
3rd Foot and Ankle Symposium

Arthritic disorders of the Foot and Ankle

Imaging

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Outline

Arthritic disorders of the Foot and Ankle

Imaging of Ligaments

Standard

New developments

Imaging of Cartilage

Standard

New developments

Alignment

Standard

New developments

MR Imaging of Ankle Ligaments

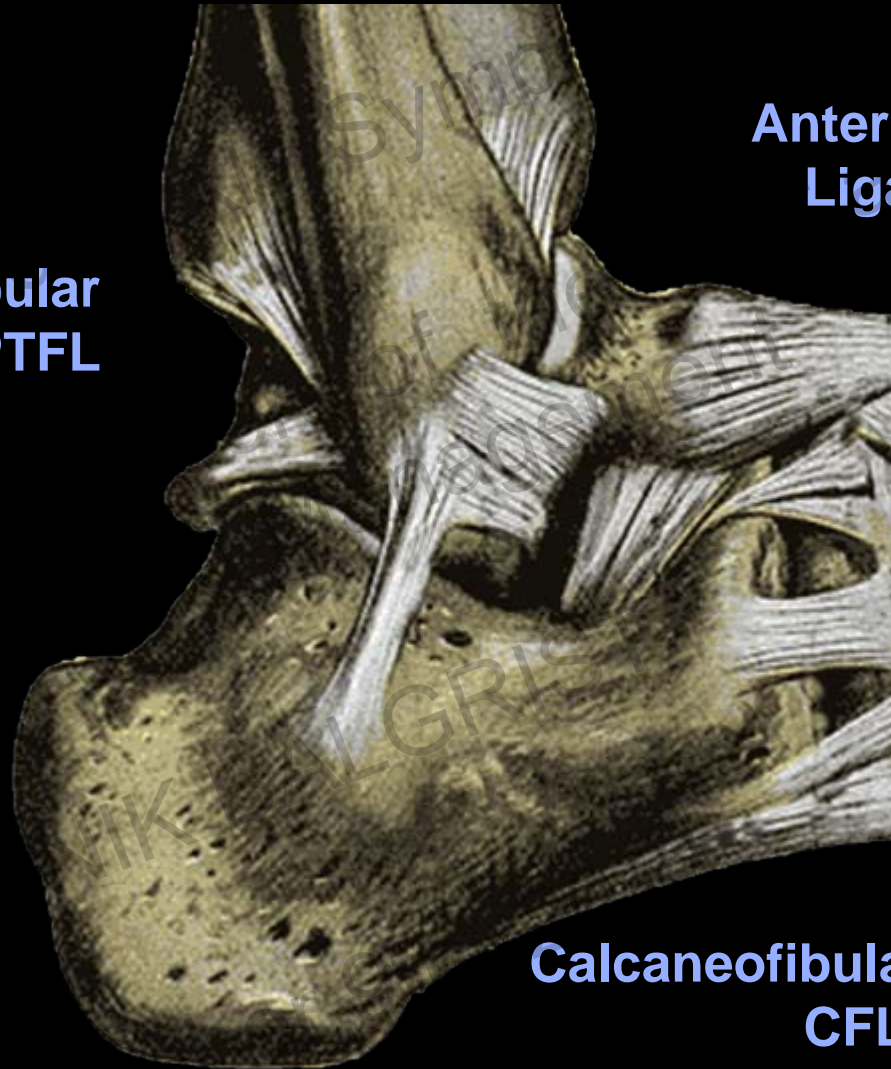
MR Technique:

- High Field (1.5 or 3T)
- Dedicated coil
- Standard T2w Fast spin echo (FSE) images = turbo spin echo (TSE)
- Slice thickness 2-4mm
- Matrix 512 at least in one plane
- Field of view <150 mm



Lateral Ligaments

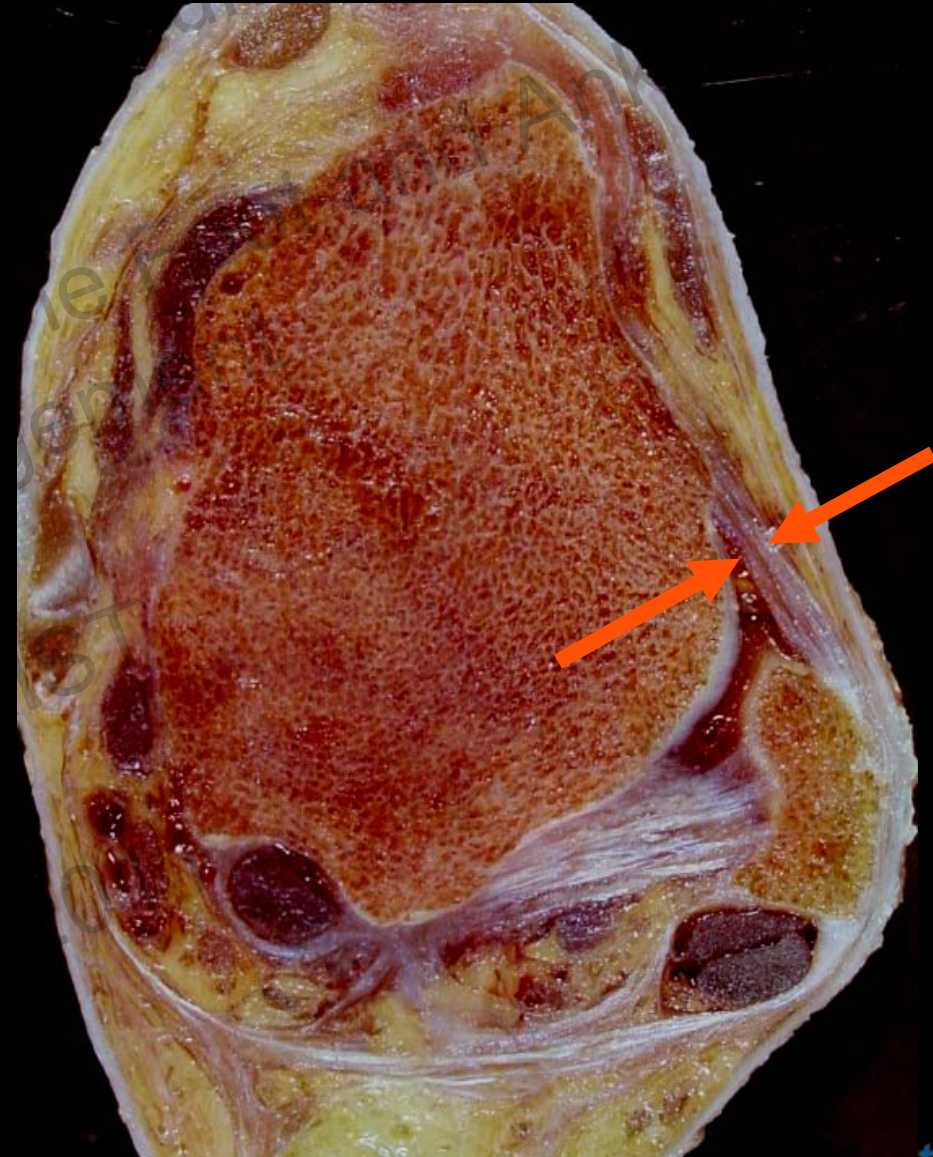
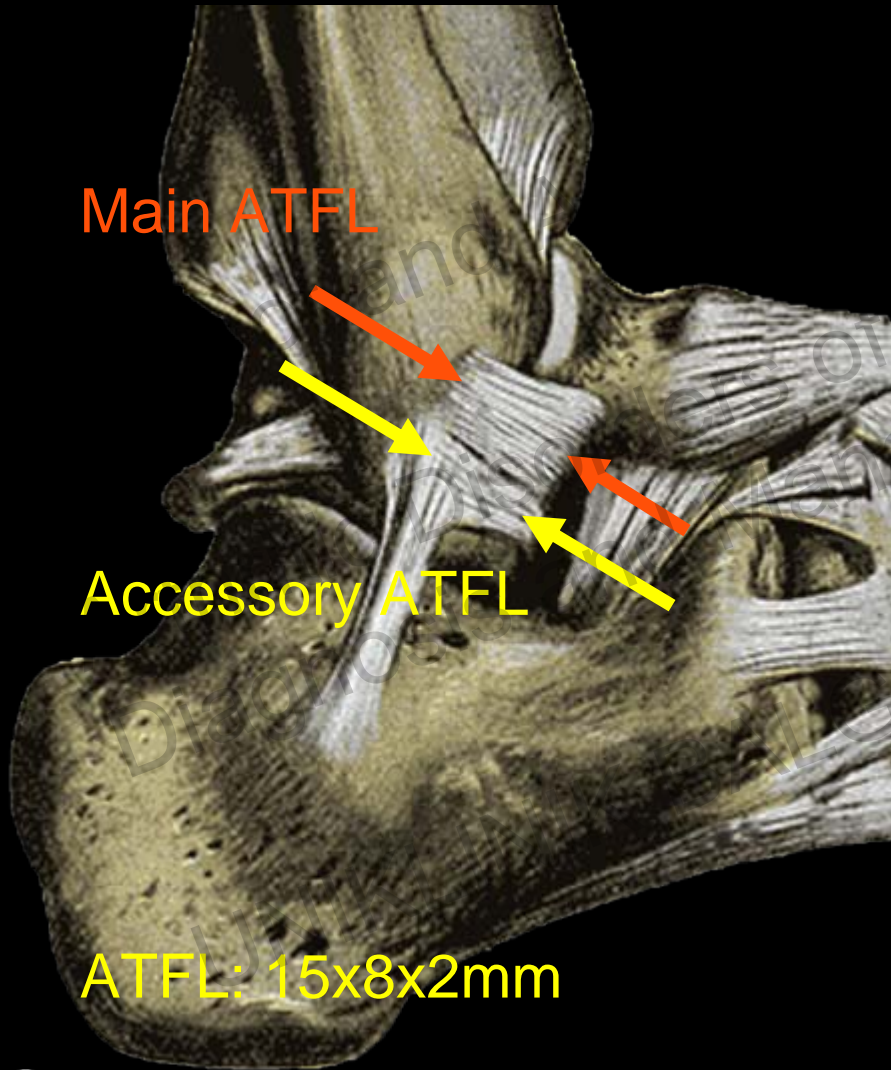
**Posterior Talofibular
Ligament PTFL**



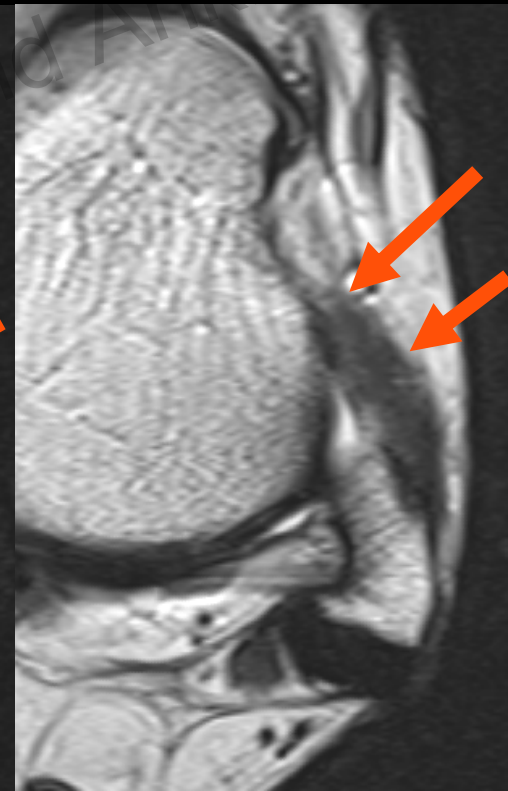
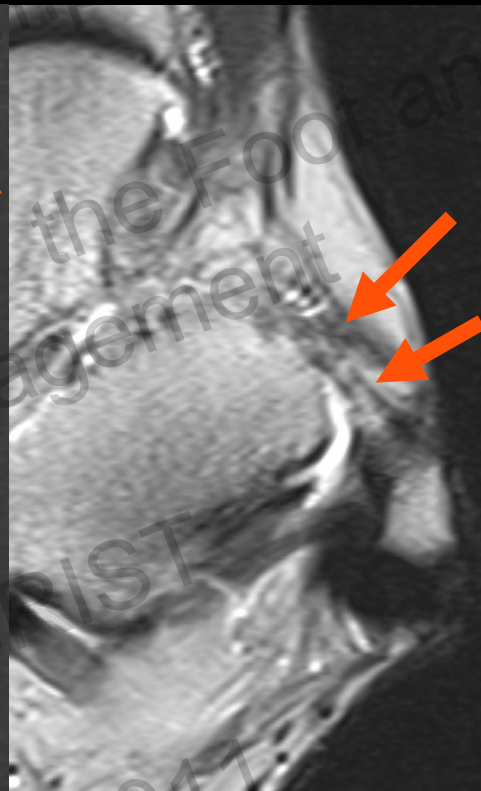
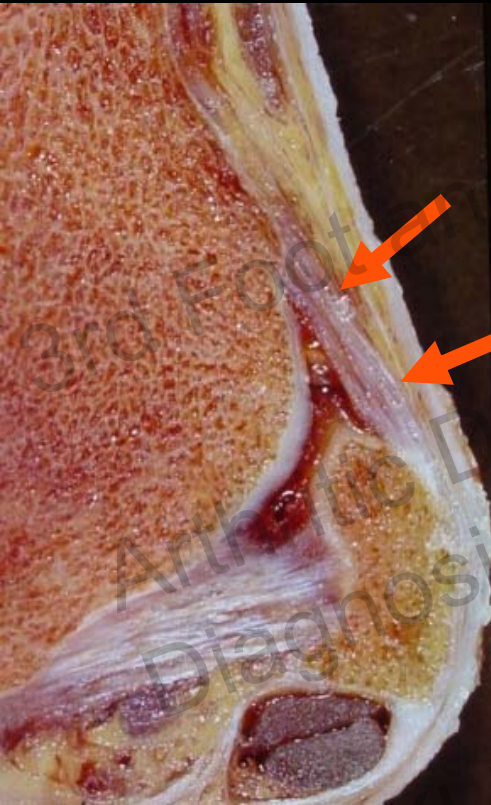
**Anterior Talofibular
Ligament ATFL**

