The Triangular Fibrocartilage Complex

Jeremy Grubin

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Outline

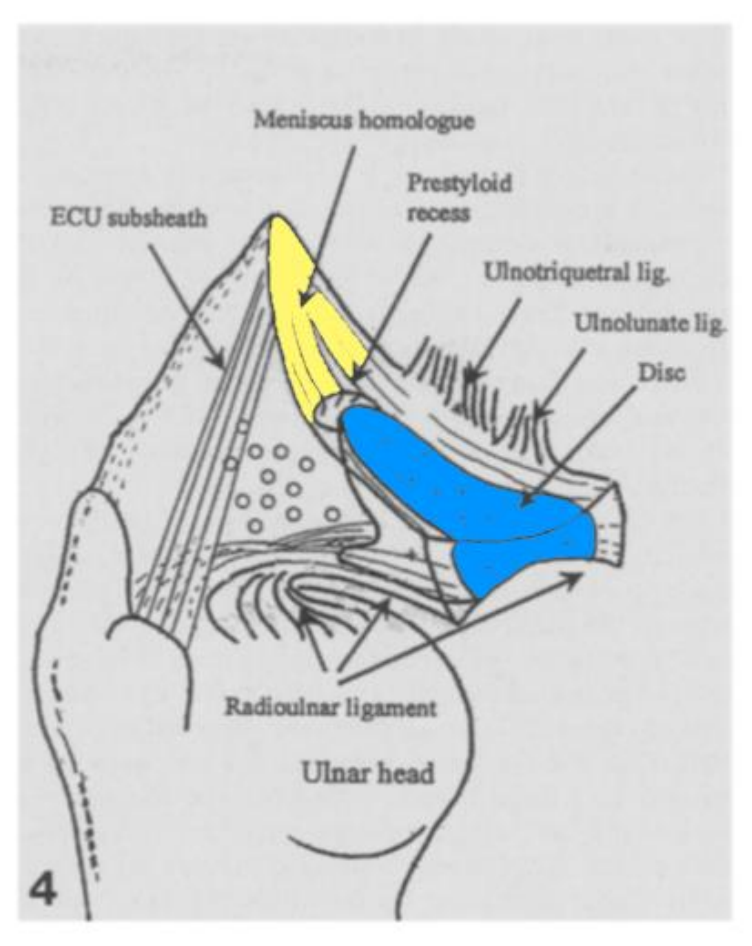
- Histoanatomy
- Function
- History and Physical
- Imaging
- Classification
- Treatment

Components of TFCC

- Fibrocartilaginous disc proper/articular disc/TFC/horizontal portion
- Meniscus homologue/meniscal homologue
- Dorsal and volar radioulnar ligaments
- Sheath of extensor carpi ulnaris
- Ulnolunate and ulnotriquetral ligaments
- Ulnar collateral ligament/ulnar joint capsule

Components of TFCC

- Fibrocartilaginous disc proper
  - Hammock-like concavity supporting carpus distally
  - Arises from radius as fibrocartilaginous extension of hyaline articular cartilage
  - Splits into two lamina ulnarly
    - Upper/proximal lamina attaches to styloid process and ulnar head
    - Lower/distal lamina extends beyond ulna and blends with sheath of extensor carpi ulnaris and ulnar collateral ligament
    - Triangular ligament – both laminae
  - Superficial radioulnar fibers surround disc and insert onto ulnar styloid
  - Deep radioulnar fibers called ligamentum subcruentum insert on to fovea and ulnar styloid base
- Meniscus homologue
- Radioulnar ligament
- Sheath of extensor carpi ulnaris
- Ulnolunate and ulnotriquetral ligaments
- Ulnar collateral ligament



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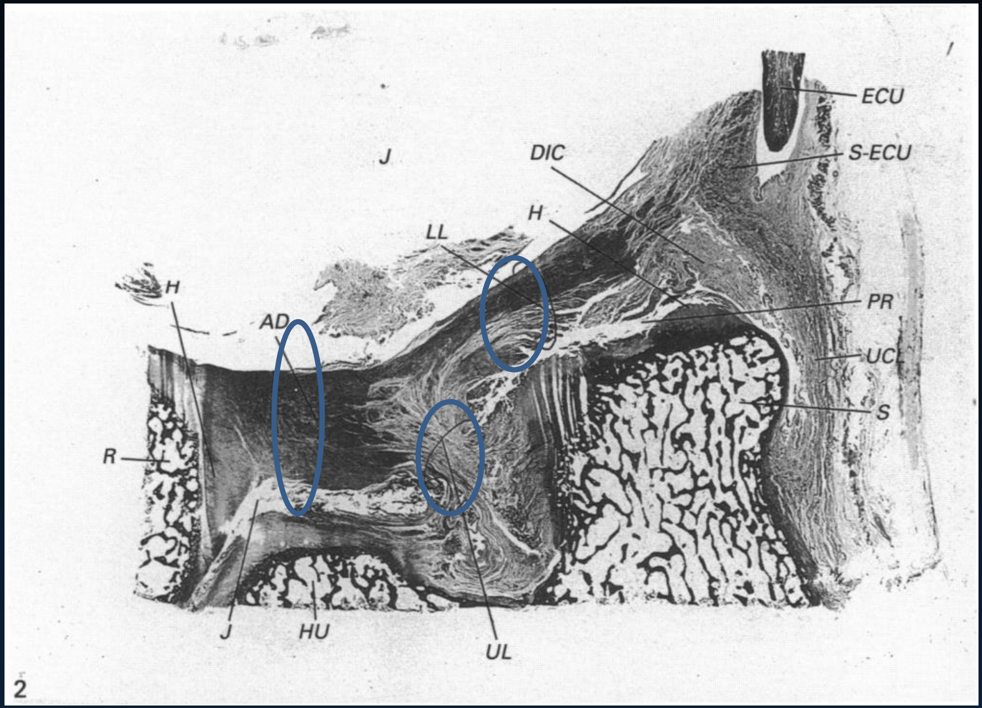

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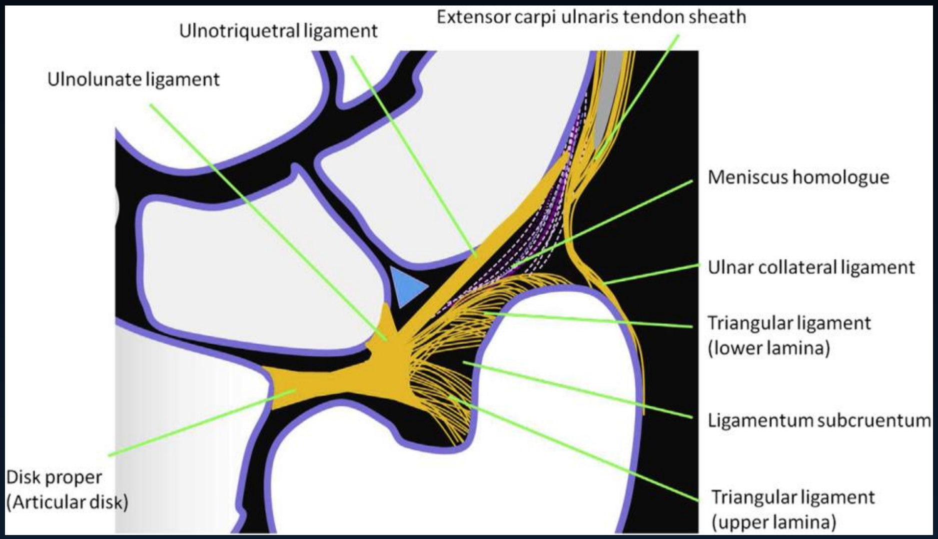

Yoshioka et al. Magnetic resonance imaging of triangular fibrocartilage. J Magn Reson Imaging. 2012.

Components of TFCC

- Fibrocartilaginous disc proper
- Meniscus homologue
  - Ulnar internal wall of radiocarpal joint
  - Similar to ropes supporting a hammock
  - Ill defined region of irregular, dense fibrous connective tissue
  - Integral part of lower lamina
  - Attaches to triquetrum
- Radioulnar ligament
- Sheath of extensor carpi ulnaris
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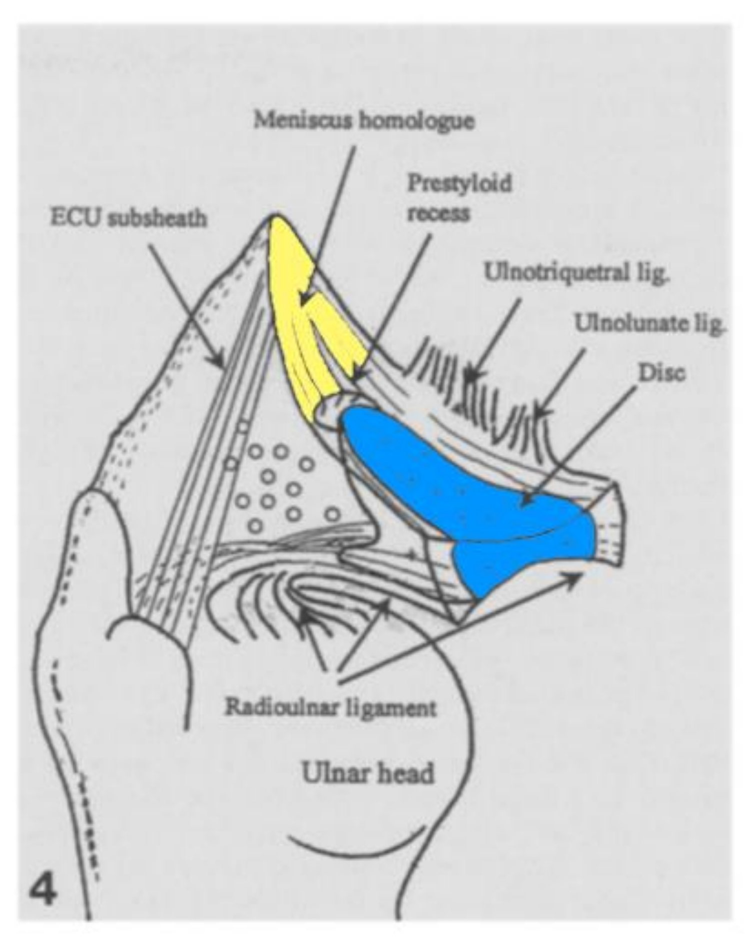

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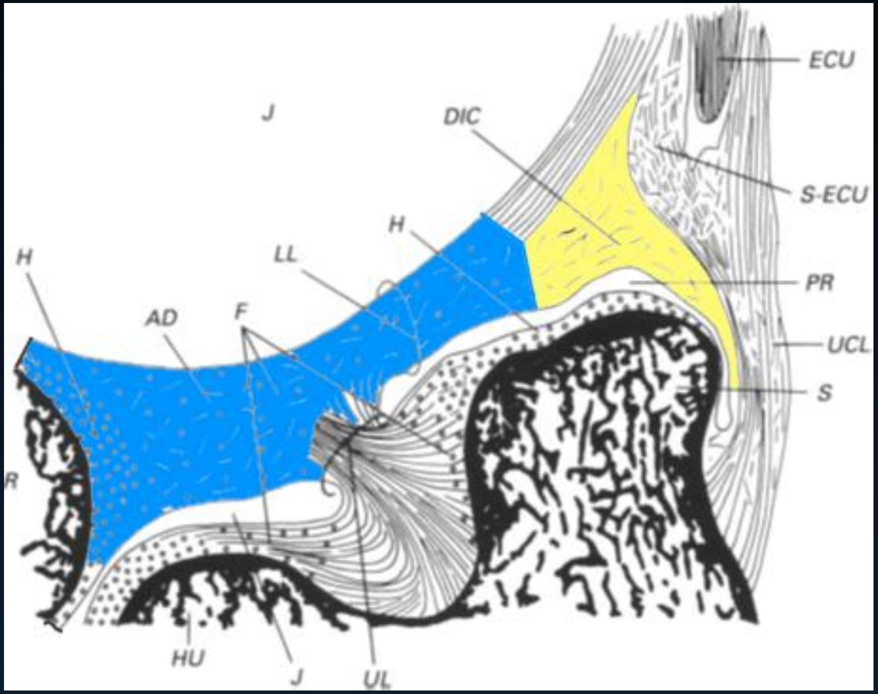

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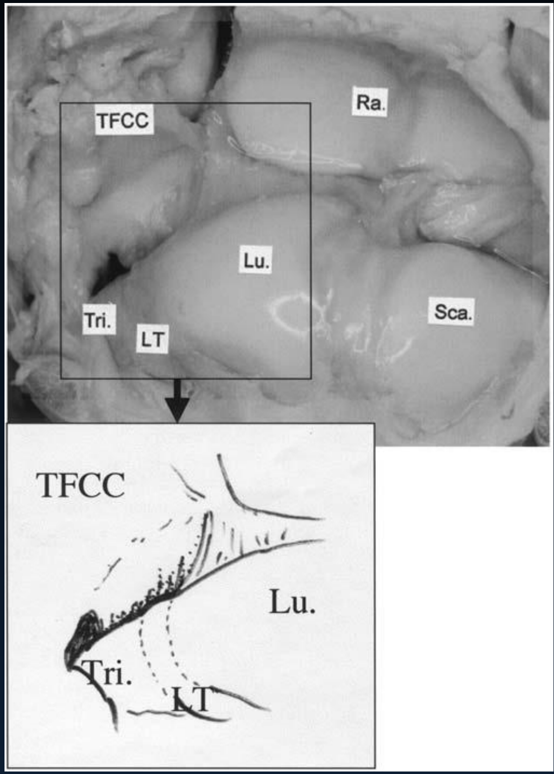
Meniscal Homologue

- Meniscal homologue and its end attach to triquetrum and fifth metacarpal
- 4 subtypes of meniscal homologue attachments to triquetrum
  - Group 1 (28%) – small, thin structure with focal attachment
  - Group 2 (39%) – small, thick structure with focal attachment
  - Group 3 (38%) – thick structure with broad attachment between 1/3-1/4 of triquetrum
  - Group 4 (5%) – broad attachment covering entire triquetrum



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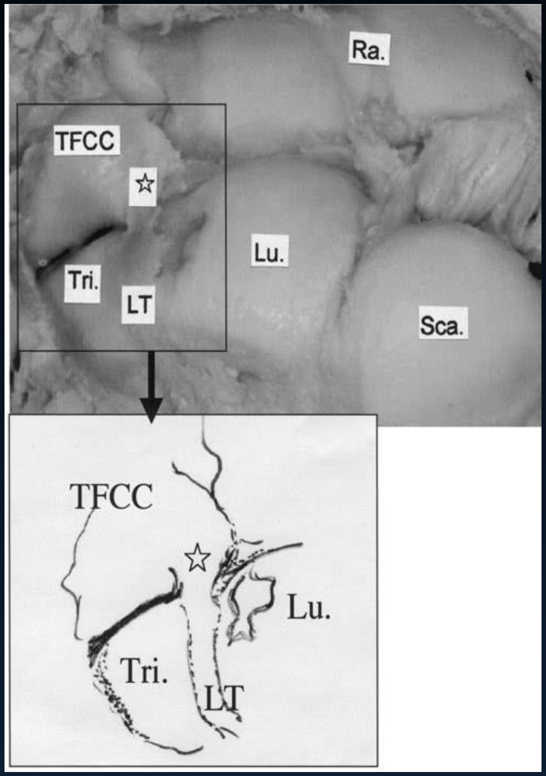

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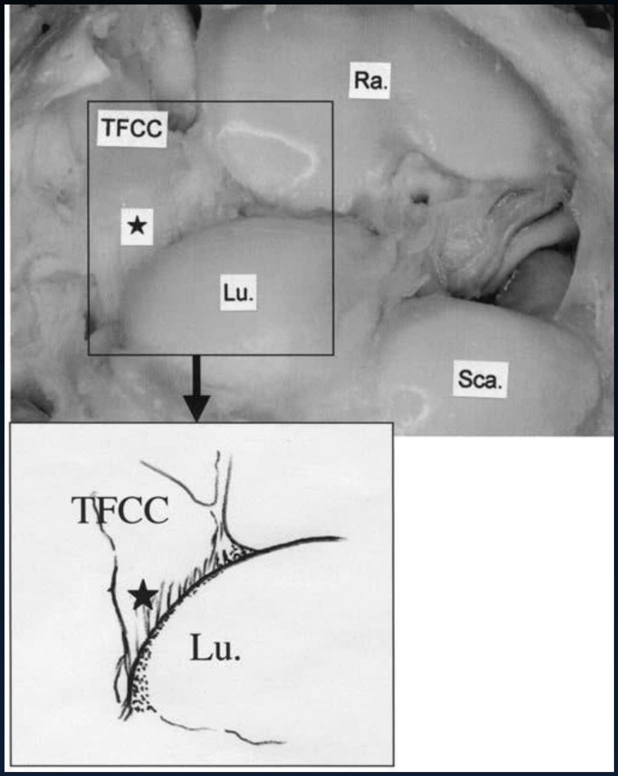

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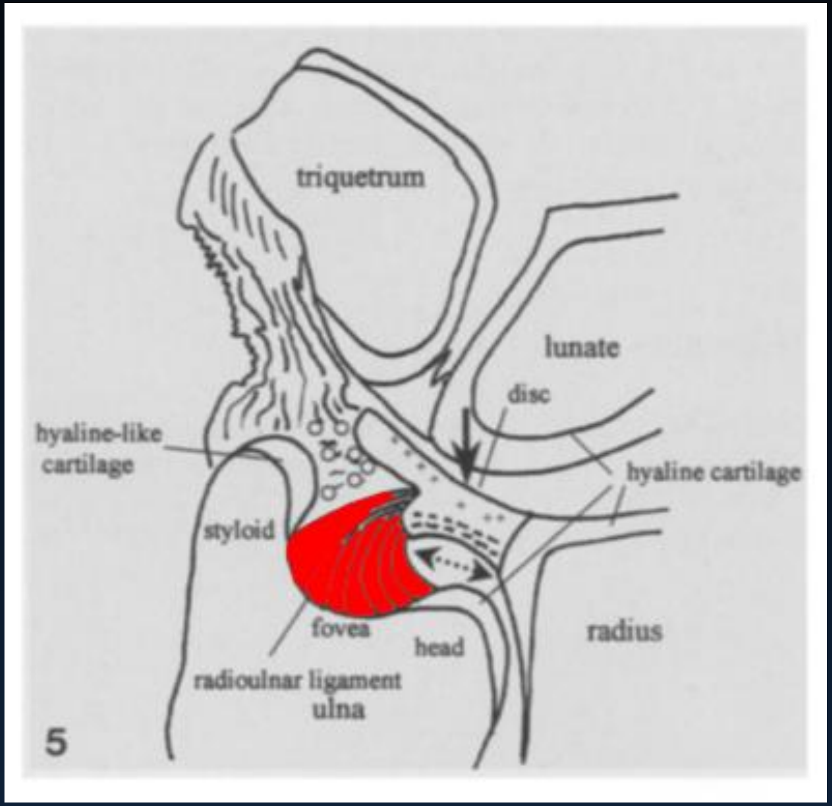
- Radioulnar ligament
  - Attaches to ulna at fovea and basistyloid
  - Bifurcates volarly and dorsally to enclose and partially coalesce with disc
  - Inserts around distal rim of sigmoid notch of radius
  - Dorsal radioulnar ligament blends with sheath of extensor carpi ulnaris
  - Stabilizes distal radioulnar joint
- Sheath of extensor carpi ulnaris
- Ulnolunate and ulnotriquetral ligaments
- Ulnar collateral ligament



