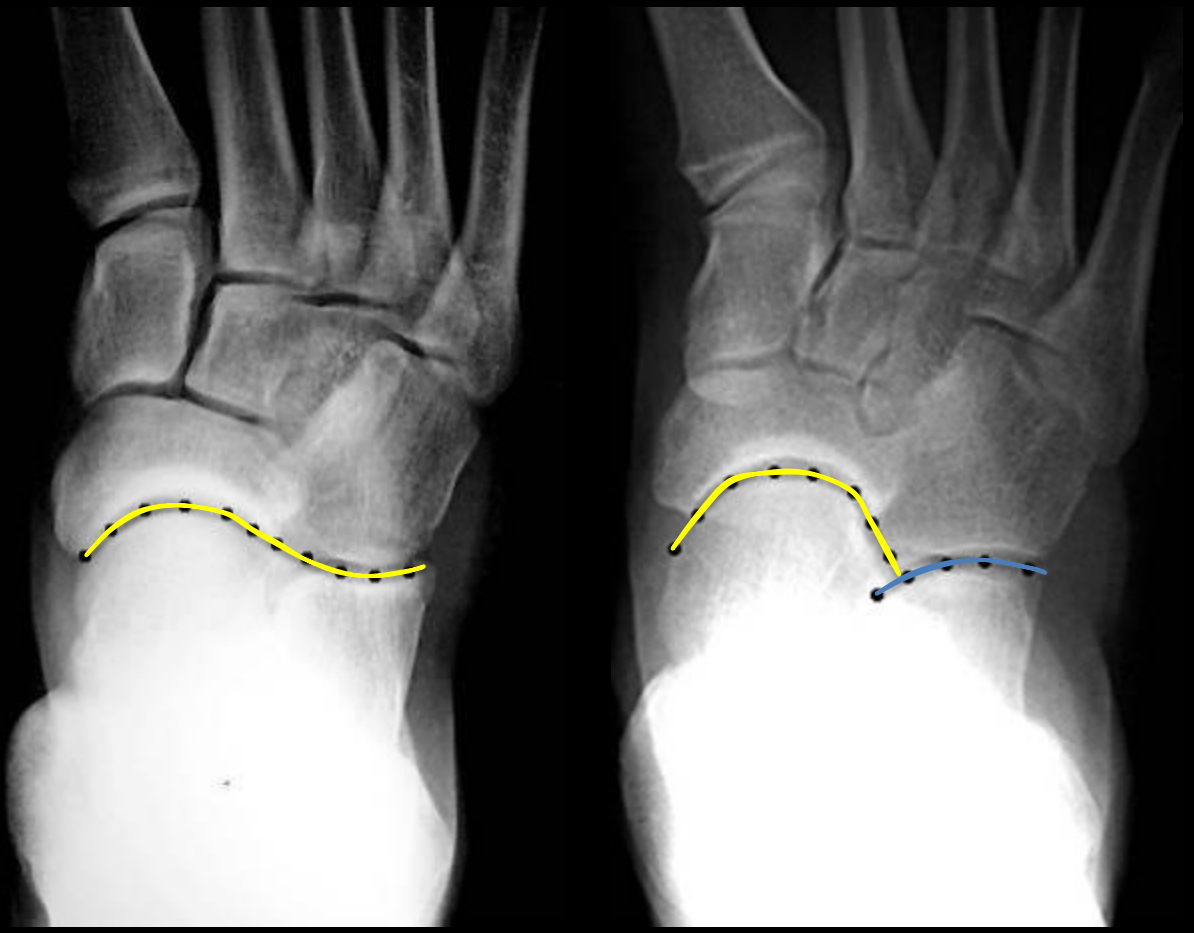
-Intersection of a line bisecting the head and neck of the talus and a line parallel with the lateral surface of the calcaneus.

-Normal is 15-30 degrees. Angle greater than 30 degrees indicates hindfoot valgus.



CYMA LINE





CYMA LINE

Cuboid
Fracture

MRI Assessment

- ✓ To confirm the clinical findings, assess equivocal cases, and exclude other related etiologies
- ✓ For preoperative evaluation when surgical intervention is contemplated
- ✓ To assess the extent of cartilage, tendon, and ligament involvement and lateral bony impingement

- MRI staging approach correlates the primary and secondary MRI features of PTT dysfunction with the clinical staging system widely described in the orthopedic literature

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

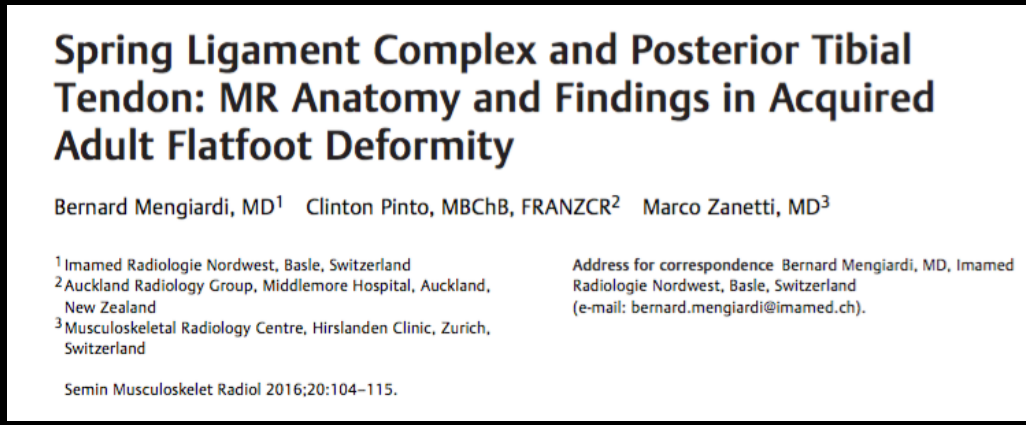
journal homepage: www.jfas.org

ELSEVIER

Review Articles

3-Tesla Magnetic Resonance Imaging Evaluation of Posterior Tibial Tendon Dysfunction with Relevance to Clinical Staging

Avneesh Chhabra, MD[1], Theodoros Soldatos, MD[2], Majid Chalian, MD[2], Neda Faridian-Aragh, MD[2], Jan Fritz, MD[3], Laura M. Fayad, MD[4], John A. Carrino, MD, MPH[5], Lew Schon, MD[6]



Spring Ligament Complex and Posterior Tibial Tendon: MR Anatomy and Findings in Acquired Adult Flatfoot Deformity

Bernard Mengiardi, MD[1] Clinton Pinto, MBChB, FRANZCR[2] Marco Zanetti, MD[3]

[1] Imamed Radiologie Nordwest, Basle, Switzerland
[2] Auckland Radiology Group, Middlemore Hospital, Auckland, New Zealand
[3] Musculoskeletal Radiology Centre, Hirslanden Clinic, Zurich, Switzerland

Address for correspondence Bernard Mengiardi, MD, Imamed Radiologie Nordwest, Basle, Switzerland (e-mail: bernard.mengiardi@imamed.ch).

Semin Musculoskelet Radiol 2016;20:104–115.

PTTD Clinical Staging

Stage	Description
I	No deformity
IIa	Moderate flexible deformity (minimal talonavicular abduction, <30% talonavicular uncoverage)
IIb	Severe flexible deformity with either abduction through TN joint (>30% talonavicular uncoverage) or subtalar impingement
III	Fixed deformity (involving the triple-joint complex)
IVa	Hindfoot valgus and flexible ankle valgus without significant ankle arthritis
IVb	Hindfoot valgus with rigid ankle valgus or flexible deformity with significant ankle arthritis

Vulcano et al Curr Rev Musculoskel Med 2013

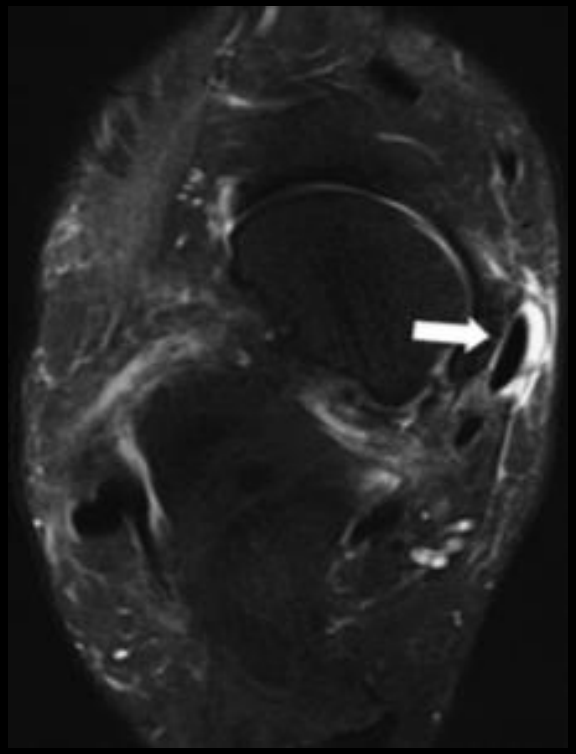
☑Primary finding – PTT Tenosynovitis, tendinosis, partial or full-thickness tears

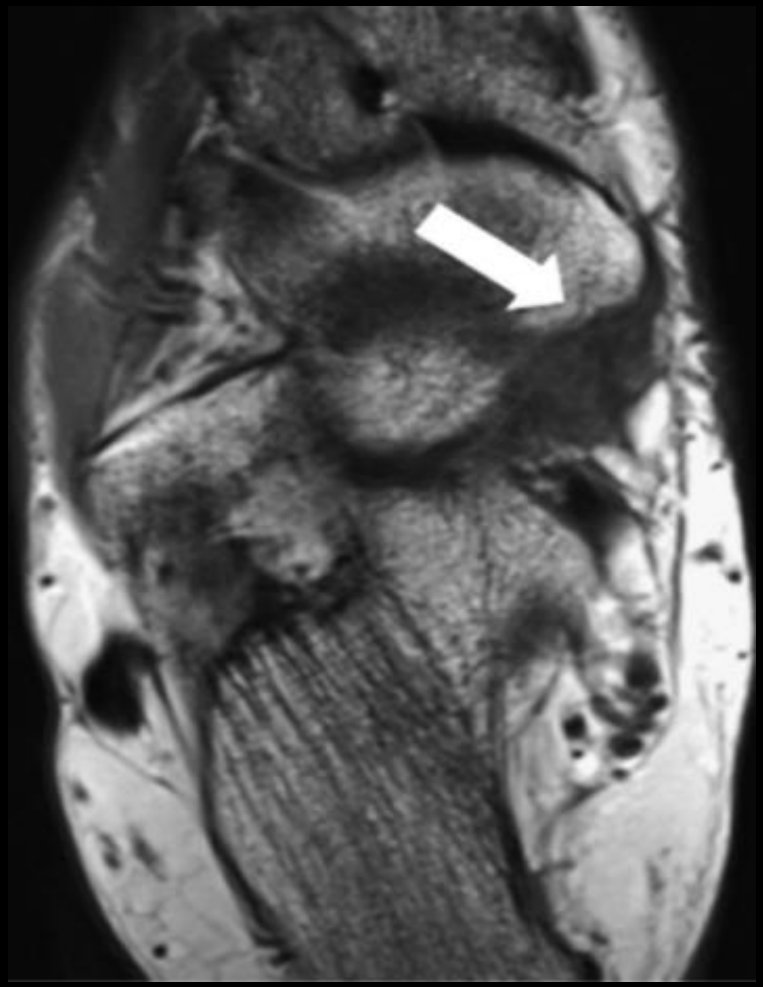
PTT Injury Type	Findings
I	Homogeneous tendon, slightly enlarged with 1-2 longitudinal splits
II	Heterogeneous, attenuated tendon with wider longitudinal splits
III	Complete or near-complete tear of the PTT with few or no remaining intact fibers

- ☑Secondary Findings
  - ☑Spring ligament failure
  - ☑Talonavicular malalignment
  - ☑Lateral Hindfoot Impingement
  - ☑Deltoid ligament failure
  - ☑Sinus Tarsi Syndrome
  - ☑Plantar fasciitis
  - ☑Osteoarthritis
    - ☑Ankle
    - ☑Subtalar Joint

PTT Dysfunction

- Stage I
  - ☑ Insertional Tendinosis
  - ☑ Tenosynovitis
  - – Spring ligament intact