**Calcaneofibular Ligament
CFL**

Anterior Talofibular Ligament ATFL



Anterior Talofibular Ligament ATFL

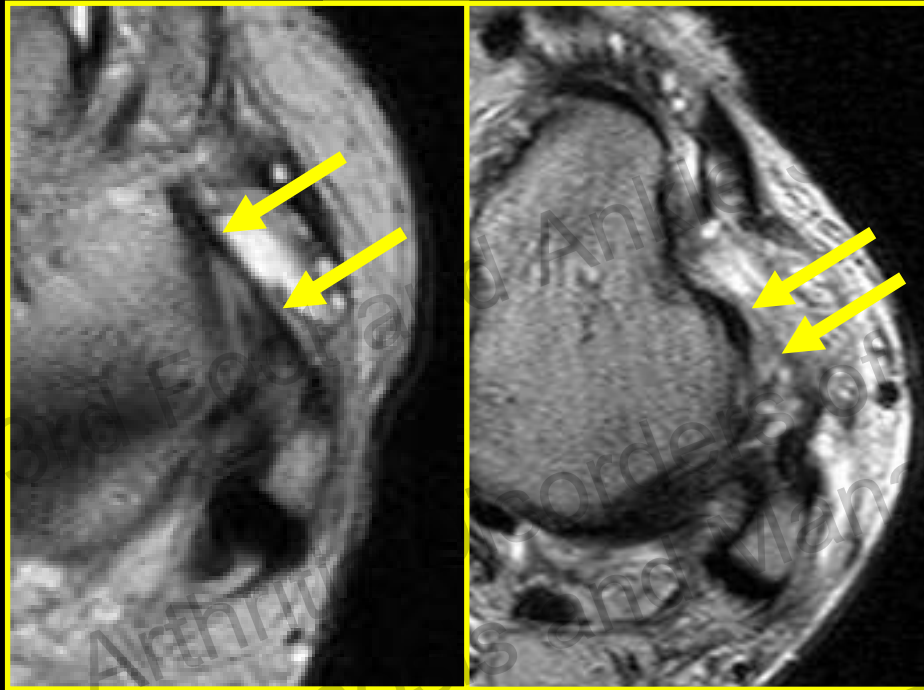


Normal

Tear

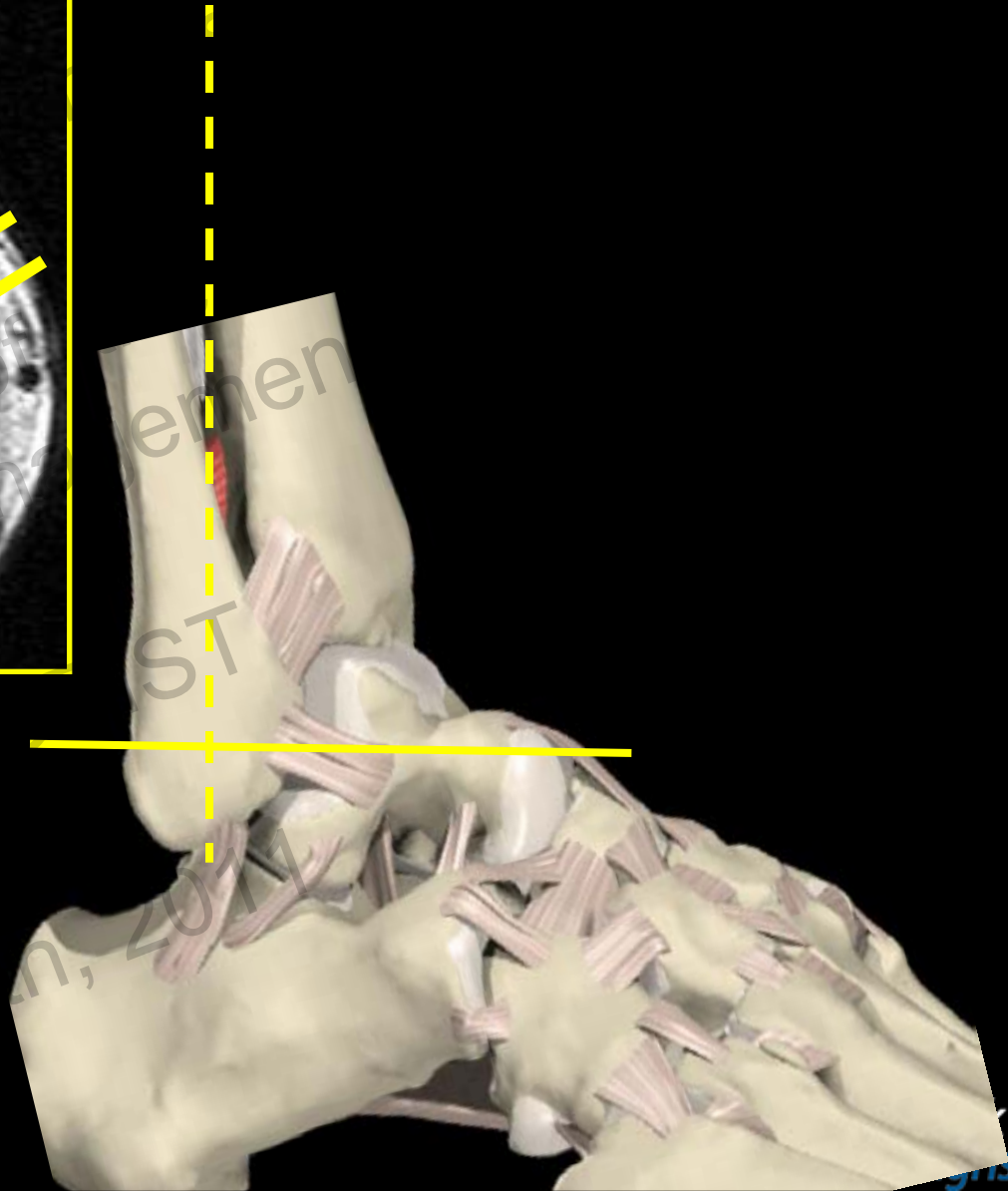
Scaring

Anterior Talofibular Ligament ATFL



Normal Tear

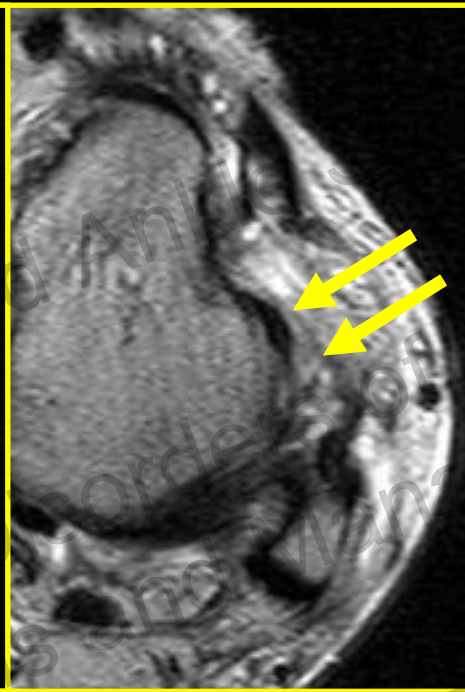
Pitfall: ATFL Pseudotear



Anterior Talofibular Ligament ATFL



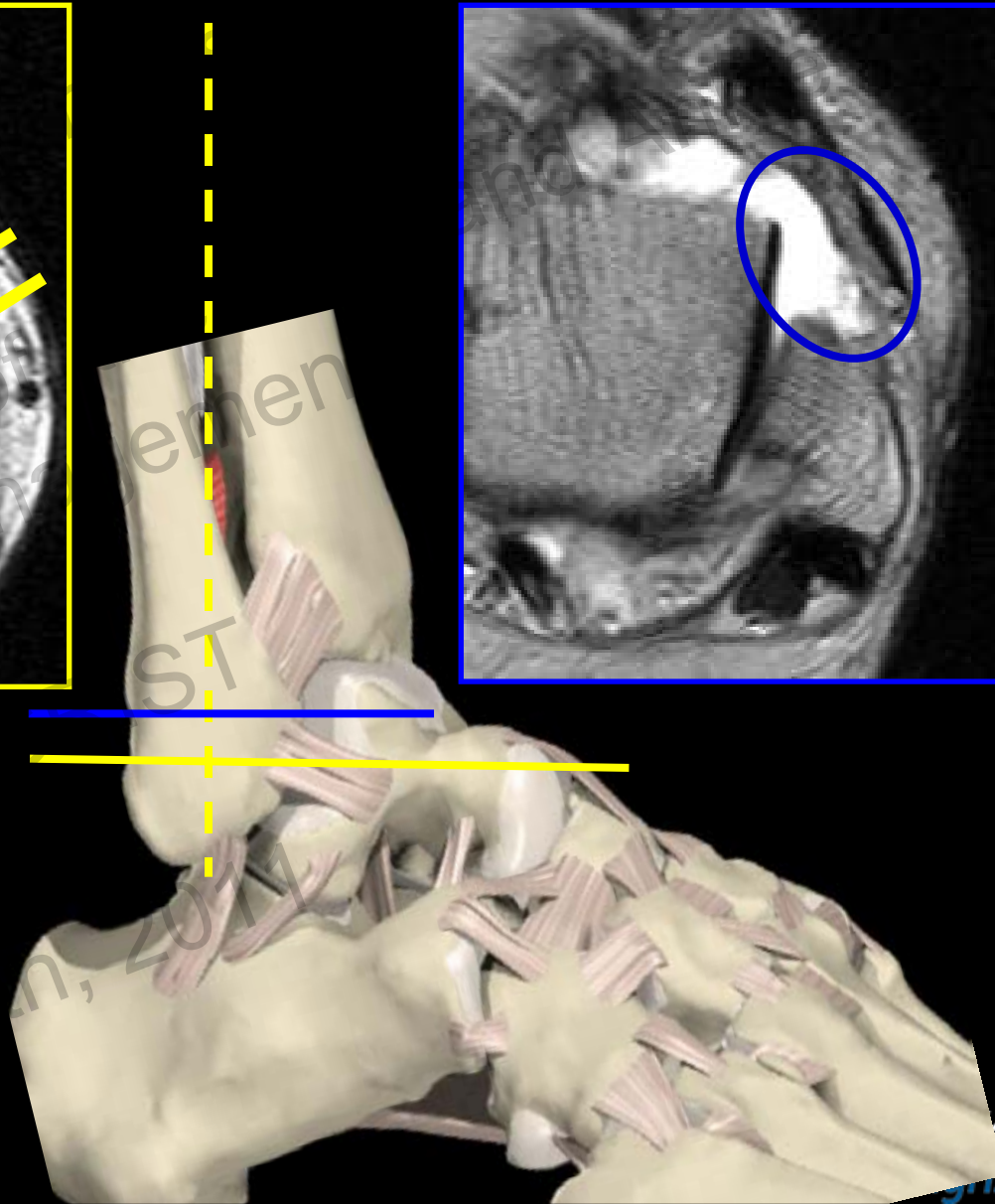
Normal



Tear



Pitfall: ATFL Pseudotear



Calcaneofibular Ligament CFL

75%

10-45°

19%

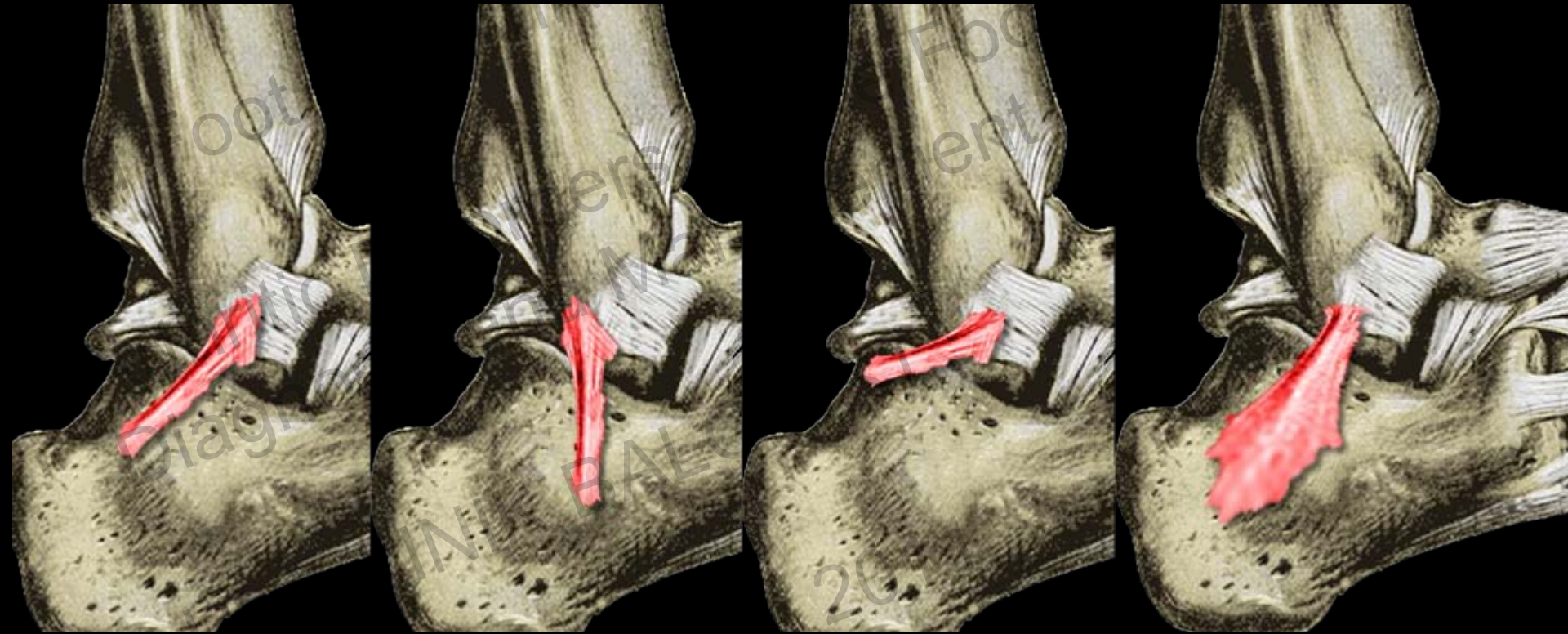
0°

4%

90°

3%

Fan

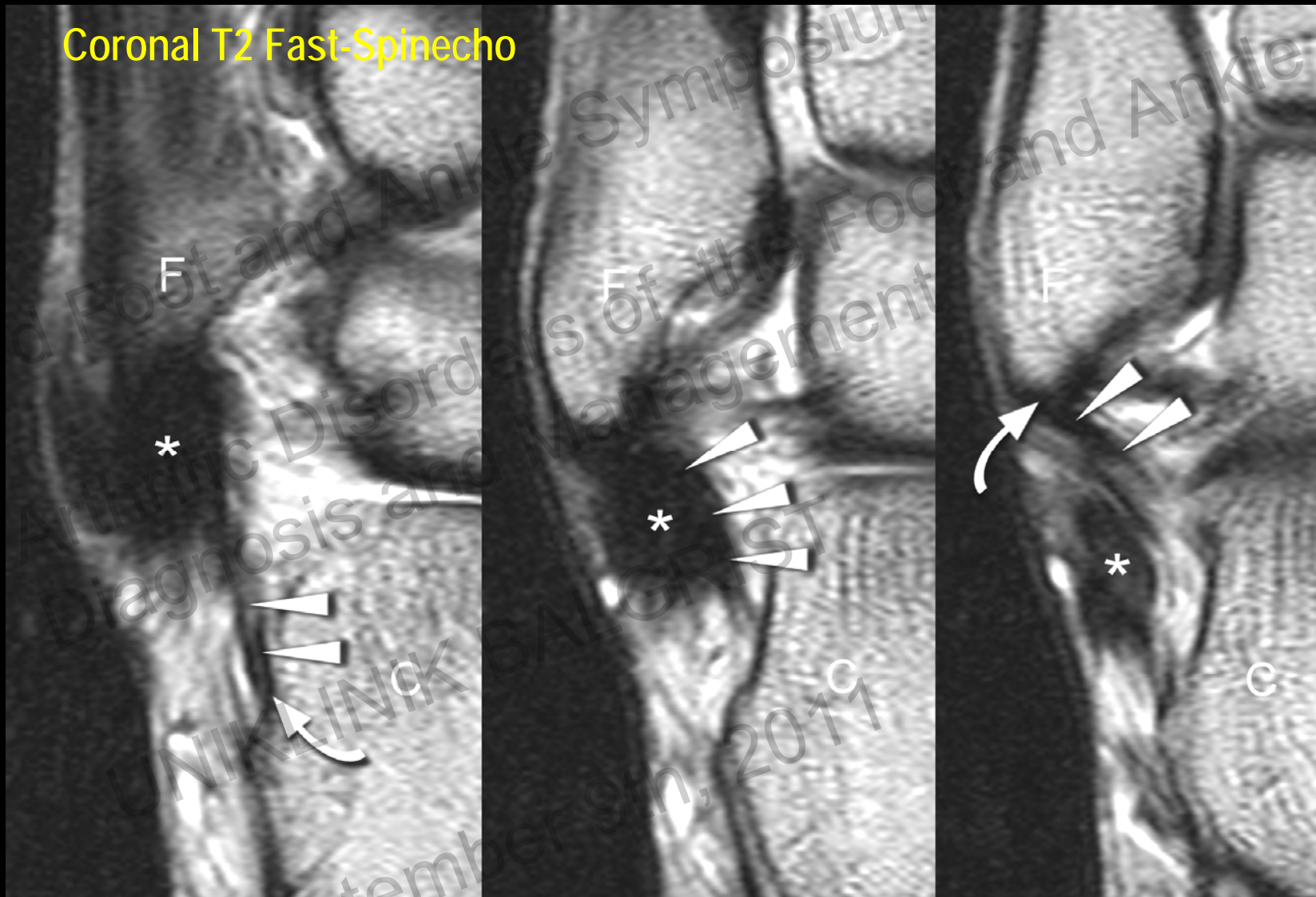


Calcaneofibular Ligament CFL



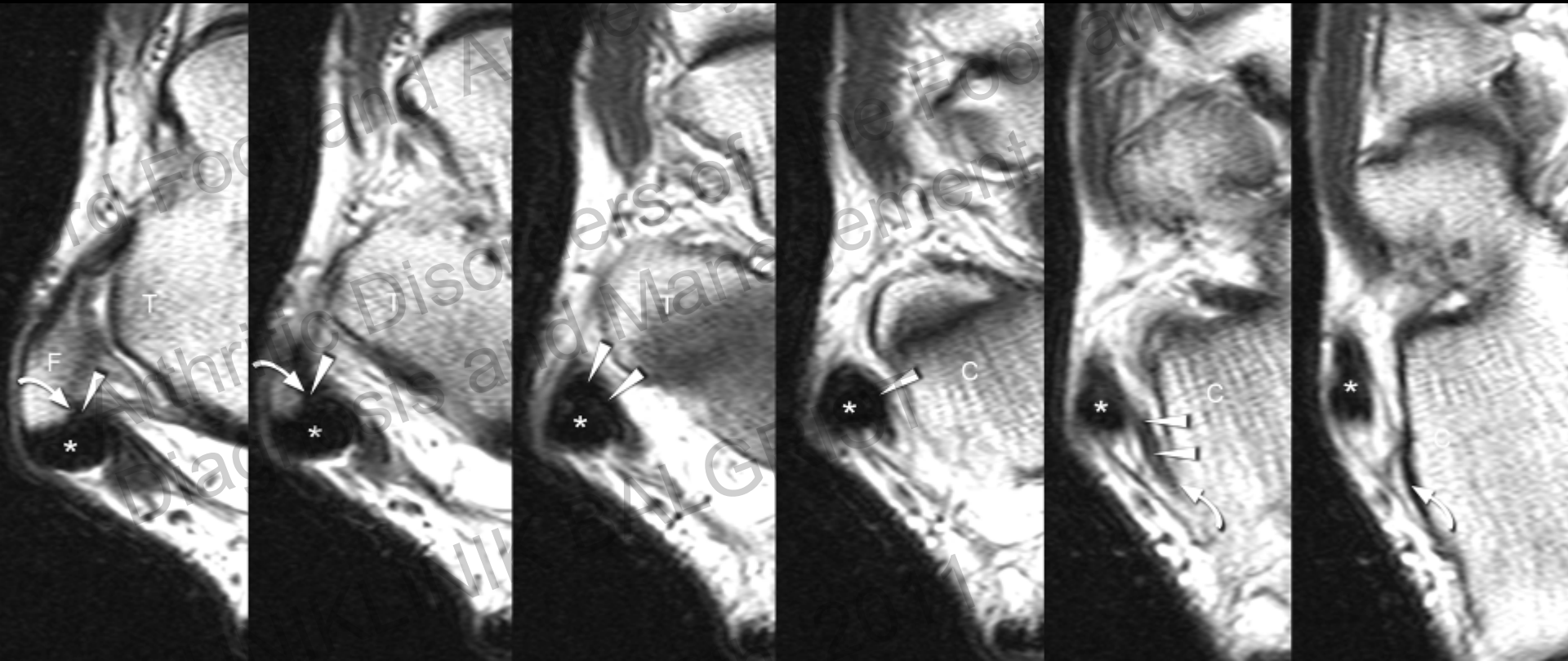
Calcaneofibular Ligament CFL

Coronal T2 Fast-Spinecho



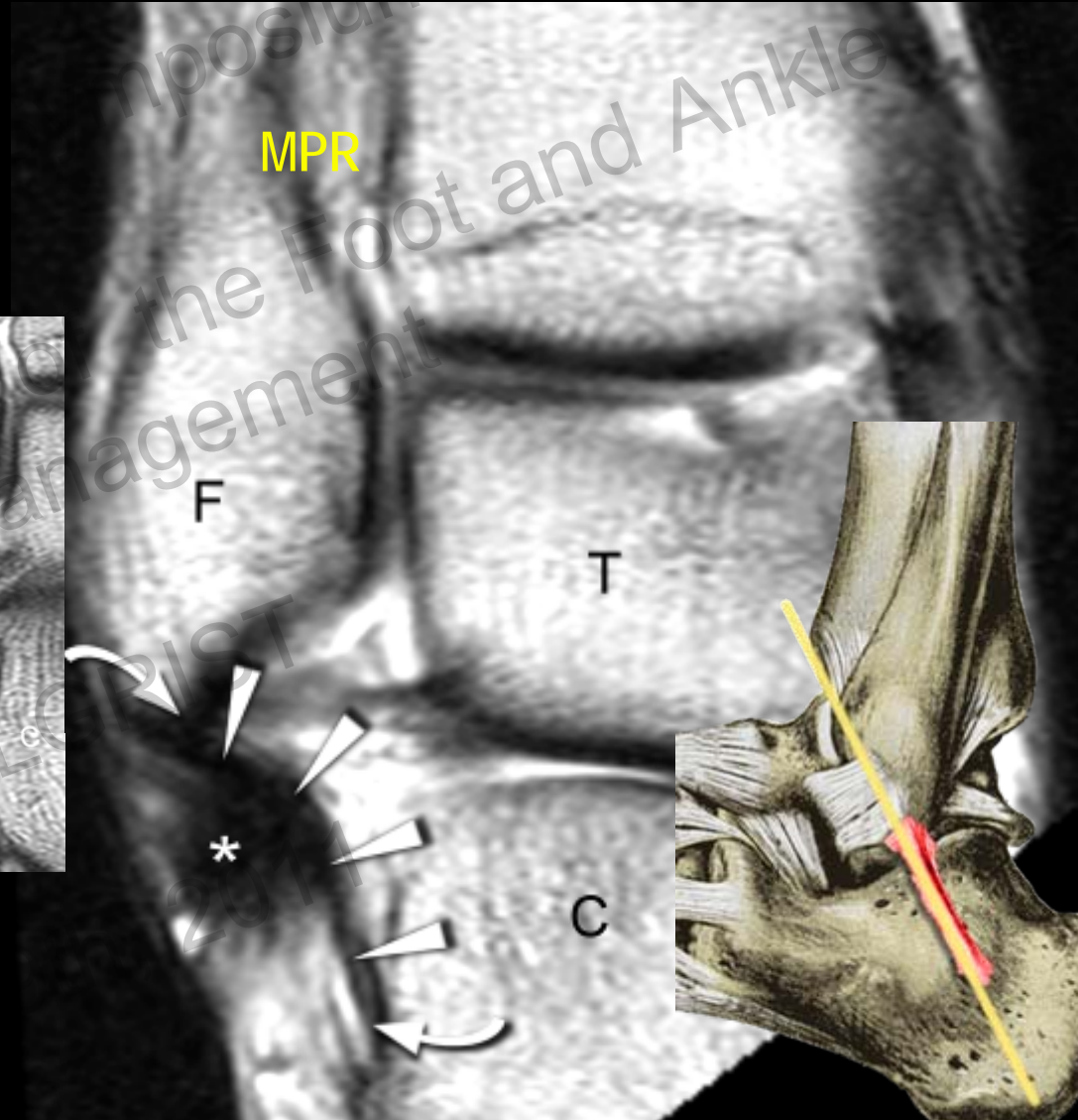
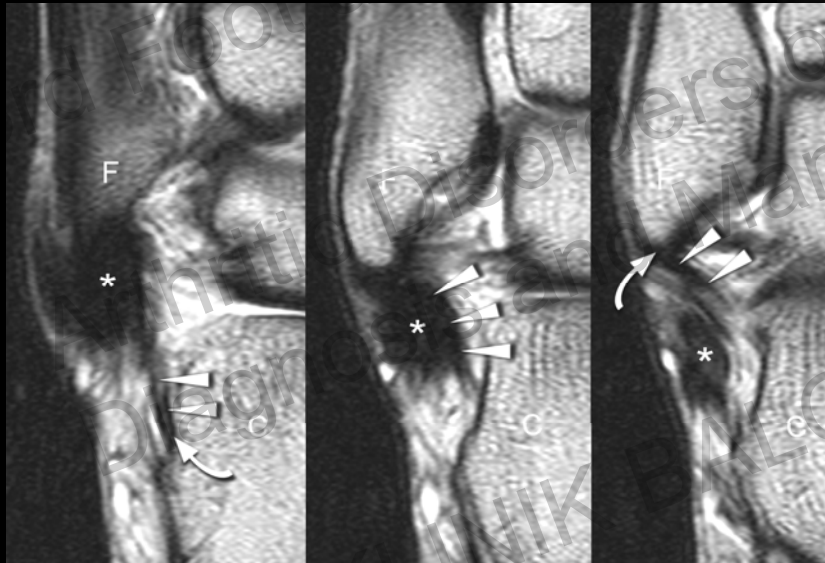
Calcaneofibular Ligament CFL