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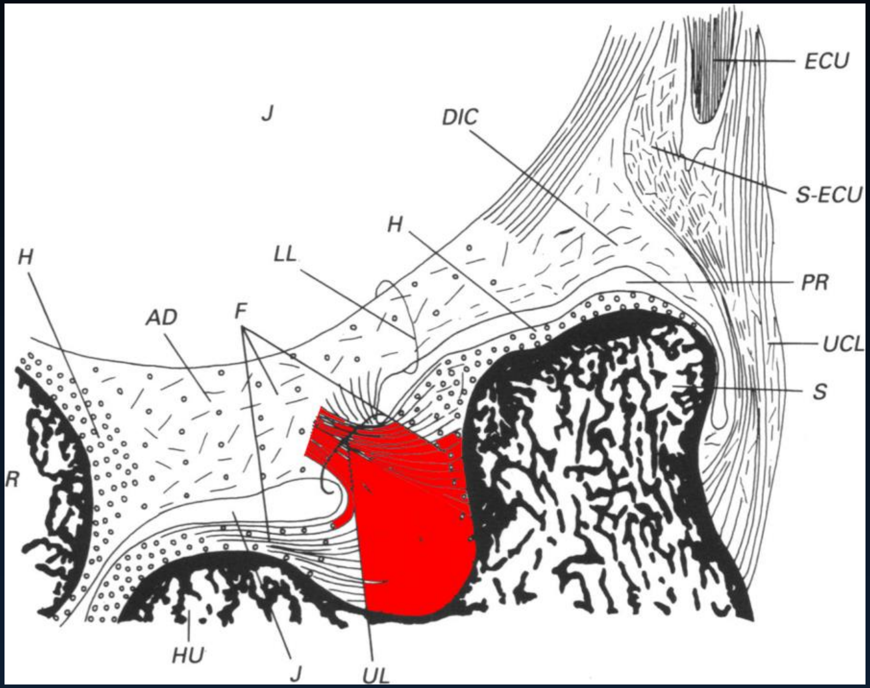

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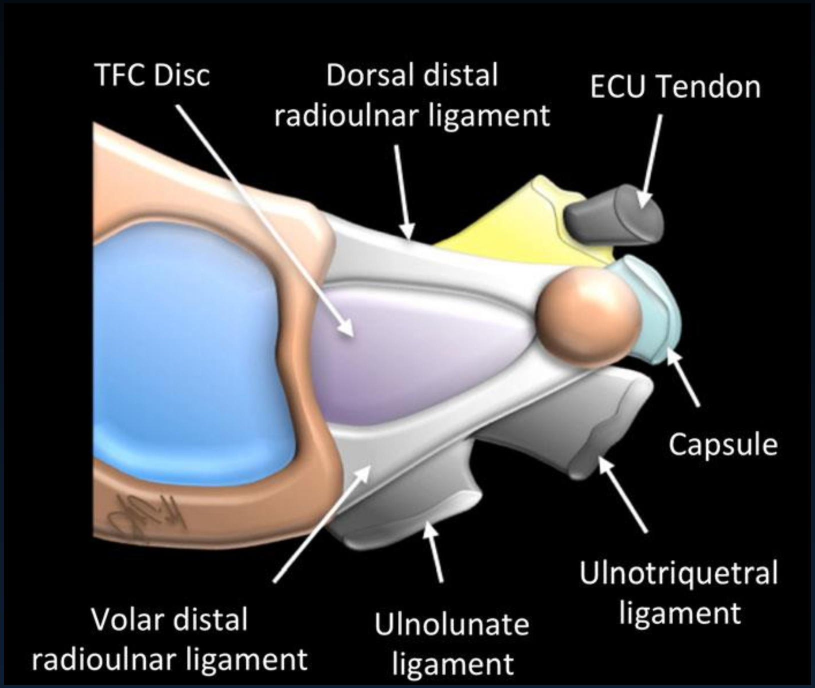

Bae et al. MR morphology of triangular fibrocartilage complex: correlation with quantitative MR and biomechanical properties. Skeletal Radiol. 2016.

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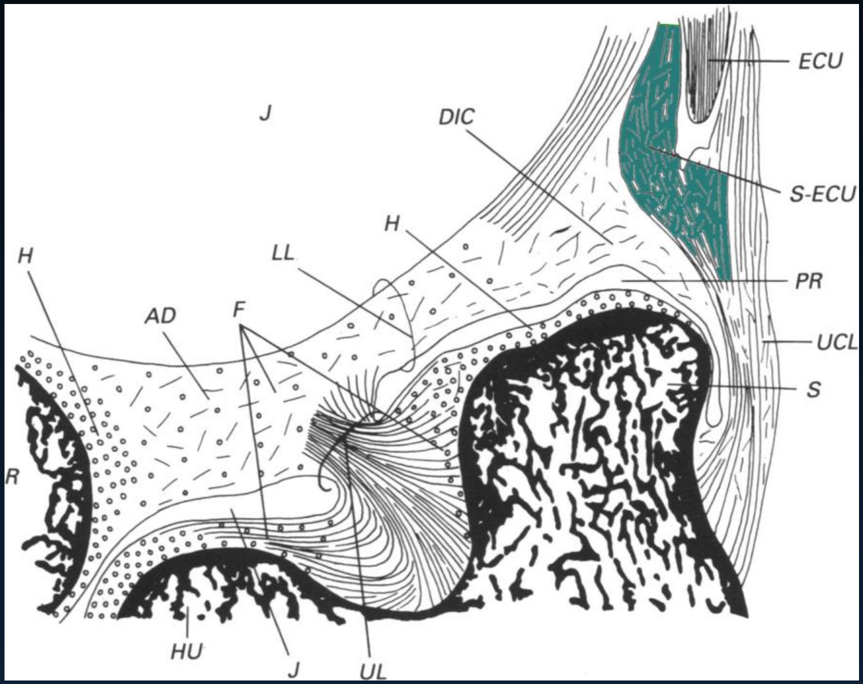

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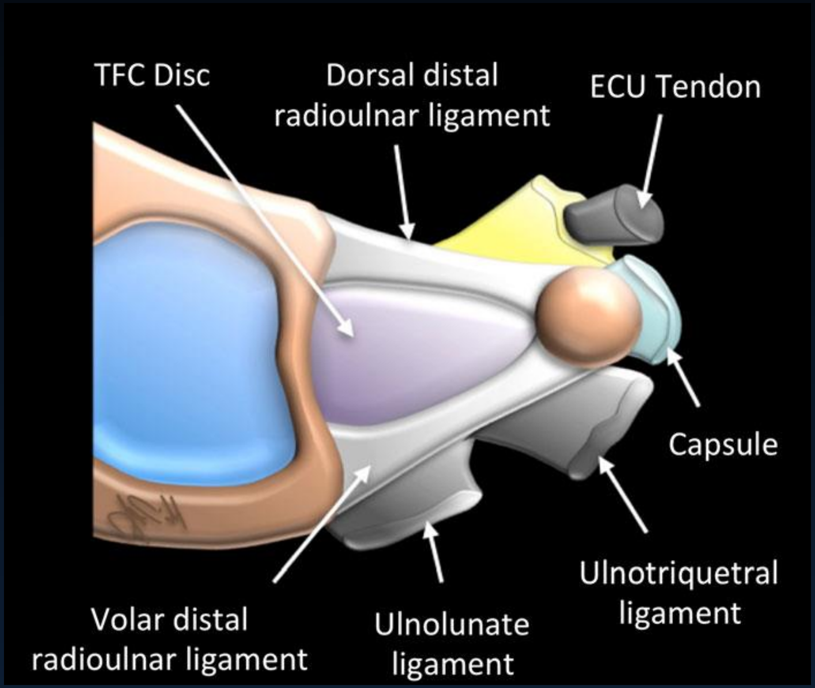

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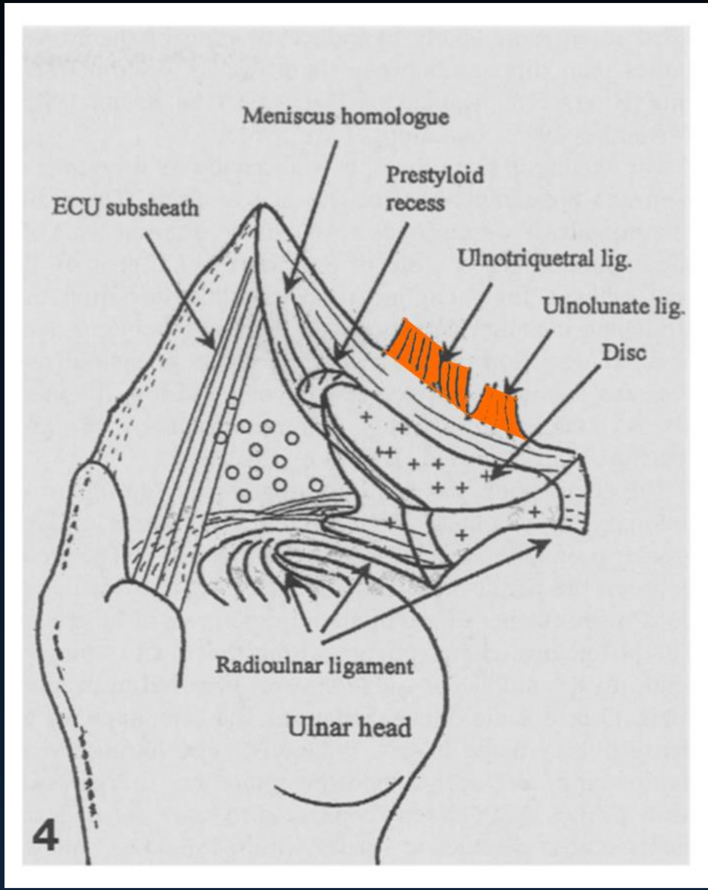

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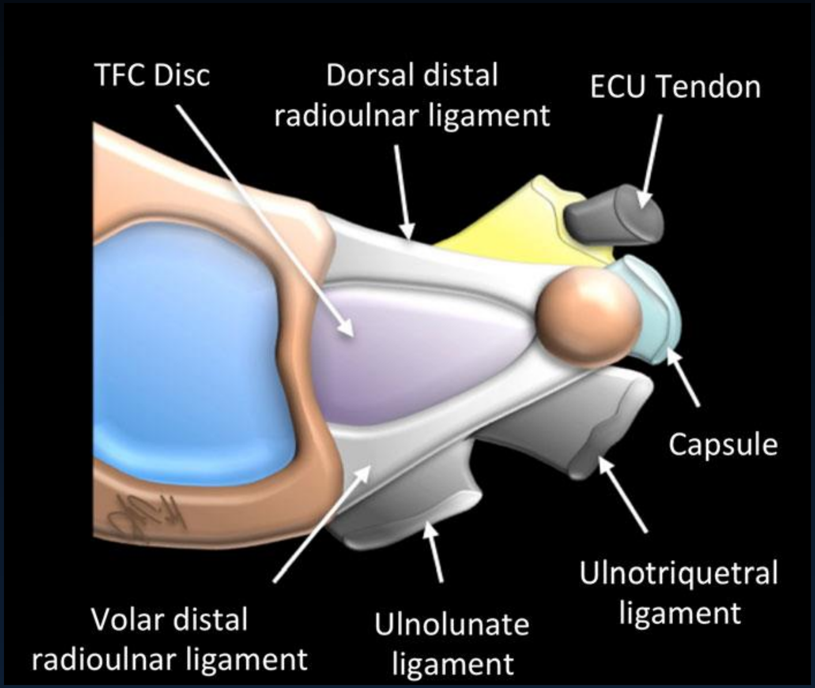

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- Sheath of extensor carpi ulnaris
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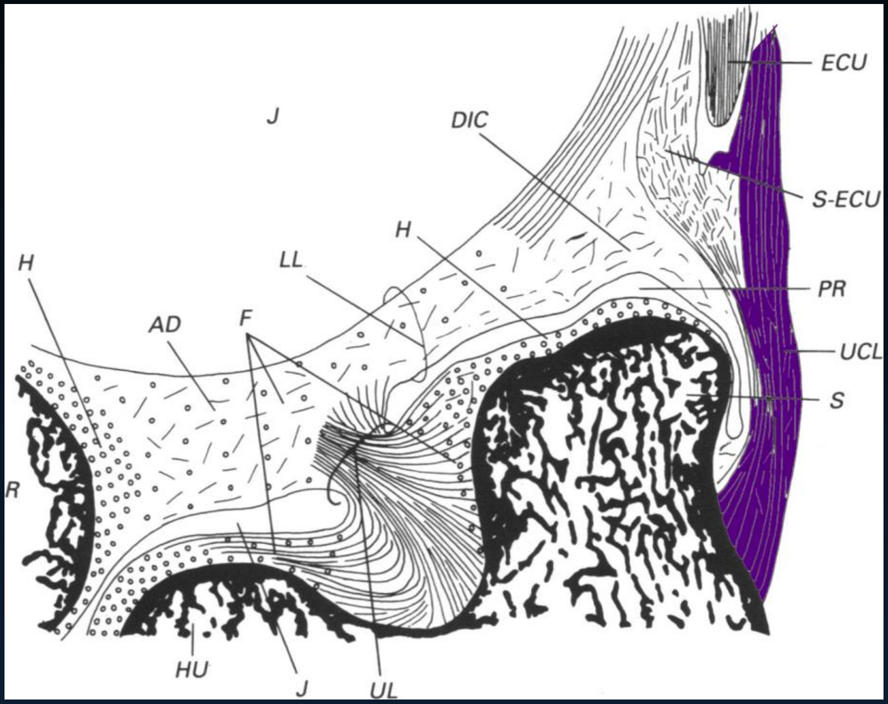
- Ulnar collateral ligament
  - Loose, poorly defined
  - Longitudinally oriented collagen fibers
  - Attaches to ulnar aspect of base of ulnar styloid



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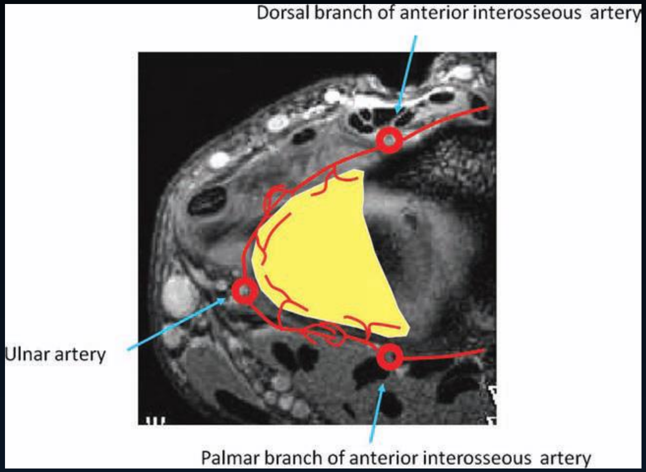
Additional Anatomic Considerations

- Blood supply
  - Terminal portions of the anterior and posterior interosseous arteries
  - Peripheral 10-40% vascularized, good healing potential
  - Central portion avascular, poor healing potential
- Innervation (study of 11 cadaveric specimens)
  - Volar and ulnar portions by dorsal cutaneous branch of ulnar nerve (100%), medial antebrachial cutaneous nerve (91%), volar branch of ulnar nerve (73%), anterior interosseous nerve (27%), posterior interosseous nerve (18%), palmar branch of median nerve (9%)
  - Central and radial portions devoid of nerve fascicles
- Ulnar variance
  - Negative – less wear
  - Positive – more wear
  - Studies show ulnar length reduction triggers repair and 50% of wrists show cartilage regeneration



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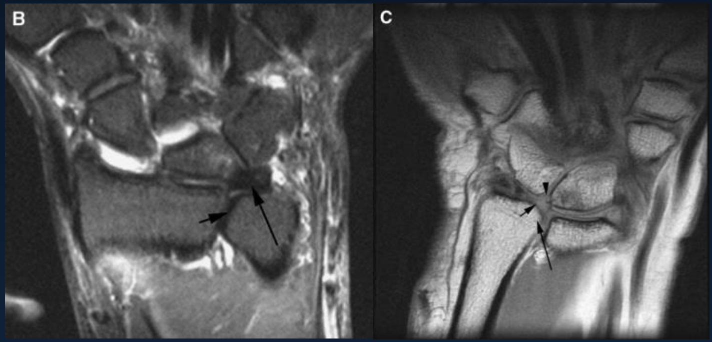

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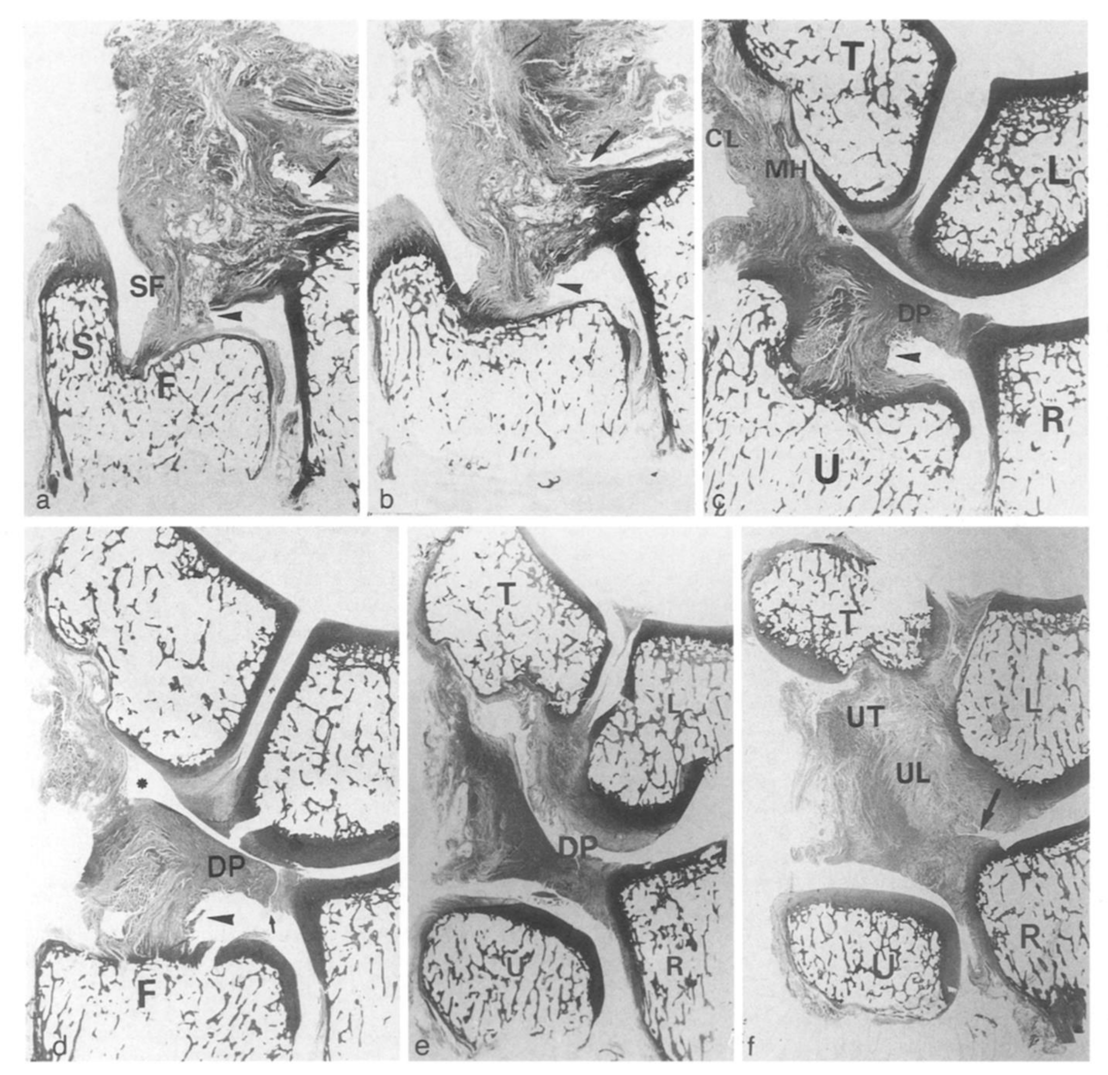
i. Steinbach LS, Chung CB, eds. MRI of the upper extremity: shoulder, elbow, wrist, and hand. Philadelphia: Lippincott William s& Wilkins, 2009.
ii. Zlatkin et al. MR imaging of ligaments and triangular fibrocartilage complex of the wrist. Radiol Clin North Am. 2006.