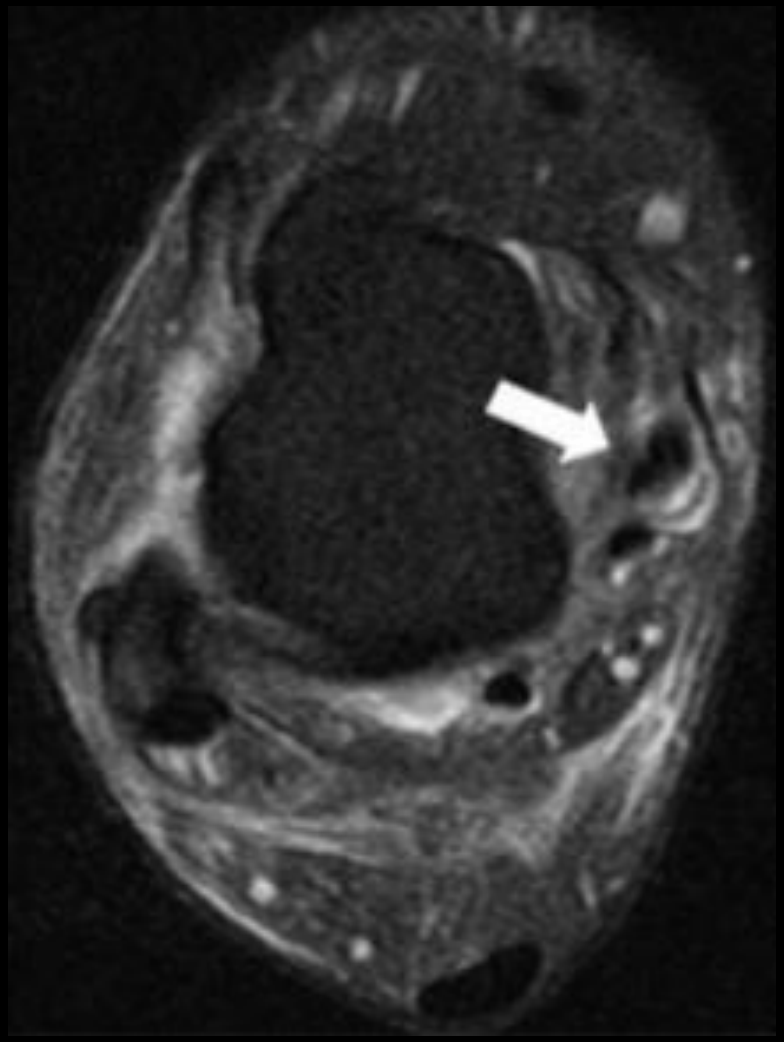




Chhabra

PTT Dysfunction

- Stage II
  - ☑Type I/II tear with tendinosis/tenosynovitis
  - ☑+/- Talonavicular uncoverage/hindfoot valgus
  - ☑Spring ligament abnormality



PTT Dysfunction

- Stage II
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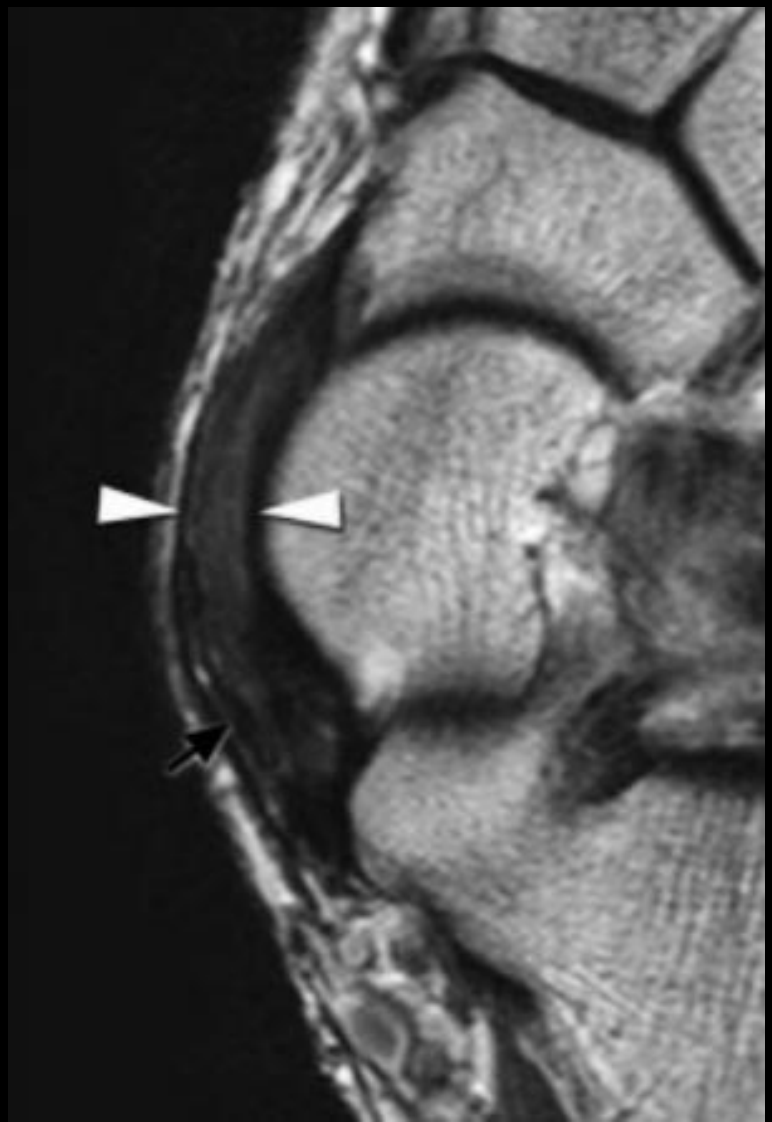
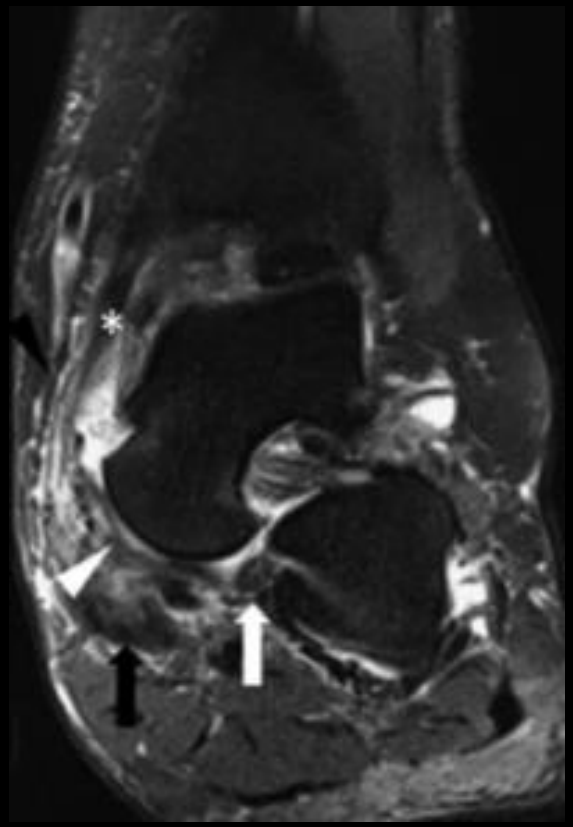
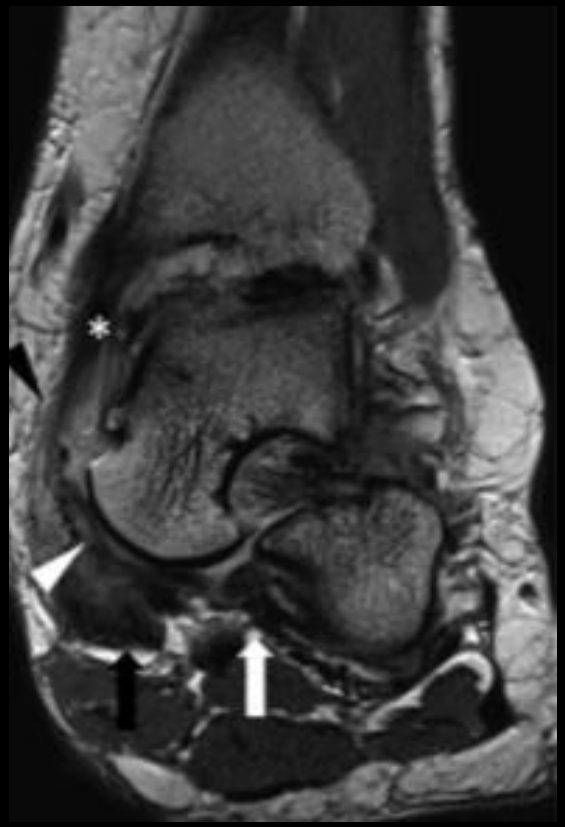


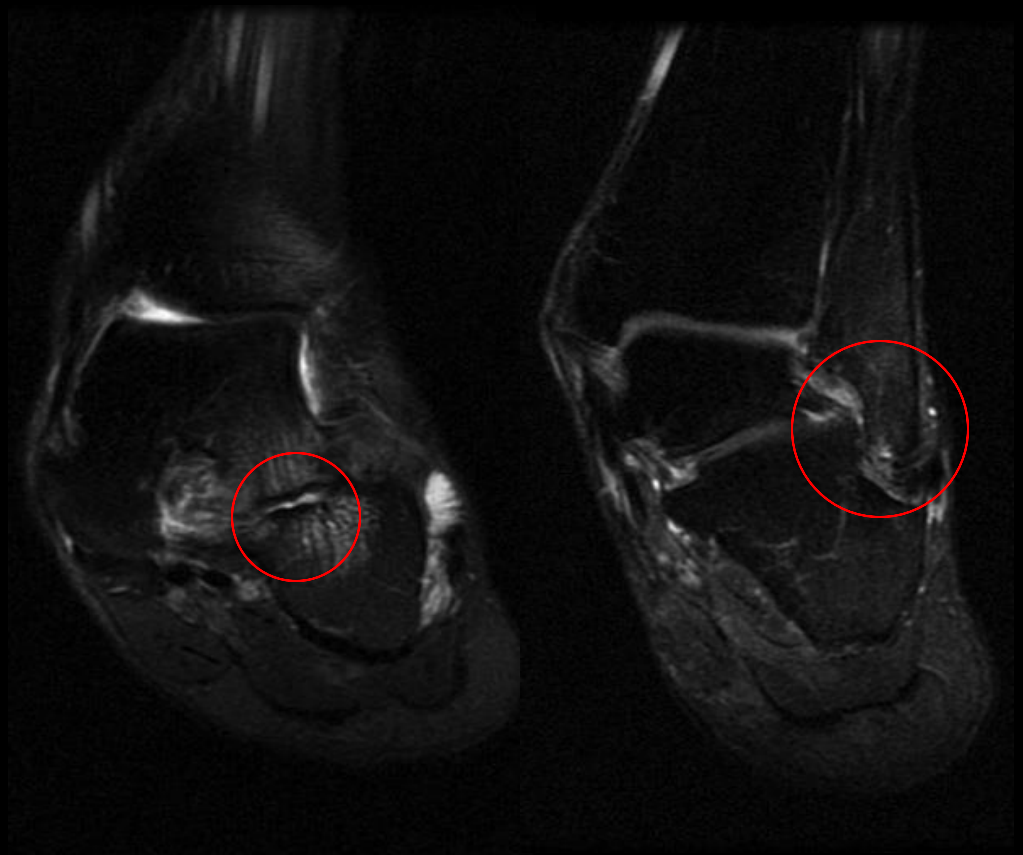
PTT Dysfunction

- Stage III
  - ☑ Type II/III tear w severe Tendinosis/tenosynovitis
  - ☑ Talar uncoverage
  - ☑ Hindfoot valgus
  - ☑ Spring ligament abnormality
  - ☑ Early talocalcaneal and/or calcaneofibular impingement
  - ☑ Subtalar joint OA





Lateral Hindfoot Impingement

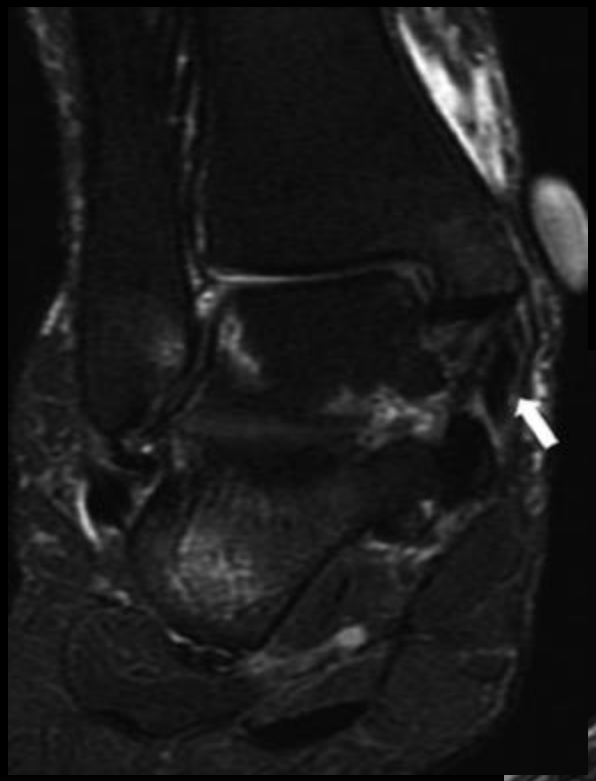


Talocalcaneal Impingement

Subfibular Impingement

PTT Dysfunction

- Stage IV
  - ☑Chronic superficial and deep deltoid sprain
  - ☑Tibiotalar OA
  - ☑Talocalcaneal and calcaneofibular impingement