Axial T2 Turbo-Spinecho

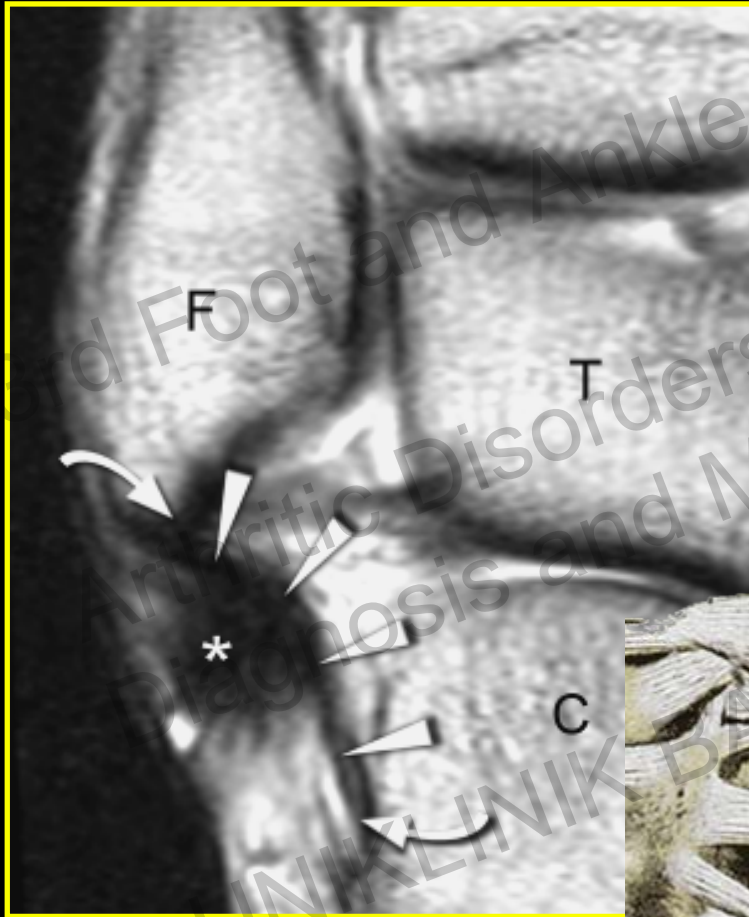


Calcaneofibular Ligament CFL

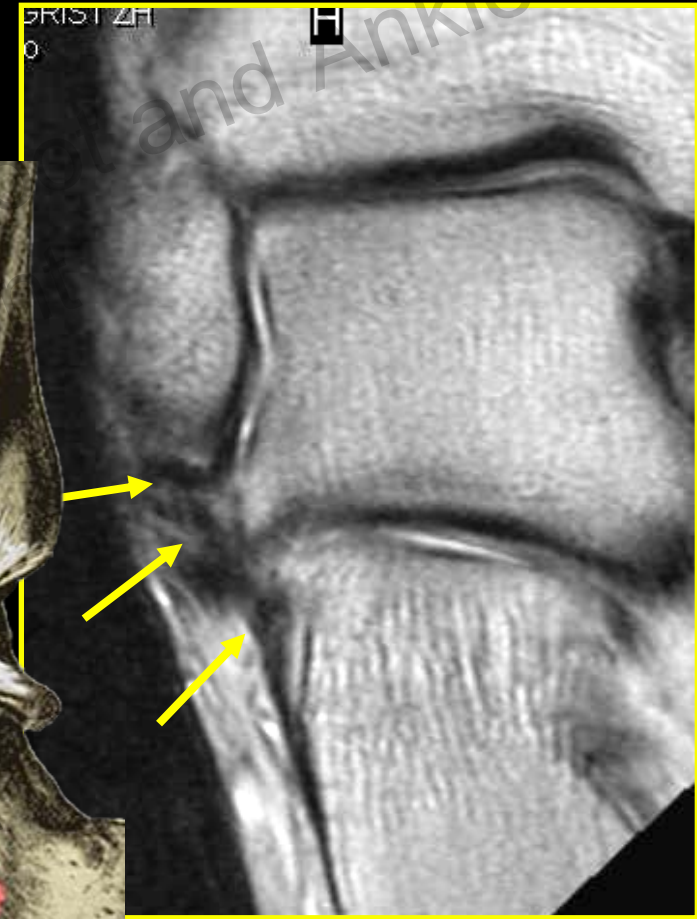
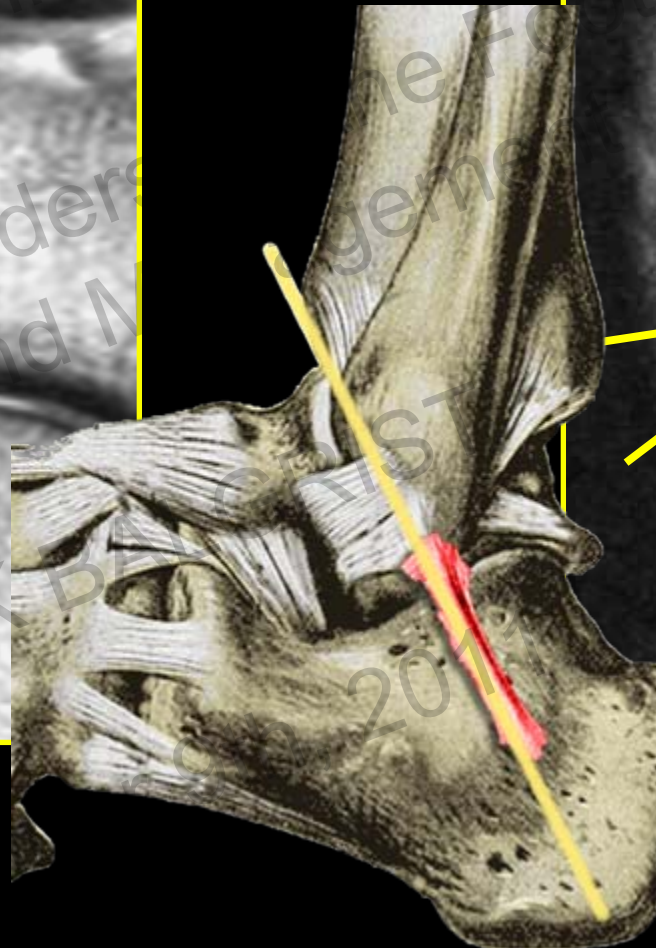
Coronal T2 TSE



Calcaneofibular Ligament CFL

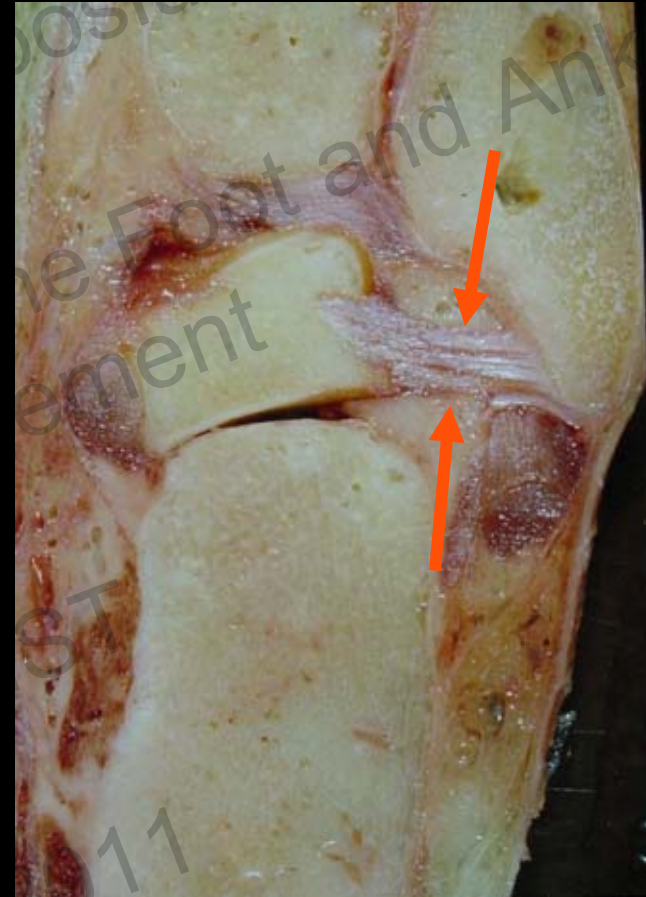


Normal



Tear

Posterior Talofibular Ligament PTFL



Strongest Ligament, Tears of the PTF are rare

Medial Collateral Ligament

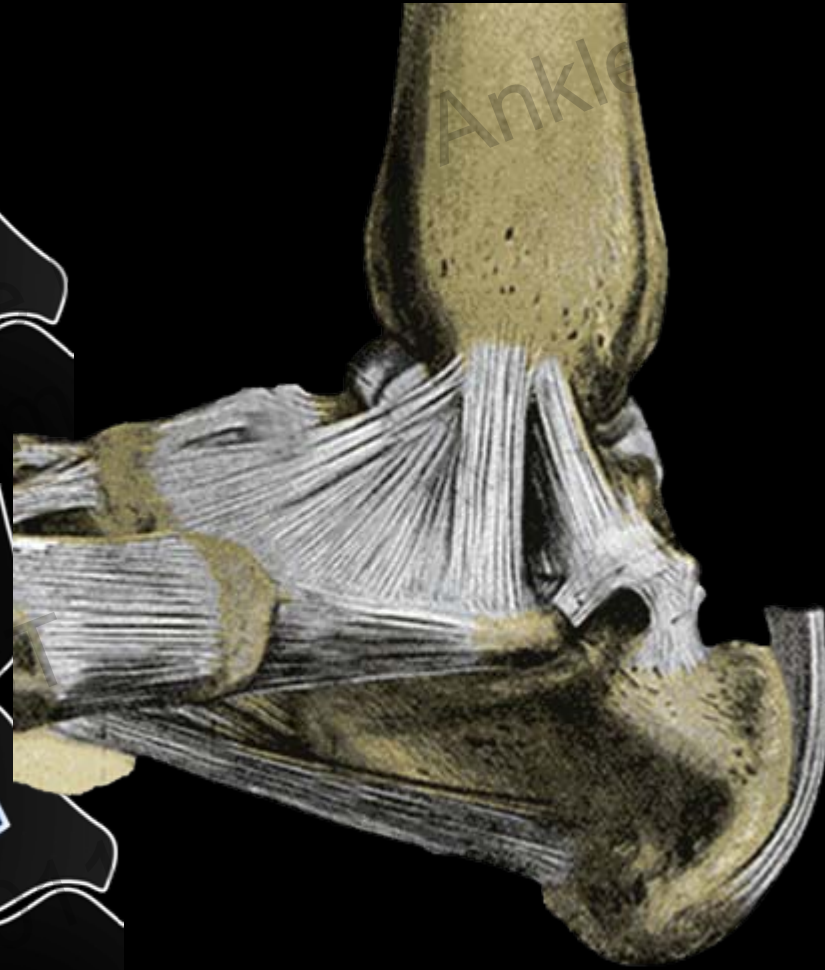
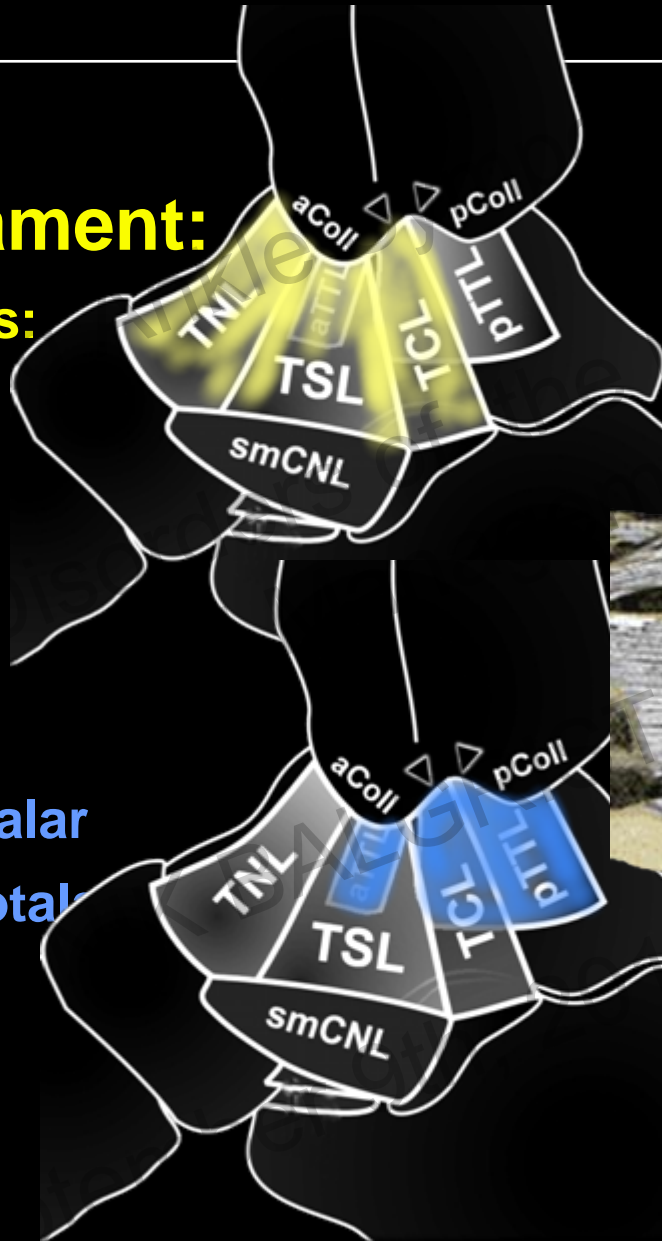
Deltoid Ligament:

Superficial layers:

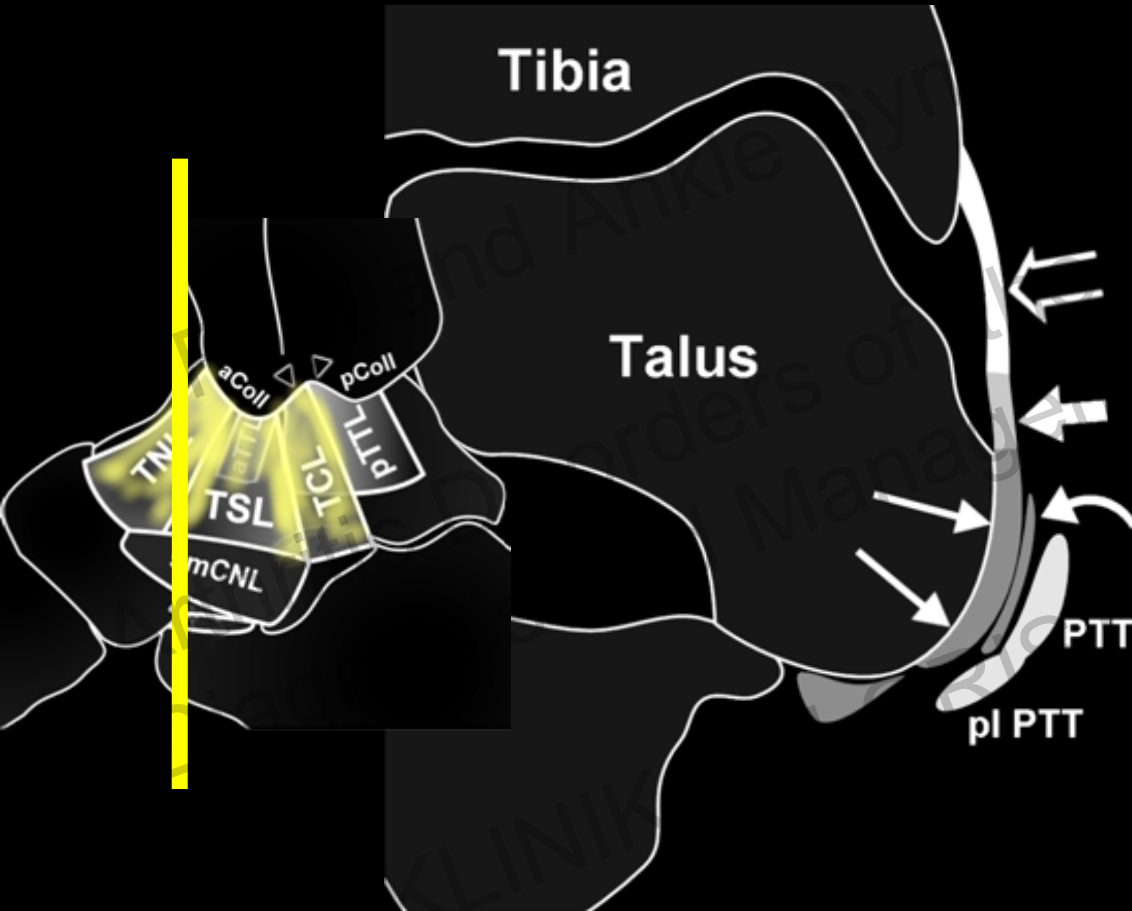
- tibionavicular
- tibiospring
- tibiocalcaneal

Deep layers:

- anterior tibiotalar
- posterior tibiotalar



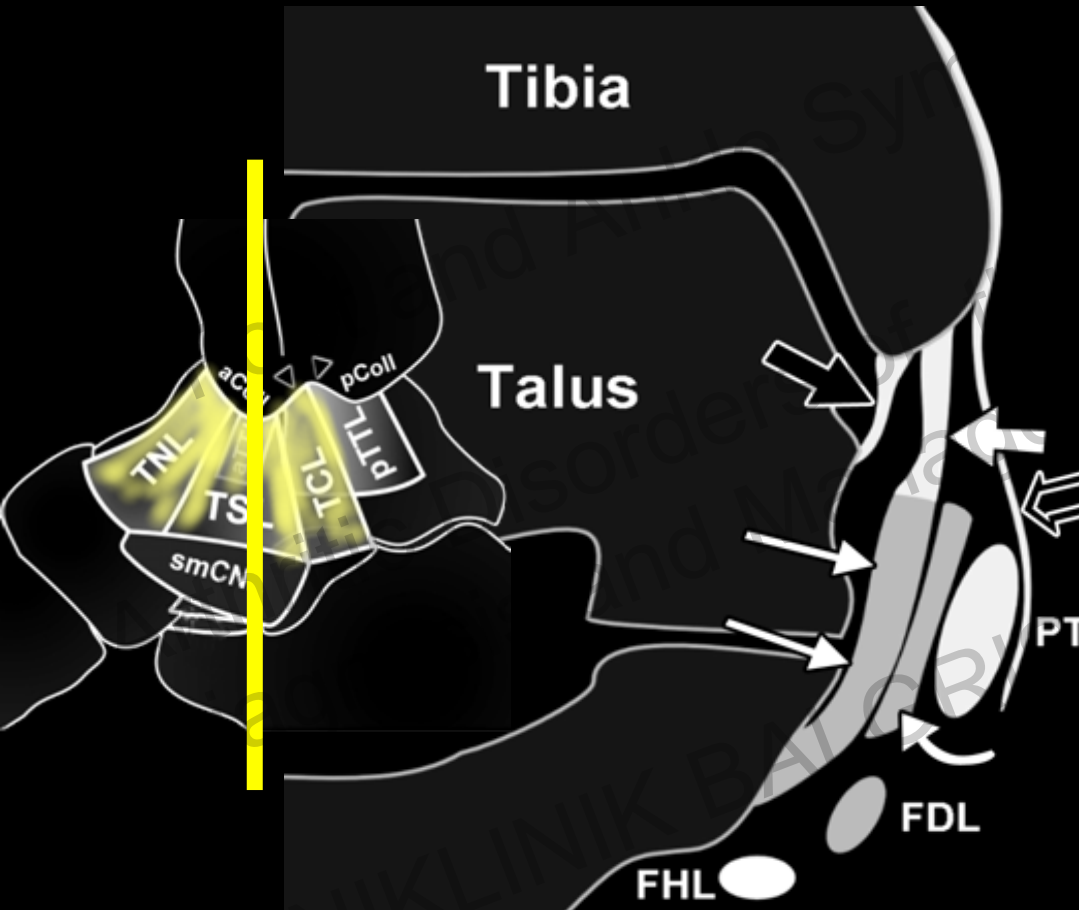
Superficial: Tibionavicular Ligament



Not always present (55%)

Most injuries of the medial collateral ligament occur at the proximal attachment of the TNL and TSL.

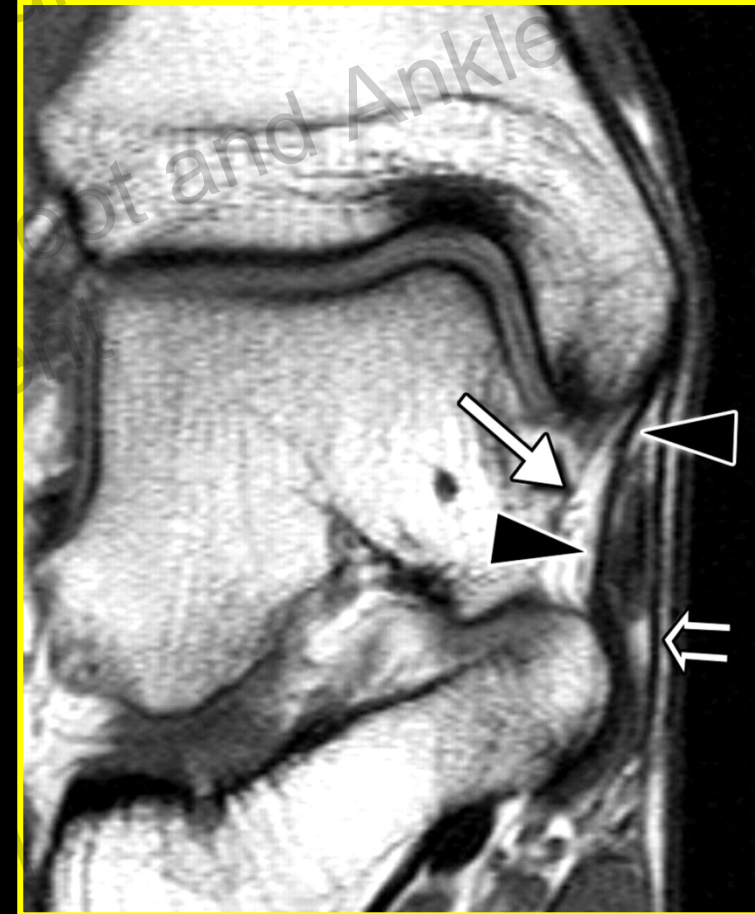
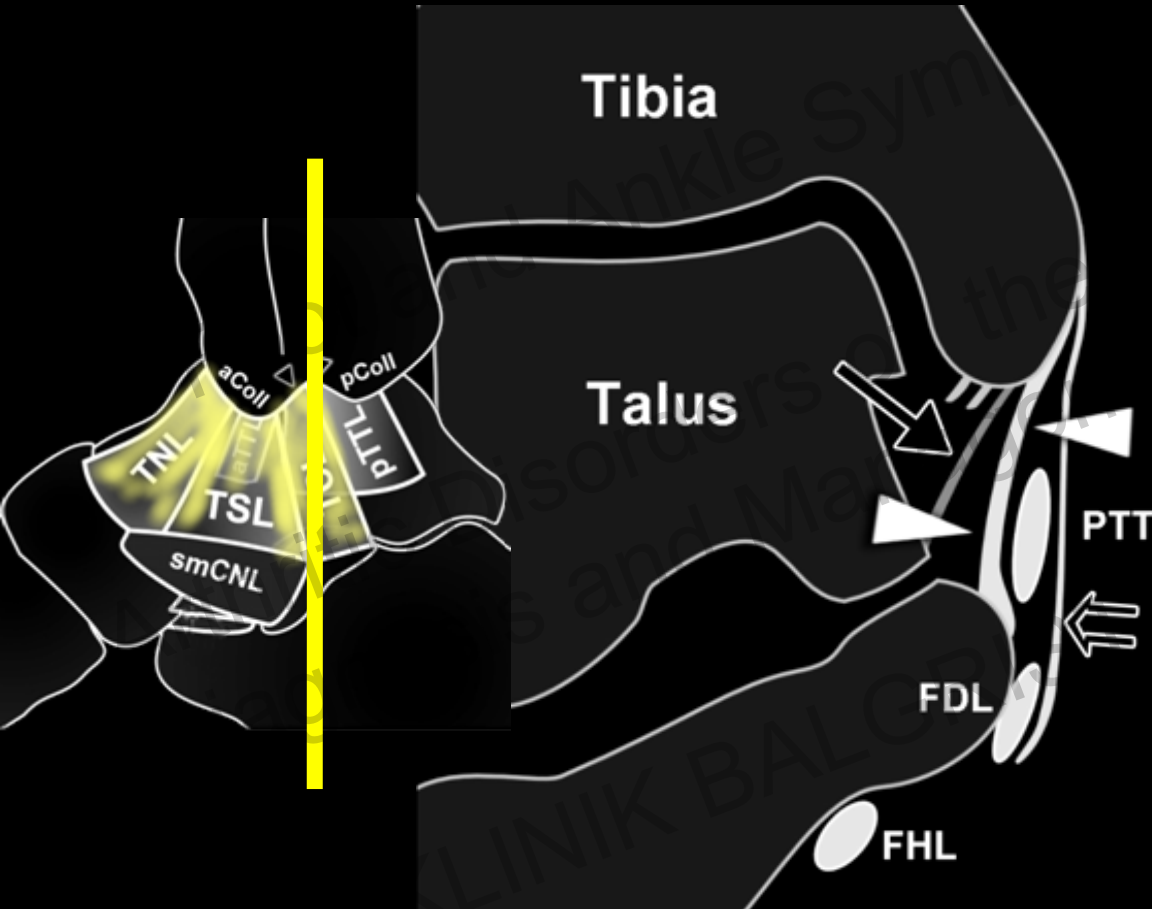
Superficial: Tibiospring Ligament