Anatomy

dorsal



volar

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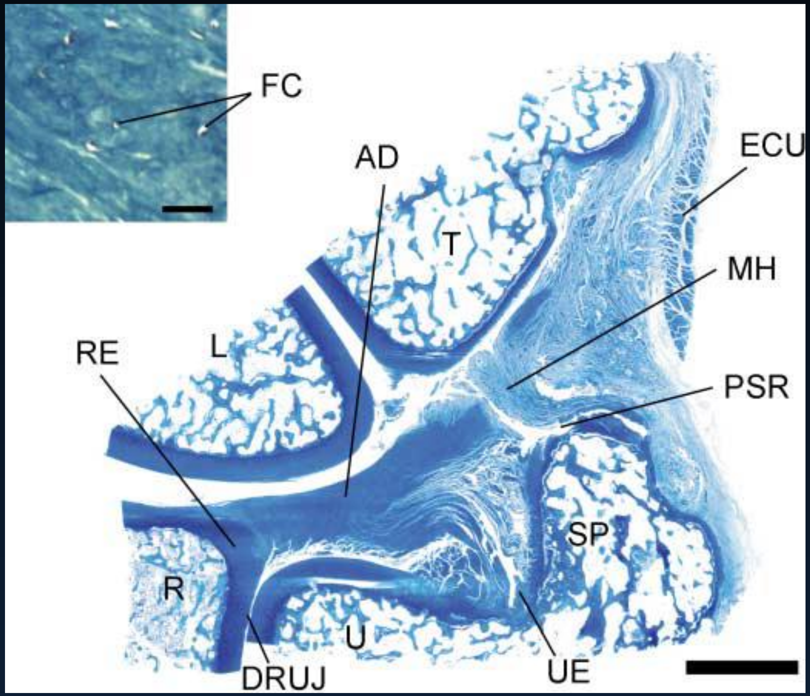
Histology

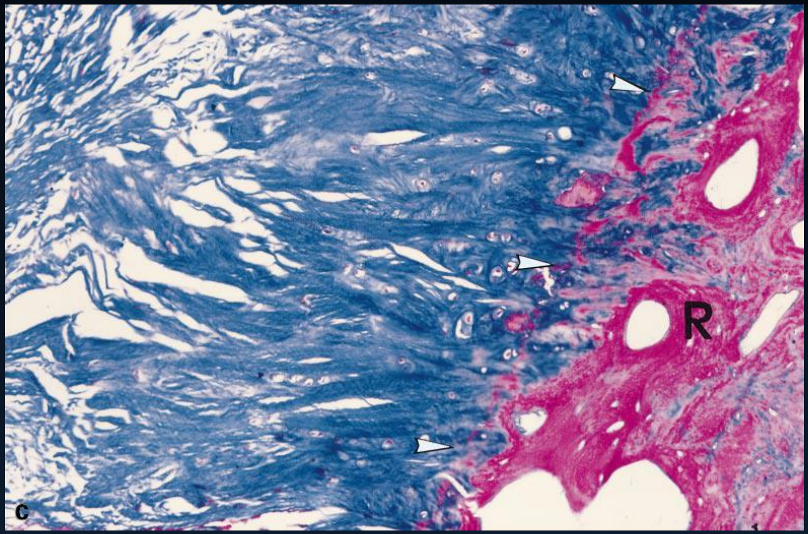
- Inhomogeneous structure
  – Meniscus homologue more fibrous
  – Articular disc more fibrocartilaginous, particularly radially
- Disc contains aggrecan, collagen and other molecules which may be a target of RA



Milz et al. An immunohistochemical study of the triangular fibrocartilage complex of the wrist: regional variations in cartilage phenotype. J Anat. 2007.

Histology – Radial Insertion

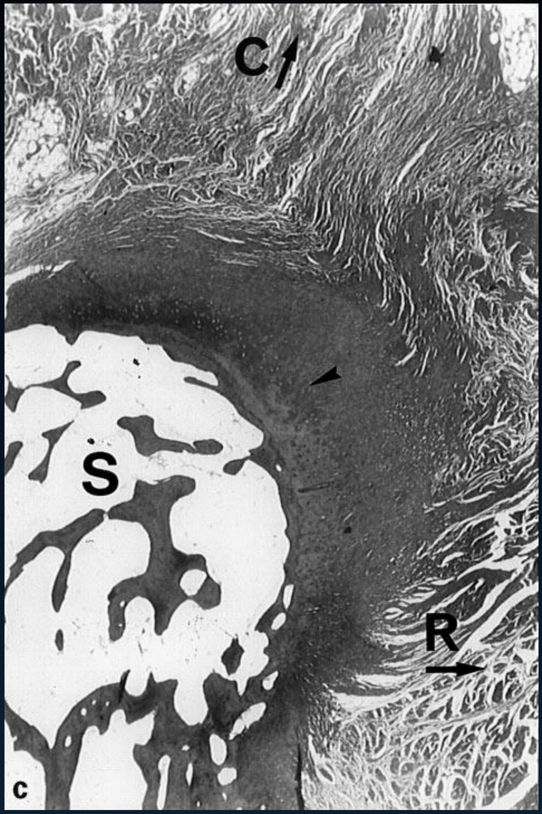
- Fibrocartilaginous disc
  - Firmly inserts onto radius via Sharpey’s fibers, transitions from more fibrous to more cartilaginous, and coalesces into hyaline cartilage at sigmoid notch
- Meniscus homologue
- Radioulnar ligament
- Sheath of extensor carpi ulnaris
- Ulnolunate and ulnotriquetral ligaments



Nakamura et al. Origins and insertions of the triangular fibrocartilage complex: a histological study. J Hand Surg Br.

Histology – Ulnar Styloid Tip

- Fibrocartilaginous disc
- Meniscus homologue
  - Loose fibers extending from radial to ulnar and coalescing into distal ulnar side of disc
  - Confluent with fibers of ulnar joint capsule
- Radioulnar ligament
- Sheath of extensor carpi ulnaris
- Ulnolunate and ulnotriquetral ligaments



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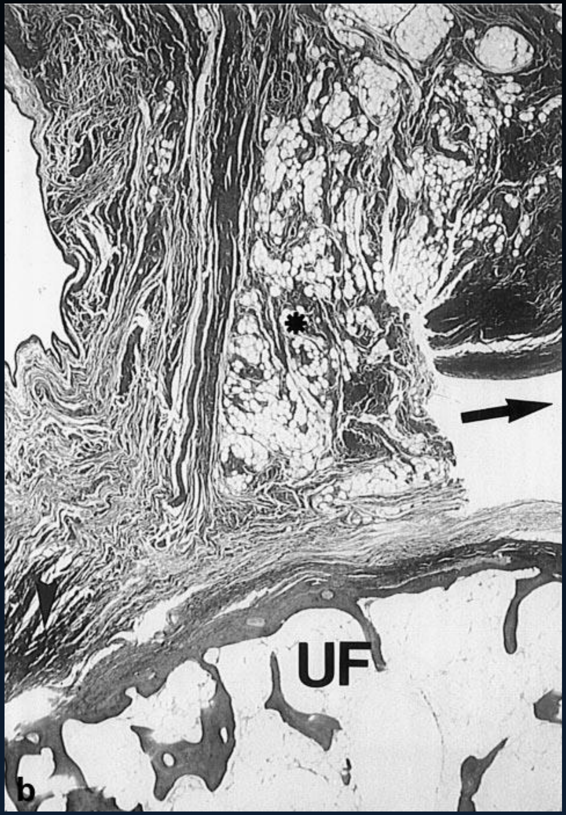
Histology - Dorsal

- Fibrocartilaginous disc
- Meniscus homologue
- Radioulnar ligament
  - Origin at fovea and base of the ulnar styloid contains loosely arranged collagen fibers dorsally
- Sheath of extensor carpi ulnaris
  - Ulnar to origin of radioulnar ligament
  - Contains collagen fibers, Sharpey's fibers, and few chondrocytes with vertical orientation
- Ulnolunate and ulnotriquetral ligaments



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Histology - Central

- Fibrocartilaginous disc
- Meniscus homologue
- Radioulnar ligament
  - Foveal fibers oriented vertically
- Sheath of extensor carpi ulnaris
- Ulnolunate and ulnotriquetral ligaments

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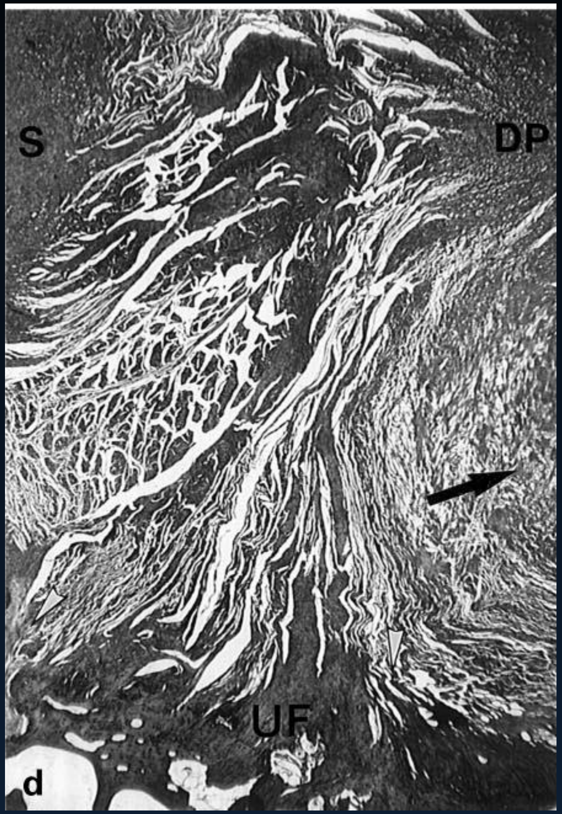
Histology - Central

- Fibrocartilaginous disc
- Meniscus homologue
- Radioulnar ligament
  - More volarly, collagen becomes denser
  - Foveal fibers oriented vertically
  - Styloid fibers oriented horizontally
  - Both sets of fibers curve and course towards radius
  - Some central fibers confluent with fibrocartilaginous disc
- Sheath of extensor carpi ulnaris
- Ulnolunate and ulnotriquetral ligaments



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Histology - Volar

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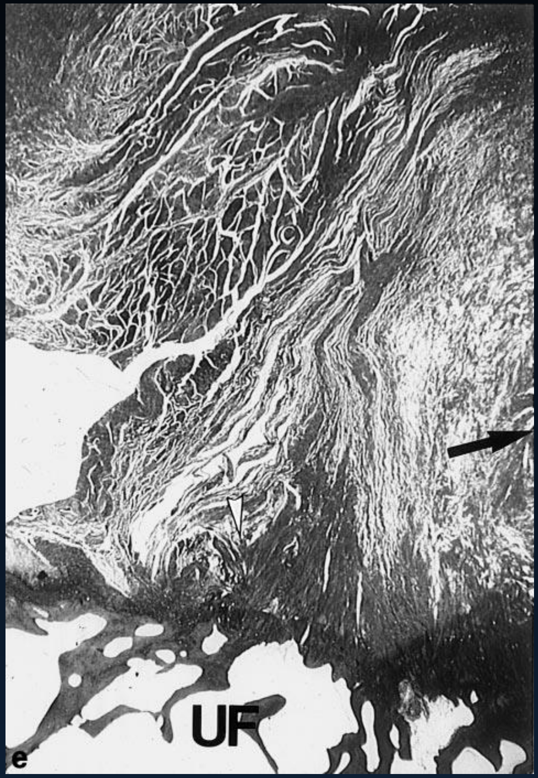

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Functions of TFCC

- Unique to hominids
- Likely developed to isolate ulna from carpus and allow brachiation
- Supports the carpus
- Stabilizes ulnocarpal and distal radioulnar joints
  - Volar radioulnar ligament – major constraint to volar translation and supination of radius relative to ulna
  - Dorsal radioulnar ligament – major constraint of dorsal translation and pronation
- Distributes loads between carpus and ulna
- Permits complex movements of wrist
- Allows smooth motion of wrist

History and Physical

- Important to elicit if there was a single trauma
- Symptoms – ulnar sided pain with rotation or when lifting heavy objects
- Physical exam findings
  - Swelling along prestyloid recess or ECU tendon sheath
  - Grip weakness
  - Crepitus
  - Sense of instability
  - Tenderness to palpation
    - Ulnar snuff box (ulnovolar to ECU between triquetrum and ulnar head) – foveal disruption of TFCC, prestyloid recess synovitis, meniscus homologue pathology, ulnotriquetral ligament injury
    - Ulnar aspect of lunate, distal surface of ulnar head, proximal tip of hamate – ulnocarpal abutment

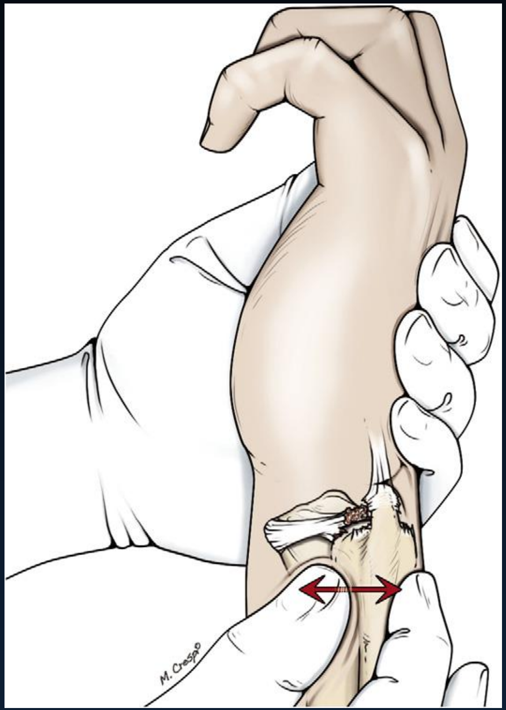
Functional testing

- Fovea sign – point tenderness over ulnar joint capsule just volar to extensor carpi ulnaris tendon
- Screwdriver test – ulnar sided pain with passive maximum ulnar deviation and active forearm rotation against resistance
- GRIT test – pain limited grip strength in supination versus pronation
- Ulnocarpal stress test (TFC grind test) – ulnar sided wrist pain with rotation from supination to pronation while an axial load is applied, the forearm is in vertical position, and the wrist is in maximum ulnar deviation
- TFC shear test (pisiform boost test, ulno-menisco-triquetral dorsal glide test) – pain when pisiform is pushed dorsally by thumb while index and middle fingers translate ulnar head volarly
- Press test – ulnocarpal pain when seated patient lifts body weight off chair using affected wrist
- Ulnocarpal meniscoid test (waiter's test) – bringing wrist passively from extension to ulnar deviation and then flexing and applying axial load eliciting pain with supination

Atzei et al. Foveal TFCC tear classification and treatment. Hand Clin. 2011

Functional testing of DRUJ

- Piano key sign – prominent ulnar head with hand lying flat, dislocates dorsally again after being reduced volarly
- Bilateral test for potential subluxation of the DRUJ – palpate both DRUJs with index and middle fingers to assess for relative movement between radius and ulna
- Ballotment test of distal ulna – radius held by examiner, distal ulna moved dorsally and volarly; compared to contralateral side



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Imaging

- Radiography
  - First step in evaluation in trauma
  - Useful to assess for fractures, ulnar variance, arthritis
  - Neutral rotation PA, lateral, and oblique views
- Arthrography
  - Triple injection favored
  - High rate of false negatives, only detects 50% of tears
- MRI
  - Accurate for partial tears and central or radial TFCC lesions (91% sensitivity for central degenerative perforations, 86-100% sensitivity for radial tears)
  - Low sensitivity for peripheral ulnar insertion TFCC lesions (25-50% sensitivity for ulnar avulsions, 17% sensitivity for peripheral TFCC tears)
- MR arthrography
  - Sensitivity 97%, specificity 96%, accuracy 97%

Wrist Arthrography

- Triple compartment arthrography – previous gold standard imaging modality for TFCC assessment
- Study of 150 patients comparing arthrography to arthroscopy
  - 42% agreement
  - 58% discordance
  - 80% false negative rate with normal arthrography
- 2011 meta-analysis of 12 studies (6 single compartment, 6 triple compartment) looking at detection of full-thickness tears
  - Single compartment – 72.4% sensitivity, 92% specificity
  - Triple compartment – 82.5% sensitivity, 96% specificity

Wrist Arthrography

- Radiocarpal joint - performed first
- Distal radioulnar joint - performed 3 hours later after contrast from radiocarpal injection resorbed
- Midcarpal compartment – performed 3 hours later after contrast from DRUJ injection resorbed

Levinsohn et al. Wrist arthrography: value of the three-compartment injection method. Radiology. 1991.