Treatment

- Stage I:
  - Conservative trial
  - Surgery dictated by condition of PTT - Soft tissue repair/tendon transfer
  - Often combined with medializing calcaneal osteotomy to correct heel valgus and prevent graft failure
- Stage IIA:
  - Medializing calcaneal osteotomy, FDL transfer, and gastrocnemius recession are tx of choice
  - Possible medial column procedure such as cotton osteotomy for first ray stabilization
  - Subtalar athroereisis in children

Vulcano et al Curr Rev Musculoskel Med 2013

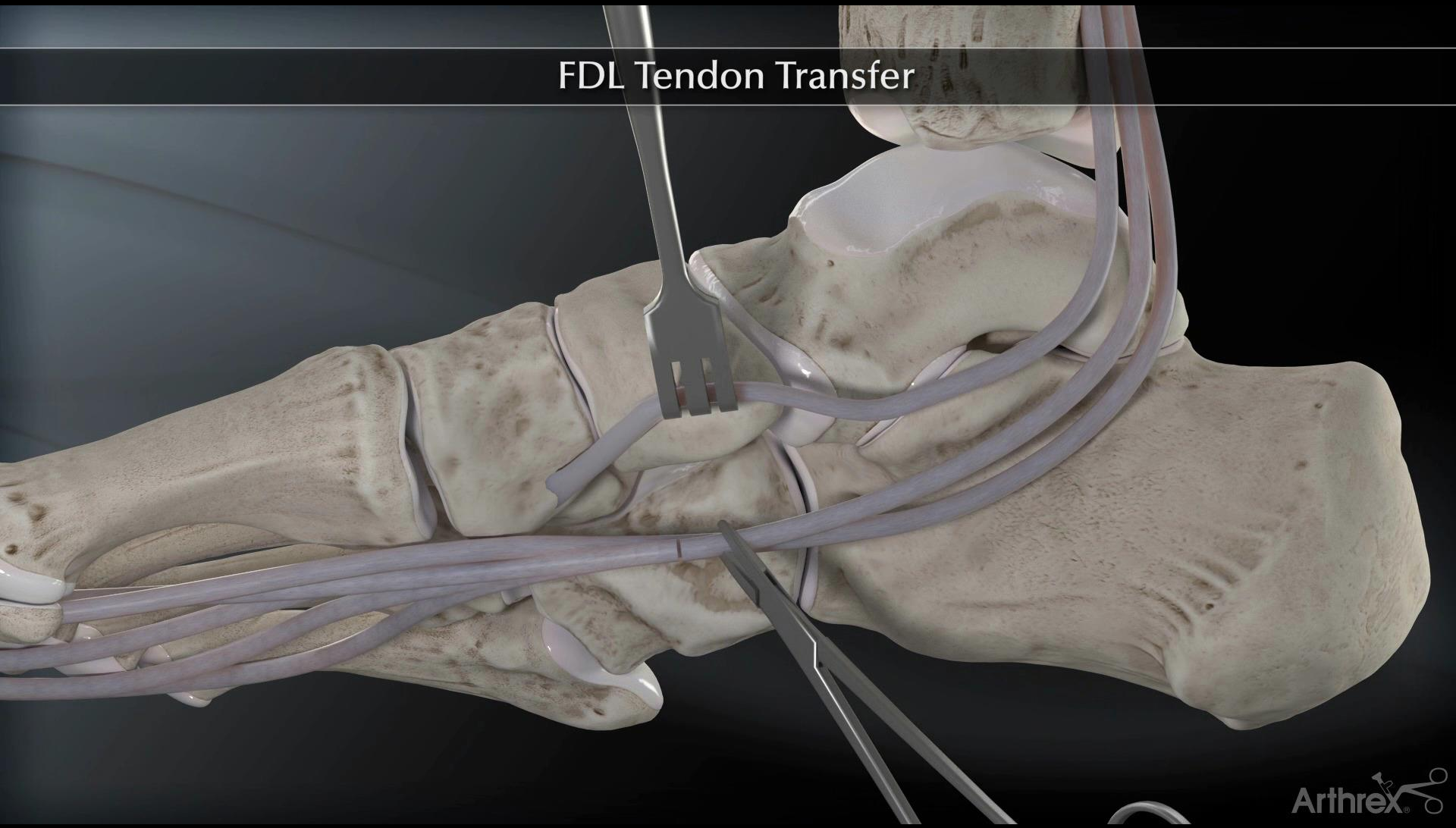
Treatment

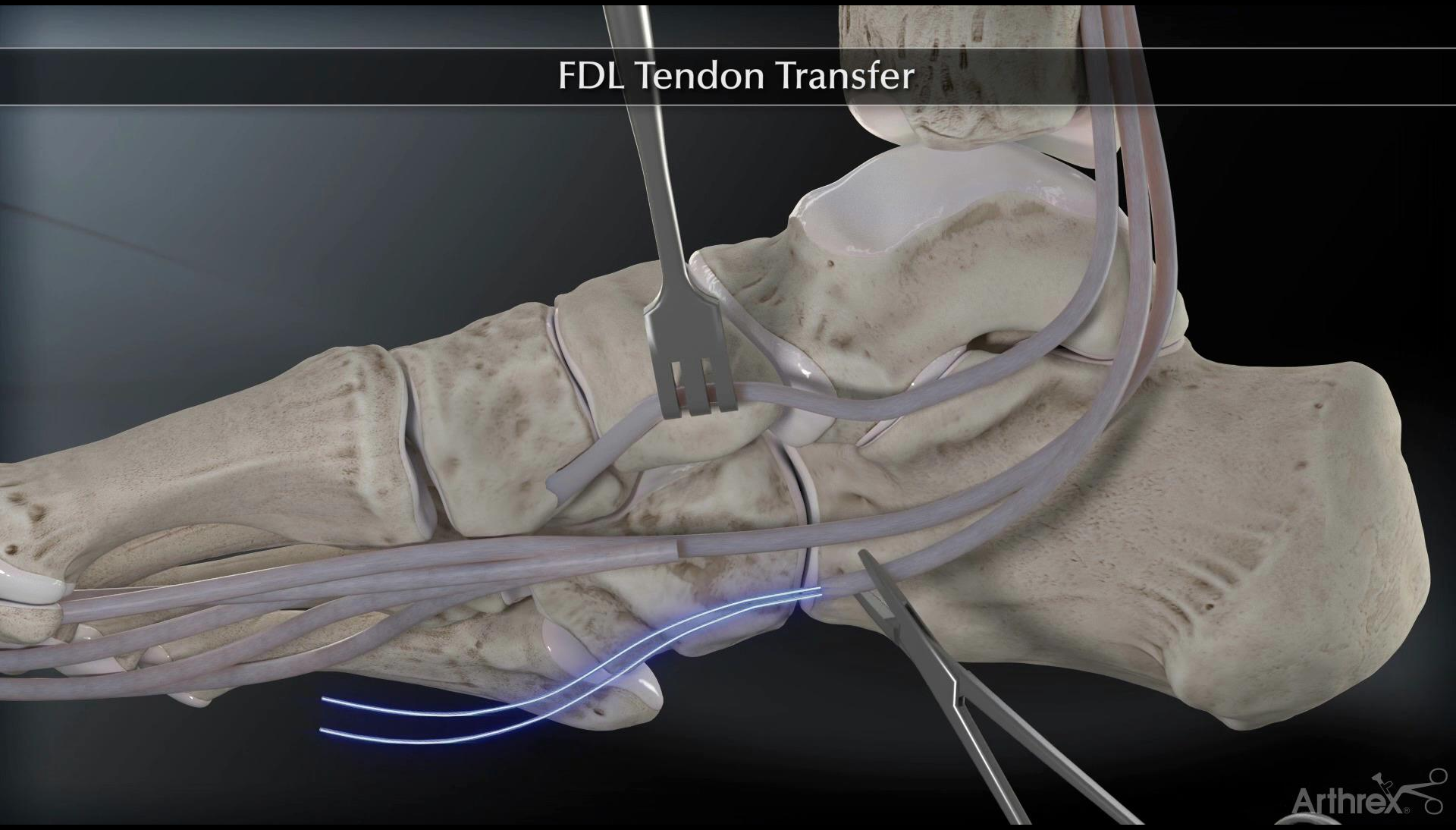
- Stage IIB:
  - Consider adding lateral column lengthening to correct talonavicular joint abduction and increase the foot arch
    - Evans type procedure or calcaneocuboid distraction arthrodesis
- Stage III:
  - Triple arthrodesis or subtalar arthrodesis
- Stage IV:

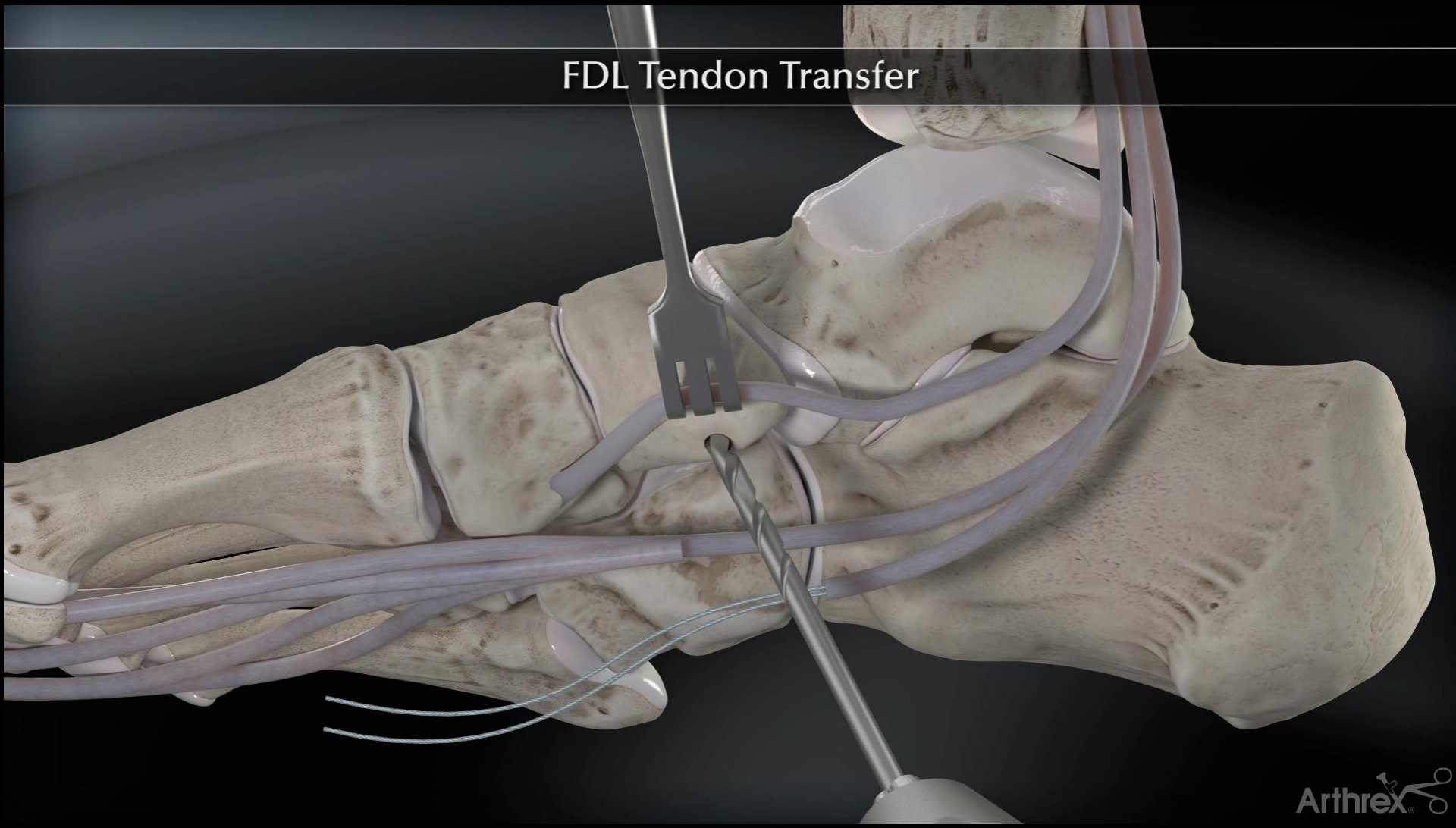
Foot/ankle deformity	Non-Arthritic, Flexible ankle	Rigid or arthritic ankle
Flexible Foot	Flatfoot reconstruction with deltoid reconstruction	Flatfoot reconstruction with ankle fusion or TAR
Rigid Foot	Triple arthrodesis with deltoid reconstruction	Triple arthrodesis with TAR or pantalar fusion