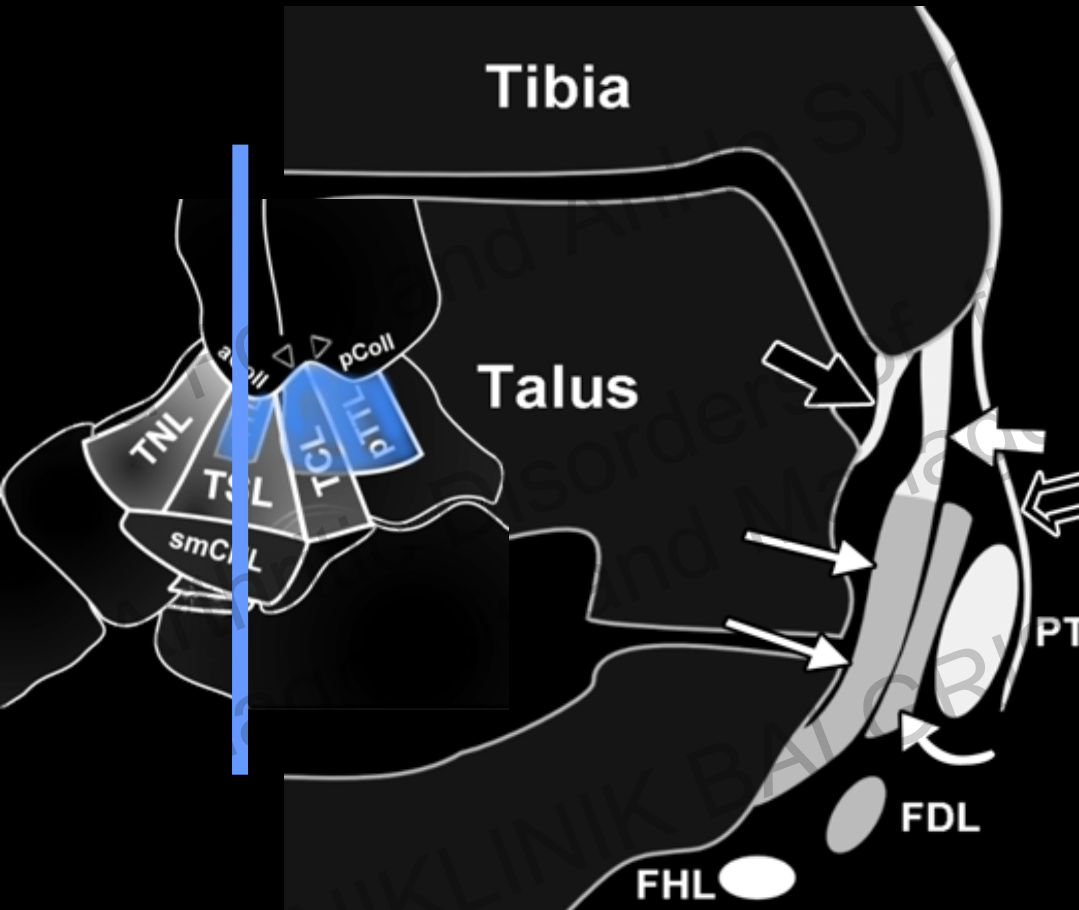
Always present

Most injuries of the medial collateral ligament occur at the proximal attachment of the TNL and TSL.

Superficial: Tibiotalar Ligament

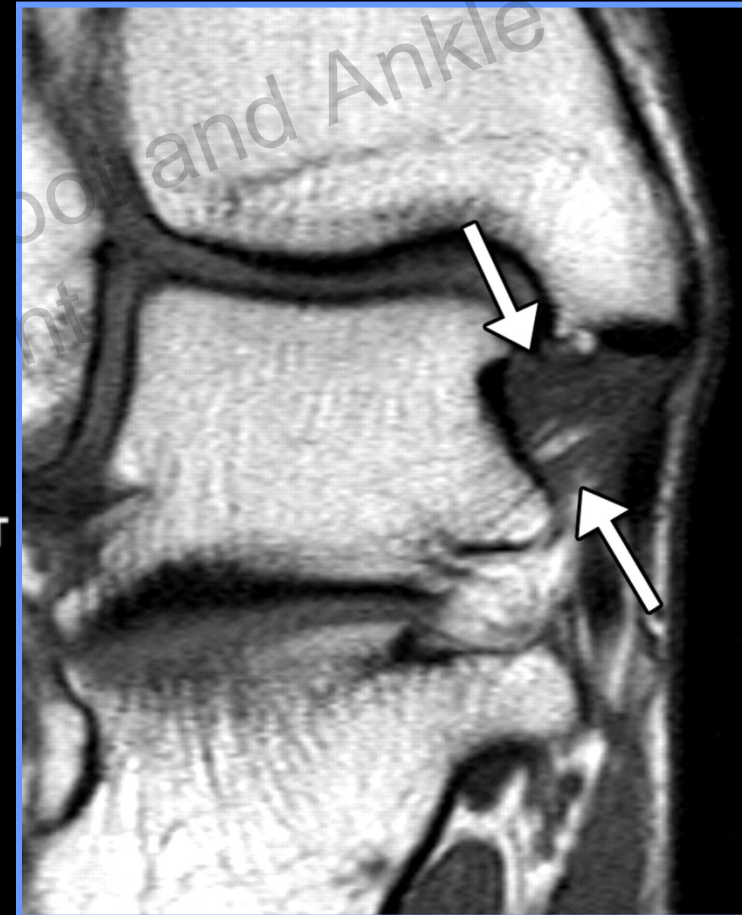
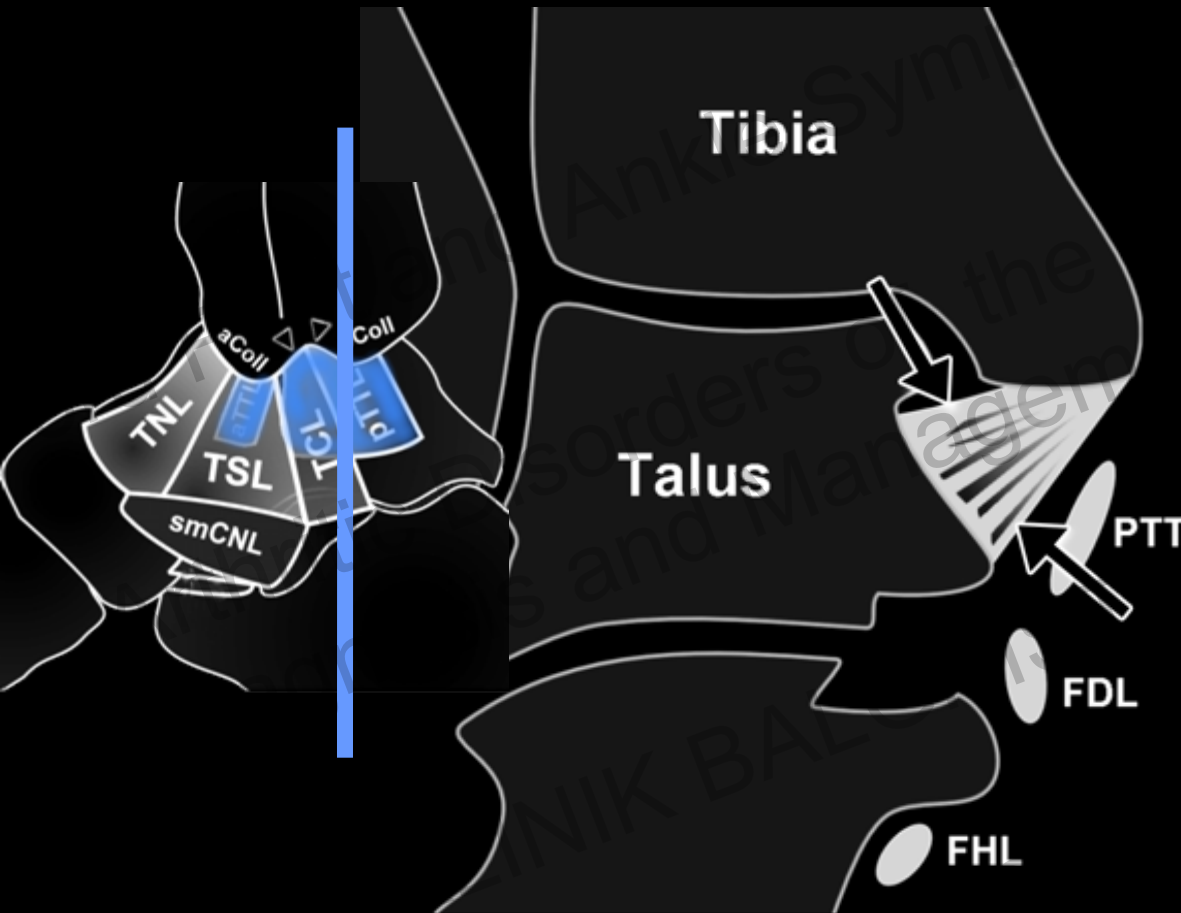


Deep: Anterior tibiotalar Ligament



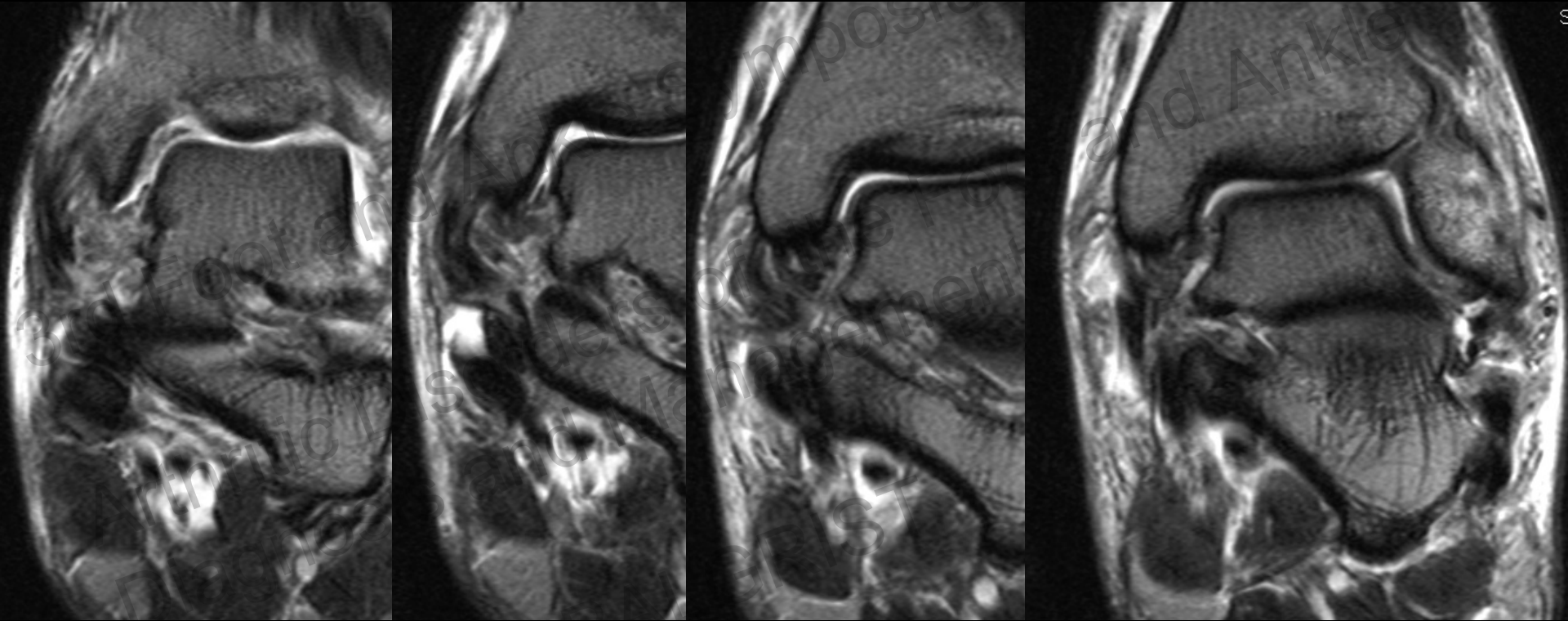
Not always present (55%)

Deep: Posterior tibiotalar Ligament



Strongest ligament. Longitudinal striations

Tears



Posterior Tibiotalar Ligament

Tibiospring ligament

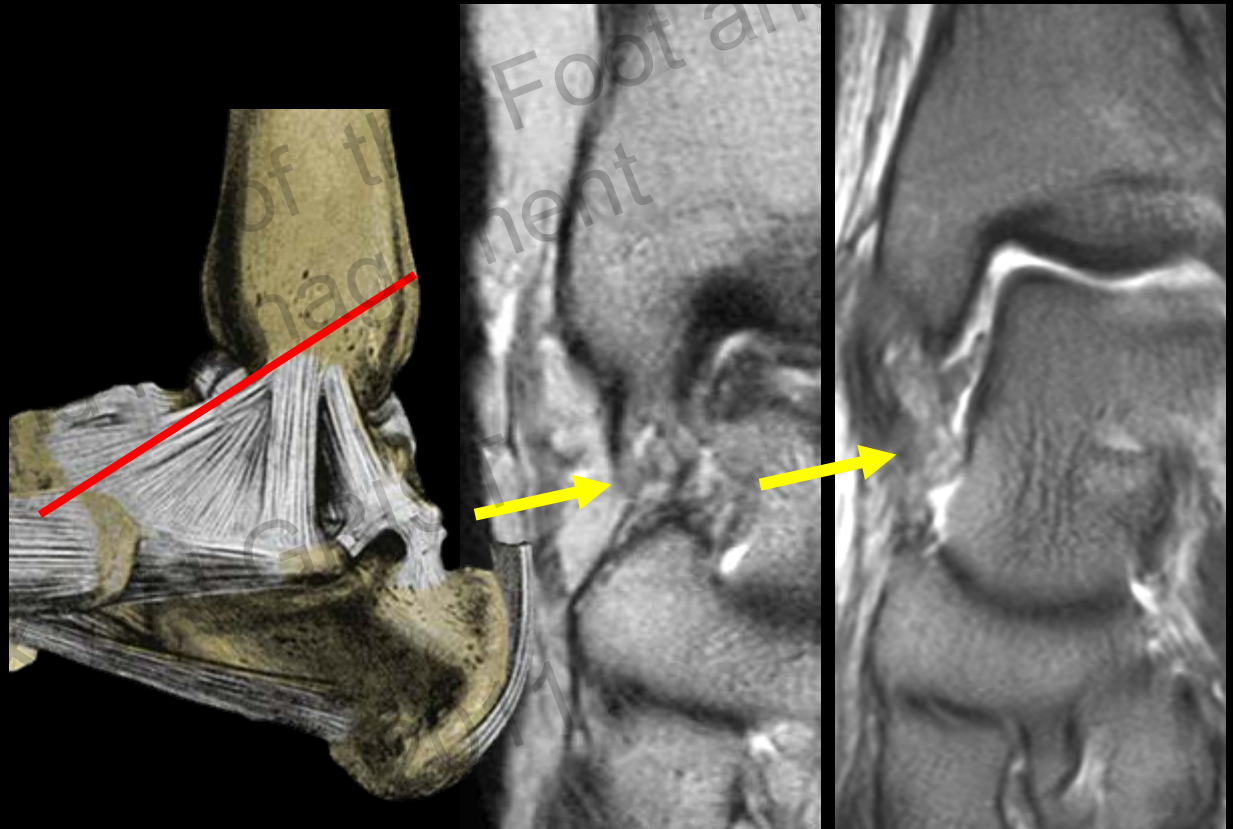
Tibiocalcaneal ligament

Tear: Tibionavicular Ligament

Normal

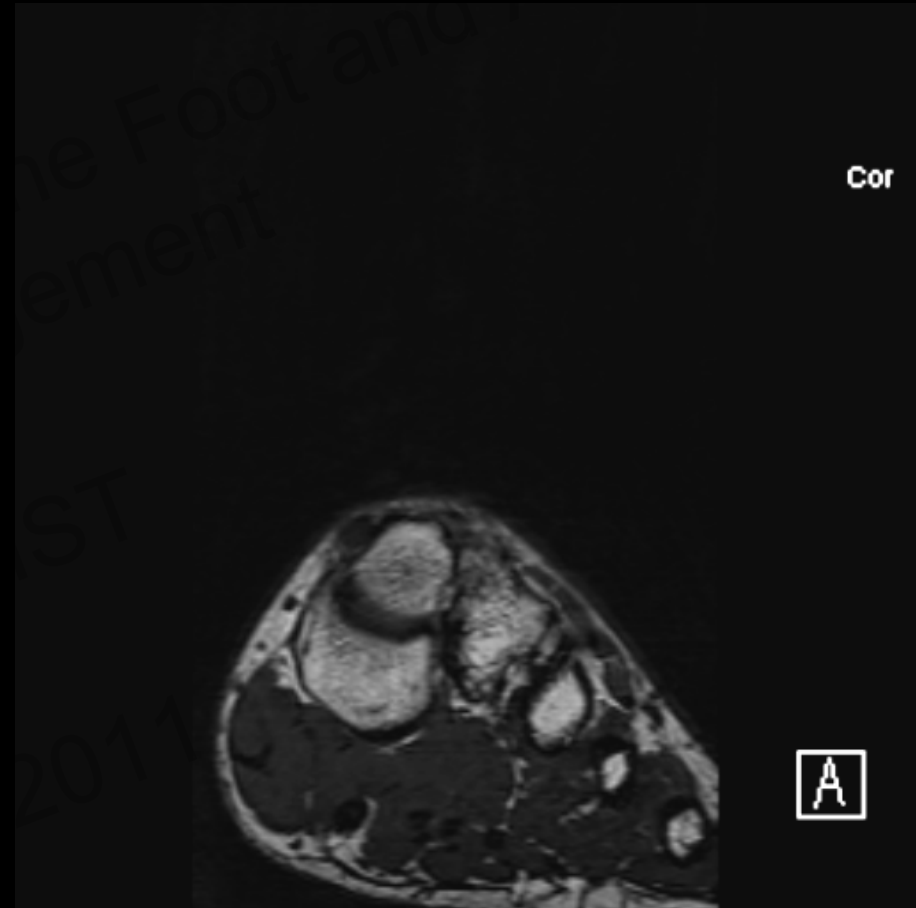


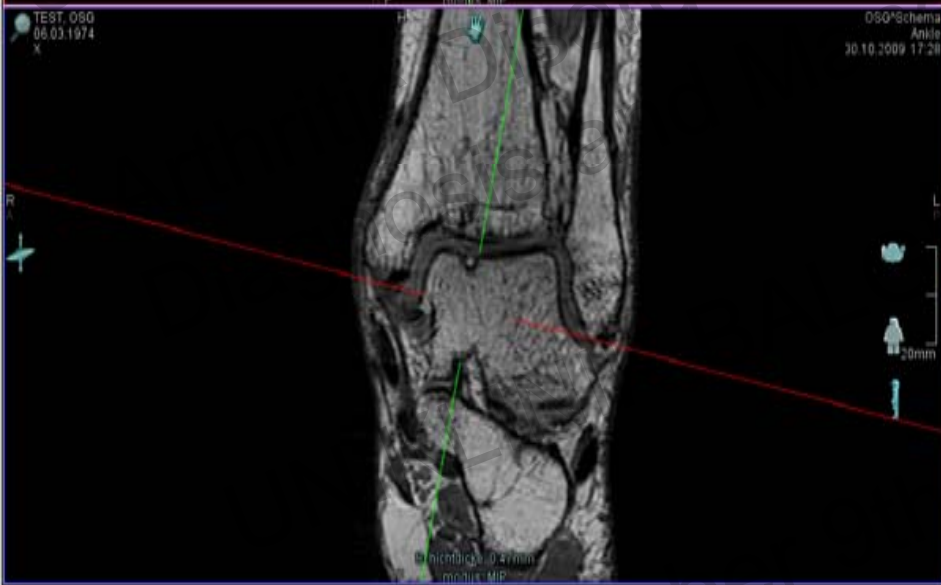
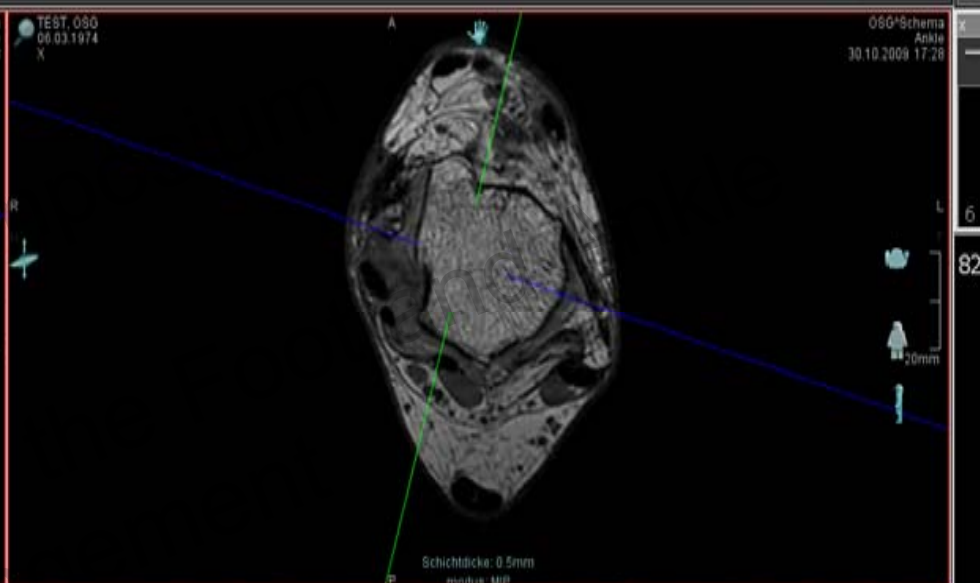
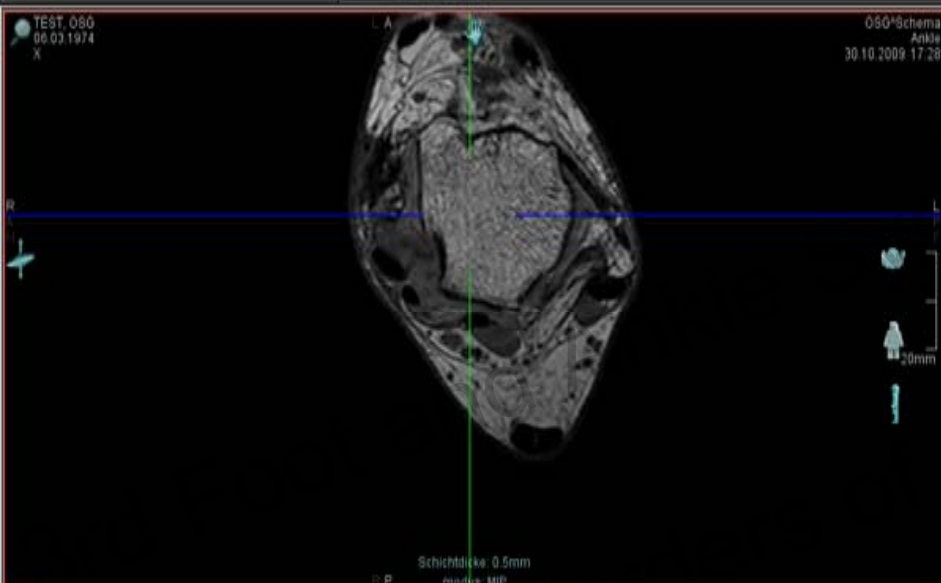
Tear