Wrist Arthrography

- 1991 study of 300 wrist arthrograms – 103 with TFCC abnormalities (32%)
  - 74 (72%) complete perforations – contrast leakage between RCJ and DRUJ
  - 15 (15%) incomplete perforations – irregular TFCC contour, no contrast leakage
  - 14 (14%) proximal perforations at attachment of TFCC to ulna
- MCJ injections important for lunotriquetral ligament tears – 76 in study (52%)
  - 22 (29%) after MCJ alone
  - 5 (7%) after RCJ alone
  - 49 (64%) after both

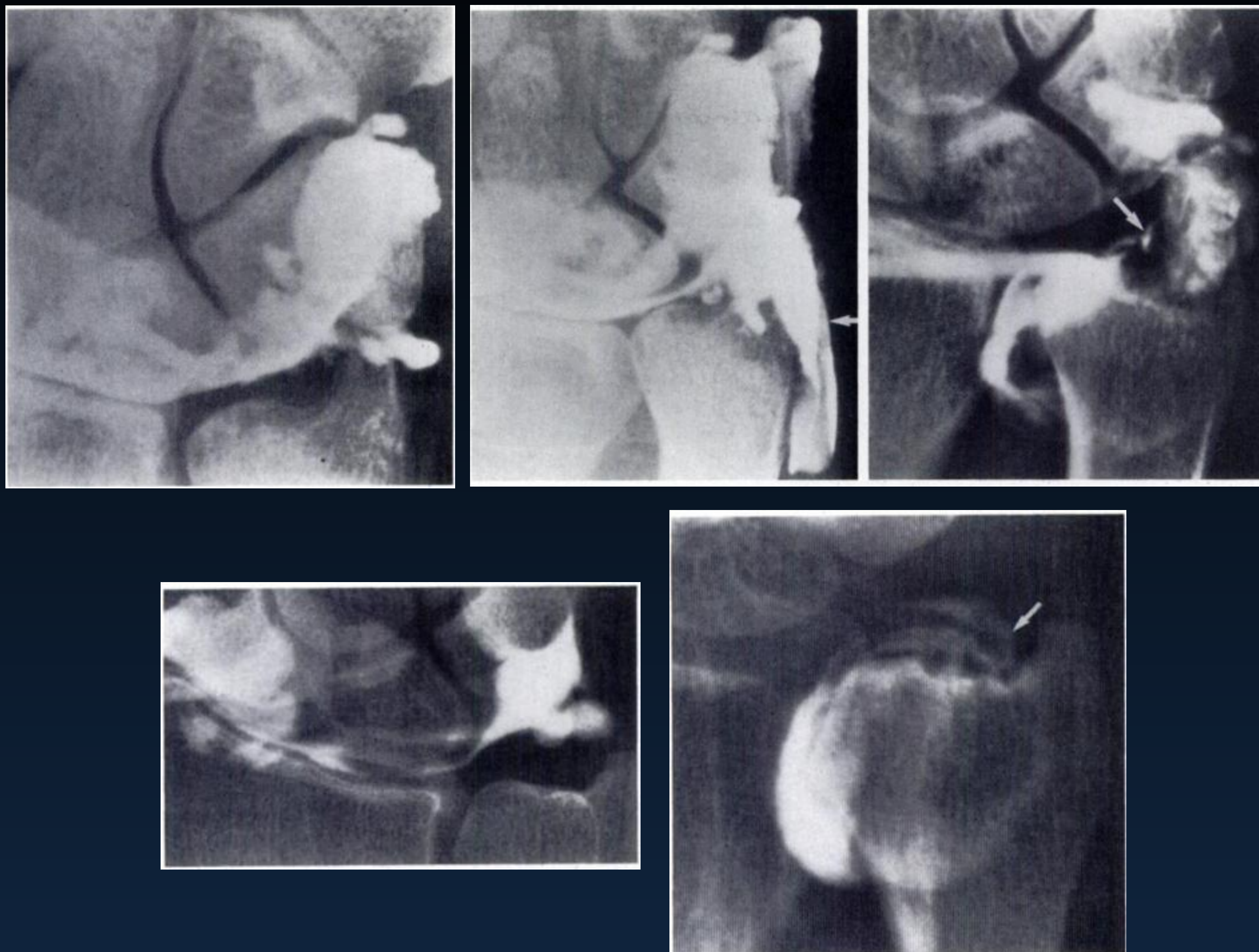
Table 2
TFCC Abnormalities Seen Following Injections

Abnormality	RCJ Alone	DRUJ Alone	Both	Total
Complete perforation	17	2	55	74
Incomplete proximal side perforation	3	11	1	15
Perforation at the site of attachment	0	14*	0	14

* Two leaks through nonunion fractures of ulnar styloid process.

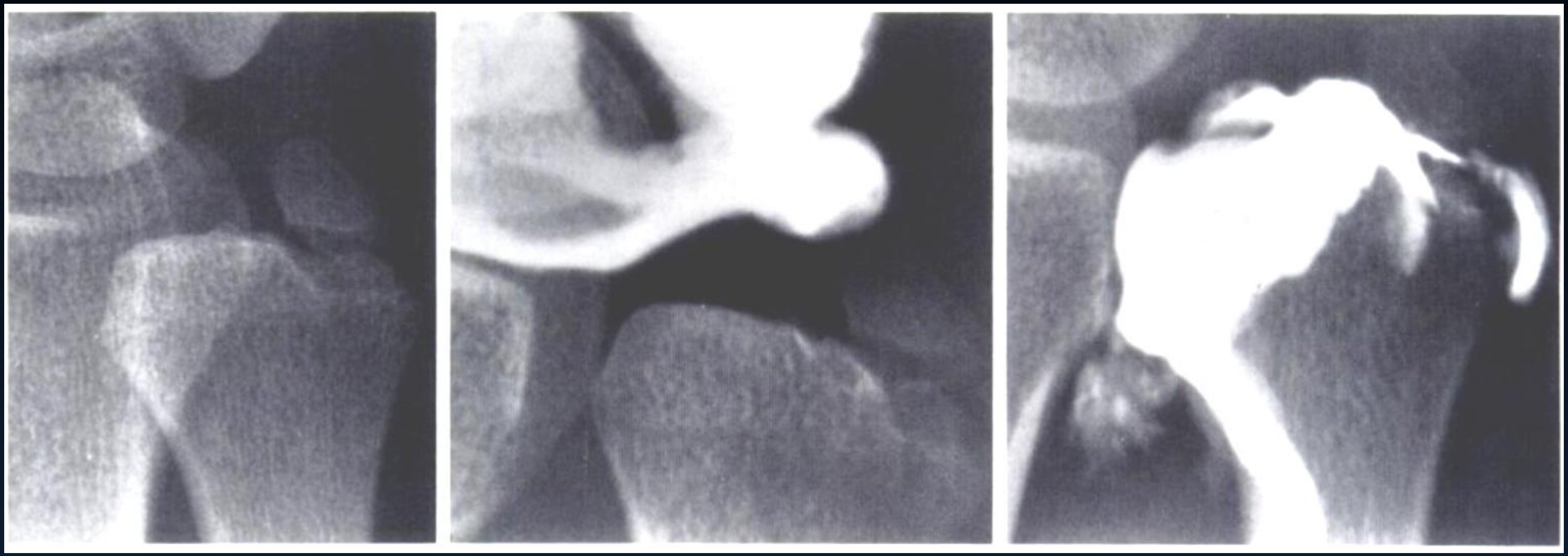
Levinsohn et al. Wrist arthrography: value of the three-compartment injection method. Radiology. 1991.

Wrist Arthrography



Levinsohn et al. Wrist arthrography: value of the three-compartment injection method. Radiology. 1991.

Wrist Arthrography



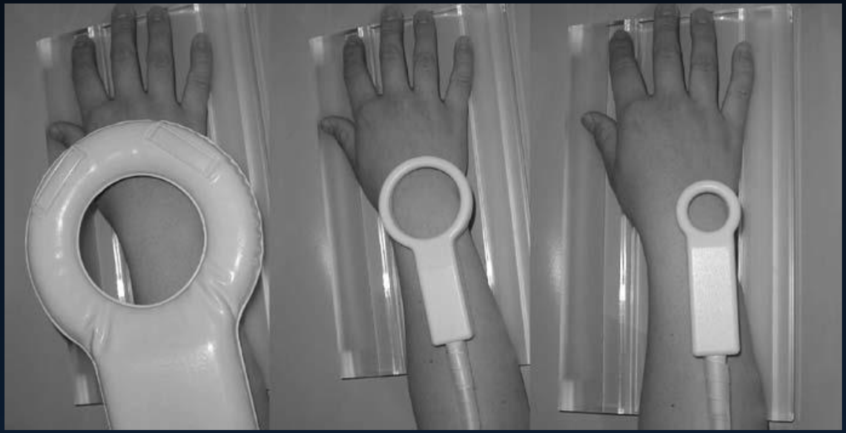
Levinsohn et al. Wrist arthrography: value of the three-compartment injection method. Radiology. 1991.

MRI Field Strength

- 3T has better SNR than 1.5 T
- 1.5T versus arthroscopy
  - 85% sensitivity
  - 75% specificity
- 3T versus arthroscopy
  - 94% sensitivity
  - 88% specificity
- High quality microscopy coil at 1.5T can be similar to a lesser coil at 3T

Coil Selection

- Study of 10 asymptomatic volunteers imaged at 1.5 T comparing conventional surface coil (80 mm) with microscopy coils (47 mm, 23 mm)
- Each patient had PD and T2*-weighted images
- Quantitative analysis - SNR of disc, lunate cartilage, and bone
- Qualitative analysis – visualization of disc, triangular ligament (lamina), meniscus homologue, ulnounate ligament, ulnotriquetral ligament
- Results – better qualitative scores on microscopy coils for all structures except ulnolunate ligament, better SNR on microscopy coils



Yoshioka et al. High-resolution MR imaging of triangular fibrocartilage complex (TFCC): comparison of microscopy coils and a conventional small surface coil. Skeletal Radiol. 2003.

Coil Selection

- Study of 9 asymptomatic volunteers imaged at 3T comparing 3 inch surface coil and wrist volume coil
- Each patient had coronal 2D GRE and 3D-GRE weighted images on both coils
- Quantitative analysis - SNR of disc, lunate cartilage, and bone
- Qualitative analysis – visualization of disc, triangular ligament (lamina), ulnounate ligament, ulnotriquetral ligament, lunotriquetral and scapholunate ligaments
- Results – higher visualization with surface coil, particularly ulnotriquetral and ulnolunate ligaments

Bittersohl et al. High-resolution MRI of the triangular fibrocartilage complex (TFCC) at 3T: comparison of surface coil and volume coil. J Magn Reson Imaging. 2007.

MRI versus MR Arthrography

- 3T MRI versus arthroscopy
  - 86% sensitivity
  - 100% specificity
- 3T MRA versus arthroscopy
  - Radiocarpal joint injection only
  - 100% sensitivity and specificity

TABLE 1: MRI Compared with Arthroscopy

Type of Tear	Tear on MRI	Tear on Arthroscopy	Sensitivity (%)	Specificity (%)
TFCC tear	19	22	86	100
Scapholunate tear	16	18	89	100
Lunatotriquetral tear	9	11	82	100

Note—TFCC = triangular fibrocartilage complex.

TABLE 2: MR Arthrography Compared with Arthroscopy

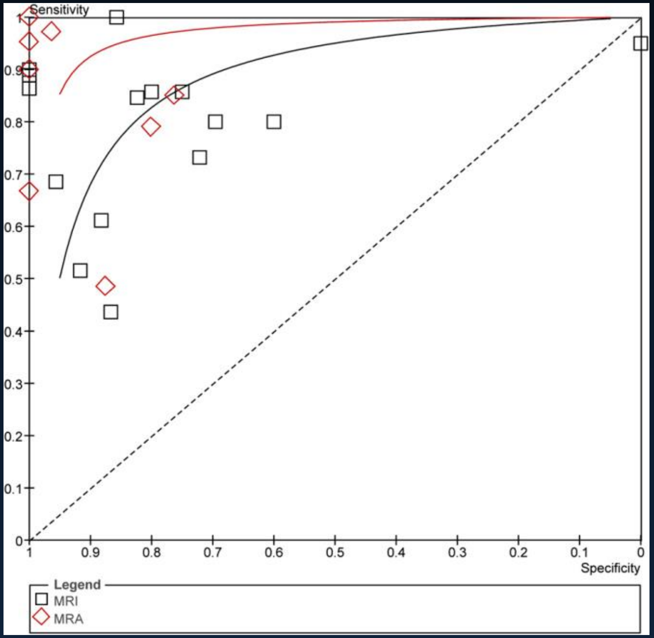
Type of Tear	Tear on MR Arthrography	Tear on Arthroscopy	Sensitivity (%)	Specificity (%)
TFCC tear	16	16	100	100
Scapholunate tear	12	12	100	100
Lunatotriquetral tear	8	8	100	100

Note—There were also three microperforations on MR arthrography in which no intrinsic ligament tear was seen. These were considered false-positive findings on MR arthrography. TFCC = triangular fibrocartilage complex.

Magee T. Comparison of 3-T MRI and arthroscopy of intrinsic wrist ligament and TFCC tears. AJR Am J Roentgenol. 2009.

MRI versus MR Arthrography

- Meta-analysis of 21 studies comparing MRI to MRA

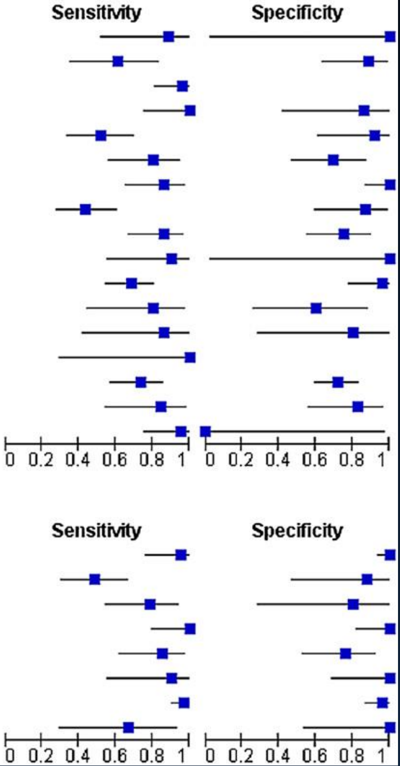


MRI

Study	TP	FP	FN	TN	Sensitivity	Specificity
Cerofolini et al, 1990	8	0	1	1	0.89 [0.52, 1.00]	1.00 [0.03, 1.00]
De Smet, 2005	11	2	7	15	0.61 [0.36, 0.83]	0.88 [0.64, 0.99]
Gabl et al, 1996	27	0	1	0	0.96 [0.82, 1.00]	Not estimable
Golimbu et al 1989	13	1	0	6	1.00 [0.75, 1.00]	0.86 [0.42, 1.00]
Haims et al, 2003	17	1	16	11	0.52 [0.34, 0.69]	0.92 [0.62, 1.00]
Johnstone et al, 1997	16	7	4	16	0.80 [0.56, 0.94]	0.70 [0.47, 0.87]
Magee, 2009	19	0	3	27	0.86 [0.65, 0.97]	1.00 [0.87, 1.00]
Morley et al, 2001	17	2	22	13	0.44 [0.28, 0.60]	0.87 [0.60, 0.98]
Oneson et al, 1997	24	7	4	21	0.86 [0.67, 0.96]	0.75 [0.55, 0.89]
Pederzini et al, 1992	9	0	1	1	0.90 [0.55, 1.00]	1.00 [0.03, 1.00]
Potter et al, 1997	37	1	17	22	0.69 [0.54, 0.80]	0.96 [0.78, 1.00]
Scheck et al, 1999	8	4	2	6	0.80 [0.44, 0.97]	0.60 [0.26, 0.88]
Schweitzer et al, 1992	6	1	1	4	0.86 [0.42, 1.00]	0.80 [0.28, 0.99]
Shih et al, 2000	3	0	0	0	1.00 [0.29, 1.00]	Not estimable
Shionova et al, 1998	30	17	11	44	0.73 [0.57, 0.86]	0.72 [0.59, 0.83]
Totterman et al, 1996	11	3	2	14	0.85 [0.55, 0.98]	0.82 [0.57, 0.96]
Zlatkin et al, 1989	19	1	1	0	0.95 [0.75, 1.00]	0.00 [0.00, 0.97]

MRA

Study	TP	FP	FN	TN	Sensitivity	Specificity
Braun et al 2003	20	0	1	54	0.95 [0.76, 1.00]	1.00 [0.93, 1.00]
Haims et al, 2003	16	1	17	7	0.48 [0.31, 0.66]	0.88 [0.47, 1.00]
Joshy et al, 2008	15	1	4	4	0.79 [0.54, 0.94]	0.80 [0.28, 0.99]
Magee, 2009	16	0	0	19	1.00 [0.79, 1.00]	1.00 [0.82, 1.00]
Ruegger et al, 2007	17	5	3	16	0.85 [0.62, 0.97]	0.76 [0.53, 0.92]
Scheck et al, 1999	9	0	1	10	0.90 [0.55, 1.00]	1.00 [0.69, 1.00]
Schmitt et al 2003	68	2	2	53	0.97 [0.90, 1.00]	0.96 [0.87, 1.00]
Schweitzer et al, 1992	6	0	3	6	0.67 [0.30, 0.93]	1.00 [0.54, 1.00]



Smith et al. Diagnostic accuracy of magnetic resonance imaging and magnetic resonance arthrography for triangular fibrocartilaginous complex injury: a systematic review and meta-analysis. J Bone Joint Surg Am. 2012.