Vulcano et al Curr Rev Musculoskel Med 2013

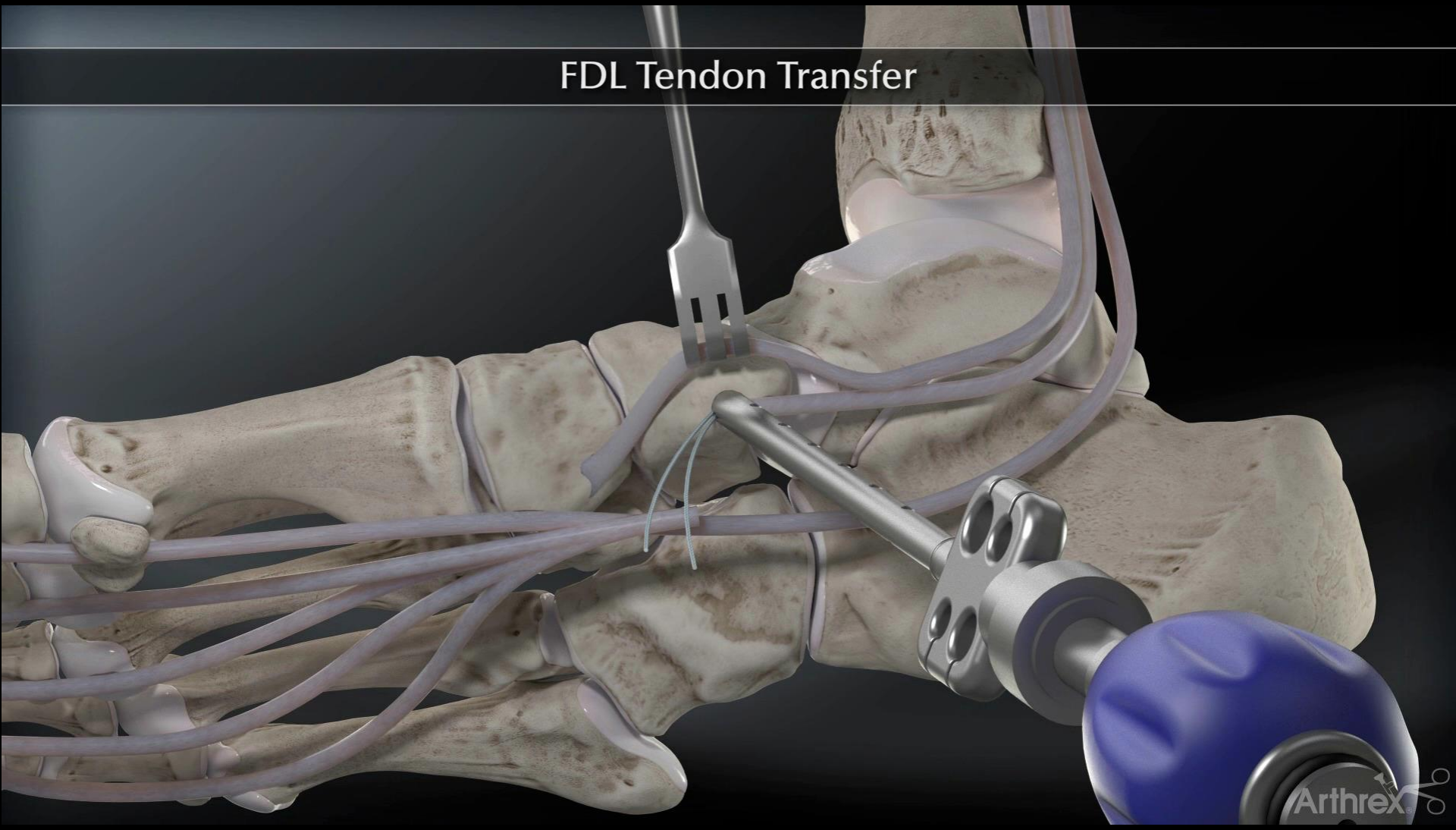
SOFT TISSUE RECONSTRUCTION



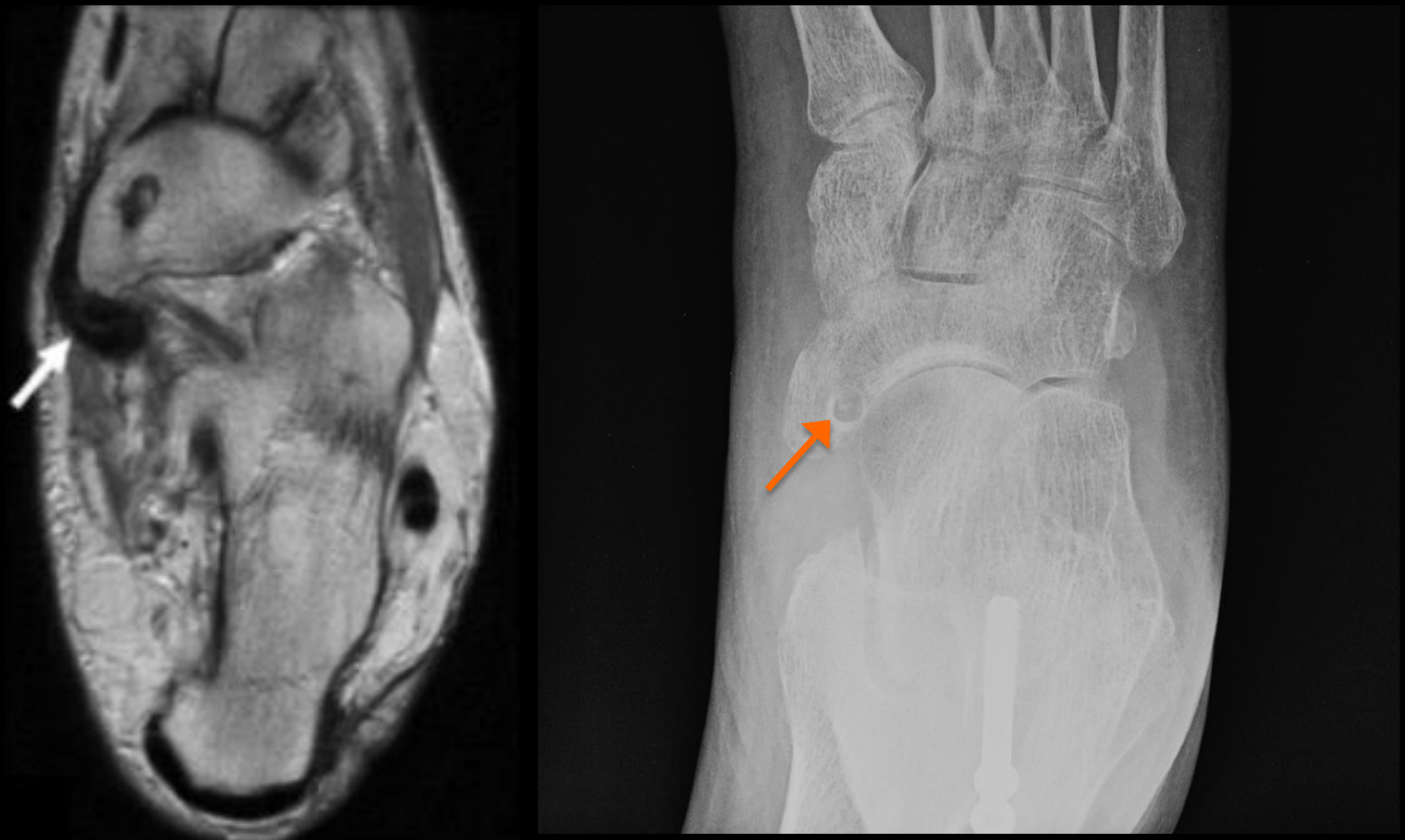

FDL Tendon Transfer
Arthrex


FDL Tendon Transfer
Arthrex

FDL Tendon Transfer

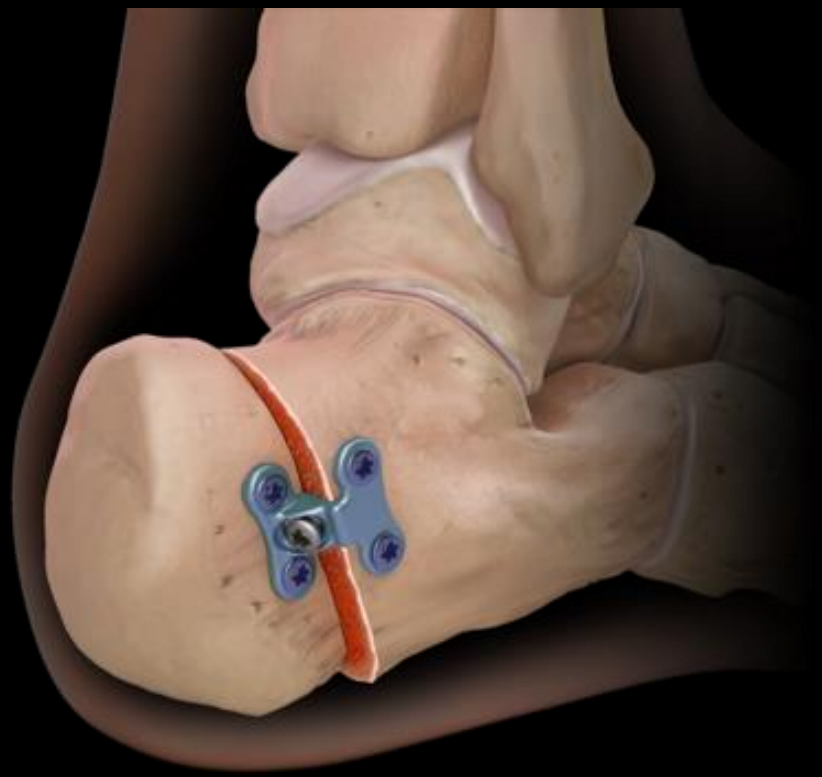


Sofka Journal of Magnetic Resonance Imaging 2011

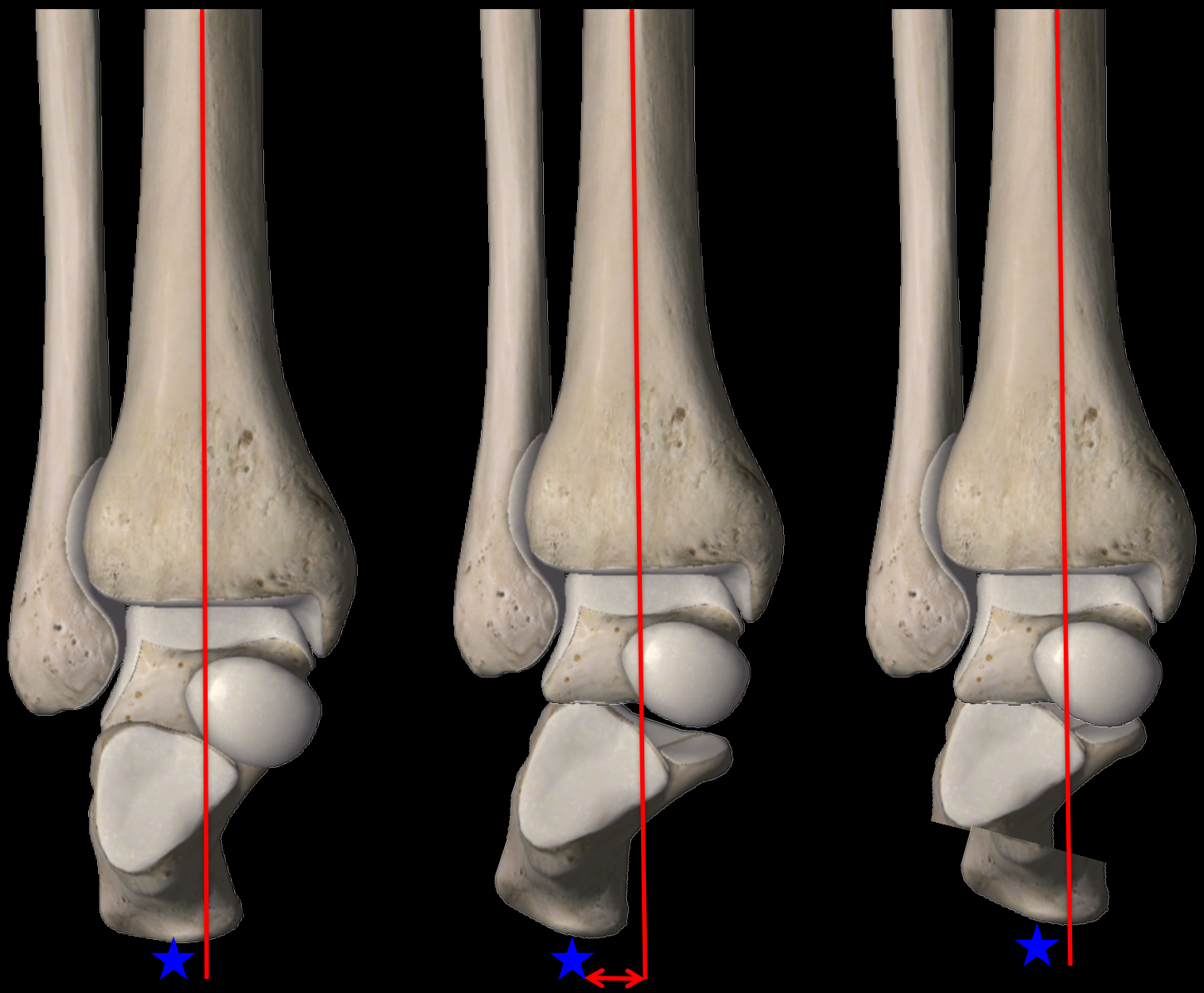


Sofka Journal of Magnetic Resonance Imaging 2011

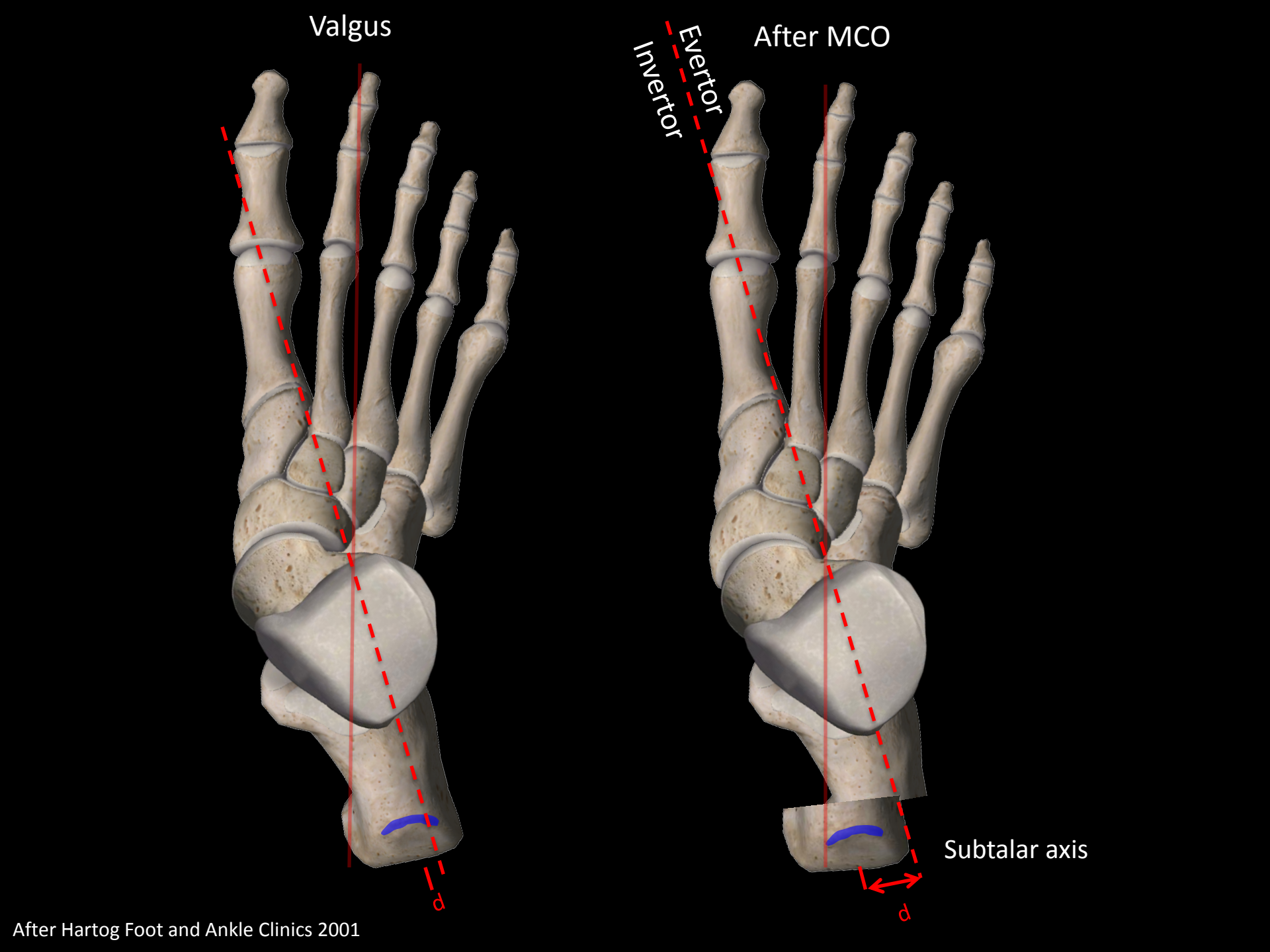
MEDIALIZING CALCANEAL OSTEOTOMY



- Rationale
  - Realign the hindfoot from heel valgus
  - Reduce antagonistic forces on relatively weak FDL tendon transfer
  - Medializes the pull of the Achilles tendon
  - Shifts body weight support from medial to lateral column



After Jastifer et al. Foot and Ankle Specialist 2015



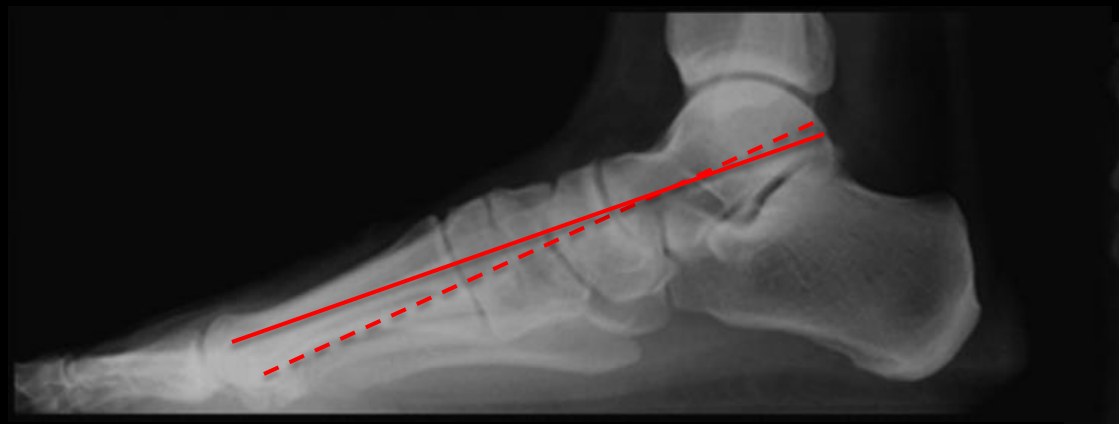