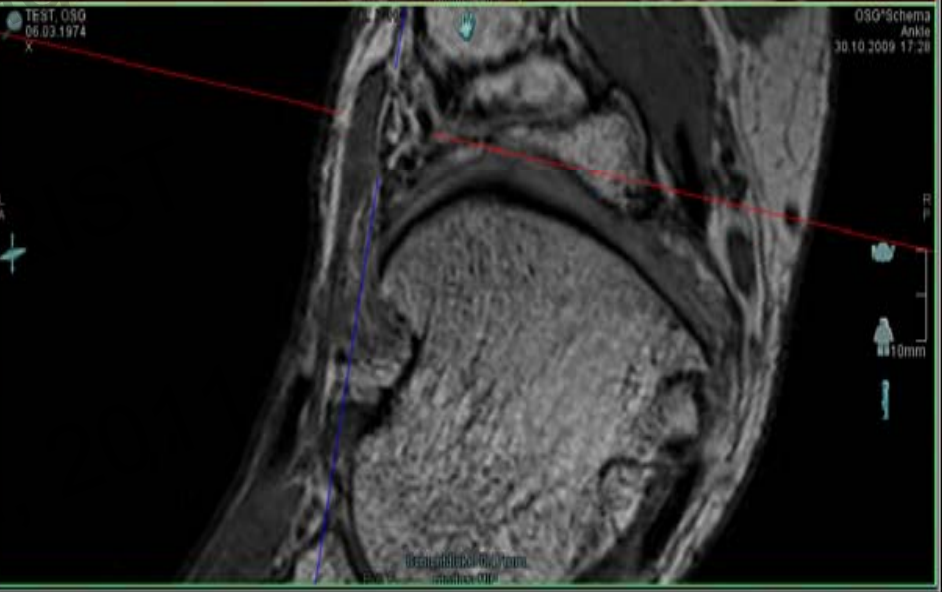
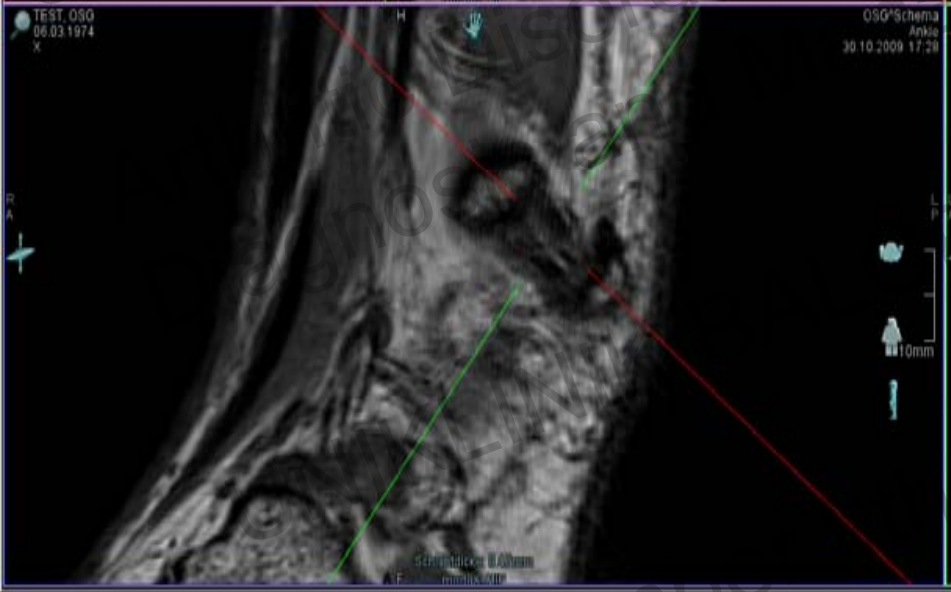
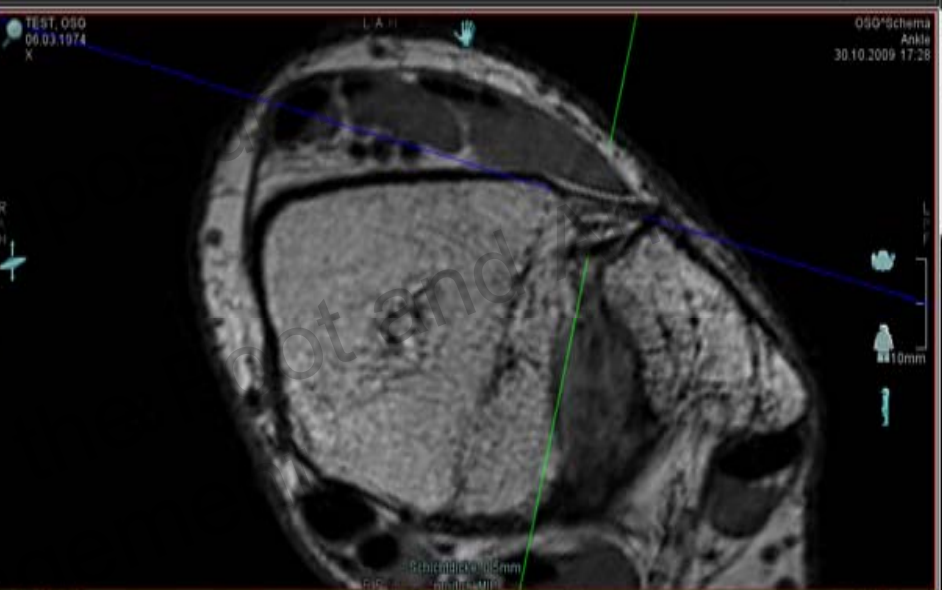
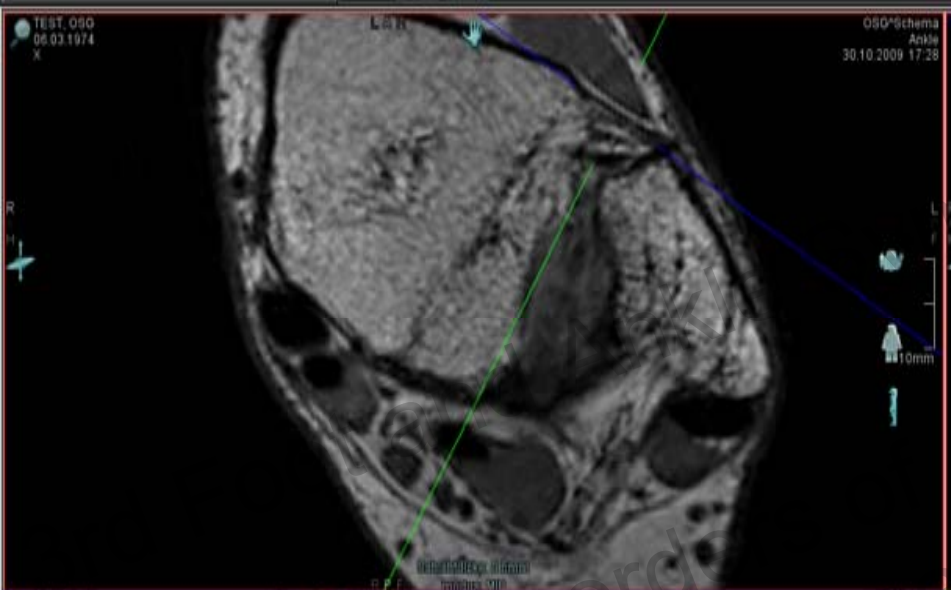
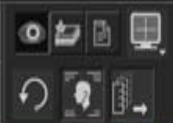


Imaging of Ligaments: New Developments

3D isovoxel datasets (0.7-0.3 mm)



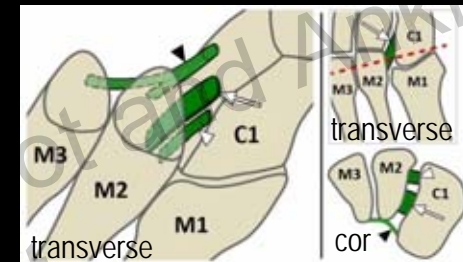




Ligaments of the Lisfranc joint

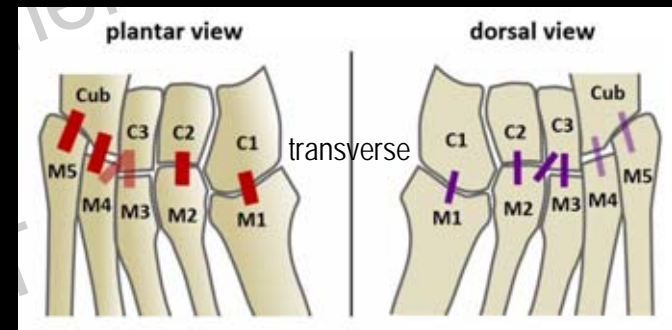
• 3 Lisfranc ligaments

- Dorsal Lisfranc ligament (dC1-M2)
- Interosseous Lisfranc ligament (pC1-M2)
- Plantar Lisfranc ligament (pC1-M2,3)



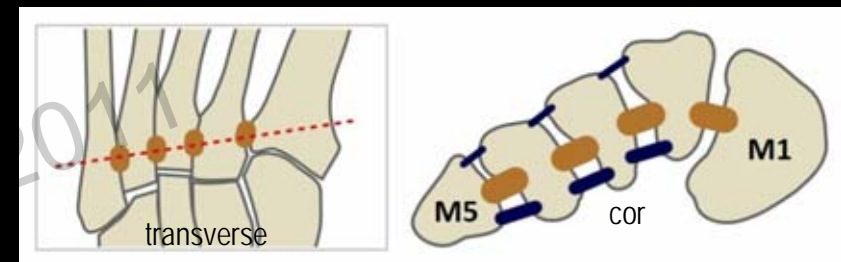
• 13 Tarsometatarsal (TMT) ligaments

- 7 dorsal TMTs
(dC1-M1, dC1-M2 (= *dorsal Lisfranc ligament*), dC2-M2, dC3-M2, dC3-M3, dC-M4, dC-M5)
- 6 plantar TMTs
(pC1-M1, pC1-M2,3 (= *plantar Lisfranc ligament*), pC2-M2, pC3-M3,4, pCub-M4, pCub-M5)

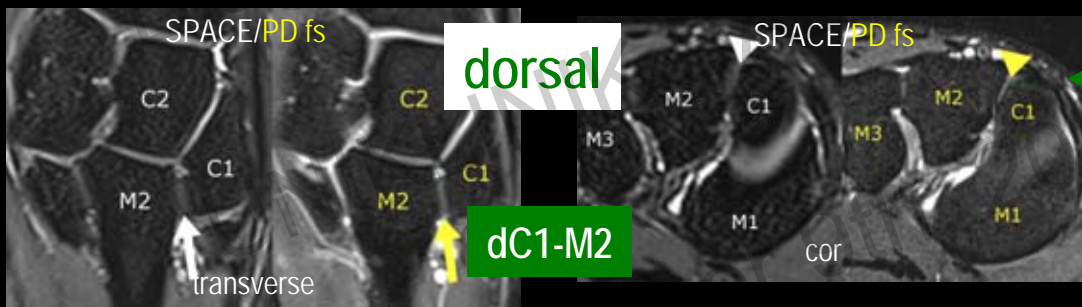
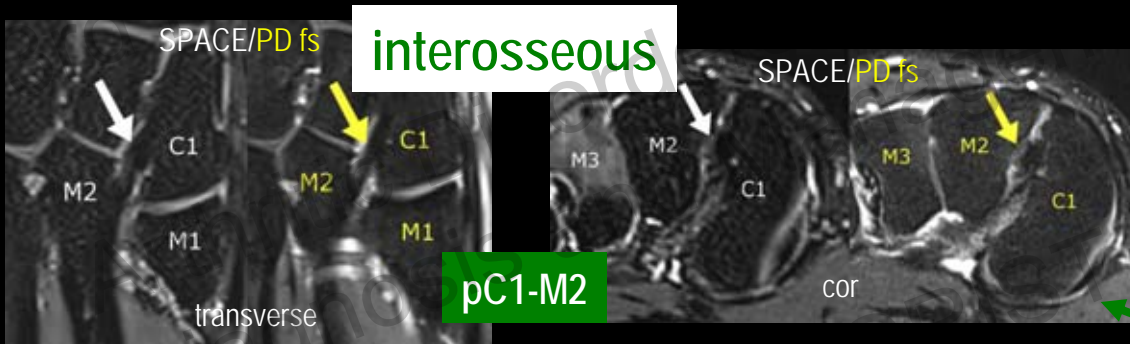
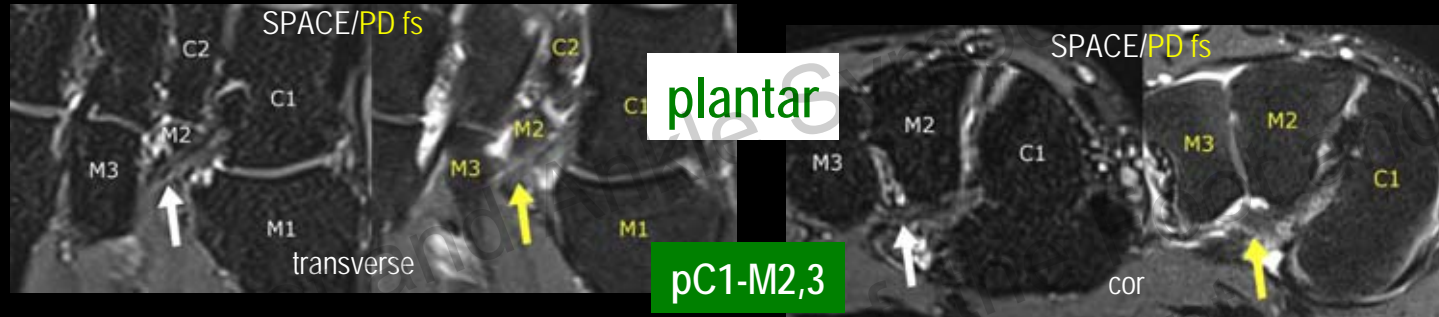


• 10 Intermetatarsal (IMT) ligaments

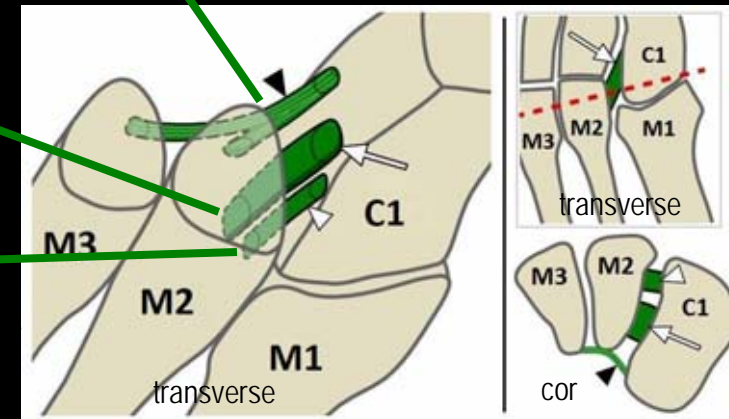
- 3 dorsal IMTs
- 4 interosseous IMTs
- 3 plantar IMTs



Examples of MR images - Asympt

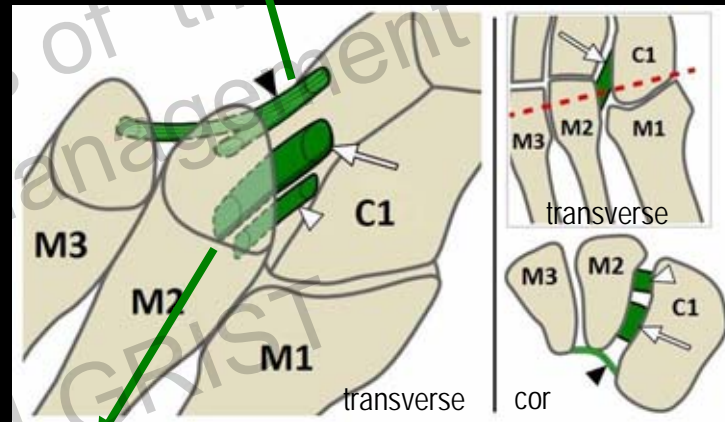
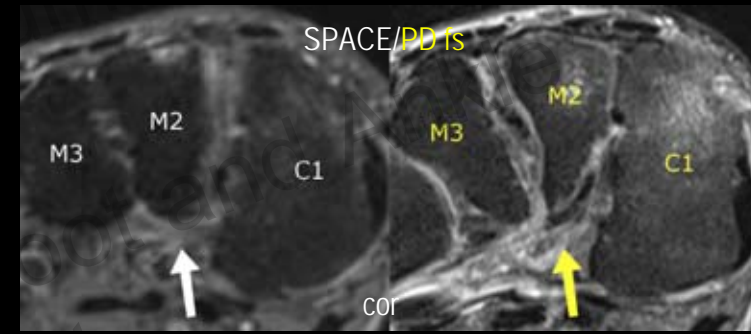
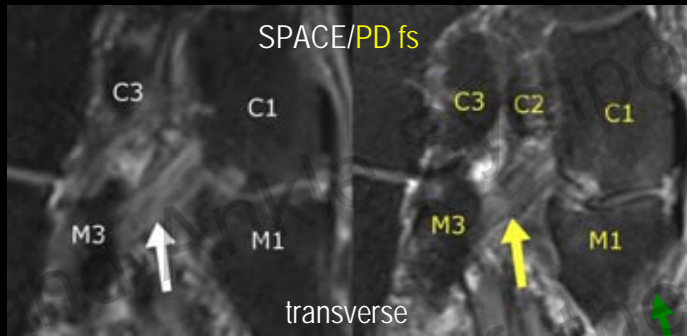


3 Lisfranc ligaments

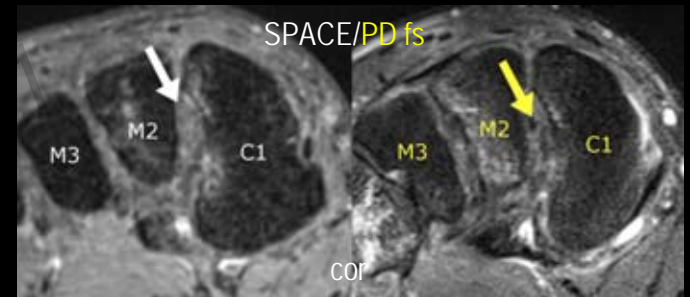
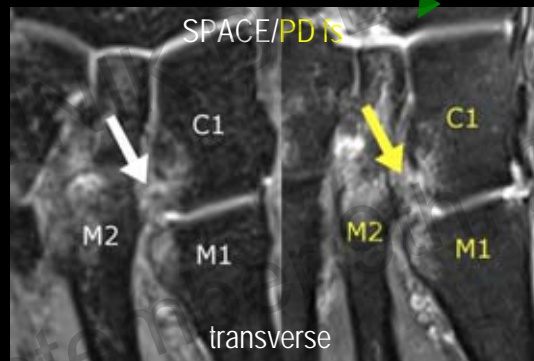


Examples of MR images - Patients

Plantar Lisfranc ligament (pC1-M2,3)