MRI for Peripheral Tears

- Retrospective review of 85 wrists from 1993-1999 scanned on 1.5T MR
- Either unenhanced or indirect MRA
- 20 peripheral/ulnar tears found at arthroscopy

TABLE 1 Results of MR Imaging When the Observer Interpreted Disruption of the Insertion as a Tear

MR Imaging Observations	Sensitivity (%)	Specificity (%)	Accuracy (%)
All MR imaging examinations			
Combined	17	79	64
Observer 1	15	77	63
Observer 2	30	68	59
Observer 3	5	91	71
Indirect MR arthrography			
Combined	12	81	74
Observer 1	9	83	63
Observer 2	18	70	56
Observer 3	9	90	68
Unenhanced MR imaging			
Combined	18	77	68
Observer 1	11	72	68
Observer 2	44	67	62
Observer 3	0	92	73

TABLE 2 Results of High Signal Intensity at Ulnar Insertion as Marker of Peripheral Triangular Fibrocartilage Tears

MR Imaging Observations	Sensitivity (%)	Specificity (%)	Accuracy (%)
All MR imaging examinations			
Combined	42	63	55
Observer 1	35	70	53
Observer 2	50	56	55
Observer 3	40	64	58
Indirect MR arthrography			
Combined	45	69	56
Observer 1	36	67	58
Observer 2	54	60	58
Observer 3	45	80	51
Unenhanced MR imaging			
Combined	37	59	55
Observer 1	33	53	49
Observer 2	44	53	51
Observer 3	33	72	64

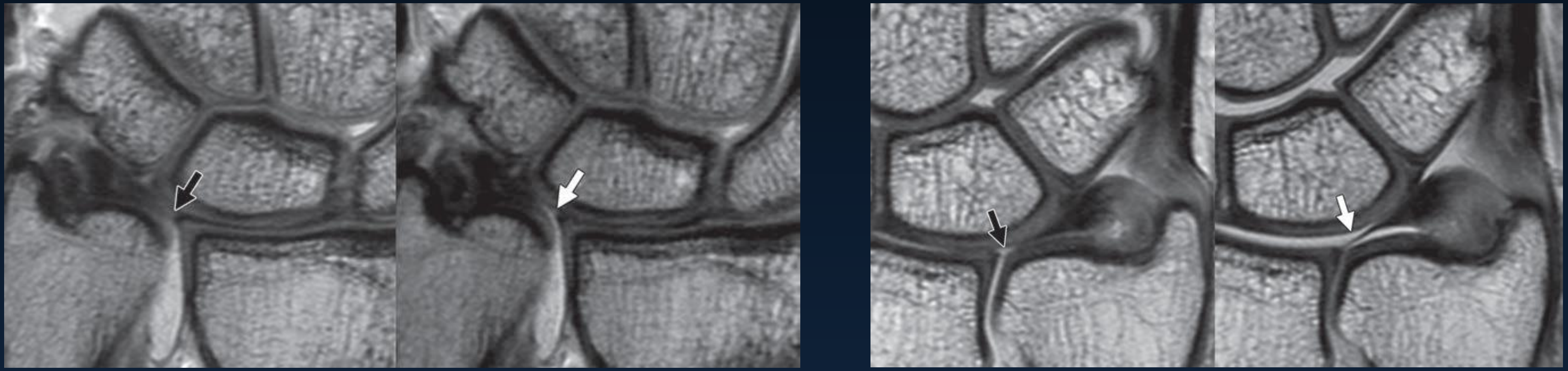
Haims et al. Limitations of MR imaging in the diagnosis of peripheral tears of the triangular fibrocartilage of the wrist. AJR Am J Roentgenol. 2002.

Traction Study

- Study of 40 consecutive MR wrist arthrograms
- 3 compartment arthrography was performed unless there were communications between compartments
- All patients had same sequences in 3 T MRI without and with a load applied (7 kg for M, 5 kg for F)

Traction Study

- Results
  - Markedly enhanced detection of scapholunate and lunotriquetral ligament tears
  - Markedly enhanced detection of TFCC tears



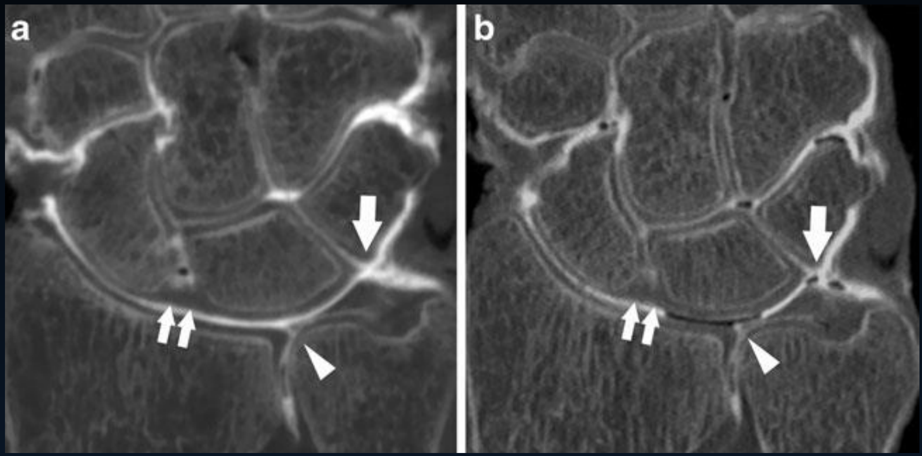
Lee et al. Wrist Traction During MR Arthrography Improves Detection of Triangular Fibrocartilage Complex and Intrinsic Ligament Tears and Visibility of Articular Cartilage. AJR Am J Roentgenol. 2016.

CT Arthrography

- Higher spatial resolution than MR arthrography
- Lower contrast resolution than MR arthrography
- Triple-injection
- Multiple studies of sensitivity, specificity, and accuracy for detection of TFCC tears
  - 92-94% in one series
  - 100% in one series
- Less accurate for peripheral TFCC tears

Cone-beam CTA versus Multidetector CTA

- Triple injection
- Equivalent for assessment of ligaments, TFCC, and cartilage
- Statistically significant radiation dose reduction with CBCT compared to MDCT



CBCT MDCT

Table 1 Sensitivity, specificity, and accuracy of cone-beam computed tomography (CB) and multidetector computed tomography (MD) for the detection of interosseous ligaments, triangular fibrocartilage complex (TFCC), and cartilage lesions

	Ligaments		TFCC		Cartilage	
	CB	MD	CB	MD	CB	MD
Sensitivity	95 (81–100)	87 (73–100)	88 (73–100)	88 (73–100)	100	83 (72–100)
Specificity	82 (62–100)	82 (62–100)	100	100	100	100
Accuracy	90 (72–100)	83 (62–100)	90 (72–100)	90 (72–100)	100	90 (72–100)

Data are expressed as percentages with confidence intervals *in parentheses*

Ramdhian-Wihlm et al. Cone-beam computed tomography arthrography: an innovative modality for the evaluation of wrist ligament and cartilage injuries. Skeletal Radiol. 2012.

CTA versus MRI versus MRA

- Study of 10 cadaveric wrists
- All had 3T MRI, then triple-injection arthrography, then CTA, then 3T MRA, then arthroscopy

Table 3 Sensitivity, specificity, and accuracy of conventional MRI (CMR), CTA, and MRA in detecting SLL, LTL, and TFCC tears

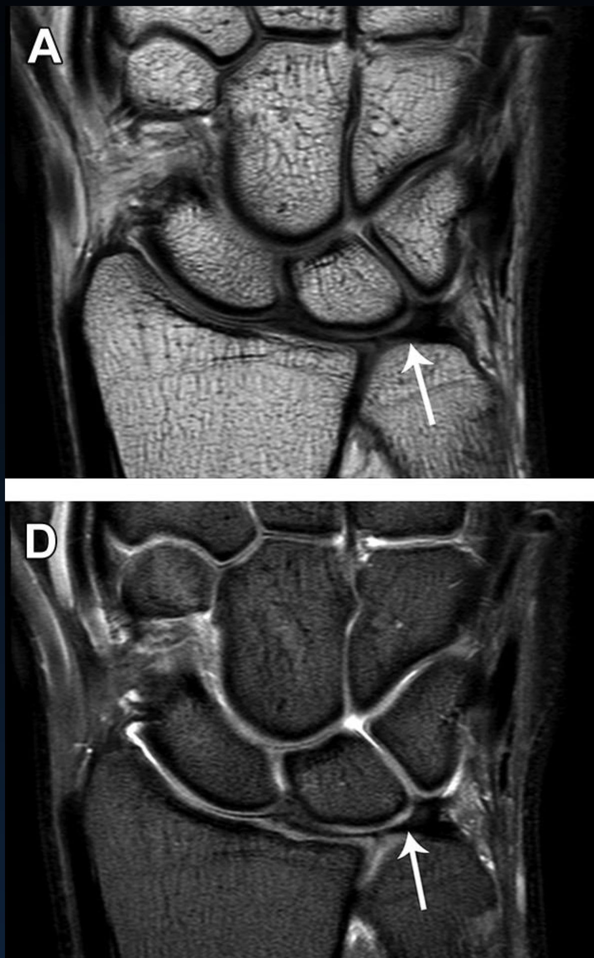
	CMR Sensitivity (%)	CMR Specificity (%)	CMR Accuracy (%)	CTA Sensitivity (%)	CTA Specificity (%)	CTA Accuracy (%)	MRA Sensitivity (%)	MRA Specificity (%)	MRA Accuracy (%)
SLL tears	66	86	80	100	100	100	100	86	90
LTL tears	60	80	70	100	80	90	100	80	90
TFCC tears	100	86	90	100	100	100	100	100	100

Lee et al. Intrinsic ligament and triangular fibrocartilage complex tears of the wrist: comparison of MDCT arthrography, conventional 3-T MRI, and MR arthrography. Skeletal Radiol. 2013.

Ultrasound

- Difficult to visualize internal structure of TFCC
- Useful for ligamentous injury

Normal MR Appearance



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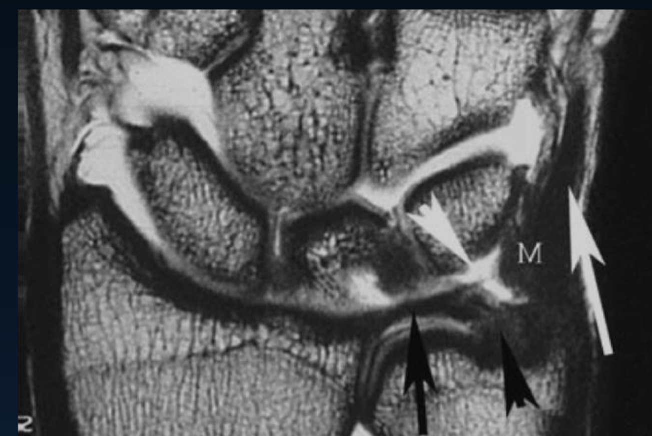
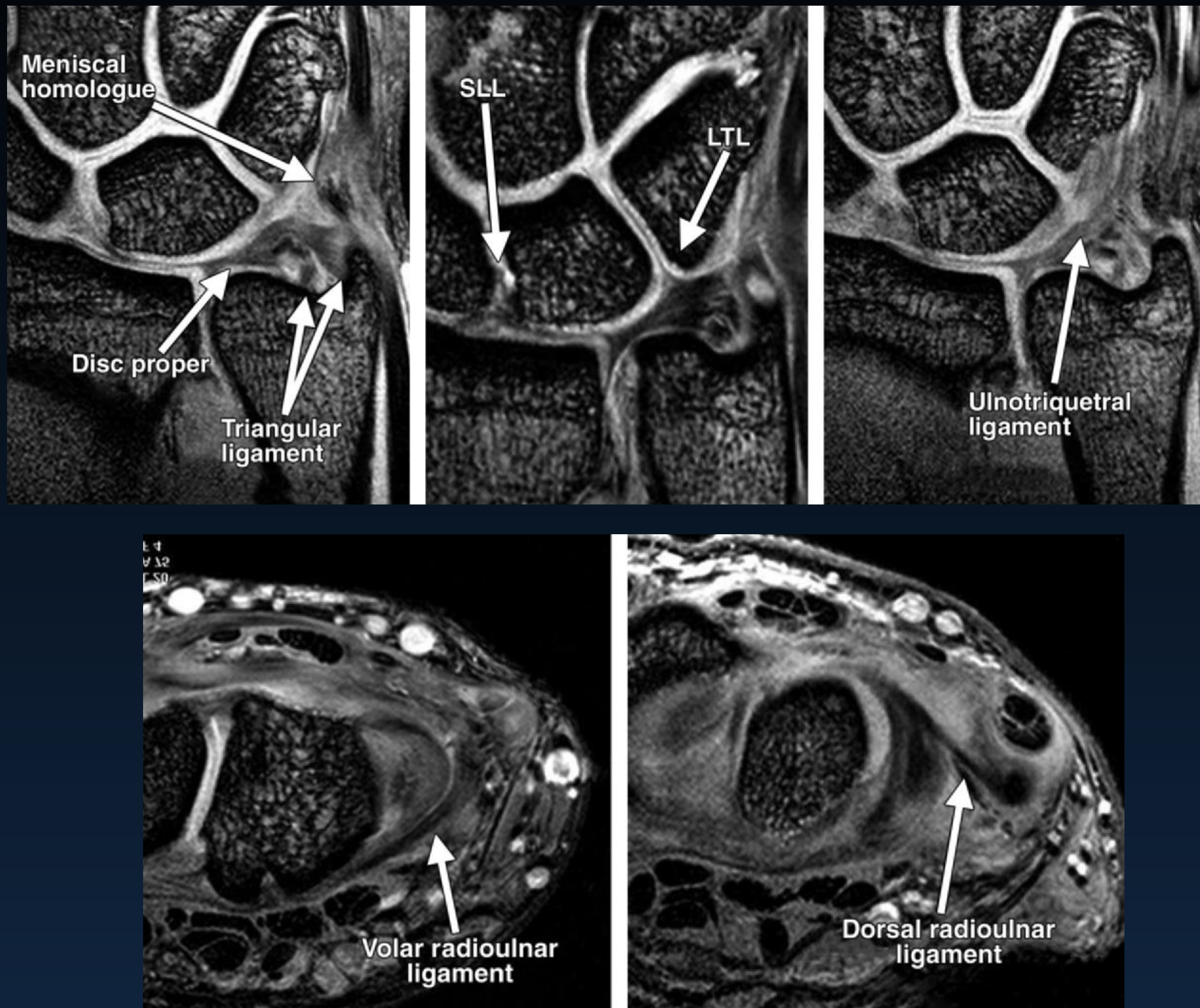


iii

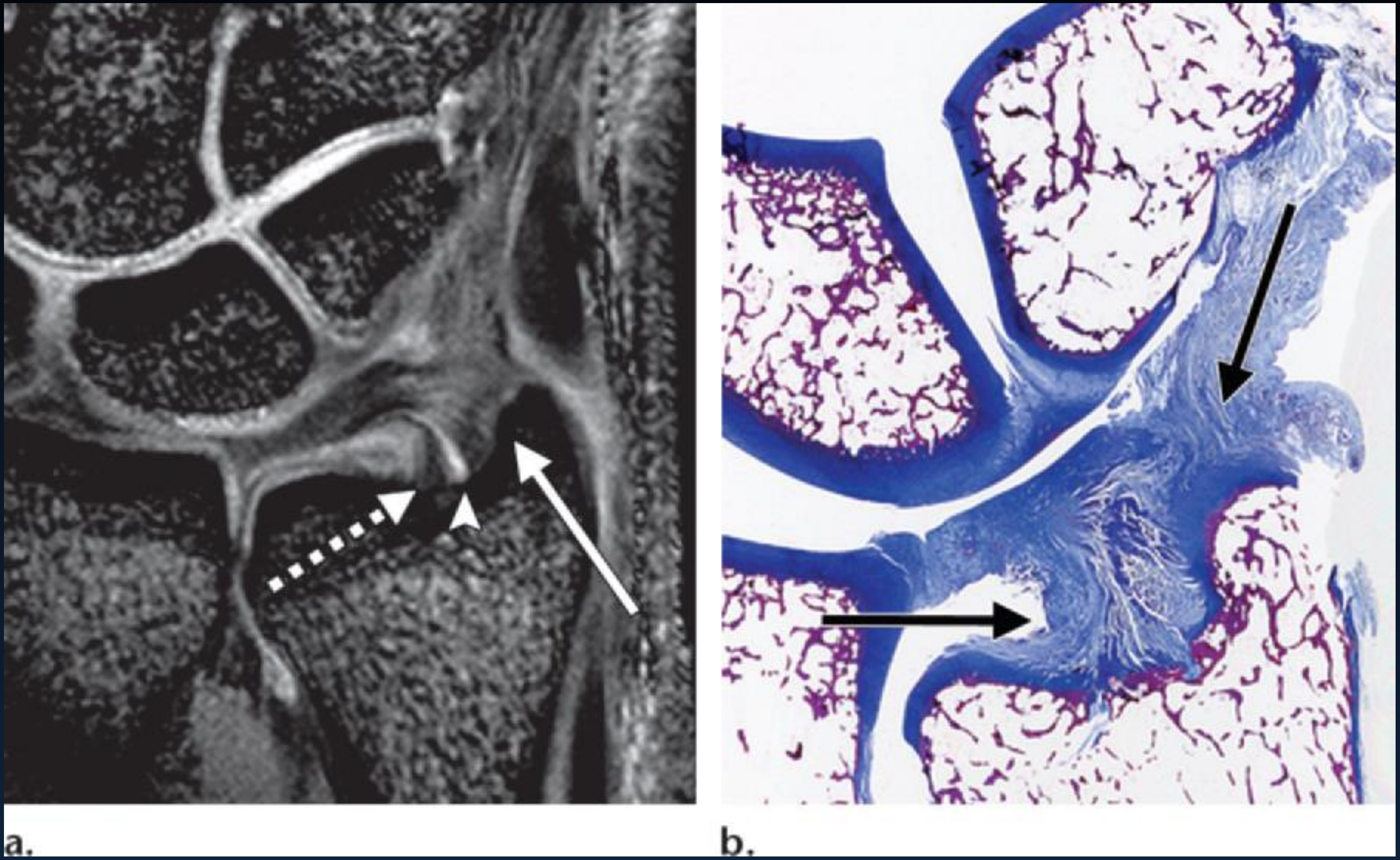
i. Cody et al. MR Imaging of the Triangular Fibrocartilage Complex. Magn Reson Imaging Clin N Am. 2015.
ii. Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.
iii. Zlatkin et al. MR imaging of ligaments and triangular fibrocartilage complex of the wrist. Magn Reson Imaging Clin N Am. 2004.

Normal MR Appearance



Burns et al. Pitfalls that may mimic injuries of the triangular fibrocartilage and proximal intrinsic wrist ligaments at MR imaging. Radiographics. 2011.

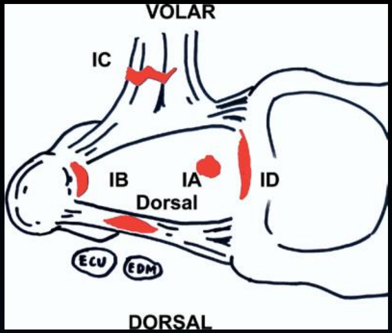
Normal MR Appearance



Burns et al. Pitfalls that may mimic injuries of the triangular fibrocartilage and proximal intrinsic wrist ligaments at MR imaging. Radiographics. 2011.