After Hartog Foot and Ankle Clinics 2001

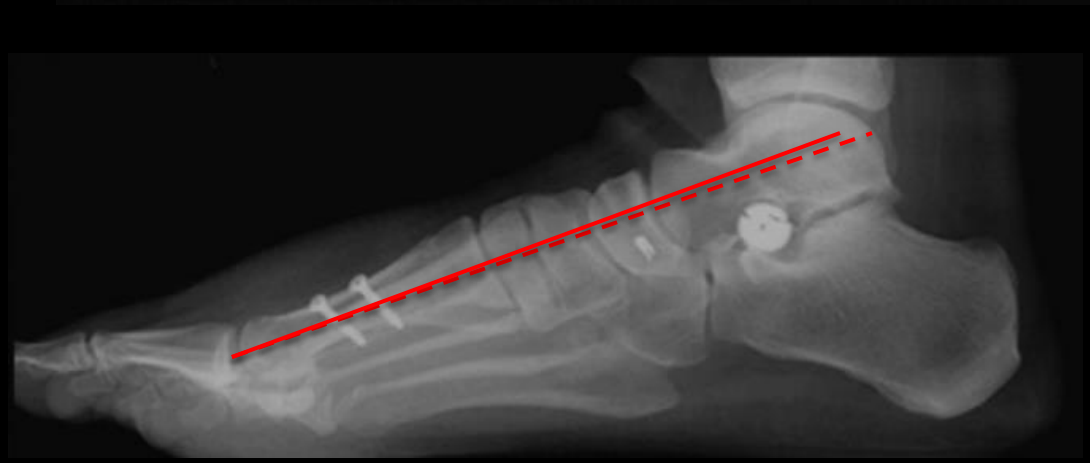
Hartog Foot and Ankle Clinics 2001

SUBTALAR ARTHROEREISIS

- Elevation of the subtalar joint and correction of hindfoot valgus through insertion of a prosthetic cylinder screw into the sinus tarsi
- Adjunct procedure for young patients patients with mild variants of PTTD
- Aids in correction of hindfoot deformity and protects the medial soft tissue reconstruction

SUBTALAR ARTHROEREISIS

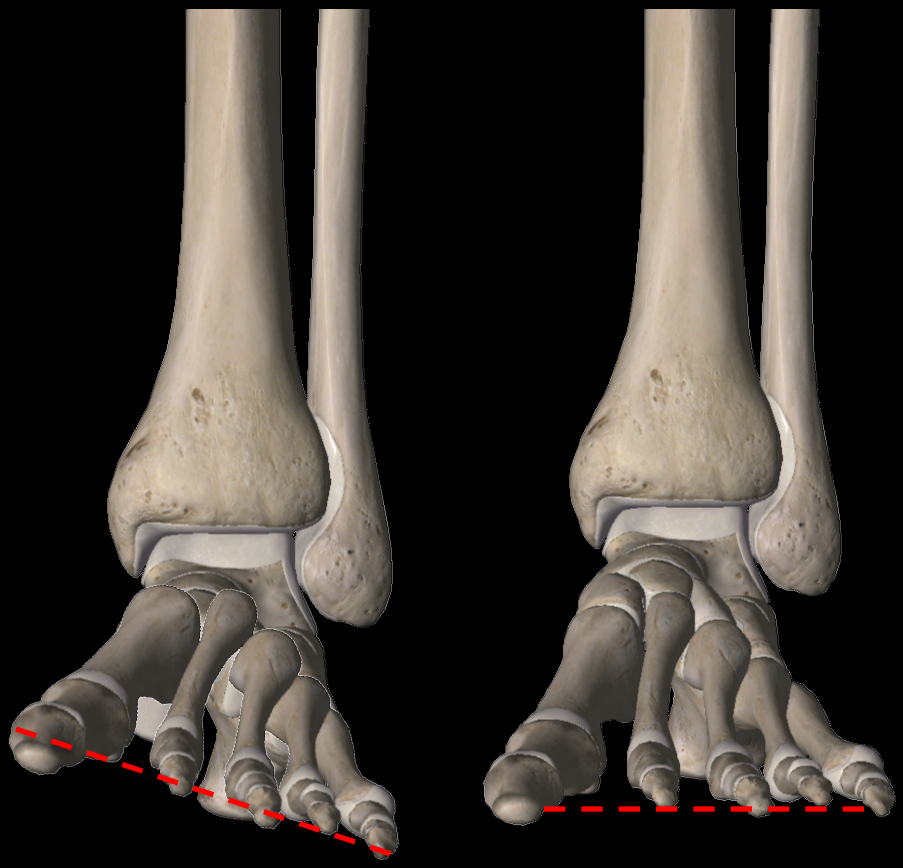




Cook et al Journal of Foot and Ankle Surgery 2011

MEDIAL COLUMN STABILIZATION

- Persistent hindfoot valgus results in first ray elevation or forefoot varus, which can be flexible and correctable or rigid and fixed
- Goal is to correct forefoot varus and stabilize the medial column