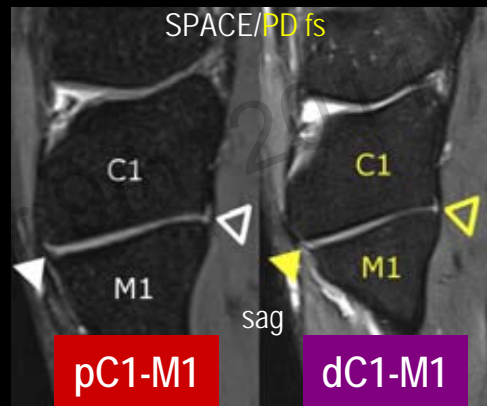
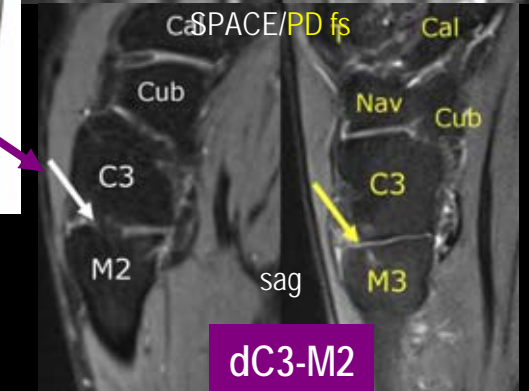
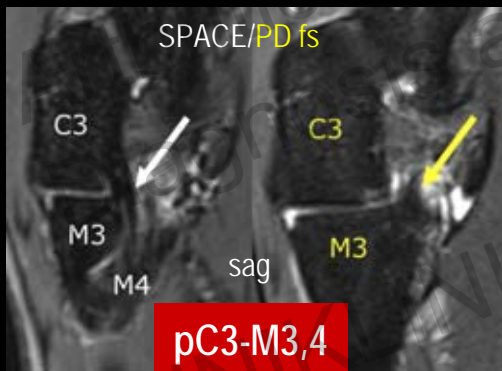
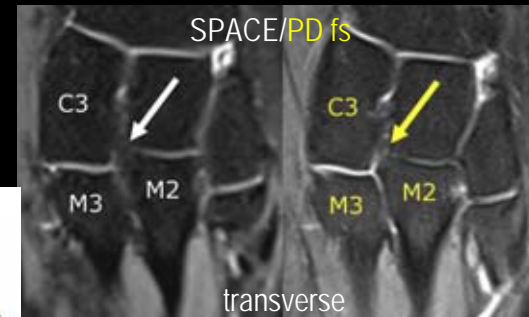
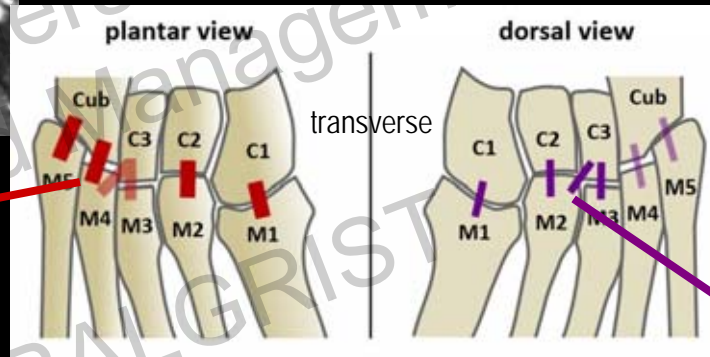
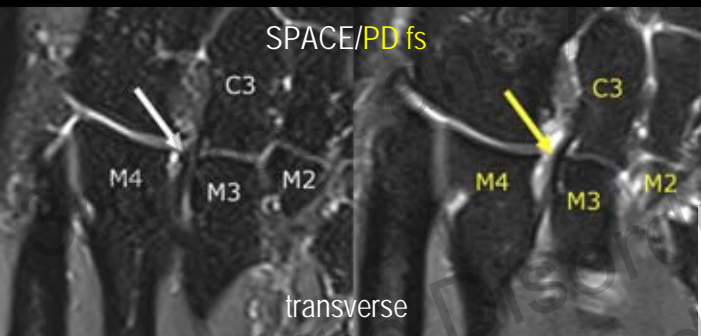


Interosseous Lisfranc ligament (pC1-M2)



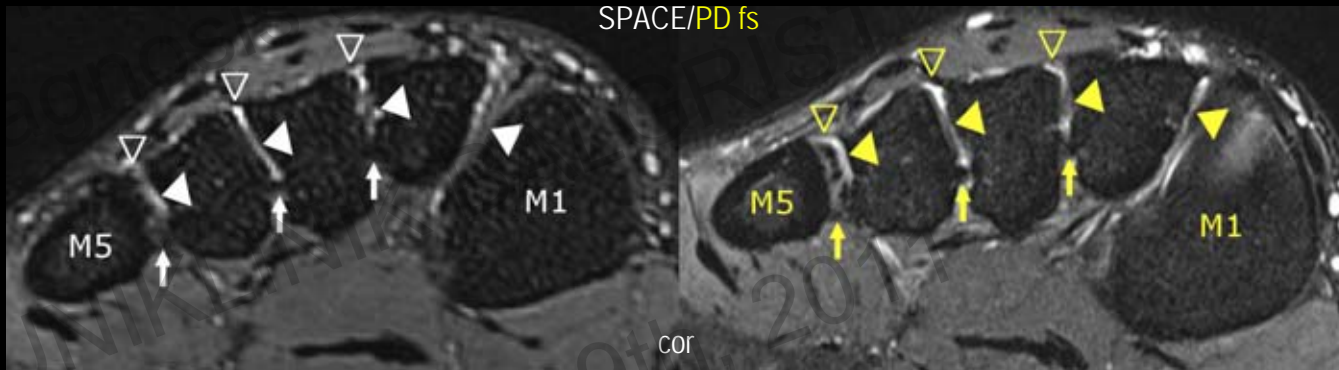
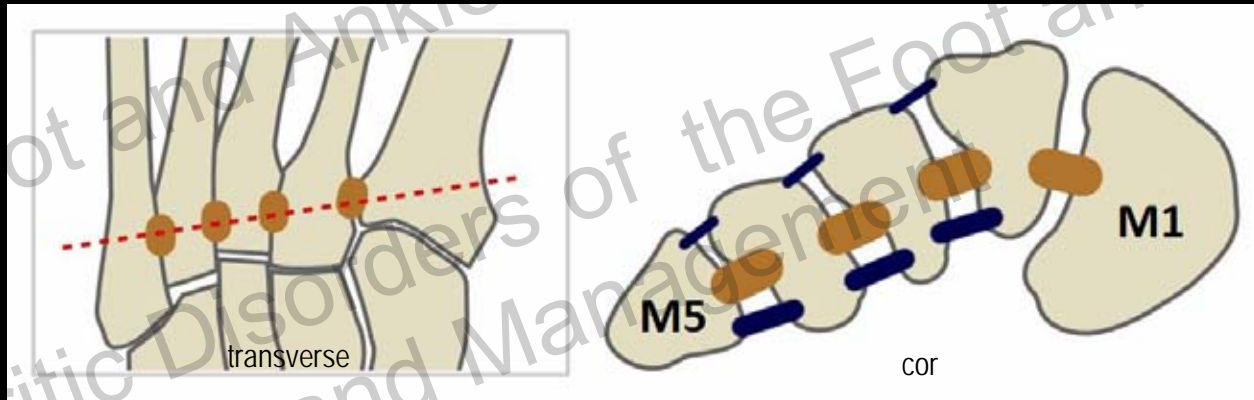
Examples of MR images - Asympt

Tarsometatarsal (TMT) ligaments



Examples of MR images - Asympt

Intermetatarsal (IMT) ligaments



- 3 dorsal IMTs
- 4 interosseous IMTs
- 3 plantar IMTs

Cartilage



MR of Cartilage

- SE PD/T2
- FSE PD FS
- SPGR
- DEFT
- FS-SSFP
- LCSSFP
- FEMR
- FFE
- FFE EPI
- FFE MTC
- FLASH
- DESS3D WE
- MEDIC 3D
- 3D VIBE

Numerous cartilage sequences

MR of Cartilage

- SE PD/T2
- FSE PD FS
- SPGR
- DEFT
- FS-SSFP
- LCSSFP
- FEMR
- FFE
- FFE EPI
- FFE MTC
- FLASH
- DESS3D WE
- MEDIC 3D
- 3D VIBE

.... the ideal sequence is still missing

MR Imaging of Cartilage

- SE PD/T2
- FSE PD FS
- SPGR
- DEFT
- FS-SSFP
- LCSSFP
- FEMR
- FFE
- FFE EPI
- FFE MTC
- FLASH
- DESS3D WE
- MEDIC 3D
- 3D VIBE

Goals:

High resolution

High contrast between cartilage
and joint fluid

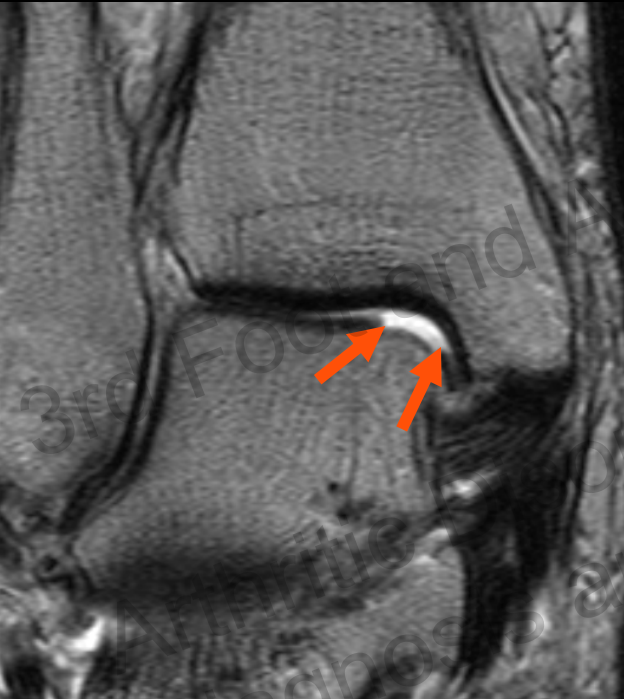
Cartilage

The Challenge:

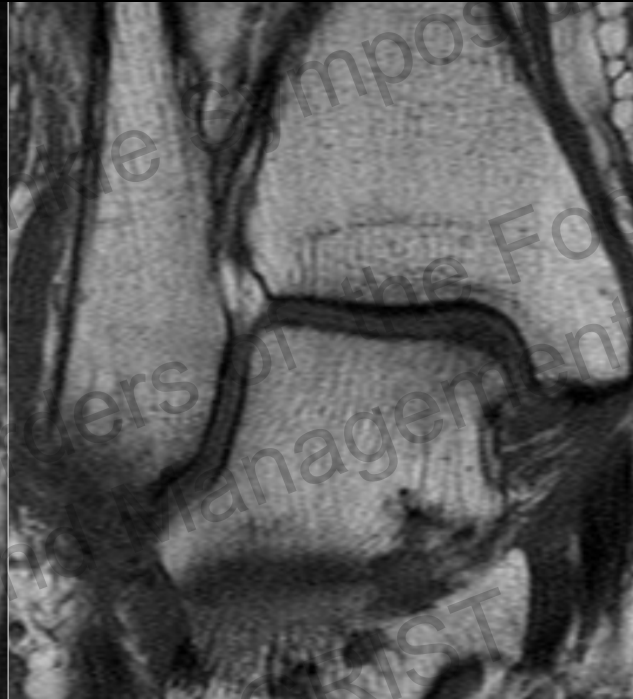


- Cartilage thickness
Tibia 1.1 - 1.6mm
Talus 0.9 - 1.6mm
- When ankle OA is already obvious clinically and on plain radiographs, cartilage degeneration is usually advanced

Spin Echo Sequences



T2 TSE

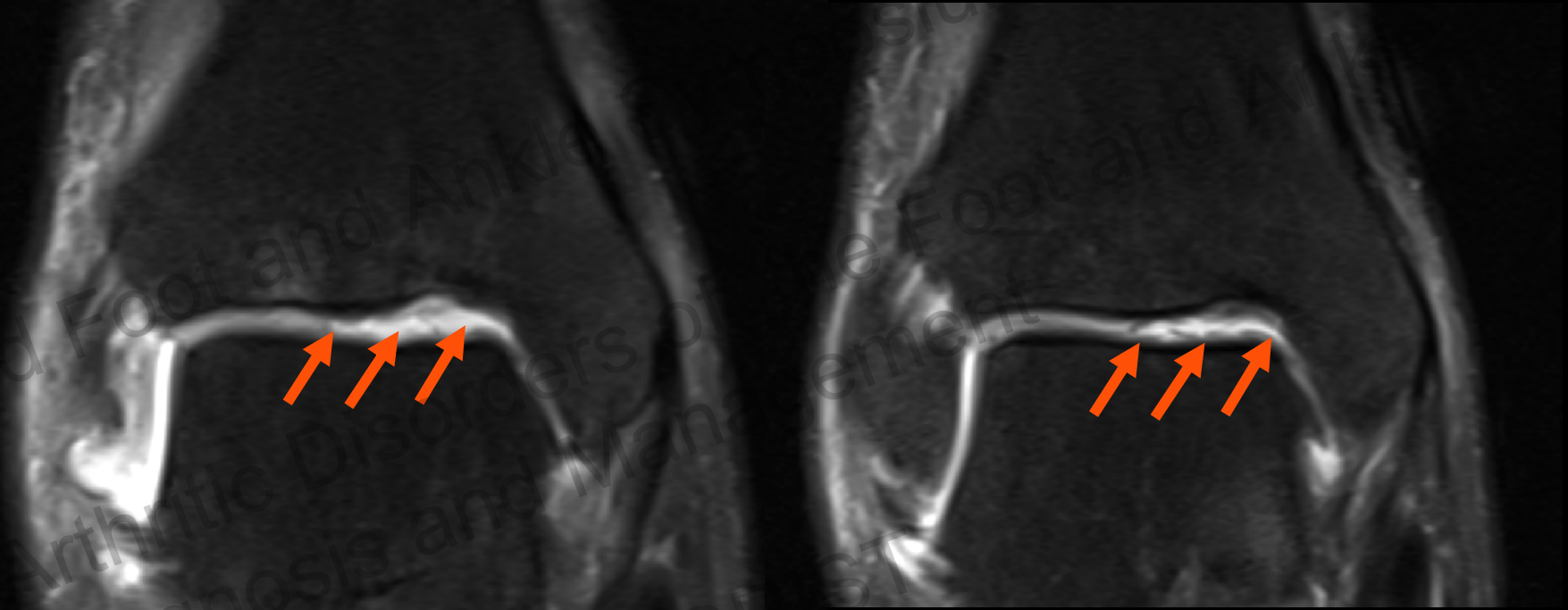


T1 SE



T1 SE
with Arthrography

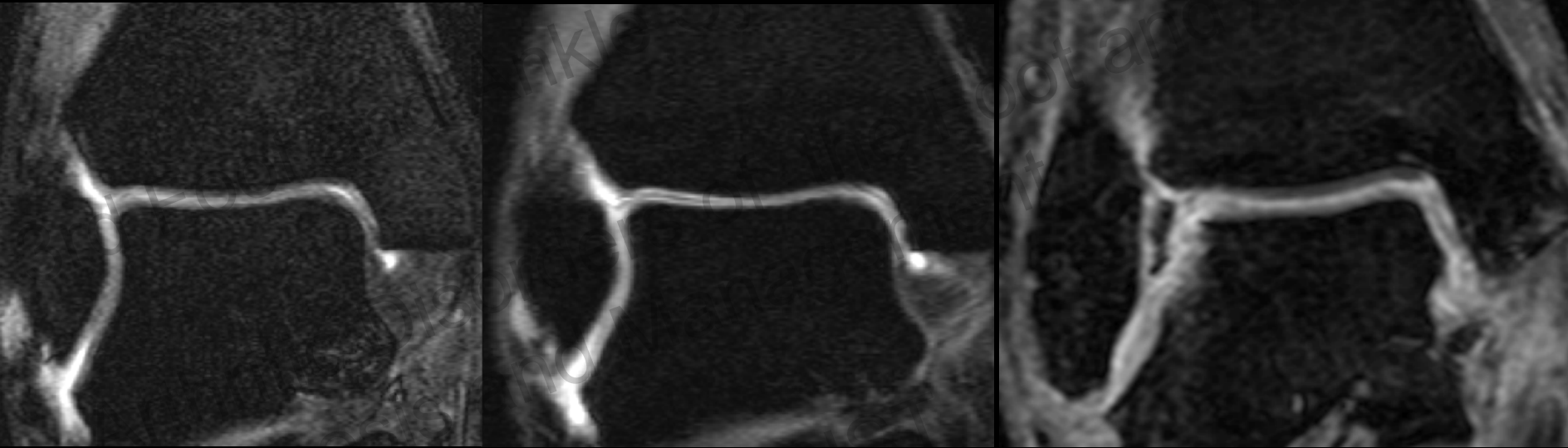
Spin Echo Sequences



Workhorse: Intermediate weighted/PD TSE with fat sat

Gradient Echo Sequences

Dedicated cartilage sequences:



FLASH

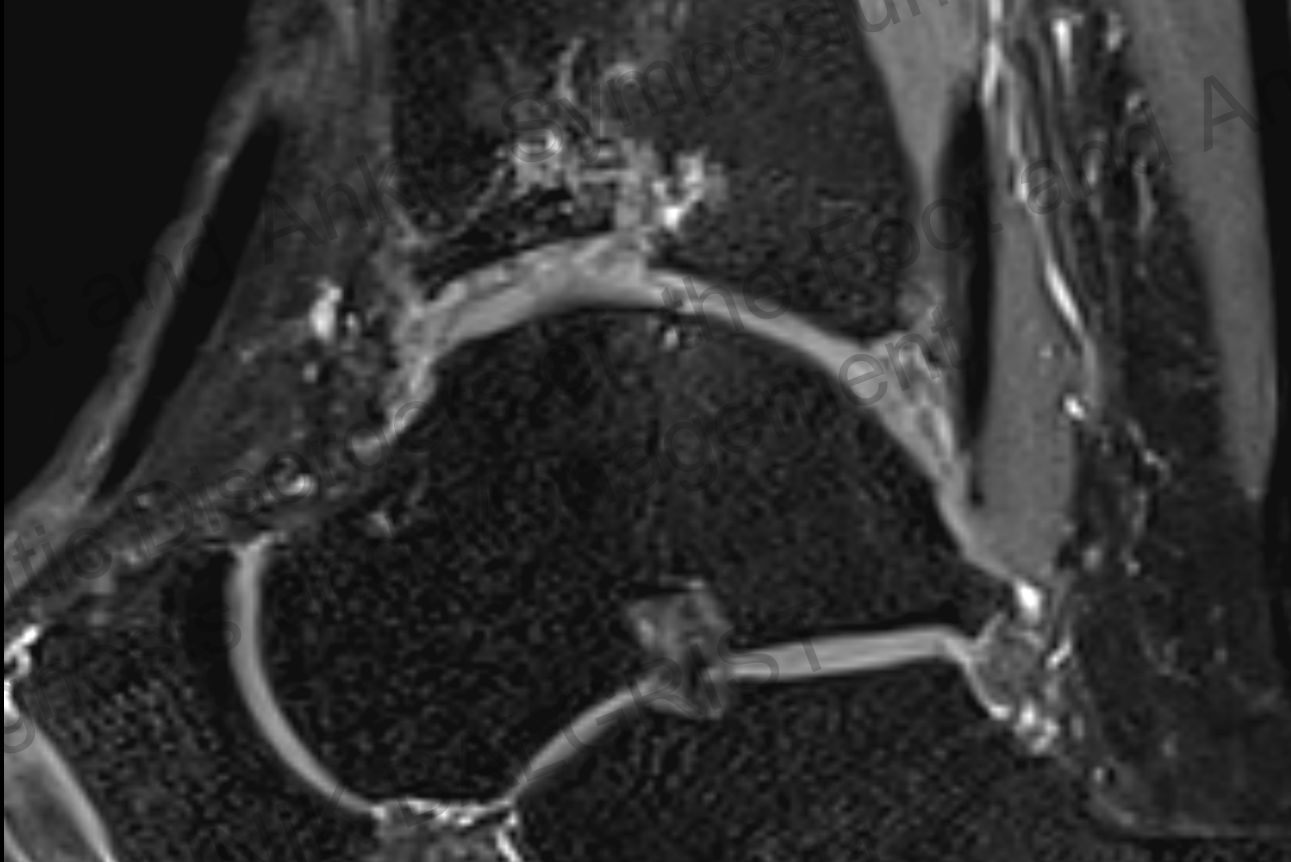
TrueFISP

DESS

Advantages: Thin Slices, 3D Acquisition

..... all sequences have similar diagnostic performance

3D Isovoxel SPACE



New development:

Combination of PD TSE fat sat and 3D acquisition: Voxel size 0.5mm

MR Imaging of Cartilage

- SE PD/T2
- FSE PD FS
- SPGR
- DEFT
- FS-SSFP
- LCSSFP
- FEMR
- FFE
- FFE EPI
- FFE MTC
- FLASH
- DESS3D WE
- MEDIC 3D
- 3D VIBE

Goals:

High resolution

High contrast between cartilage
and joint fluid

Imaging of Cartilage

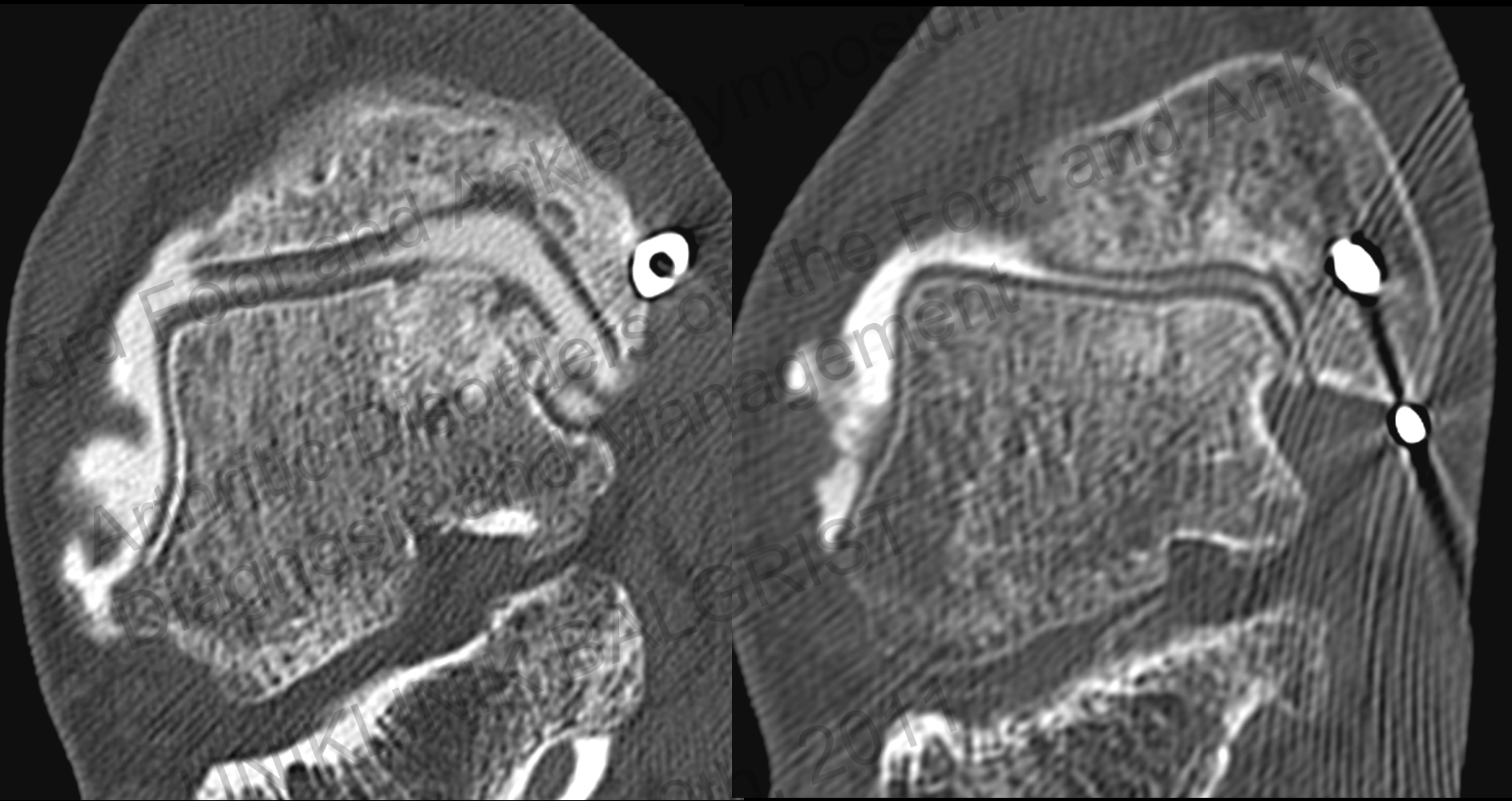


High Resolution, High Contrast: CT Arthrography

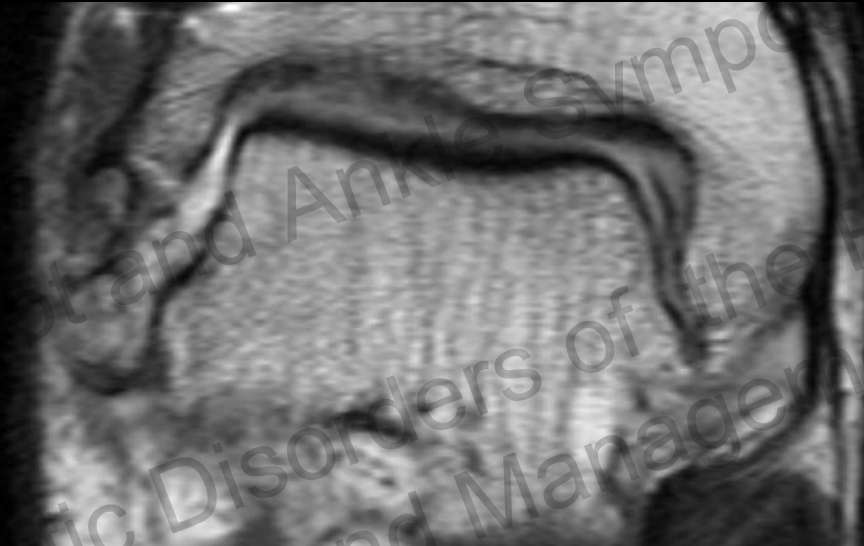
CT-Arthrography: Subtalar Joint



Postoperative: Mosaic plasty



Arthro MRT vs Arthro CT



MR-Arthrography

	Tibia	Talus
Accuracy	73%	69%
Interobserver	72%	75%

CT-Arthrography

	Tibia	Talus
Accuracy	87%	88%
Interobserver	87%	88%

Accuracy

Interobserver

Tibia

Talus

73%

69%

72%

75%

Tibia

Talus

87%

88%

87%

88%



New Developments

“**biochemical**” MR techniques

T2 mapping

T2* mapping

dGEMRIC (delayed Gadolinium enhanced MRI of cartilage)

allow quantitative grading of cartilage degeneration

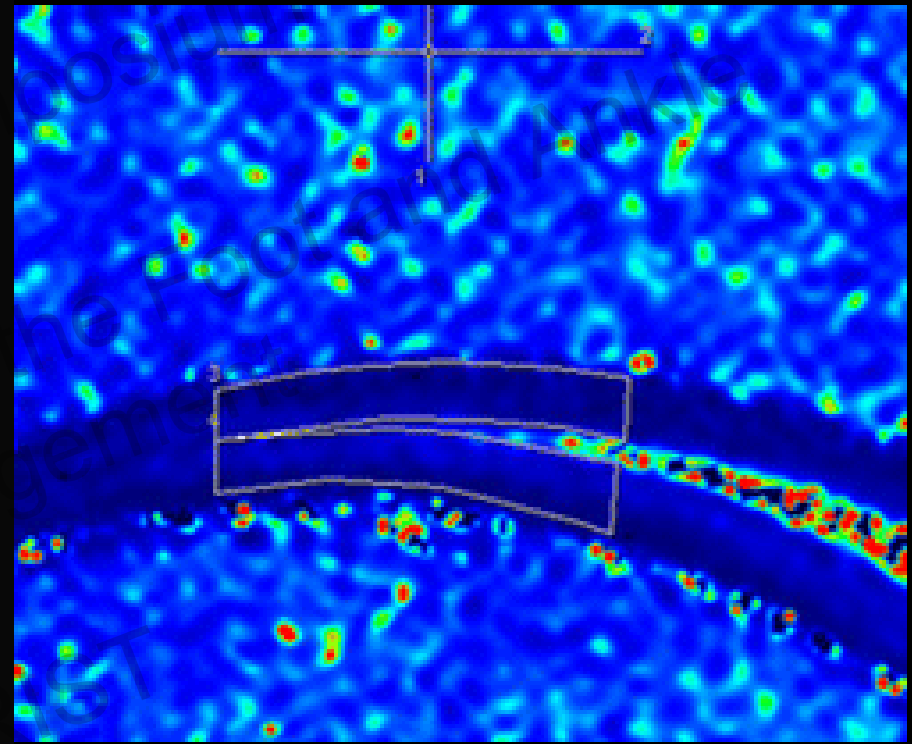
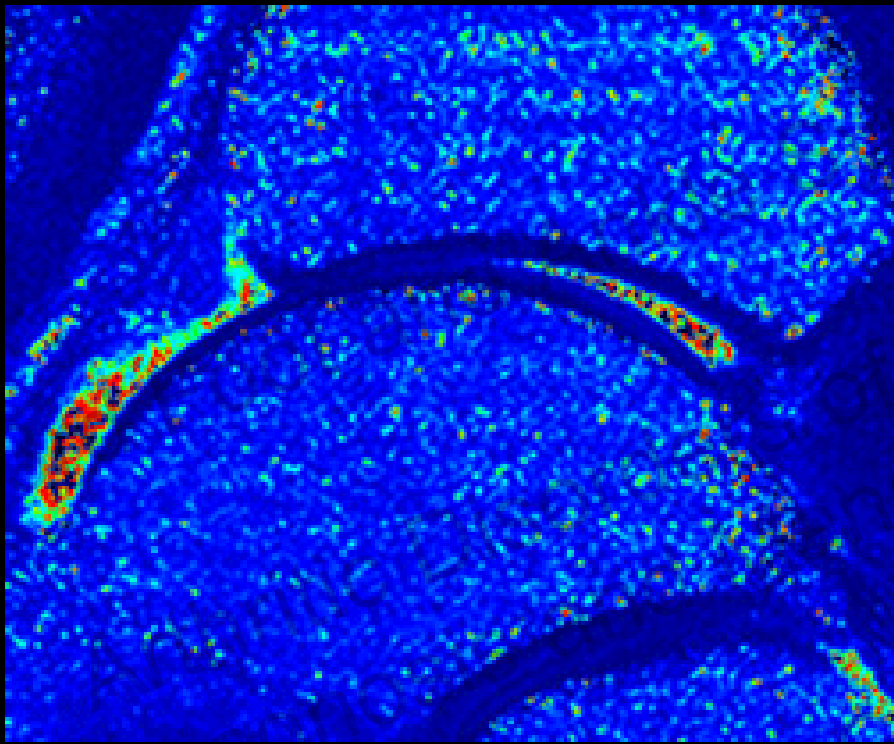
T2 Maps

collagen content and orientation/hydration

dGEMRIC

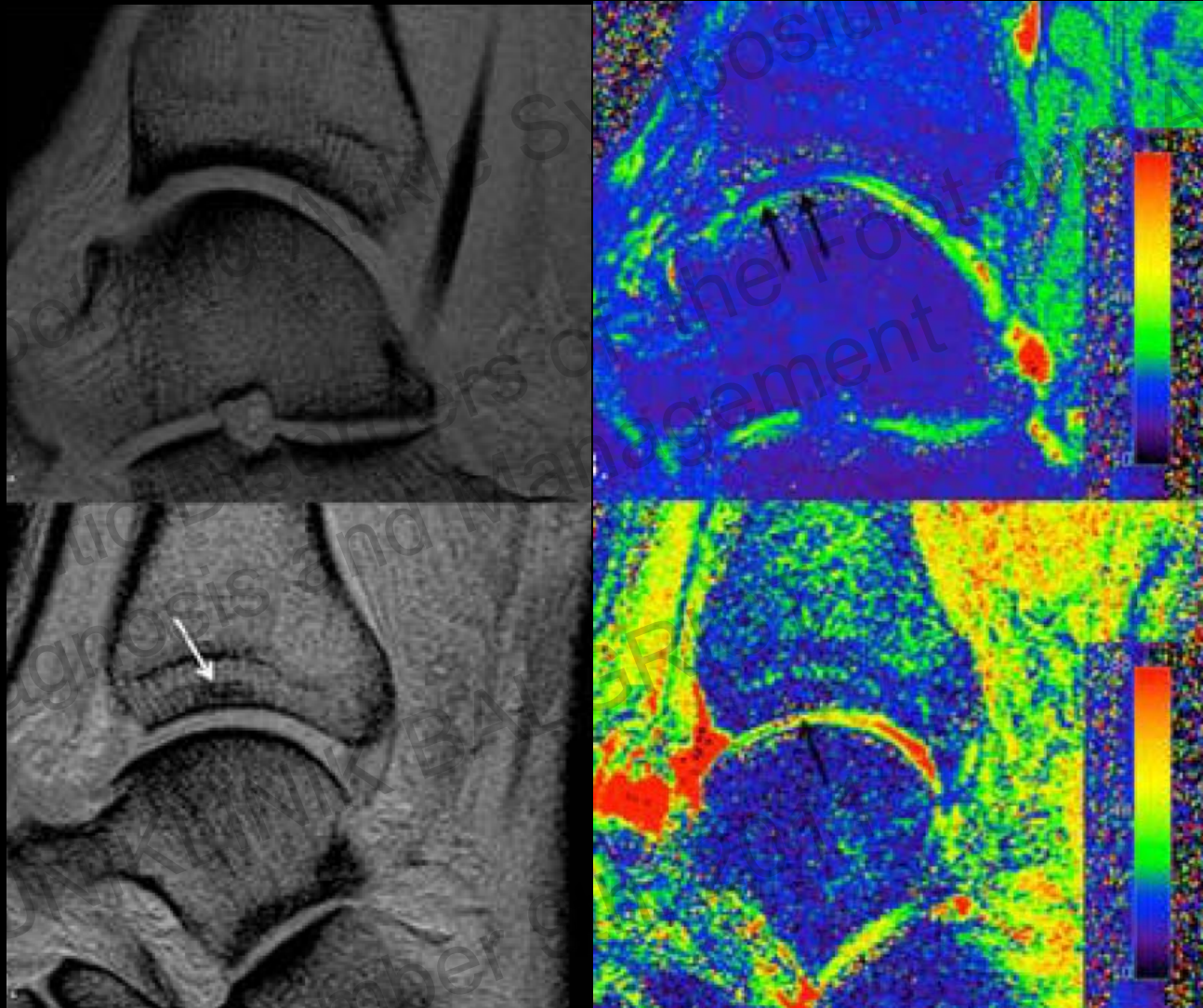
glycosaminoglycan content

Biochemical Imaging

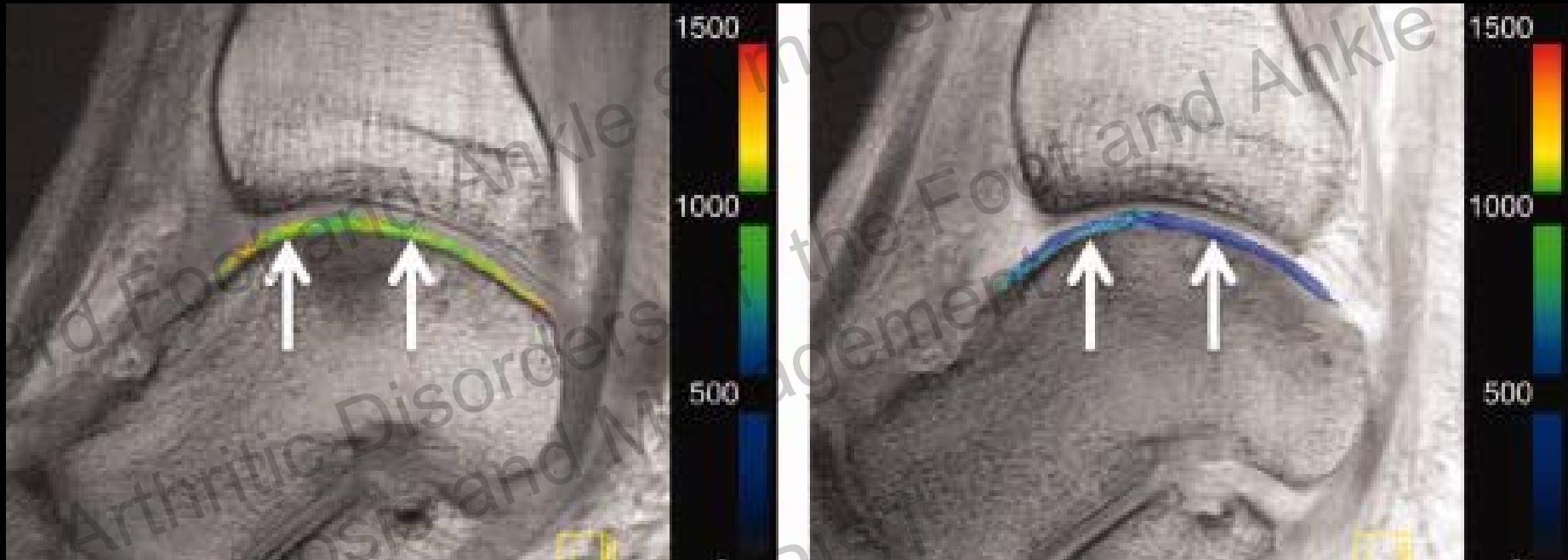


Quantitative T2 imaging
collagen content and orientation/hydration

Biochemical T2* MR quantification of ankle arthrosis in pes cavovarus



Delayed gadolinium-enhanced MRI of cartilage in the ankle



dGEMRIC

Signal drop proportional to glycosaminoglycan content

Alignment: Bases

Weight-bearing
Whole leg
Radiographs

Weight-bearing Radiographs of the foot



Alignment

lateral foot radiographs:

- calcaneal pitch angle
- lateral talocalcaneal angle
- tibiocalcaneal angle
- lateral talus-first metatarsal angle
- metatarsal stacking angle
- naviculocuboid overlap
- medial-lateral column ratio

anteroposterior foot radiographs

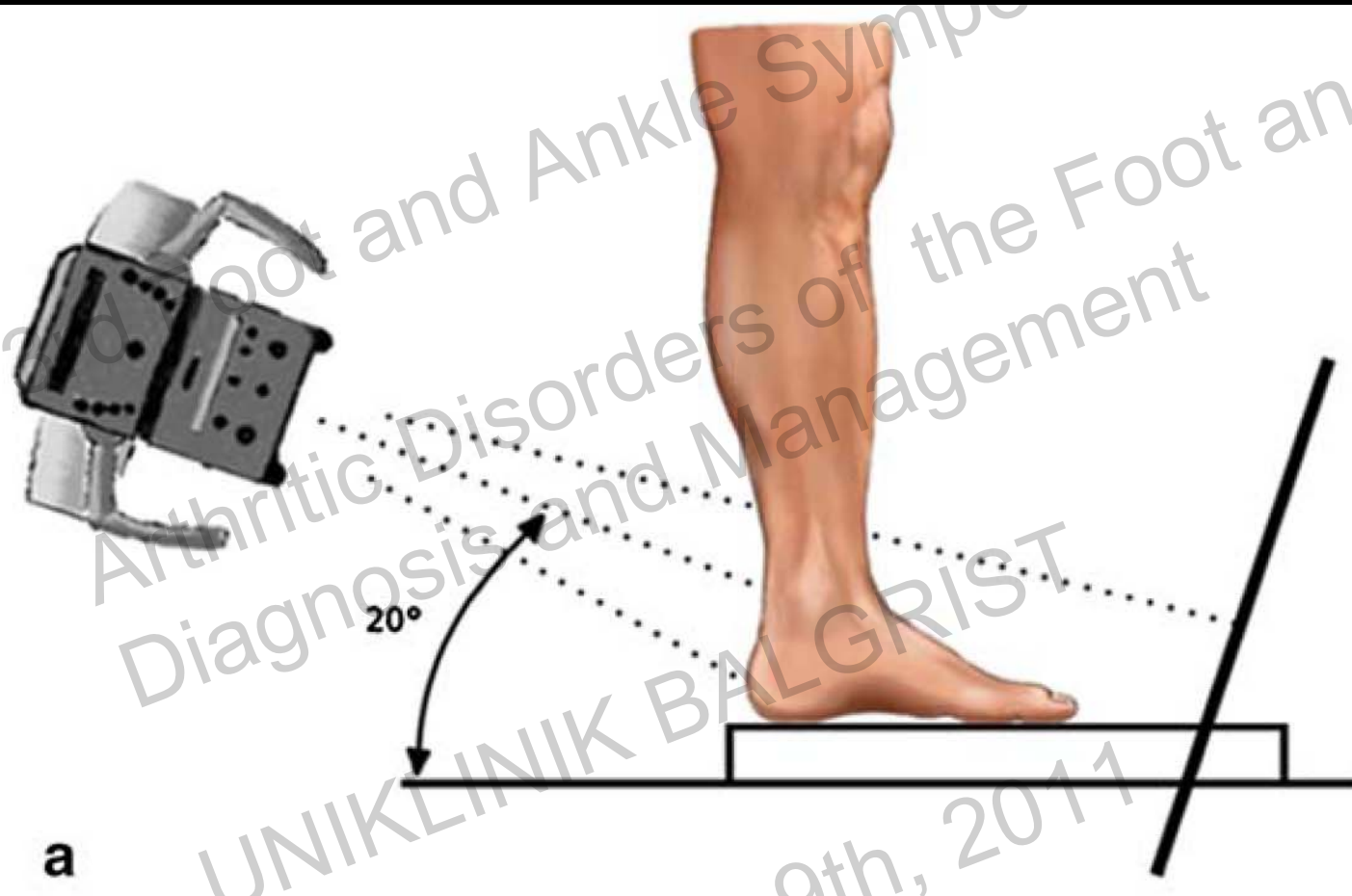
- talonavicular coverage angle
- anteroposterior talus-first metatarsal angle



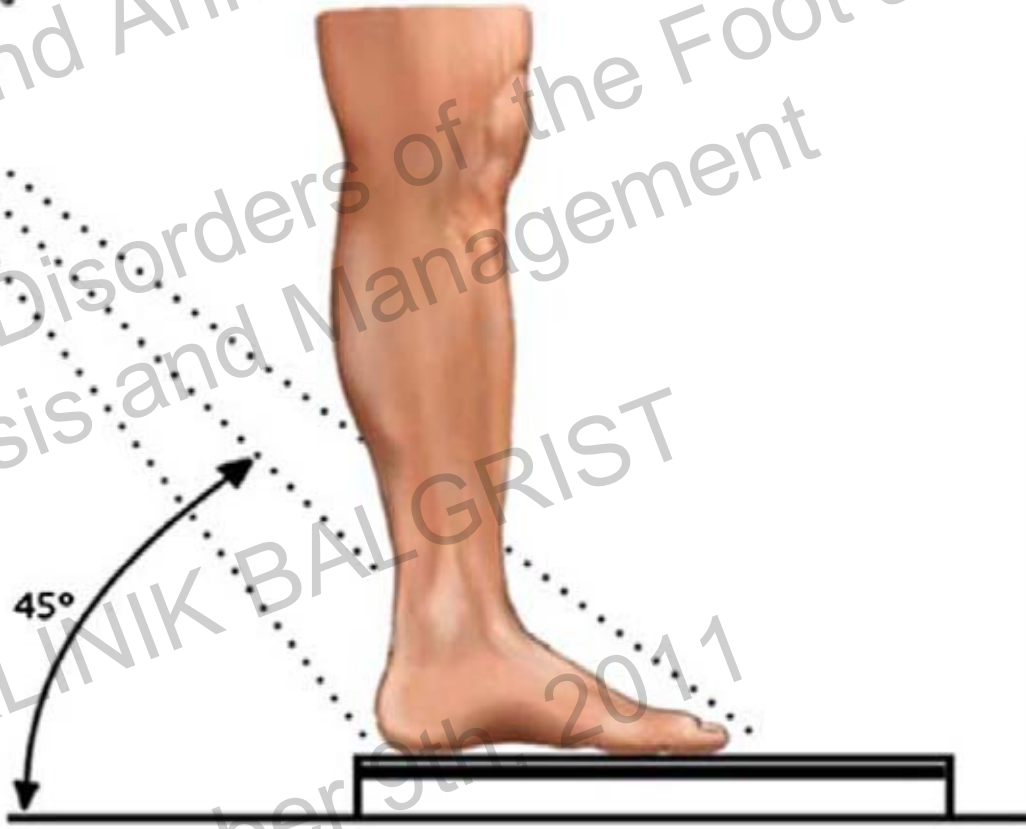
Hindfoot Alignment



Hindfoot Alignment View



Long Axial View



a

b

Measurement



1. Calcaneal axis (as described by Cobey¹)
2. Medial calcaneal contour
3. Lateral calcaneal contour
4. Moment arm (as described by Saltzman²)

Ref.:

1. Cobey JC. Posterior roentgenogram of the foot. Clin Orthop Relat Res. 1976;(118):202-207.
2. Saltzman CL, El-Khoury GY. The hindfoot alignment view. Foot Ankle Int. 1995 Sep. 1;16(9):572-576.