Palmer Classification

- Based on nature of injury
- Class 1
  - Traumatic – rotational or fall on pronated or hyperextended wrist
  - Subclassified based on location of injury
- Class 2
  - Degenerative wear and perforation
  - May be associated with chronic loading of ulnocarpal joint, ulnar impaction syndrome
  - Subclassified based on extent of degeneration



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Palmer Class 1A

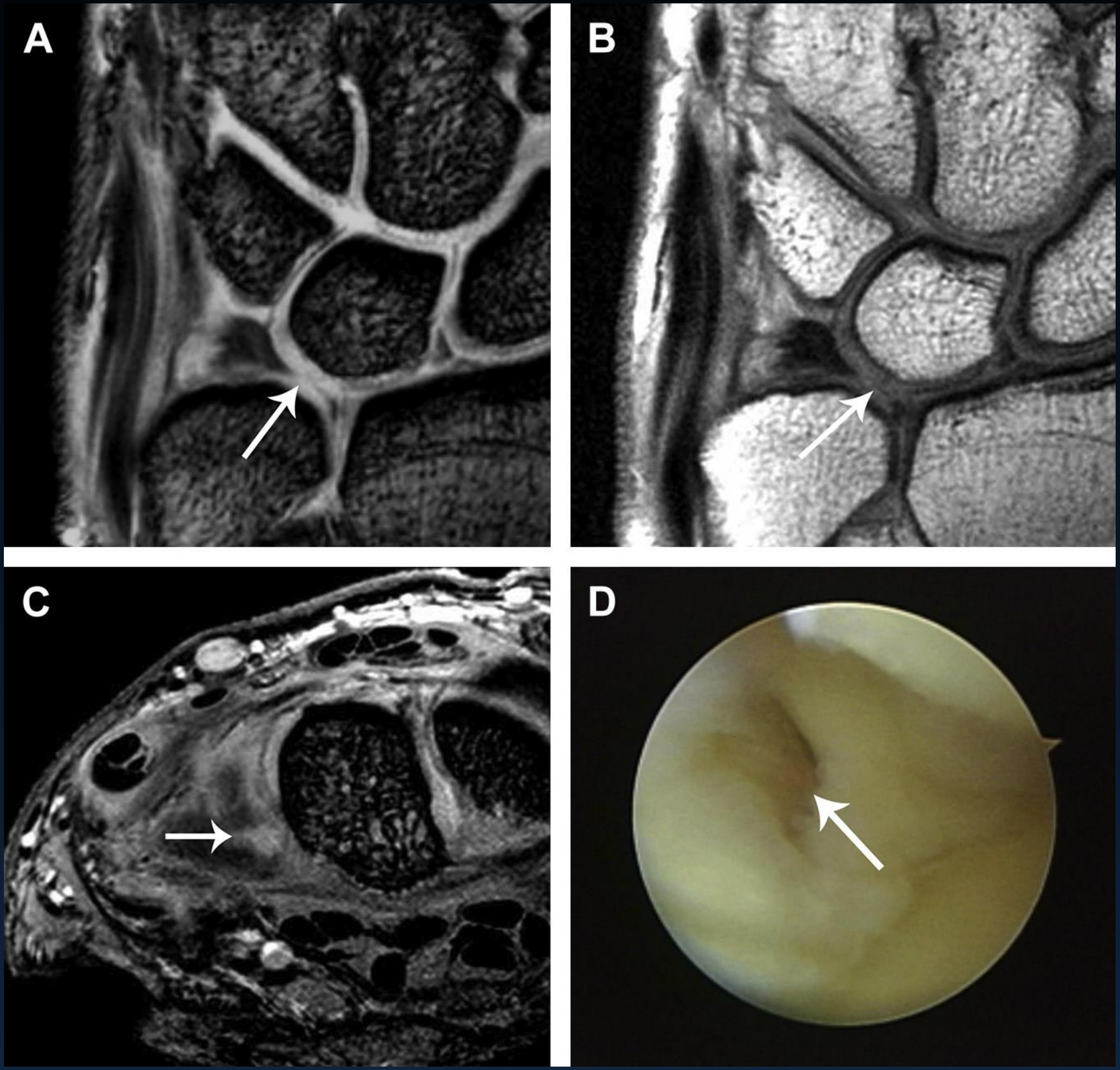
- Central tear through horizontal portion of TFCC
- Most common type of traumatic tear
- Not associated with instability
- Treatment – debridement, will not heal if not repaired


ii


iii

i. Estrella et al. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007.
ii. Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.
iii. Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

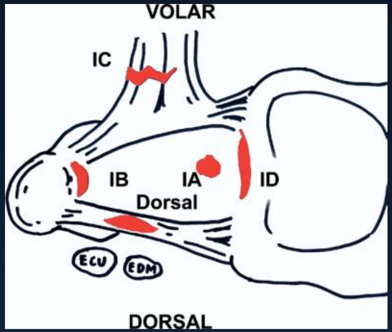
Palmer Class 1A



Cody et al. MR Imaging of the Triangular Fibrocartilage Complex. Magn Reson Imaging Clin N Am. 2015

Palmer Class 1B

- Peripheral tear of TFCC from ulnar insertion
- May have bony avulsions
- +/- DRUJ instability
- Treatment - repair



i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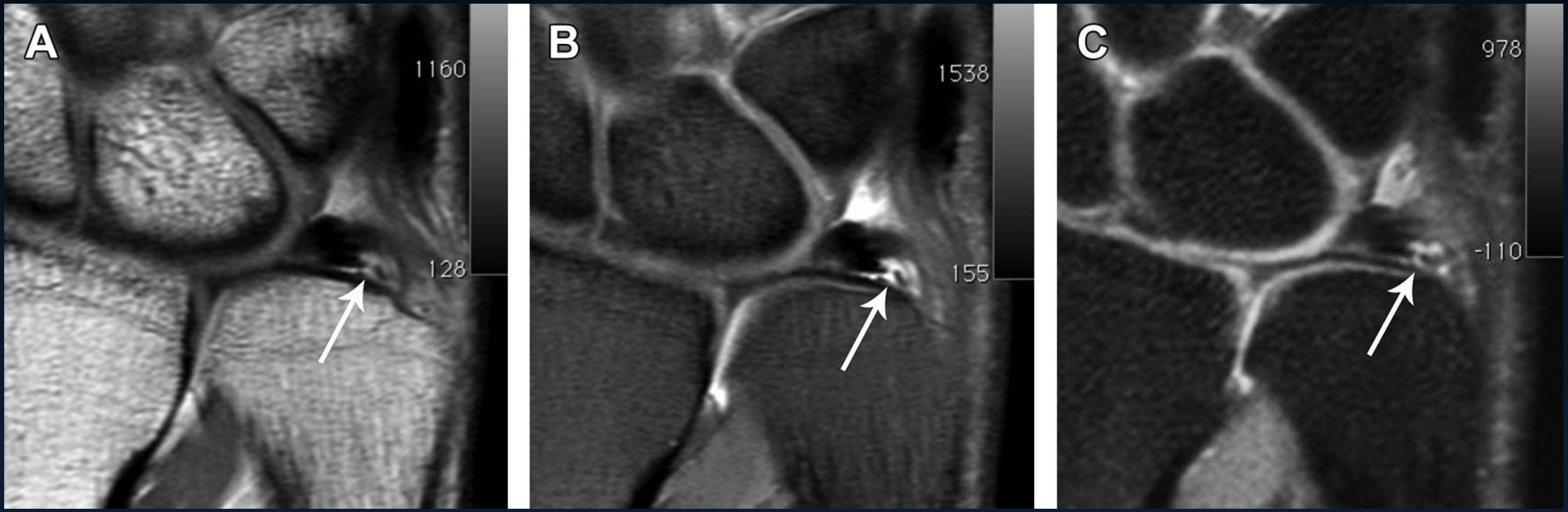
iii

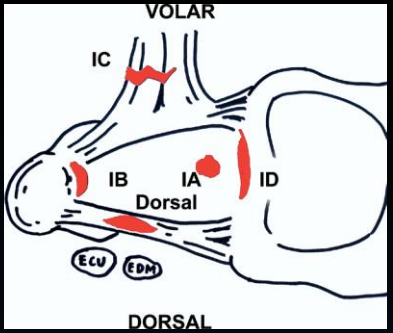
i. Estrella et al. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007.
ii. Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.
iii. Bayoumy et al. Arthroscopic grading of common wrist disorders and its role in management. J Orthop. 2015.

Palmer Class 1B



Cody et al. MR Imaging of the Triangular Fibrocartilage Complex. Magn Reson Imaging Clin N Am. 2015

Palmer Class 1C

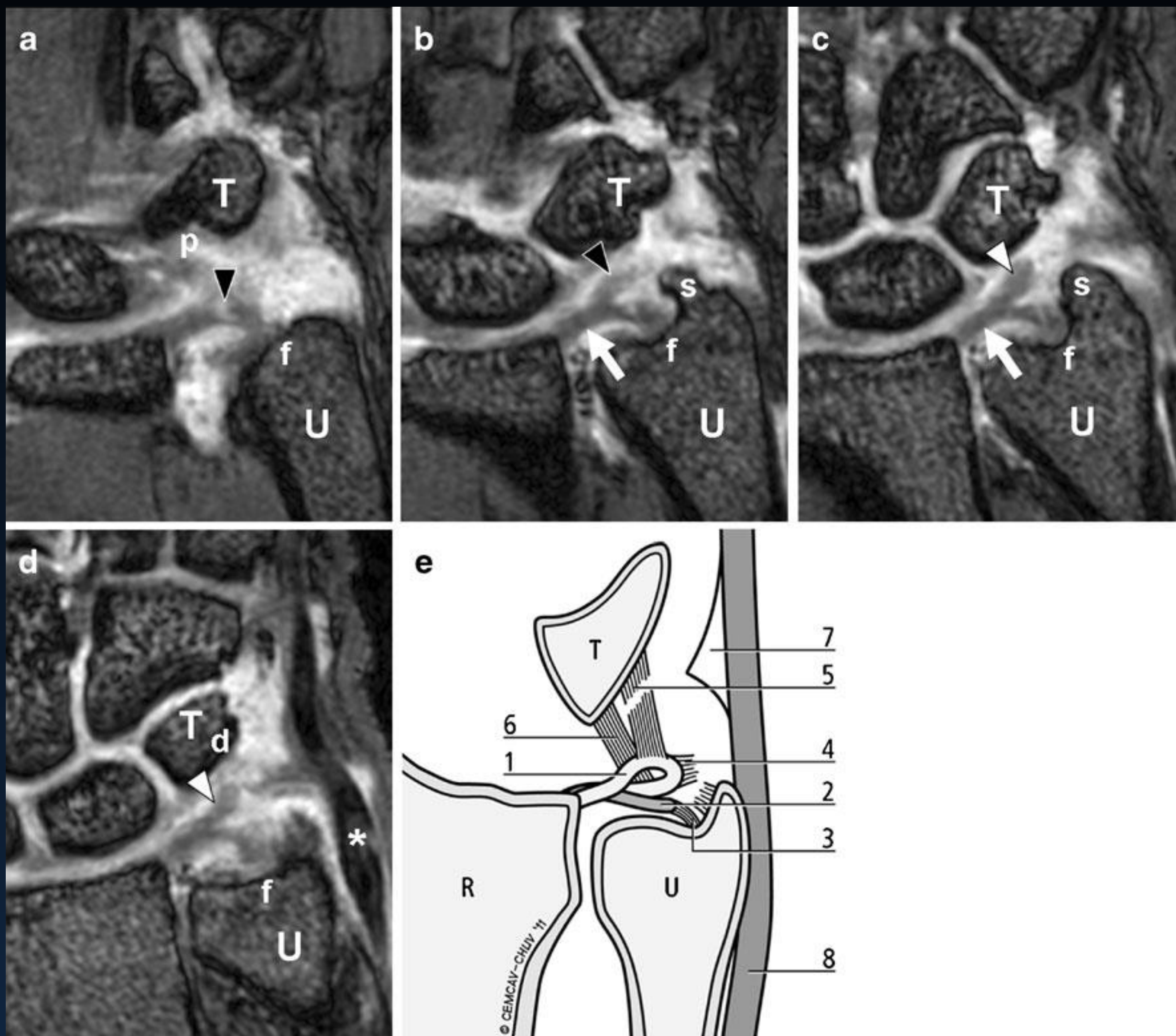


- Peripheral tear with distal avulsion of ulnolunate and/or ulnotriquetral ligaments
- Rare, high-energy injury
- Often associated with DRUJ instability
- Leads to ulnar carpal instability
- Treatment – controversial, repair or reconstruction

Estrella et al. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007.

Wait, where’s the image?

Palmer Class 1C



1 – Volar and dorsal distal radioulnar ligaments

2 – Articular disc

3 – Insertion of proximal lamina on ulnar fovea

4 – Insertion of distal lamina on ulnar styloid process

5 – Dorsal ulnotriquetral ligament

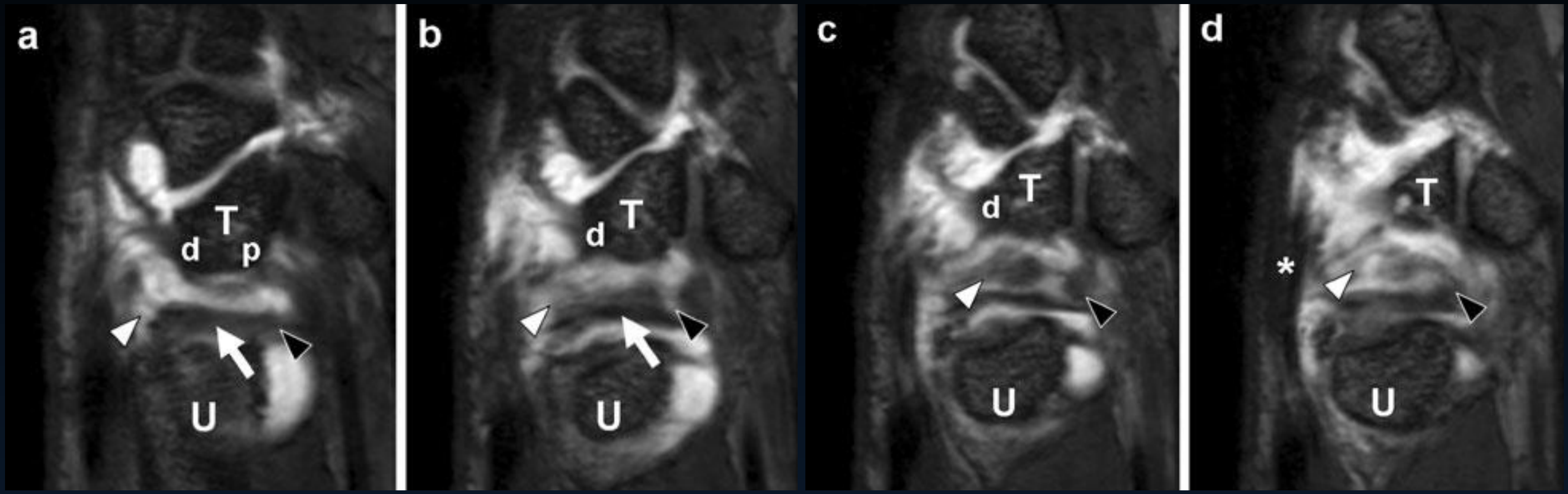
6 – Volar ulnotriquetral ligament

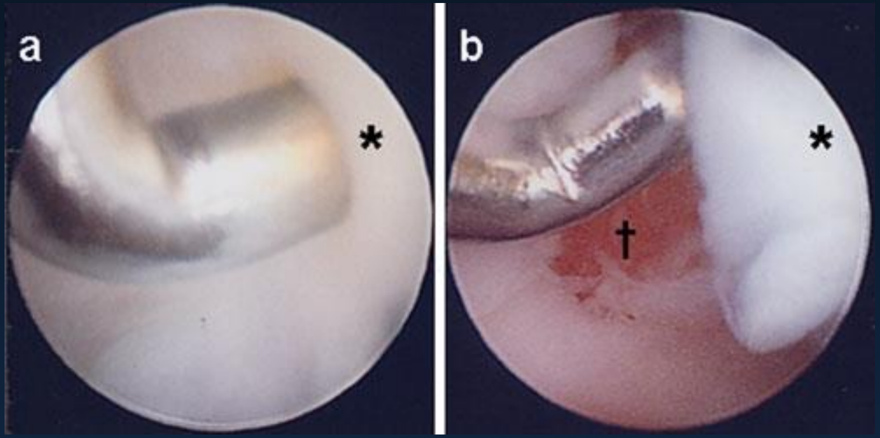
7 – Meniscus homologue

8 – Extensor carpi ulnaris tendon

Theumann et al. Bucket-handle tear of the triangular fibrocartilage complex: case report of a complex peripheral injury with separation of the distal radioulnar ligaments from the articular disc. Skeletal Radiol. 2011.

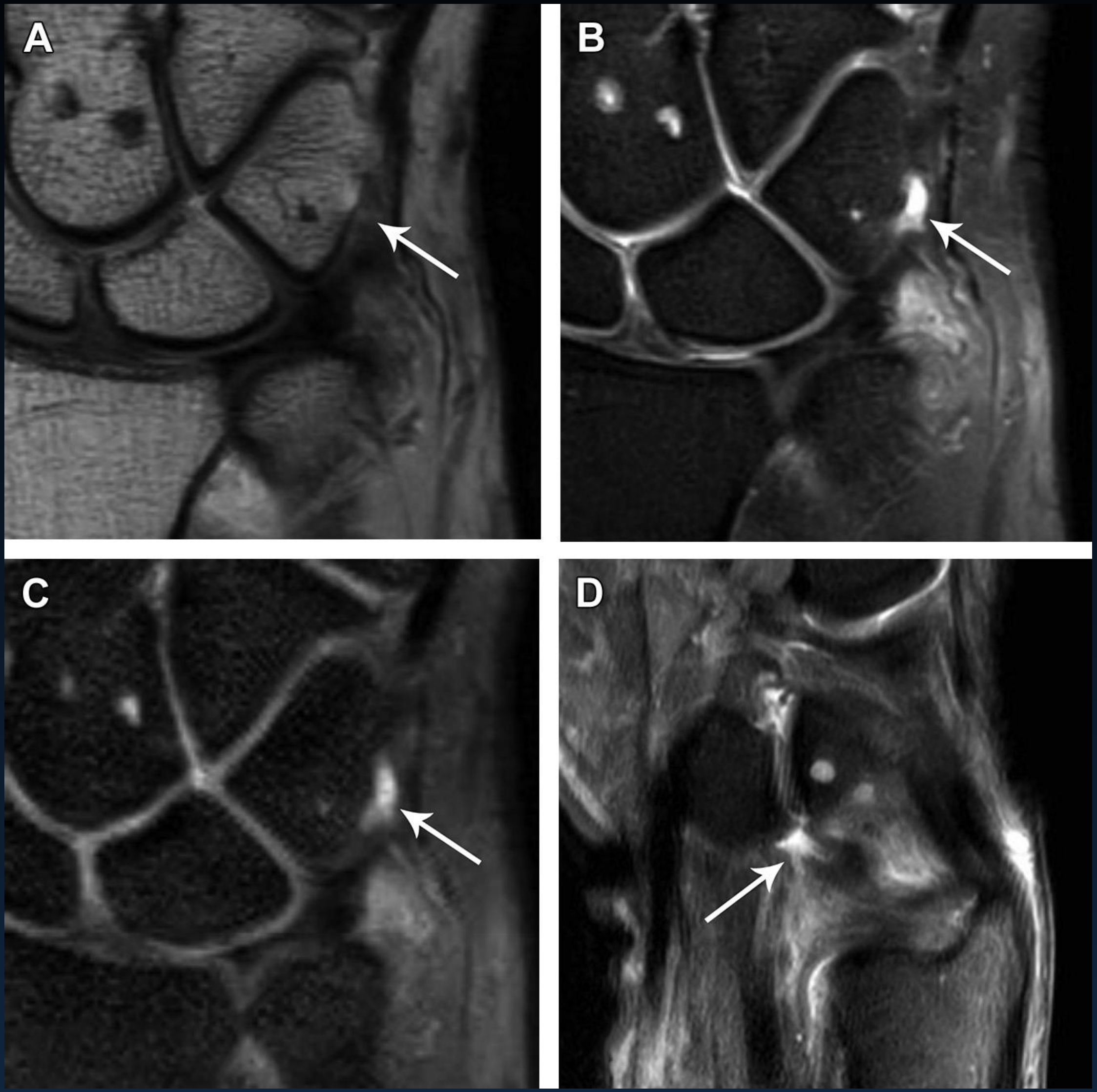
Palmer Class 1C





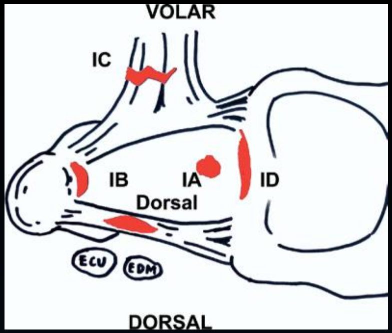
Theumann et al. Bucket-handle tear of the triangular fibrocartilage complex: case report of a complex peripheral injury with separation of the distal radioulnar ligaments from the articular disc. Skeletal Radiol. 2011.