Forefoot varus

MEDIAL COLUMN STABILIZATION

- Procedures include:
  - Naviculocuneiform arthrodesis
  - Opening wedge medial Cuneiform osteotomy (Cotton)
  - First TMT arthrodesis (Lapidus)
- Often performed in conjunction with lateral procedures

Cotton osteotomy

Lapidus Procedure

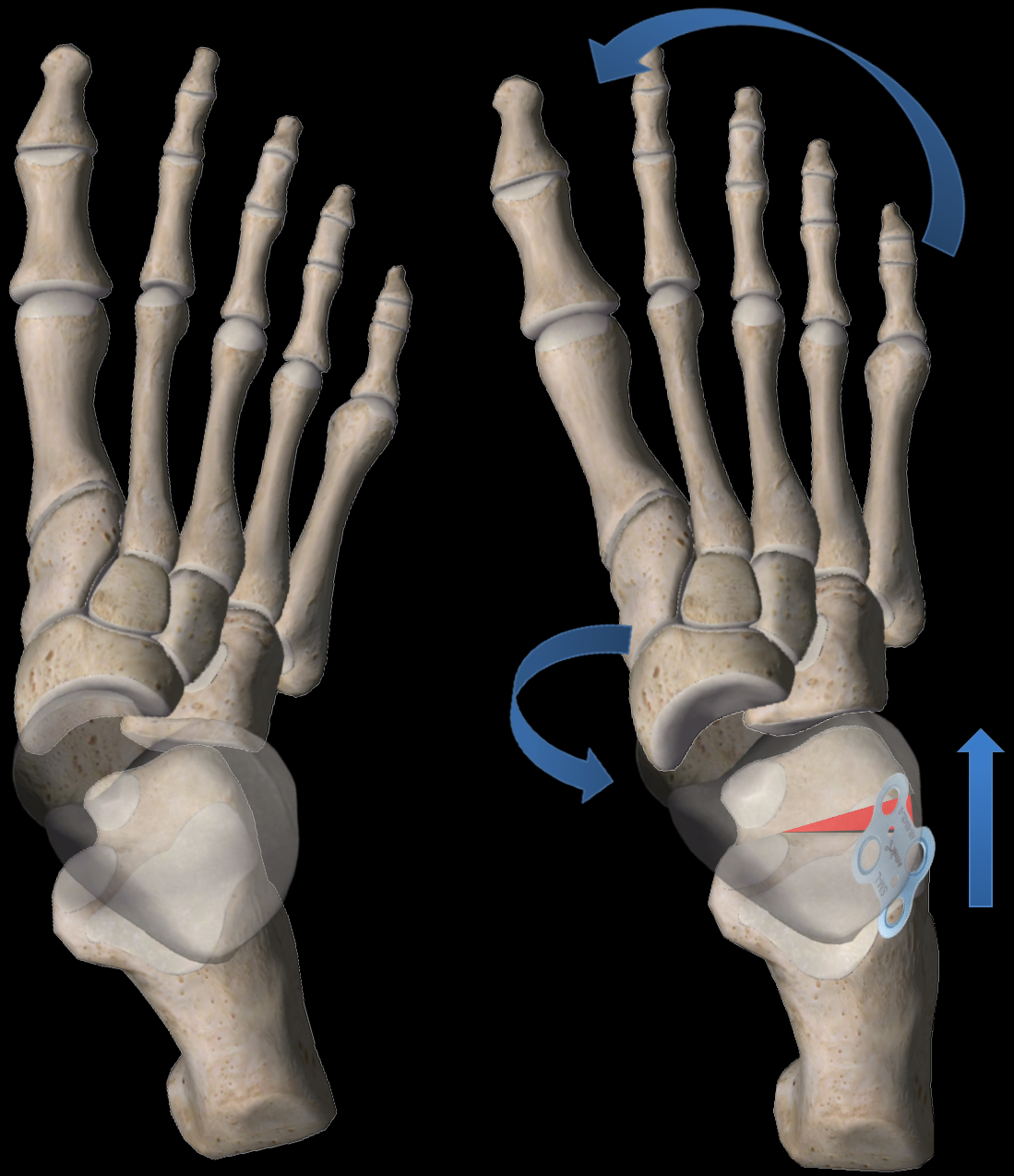
MEDIAL COLUMN STABILIZATION

LATERAL COLUMN LENGHTENING

- 3-Dimensional correction that adducts the foot at the talonavicular joint by lengthening the lateral column and derotates the hindfoot out of valgus
- Transfers the weightbearing load to the lateral column
- Calcaneocuboid distraction arthrodesis
- Lateral column lengthening through the distal calcaneus (Evans)

Evans Procedure

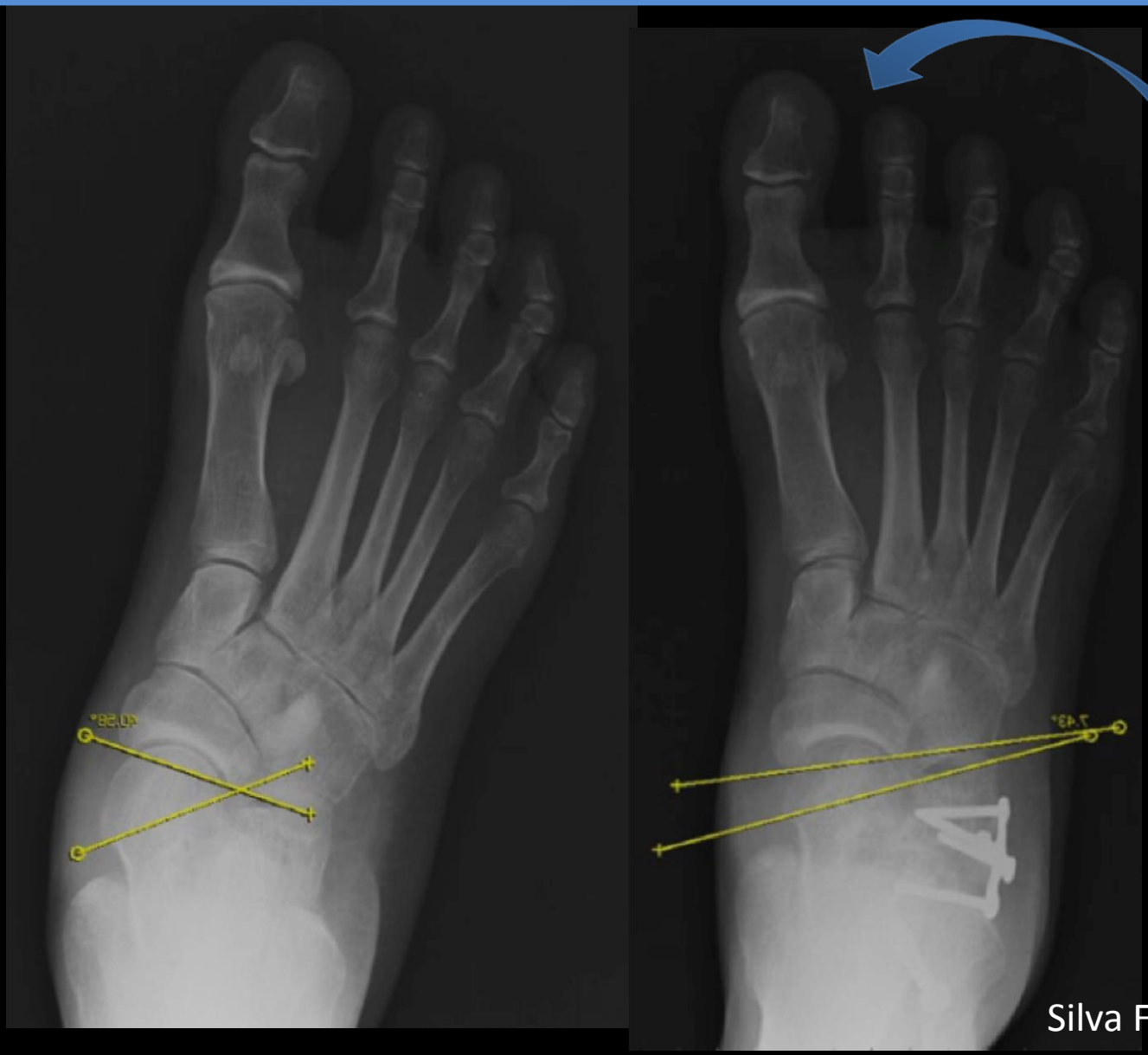
Abducted
Forefoot



Lateral Column
Lengthened to
Correct abduction

Evans Osteotomy

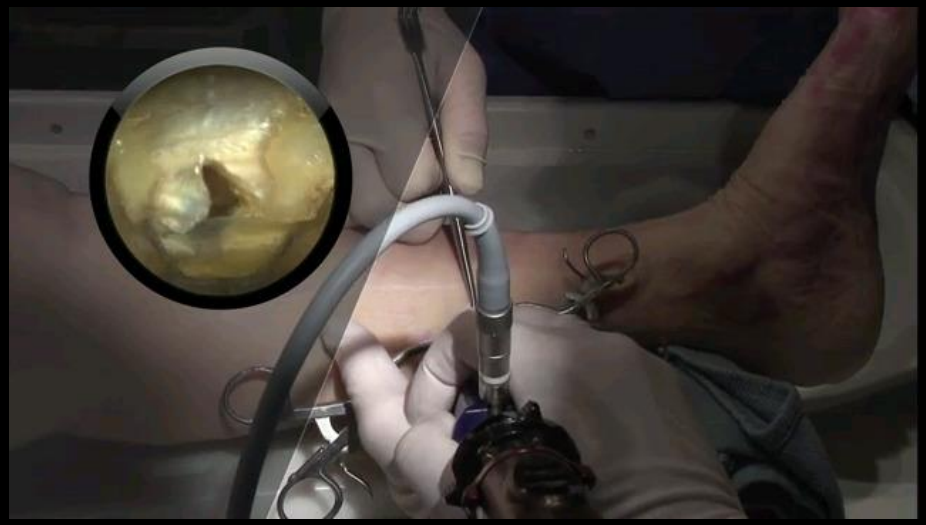
LATERAL COLUMN LENGHTENING



Silva Foot& ankle Int 2015

GASTROCNEMIUS RECESSION/ACHILLES LENGTHENING

- A tight gastrocnemius or Achilles tendon can be responsible for causing or aggravating heel valgus
- Addressed with either gastrocnemius recession or percutaneous Achilles lengthening



TRIPLE ARTHRODESIS

- Historically, triple arthrodesis is the gold standard for surgical correction of rigid flatfoot deformity
  - Subtalar
  - Calcaneocuboid
  - Talonavicular
- Converts the hindfoot into one osseous unit
- Negates the need for medial and lateral muscular stability at the ankle
- Stage III disease
- In some cases it may be possible to preserve joints