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Measurement

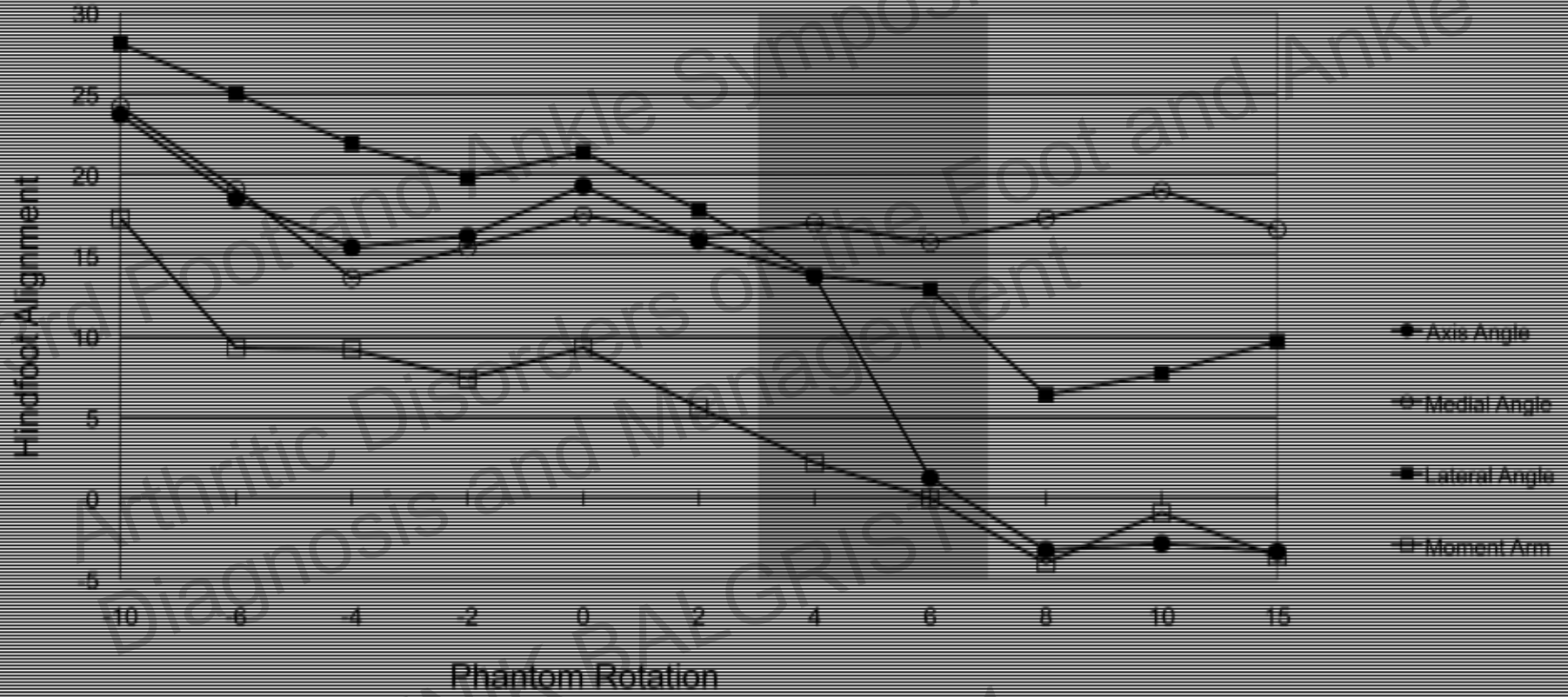


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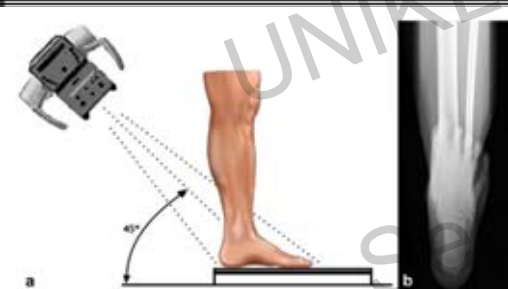
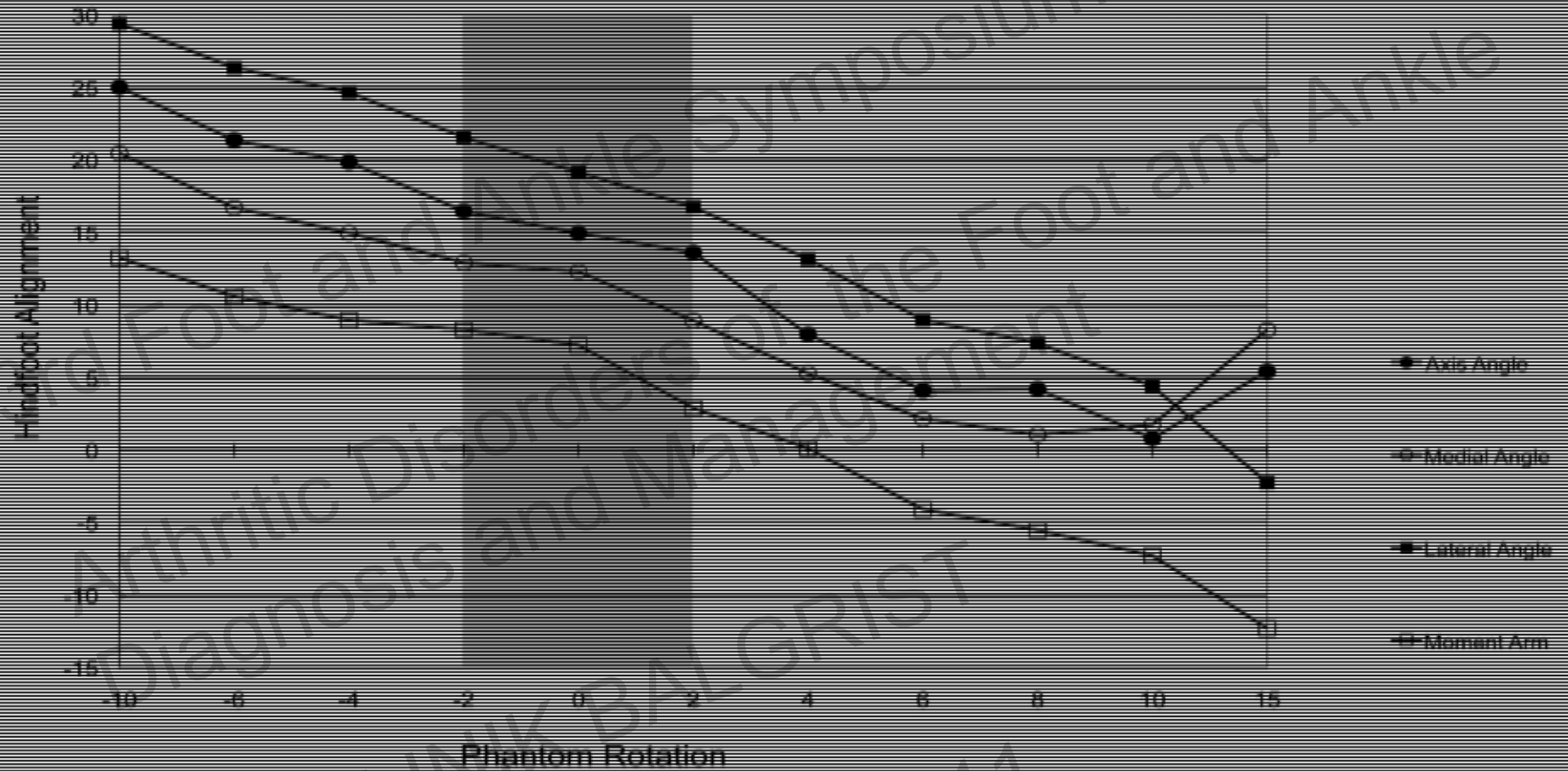
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Hindfoot Alignment View



Mal positioning of 2° = Error of up to 11°

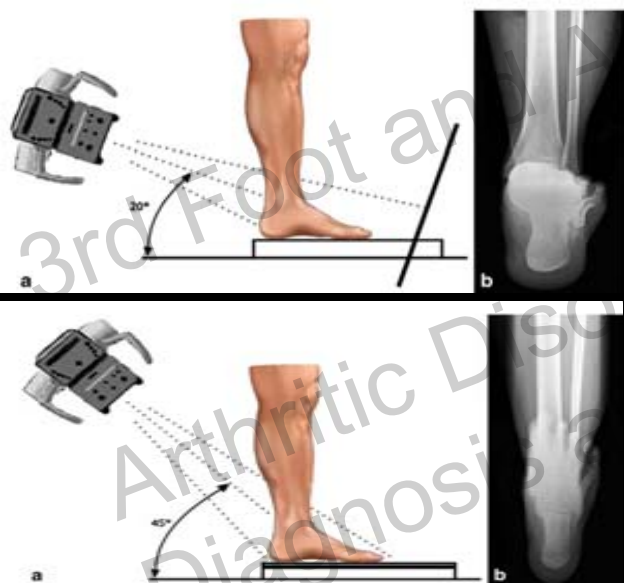
Long axial view



Mal positioning of $4^\circ = \text{Error of } 5^\circ$

Buck F, AJR in press

Interreader Agreement



Measurement Technique		Interreader Agreement Intraclass Correlation Coefficient
Hindfoot Alignment View	Calcaneal Axis (<i>Cobey</i>)	0.80
	Medial Calcaneal Contour	0.80
	Lateral Calcaneal Contour	0.90
	Moment Arm (<i>Saltzman</i>)	0.90
Long Axial View	Calcaneal Axis (<i>Cobey</i>)	0.98
	Medial Calcaneal Contour	0.97
	Lateral Calcaneal Contour	0.98
	Moment Arm (<i>Saltzman</i>)	0.94

Interreader agreement better on long axial view

Axis Angle (*Cobey*) least prone to errors due to mal positioning

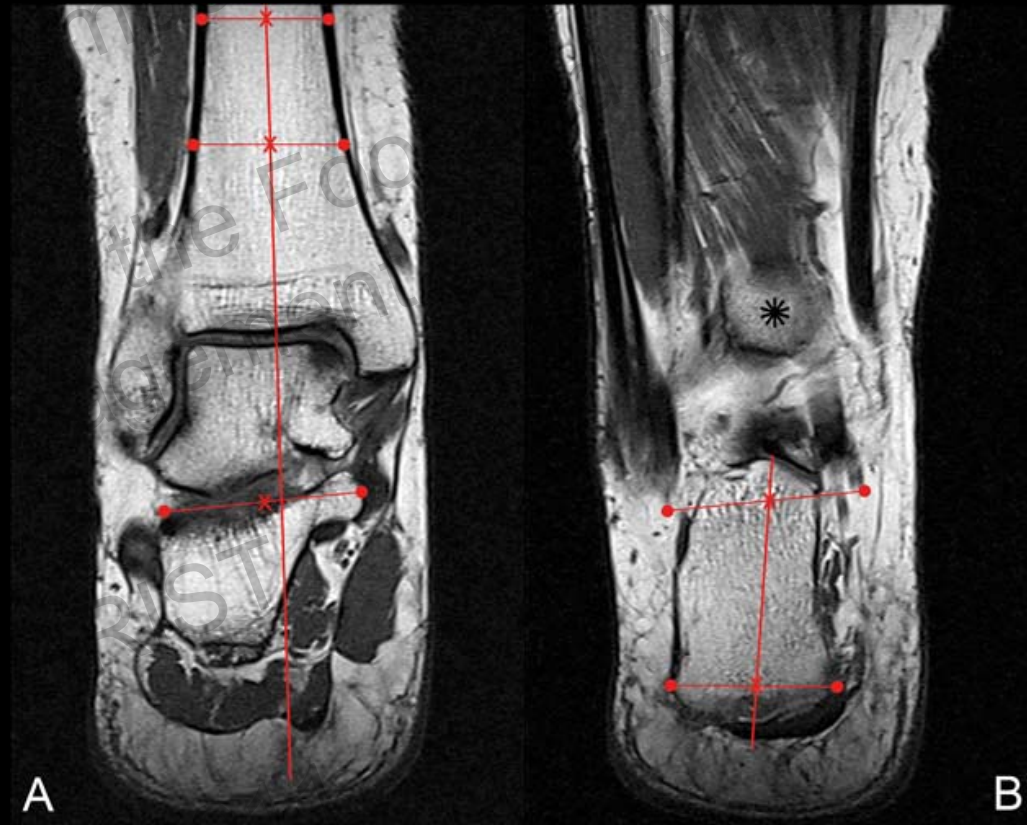
Cross Sectional imaging ?

Most posterior coronal image showing the tibia

Angle between calcaneal axis to tibial axis

Possible to see $>10^\circ$ valgus or any varus deformity on

Reference: Long axial view,



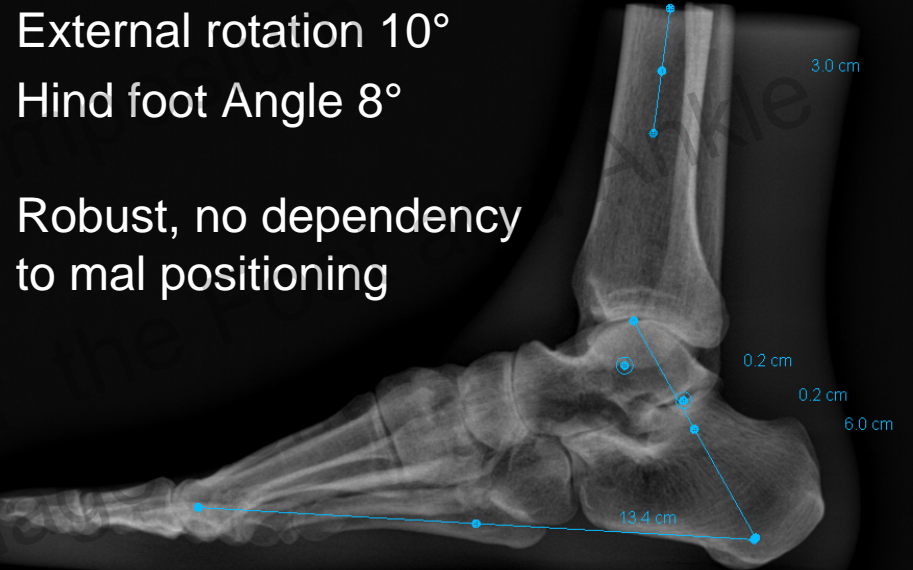
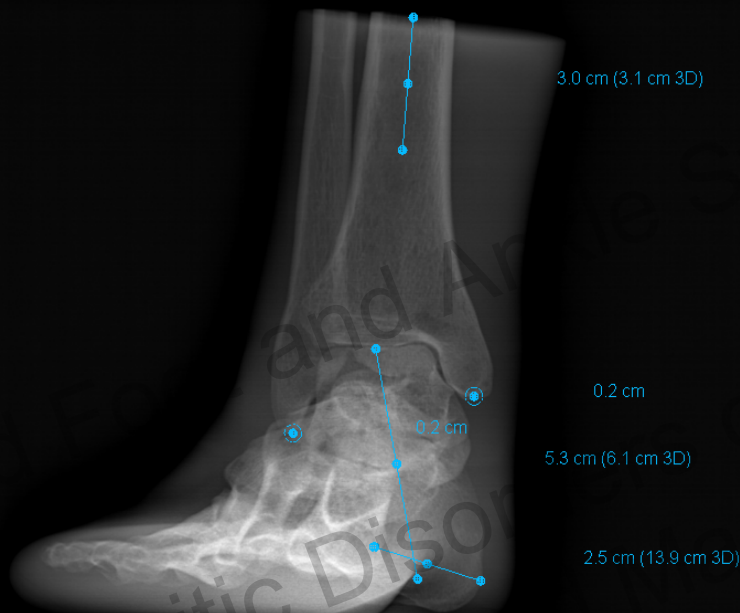
Angle Measurement in 3D Space ?



EOS ultra low dose
2D/3D Scanner:

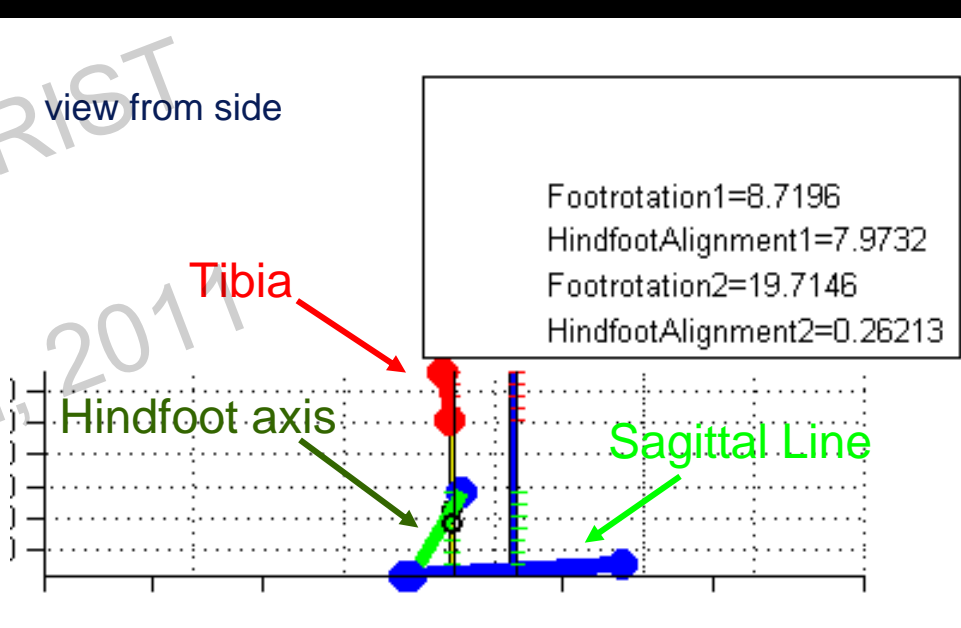
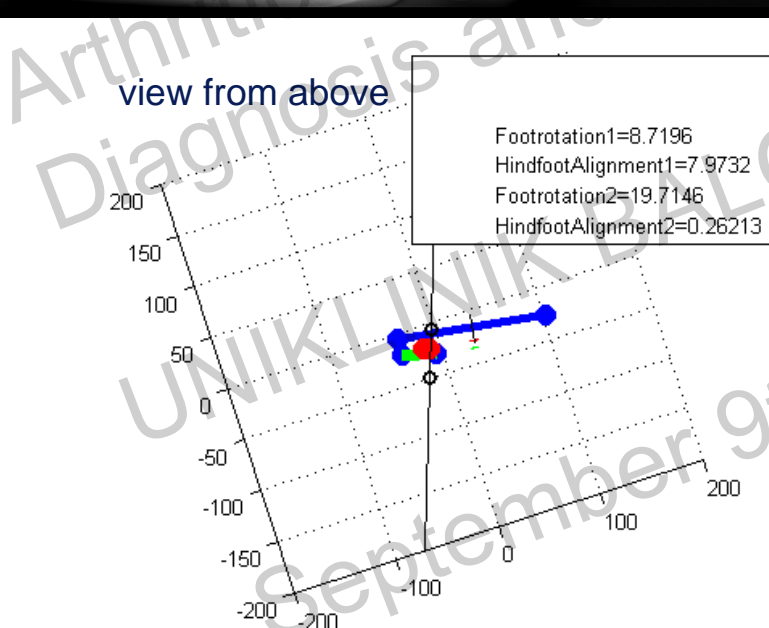
- Whole body x-Ray scanner
- Low dose (10%)
- Simultaneous biplanar image acquisition in weight bearing position
- Measurements of angles and distances in 3D Space
- 3D-Reconstruction

3D Measurement Hindfoot Alignment



External rotation 10°
Hind foot Angle 8°

Robust, no dependency to mal positioning



Outline

Arthritic disorders of the Foot and Ankle

Imaging of Ligaments

Standard

New developments

Imaging of Cartilage

Standard

New developments

Alignment

Standard

New developments

Thank you

3rd Foot and Ankle Symposium
Arthritic Disorders of the Foot and Ankle
Diagnosis and Management

UNIKLINIK BALGRIST

September 9th, 2011