Palmer Class 1C



Cody et al. MR Imaging of the Triangular Fibrocartilage Complex. Magn Reson Imaging Clin N Am. 2015

Palmer Class 1D



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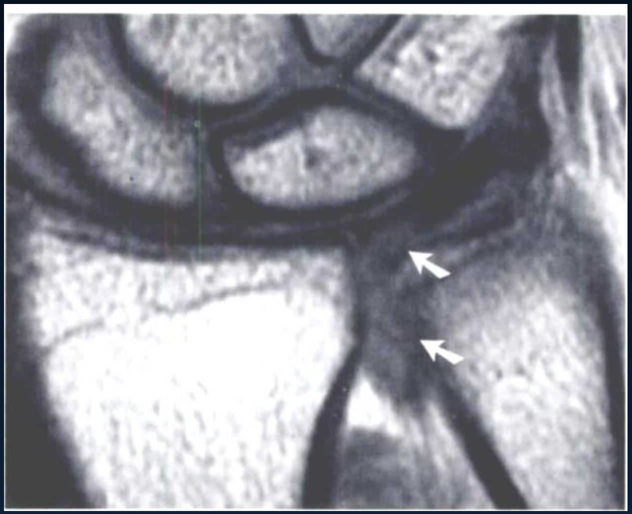
- Radial avulsion of TFCC with or without sigmoid notch fracture
- Typically involve dorsal and volar radioulnar ligament insertions
- High risk for DRUJ instability
- Treatment – repair or debridement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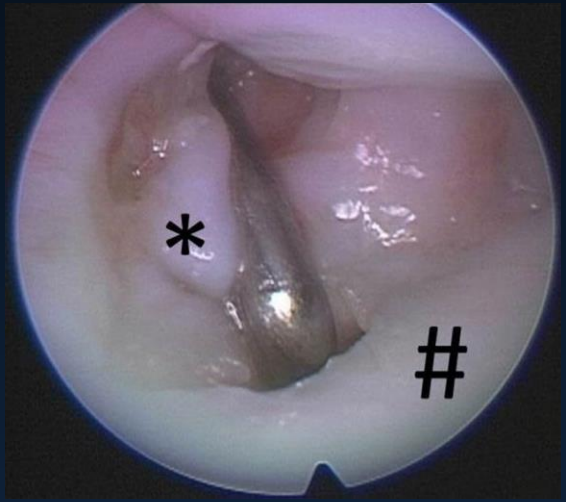
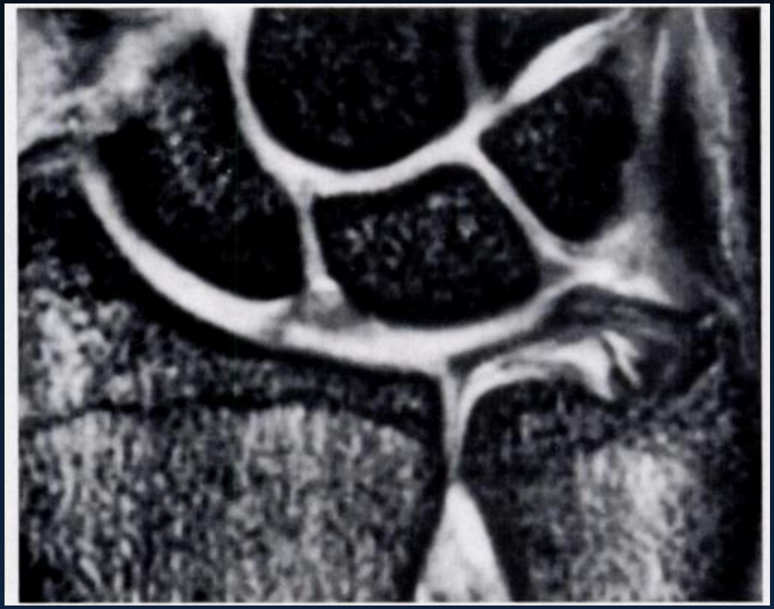


iii

i. Estrella et al. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007.
ii. Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.
iii. Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

Palmer Class 2A

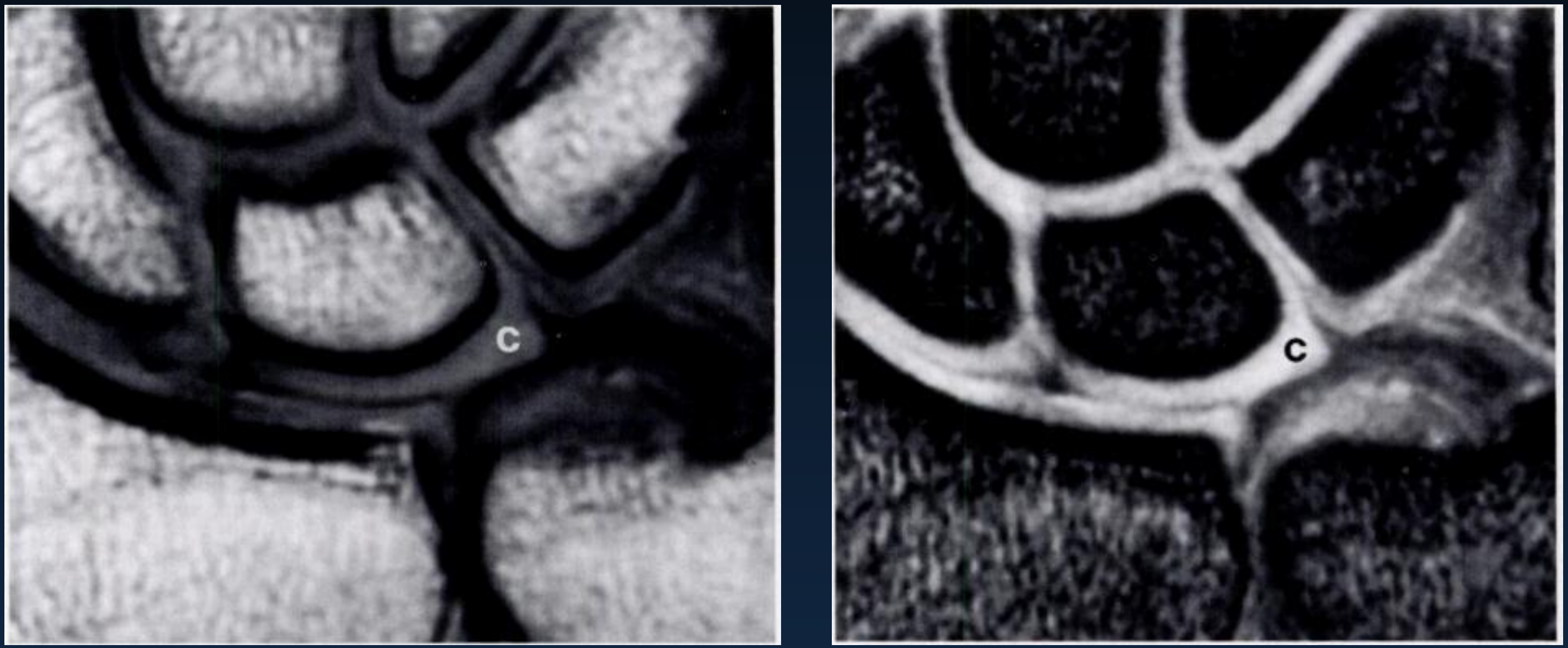
- Wear of horizontal portion of TFCC without perforation
- Treatment – ulnar shortening



Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.

Palmer Class 2B

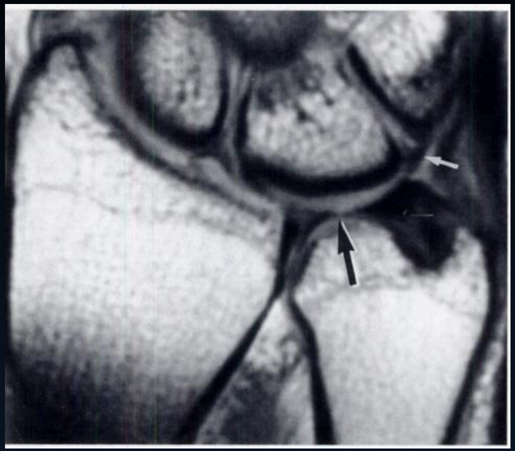
- 2A + chondromalacia of lunate and/or ulnar head
- Treatment – ulnar shortening



Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.

Palmer Class 2C

- Perforation of TFCC
- Usually in avascular portion of TFCC
- Ovoid configuration
- Treatment – debridement and wafer procedure or ulnar shortening



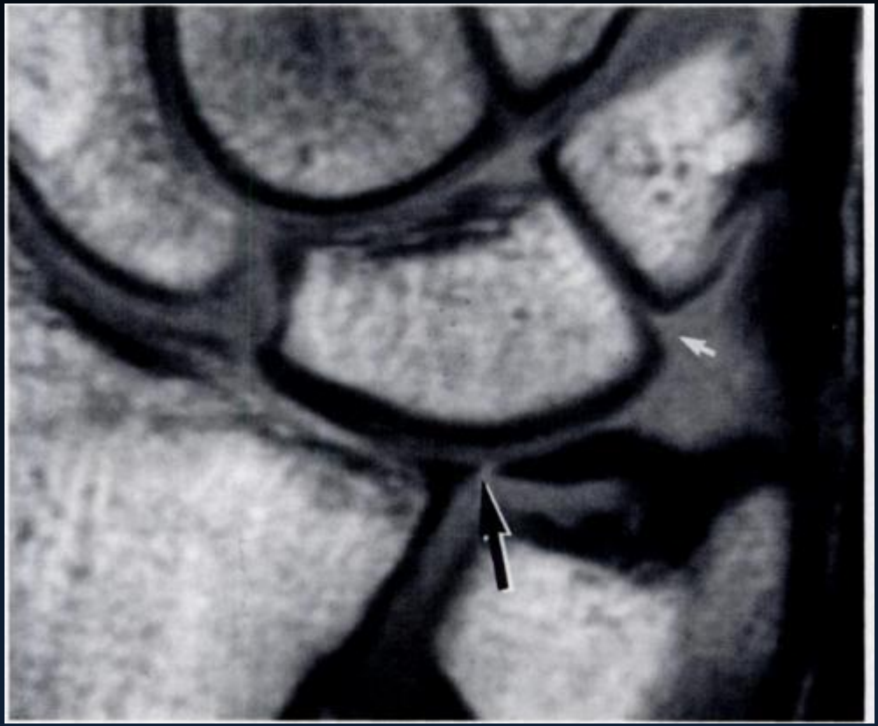
i

ii

i. Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.
ii. Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

Palmer Class 2D

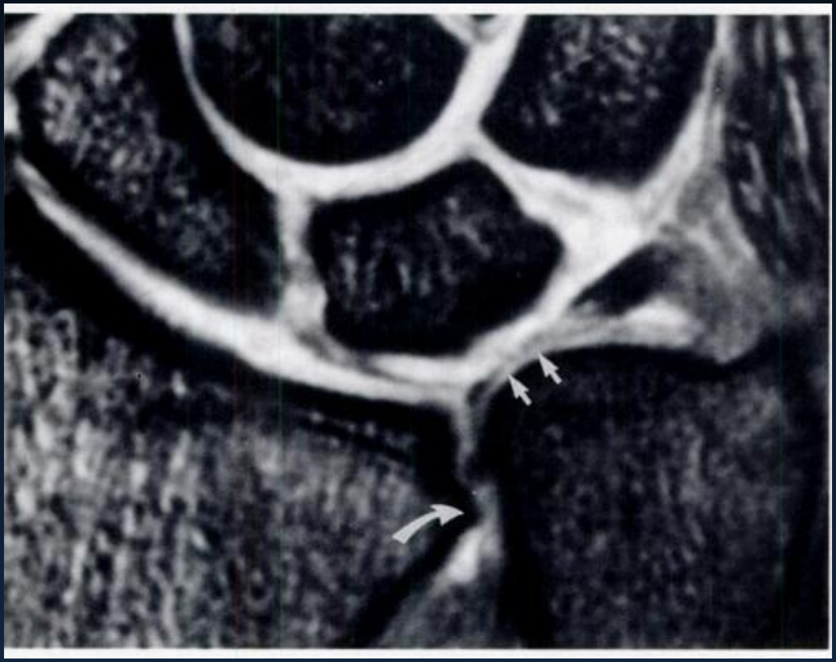
- 2C + rupture of lunotriquetral ligament
- Treatment – debridement of TFCC and lunotriquetral ligament, chondroplasty, possible reduction/fixation of lunotriquetral interval and/or ulnar shortening



Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.

Palmer Class 2E

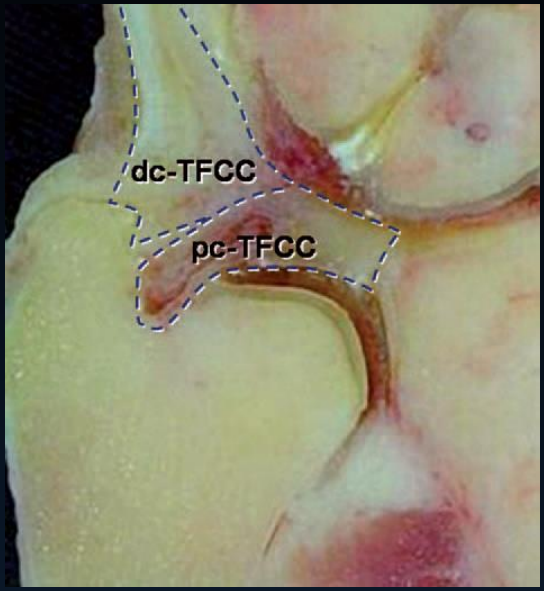
- 2D + ulnocarpal arthritis
- Treatment – debridement of joint or open salvage



Oneson et al. MR imaging interpretation of the Palmer classification of triangular fibrocartilage complex lesions. Radiographics. 1996.

Atzei Classification

- Treatment-oriented classification for peripheral TFCC tears (Palmer Class 1B)
- Breaks up periphery of TFCC into 2 regions
  - Proximal component - triangular ligament and ligamentum subcruentum
  - Distal component - distal hammock structure (meniscus homologue) and ulnar collateral ligament



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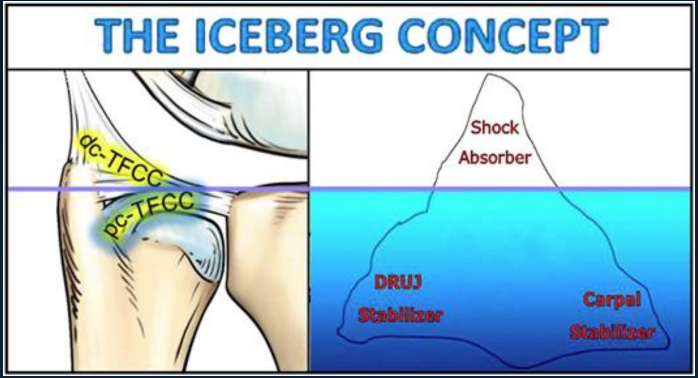
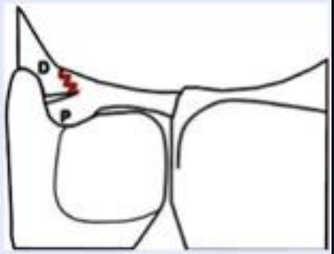


ii

i. Atzei A. New trends in arthroscopic management of type 1-B TFCC injuries with DRUJ instability. J Hand Surg Eur Vol. 2009.
ii. Atzei et al. Foveal TFCC tear classification and treatment. Hand Clin. 2011

Atzei Class 1

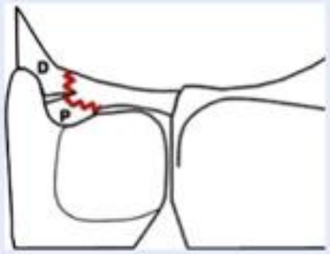
- Repairable
- Distal tear with intact proximal TFCC component
- Treatment – arthroscopic suture

	Class 1: Repairable distal tear
	
Clinical DRUJ instability	None/slight
Appearance of TFCC distal component (RC arthroscopy)	Torn
Status of TFCC proximal component (hook test/ DRUJ arthroscopy)	Intact
Healing potential of TFCC tear's margins	Good
Status of DRUJ cartilage	Good
Treatment	*Repair* Suture (lig-to-capsule)

Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

Atzei Class 2

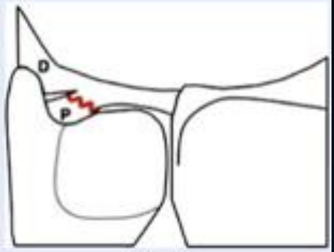
- Repairable
- Complete tear through distal and proximal components of TFCC
- Treatment – foveal reattachment of TFCC