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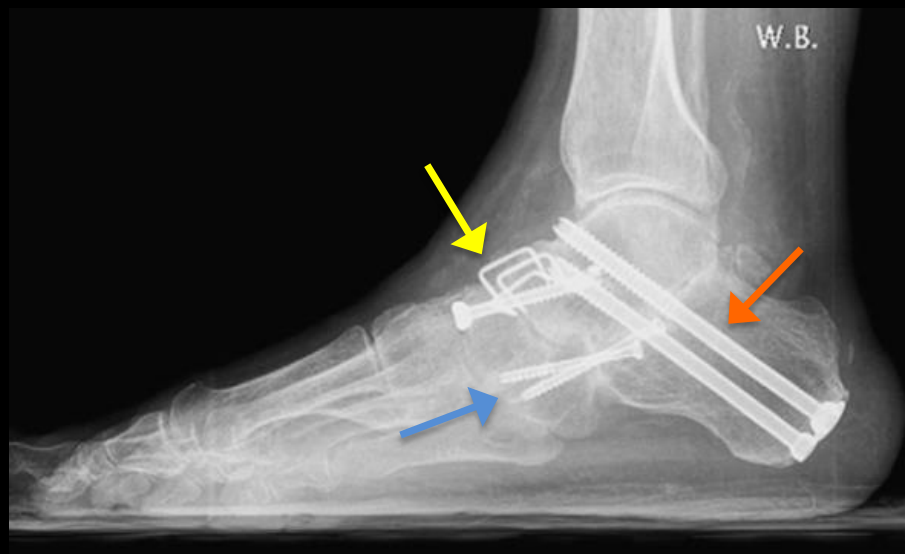
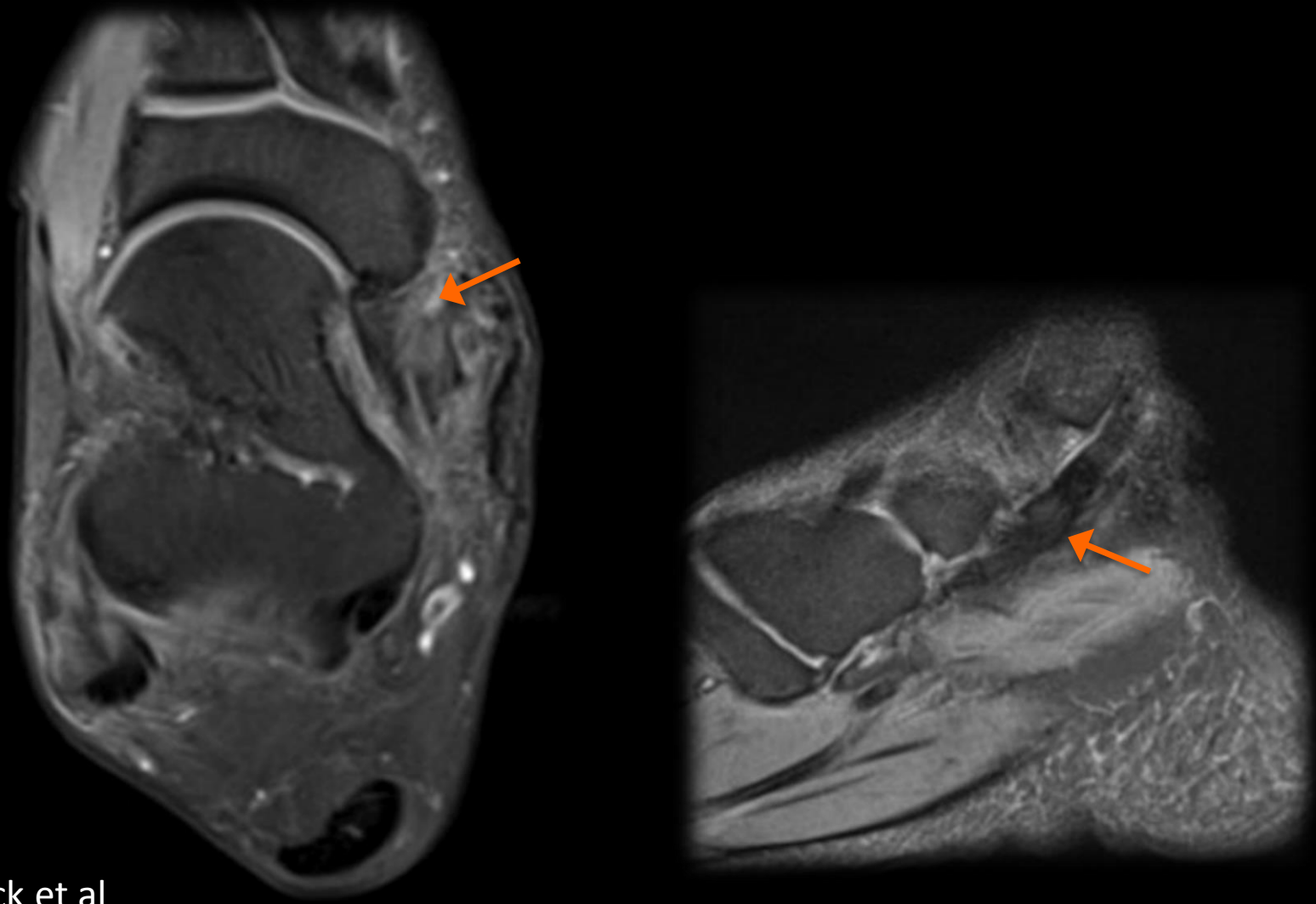


Wilson et al Foot and Ankle Clinics 2007

COMPLICATIONS

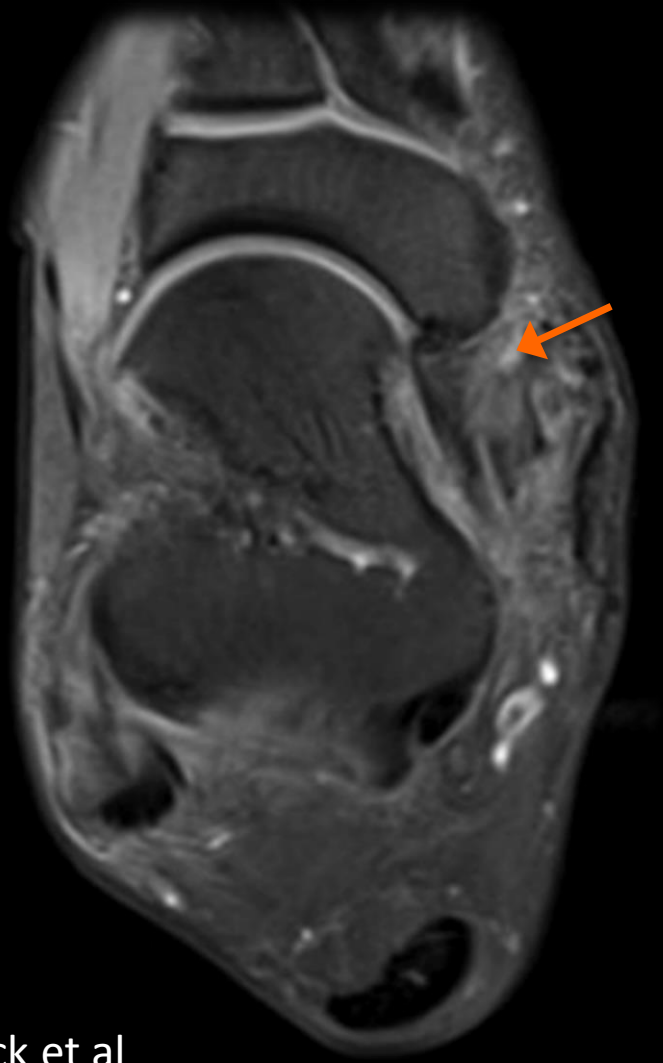
- FDL Tendinosis/Failure
- Arthroereisis plug migration/Sinus Tarsi syndrome
- Osteotomy Nonunion
- Hardware failure
- Talar Dome Injury
- Lateral Column Overload
- Nerve Injury

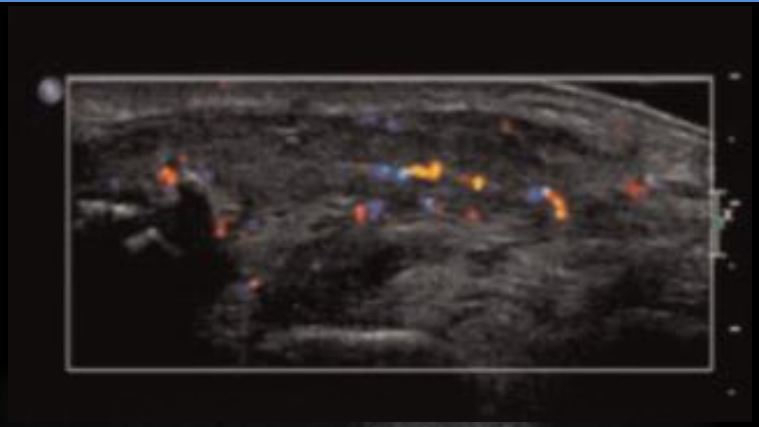
Postoperative Tendinitis

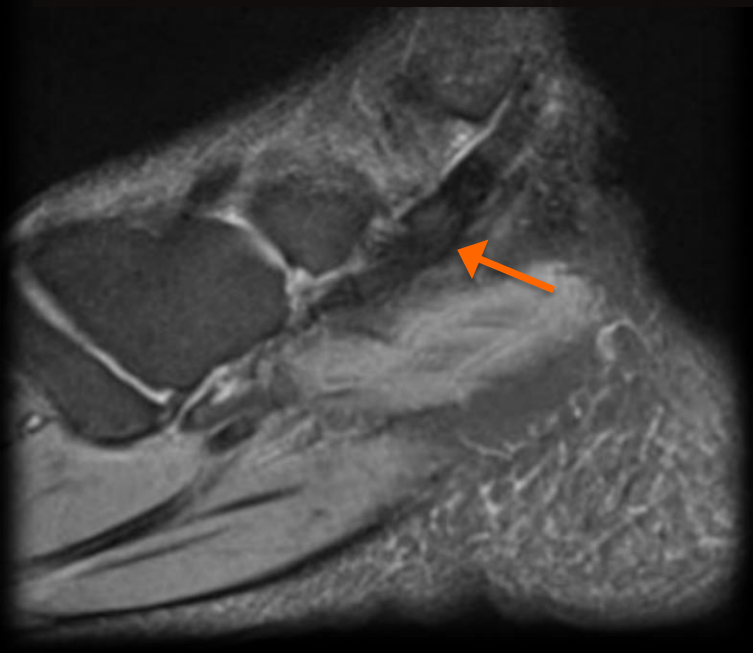


Dimmick et al

Postoperative Tendinitis

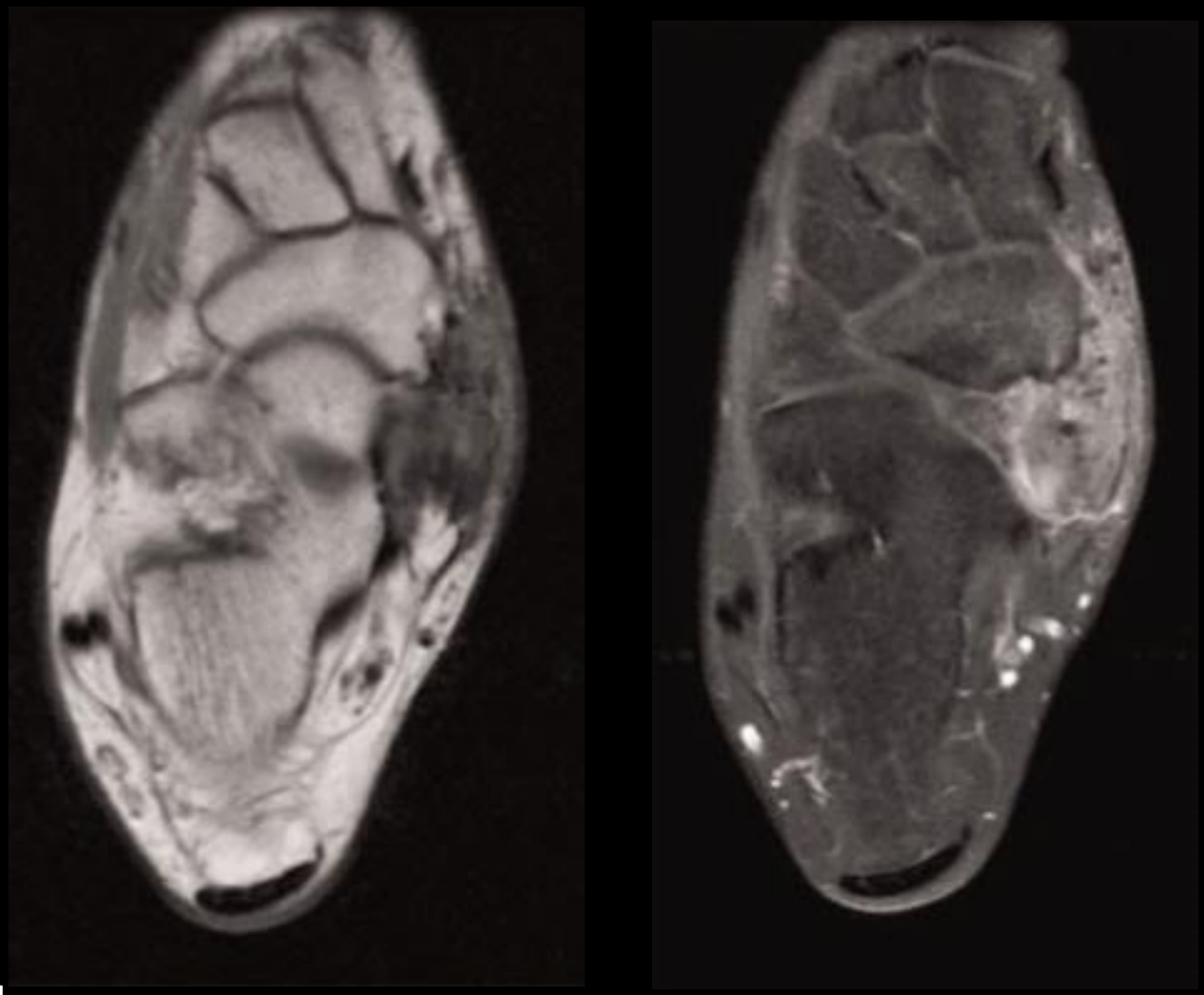






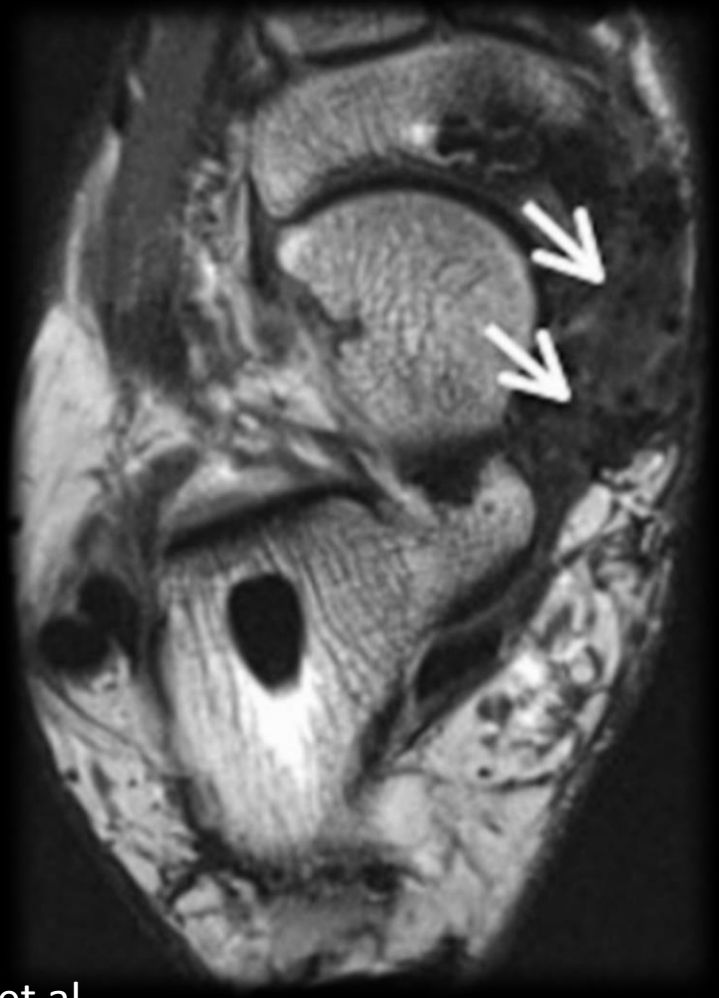
Dimmick et al

Postoperative Tendinitis



Dimmick et al

FDL TRANSFER FAILURE



Dimmick et al

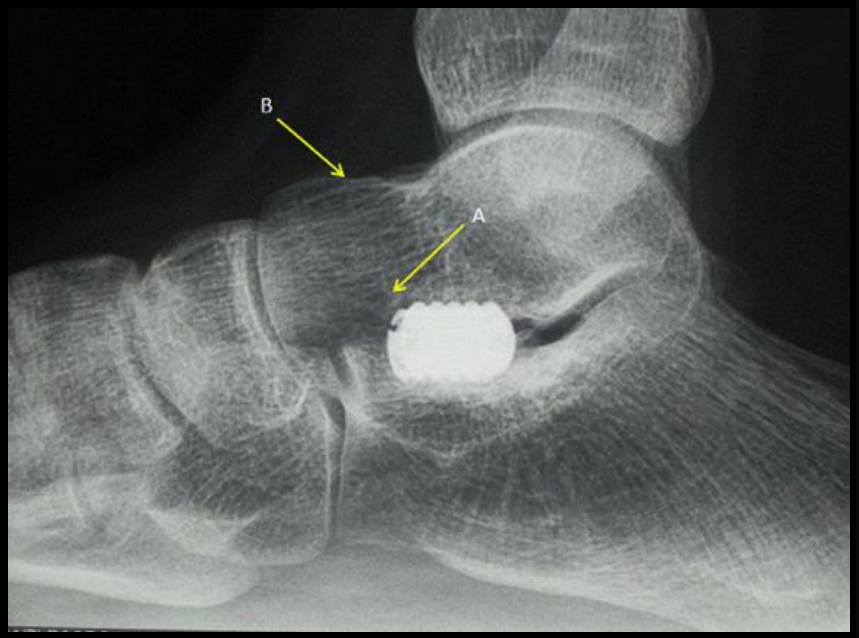
ARTHROERESIS PLUG MIGRATION

Corpuz et al

ARTHROERESIS PLUG EXTRUSION

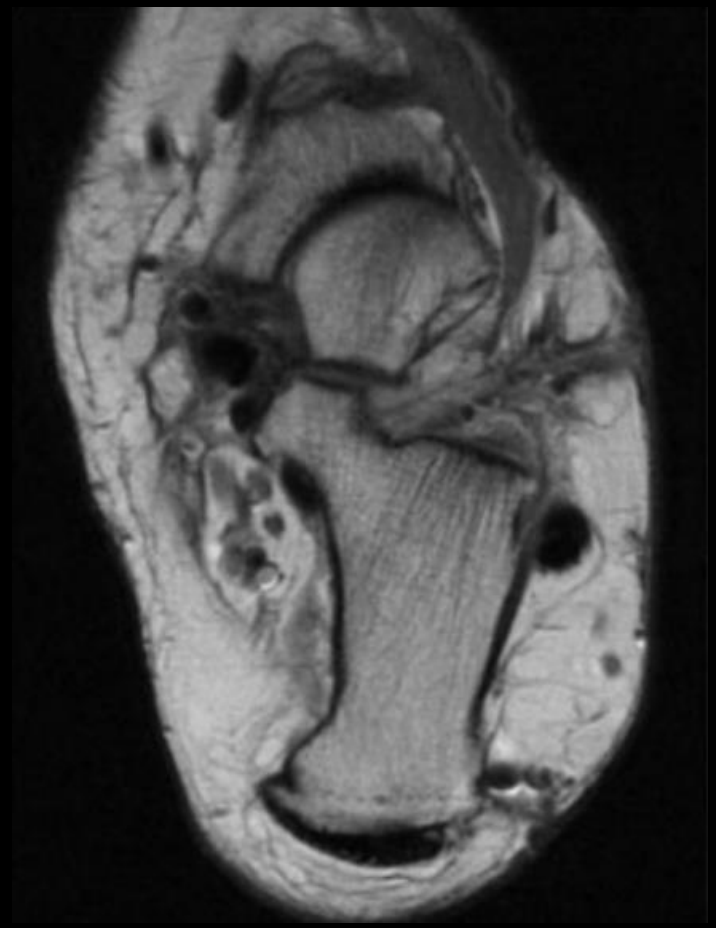
Dimmick et al

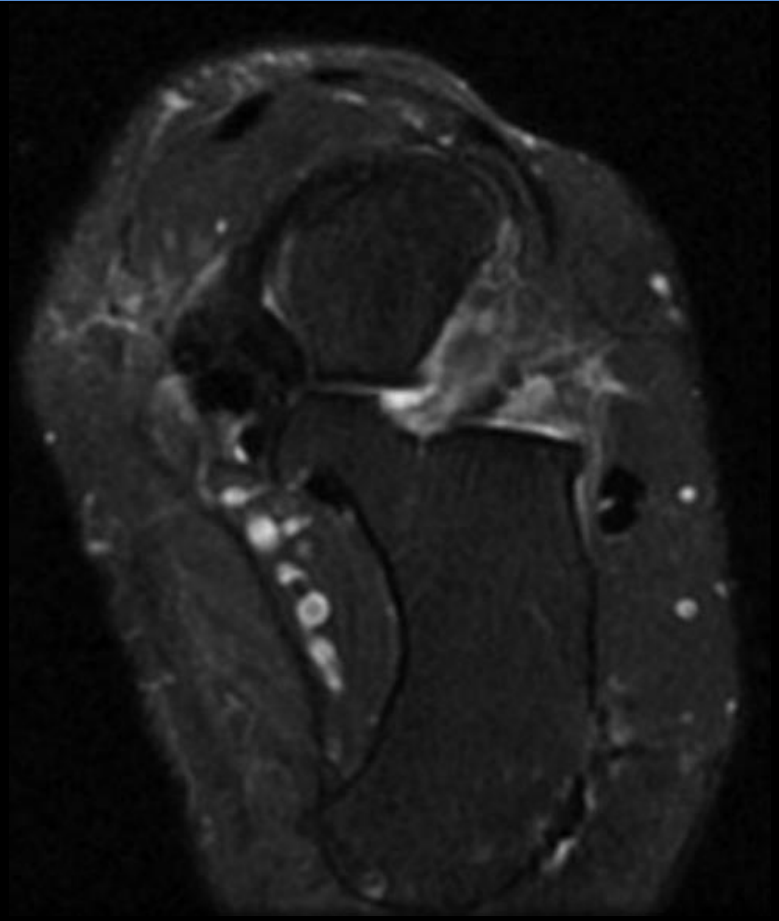
Talar Fracture Complicating Subtalar Arthroereisis



Corpuz et al

SINUS TARSI SYNDROME





Dimmick et al

TALAR DOME OSTEONECROSIS

Hermus Journal of Foot and Ankle Surgery 2011

TIBIOTALAR JOINT VIOLATION

Dimmick et al

NONUNION

Medializing calcaneal osteotomy

Dimmick et al

Lateral Column Lengthening
Calcaneal Osteotomy

NONUNION

Dimmick et al

ADJACENT JOINT OSTEOARTHRITIS

Dimmick et al

3 months

Haddad Foot and Ankle International 2009

9 months

Haddad Foot and Ankle International 2009

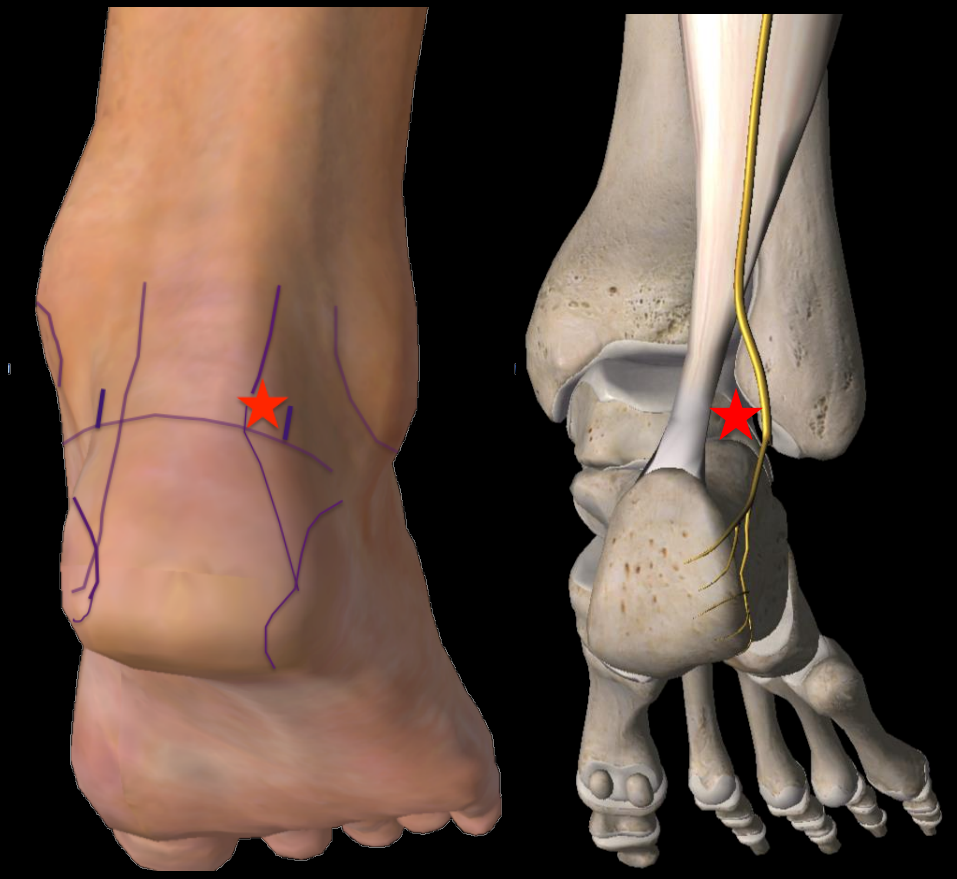
Lateral Column Overload

- Excessive varus alignment of the forefoot after lateral column lengthening can overload the lateral foot.
- Can be seen with CCDA, Evans procedure or triple arthrodesis

Tien Foot and Ankle International 2005

NERVE INJURY

- Posterolateral Portal
  - Just lateral to the Achilles tendon and about one-half inch proximal to the distal tip of the lateral malleolus
  - Used during LCL
  - Sural nerve at risk
    - Neuropraxia
    - Neuroma formation



Thank You