	Class 2: Repairable complete tear
	
Clinical DRUJ instability	Mild/severe
Appearance of TFCC distal component (RC arthroscopy)	Torn
Status of TFCC proximal component (hook test/ DRUJ arthroscopy)	Torn
Healing potential of TFCC tear's margins	Good
Status of DRUJ cartilage	Good
Treatment	*Repair* Foveal refixation

Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

Atzei Class 3

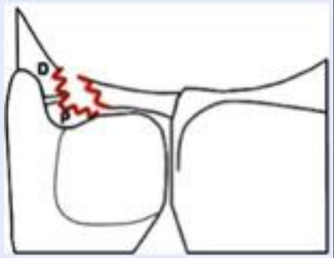
- Repairable
- Proximal tear with intact distal TFCC component
- Treatment – foveal reattachment of TFCC

	Class 3: Repairable proximal tear
	
Clinical DRUJ instability	
Appearance of TFCC distal component (RC arthroscopy)	Intact
Status of TFCC proximal component (hook test/ DRUJ arthroscopy)	Torn
Healing potential of TFCC tear's margins	Good
Status of DRUJ cartilage	Good
Treatment	

Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

Atzei Class 4

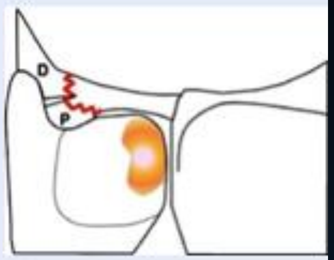
- Non-repairable
- Complete tear through distal and proximal components of TFCC
- Severe DRUJ instability
- Treatment – tendon graft reconstruction

	Class 4: Non-repairable tear
	
Clinical DRUJ instability	Severe
Appearance of TFCC distal component (RC arthroscopy)	Torn
Status of TFCC proximal component (hook test/ DRUJ arthroscopy)	Torn
Healing potential of TFCC tear's margins	Poor
Status of DRUJ cartilage	Good
Treatment	*Reconstruction* Tendon graft

Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

Atzei Class 5

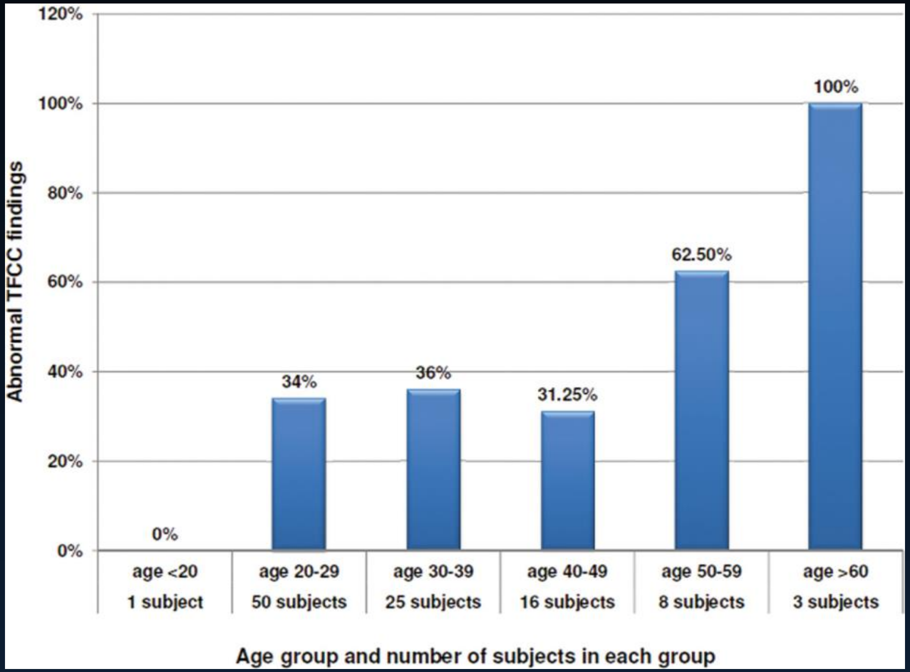
- TFCC tear with DRUJ arthritis
- Treatment – arthroplasty, joint replacement

	Class 5: Arthritic DRUJ
	
Clinical DRUJ instability	Mild/severe
Appearance of TFCC distal component (RC arthroscopy)	Variable
Status of TFCC proximal component (hook test/ DRUJ arthroscopy)	
Healing potential of TFCC tear's margins	
Status of DRUJ cartilage	Poor
Treatment	*Salvage* Arthroplasty or joint replacement

Kirchberger et al. Update TFCC: histology and pathology, classification, examination and diagnostics. Arch Orthop Trauma Surg. 2015.

Incidental Findings

- Cadaveric studies - 50% of people over age 60 have degenerative TFCC tears
- Arthrography of 52 healthy volunteers – 12% had abnormal communication across TFCC
- Arthrography of 56 patients with symptoms in CONTRALATERAL wrist – 73% had TFCC defects
- MRIs of asymptomatic wrists
  - 64/103 normal
  - 39/103 abnormal
    - Tears in 26, full thickness in 23/26
    - Abnormal signal centrally in 13
    - Findings most frequently involved articular disc



Iordache et al. Prevalence of triangular fibrocartilage complex abnormalities on MRI scans of asymptomatic wrists. J Hand Surg Am. 2012.

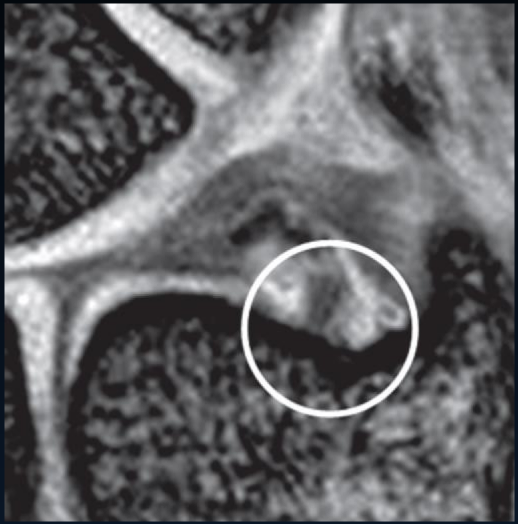
MRI Pitfalls

- Degenerative changes
  - High signal intensity within the disc without extension to an articular surface
- Proximal lamina
- Ulnar styloid tip
- Sigmoid notch of the radius
- Prestyloid recess

Burns et al. Pitfalls that may mimic injuries of the triangular fibrocartilage and proximal intrinsic wrist ligaments at MR imaging. Radiographics. 2011.

MRI Pitfalls

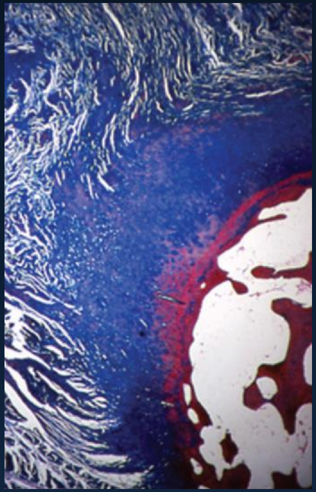
- Degenerative changes
- Proximal lamina
  - Highly vascular loose connective tissue with collagen fibers
  - High signal intensity
- Ulnar styloid tip
- Sigmoid notch of the radius
- Prestyloid recess



Burns et al. Pitfalls that may mimic injuries of the triangular fibrocartilage and proximal intrinsic wrist ligaments at MR imaging. Radiographics. 2011.

MRI Pitfalls

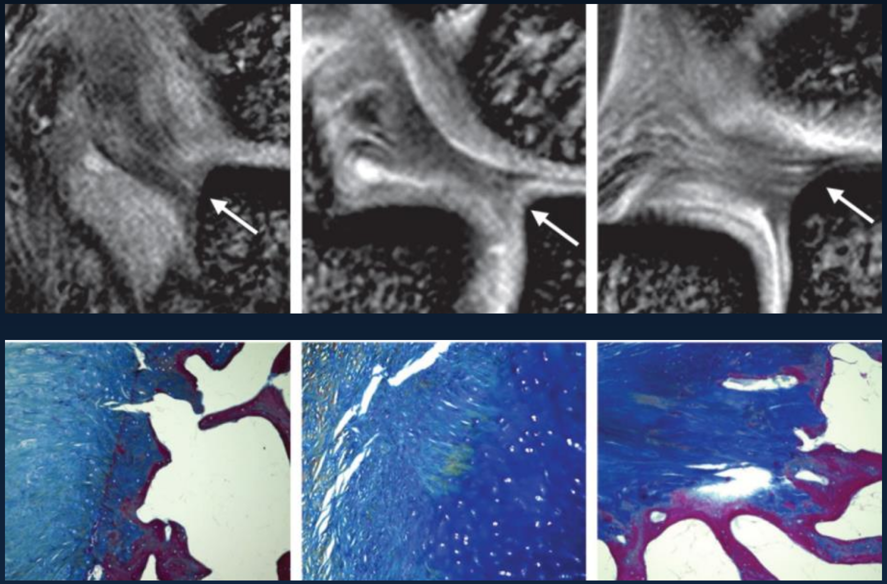
- Degenerative changes
- Proximal lamina
- Ulnar styloid tip
  - Has intermediate signal intensity hyaline cartilage
  - Should not be interpreted as a tear of the distal lamina
- Sigmoid notch of the radius
- Prestyloid recess



Burns et al. Pitfalls that may mimic injuries of the triangular fibrocartilage and proximal intrinsic wrist ligaments at MR imaging. Radiographics. 2011.

MRI Pitfalls

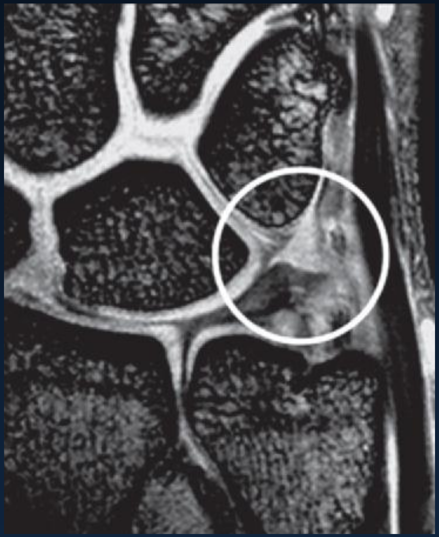
- Degenerative changes
- Proximal lamina
- Ulnar styloid tip
- Sigmoid notch of the radius
  - TFCC attaches directly to bone at marginal locations
  - Transitions from fibrocartilage to hyaline cartilage more centrally
  - Cartilage is intermediate signal intensity
- Prestyloid recess



Burns et al. Pitfalls that may mimic injuries of the triangular fibrocartilage and proximal intrinsic wrist ligaments at MR imaging. Radiographics. 2011.

MRI Pitfalls

- Degenerative changes
- Proximal lamina
- Ulnar styloid tip
- Sigmoid notch of the radius
- Prestyloid recess
  - Can be tubular or conical
  - Can mimic a tear



Burns et al. Pitfalls that may mimic injuries of the triangular fibrocartilage and proximal intrinsic wrist ligaments at MR imaging. Radiographics. 2011.

Treatment

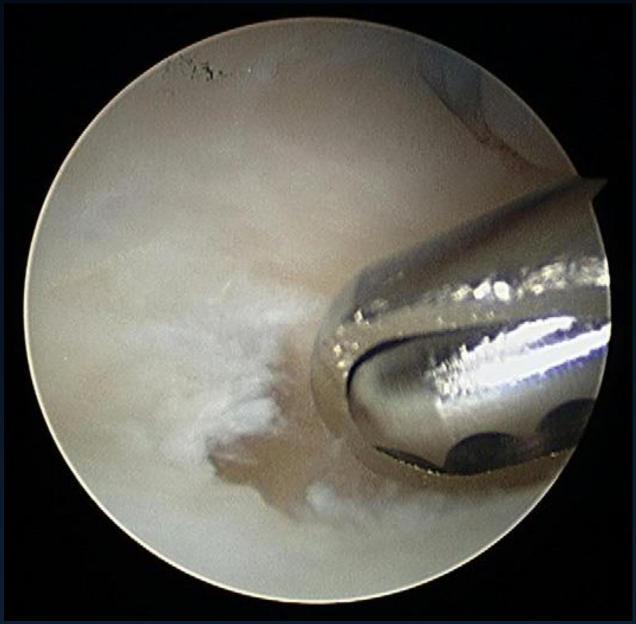
- Non-operative
  - Activity modification
  - Splinting or casting
  - NSAIDs
  - Corticosteroid injections
  - Occupational therapy
- Operative
  - Open or arthroscopic
  - Debridement
  - Repair
  - Ulnar unloading procedures

Open versus Arthroscopic Repair

- Study of 75 patients with TFCC repair between 1997-2006
- 37 arthroscopic, 39 open
- No significant differences in clinical outcomes between two groups
- Slightly better flexion/extension in arthroscopy group
- Higher risk of nerve injury in open group

Debridement

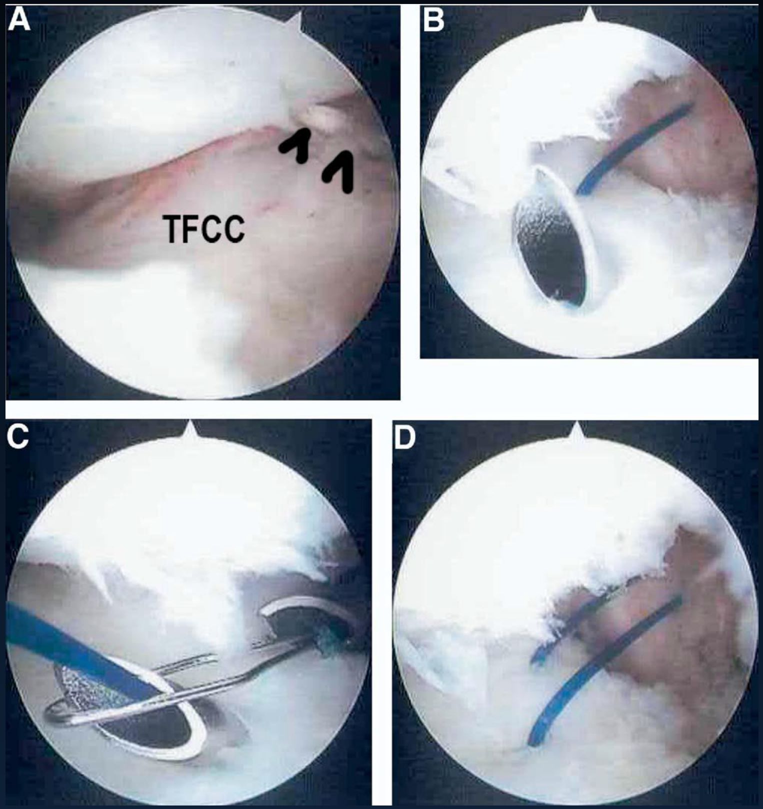
- Palmer Class 1A tears often create unstable flap of tissue
- Goal – remove all loose flap components, establish stable rim of TFCC
- Up to 80% of disc can be resected without creating instability
- 66-87% success rate for arthroscopic debridement of Palmer Class 1A tears
- Higher failure rates in ulnar positive wrists – would also involve ulnar shortening
- Ulnar shortening increases overall success rate of Class 1A debridement from 87% to 99%



Kovachevich et al. Arthroscopic and open repair of the TFCC. Hand Clin. 2010.

Repair

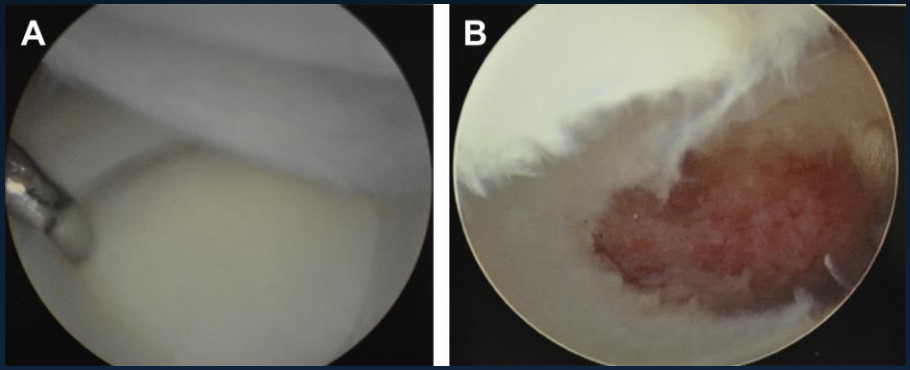
- Ulnar sided peripheral tears (Palmer 1B)
- Distract wrist, insert scope, debride area, and suture tear
- Good to excellent results in 61-91% of patients
- Some literature reports good results for Class 1C and 1D tears



Estrella et al. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007.

Wafer Procedure

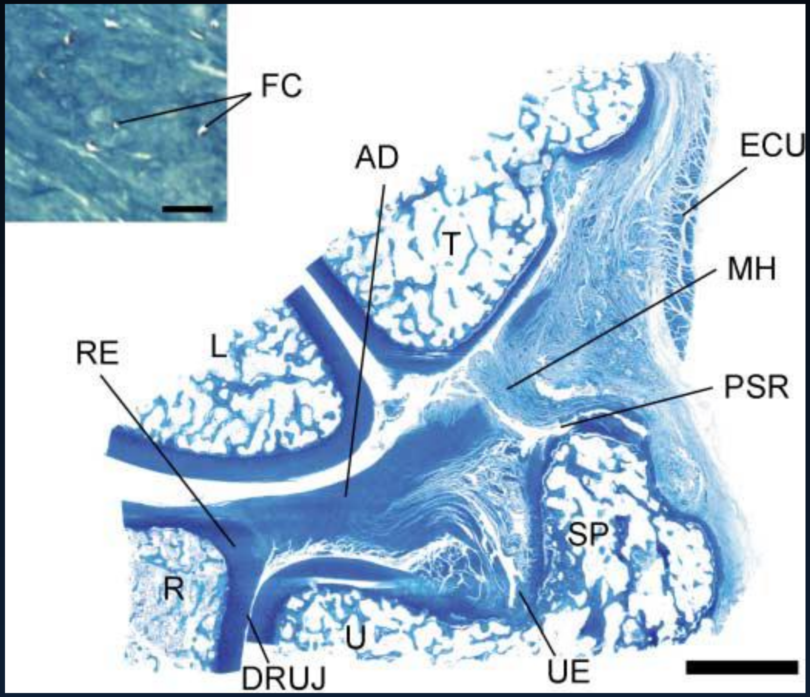
- Degenerative perforation of TFC (Palmer 2C)
- Debridement of perforation
- Debridement of underlying ulnar head cartilage and subchondral bone to correct positive ulnar variance



Ko et al. Triangular fibrocartilage complex injuries in the elite athlete. Hand Clin. 2012.

Summary

- Complex structure with multiple components
- Components have different histology and MR appearance
- Knowledge of histoanatomy allows for accurate description and characterization of MR findings



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