IFSSH Scientific Committee on Anatomy and Biomechanics

Chair: Eduardo R. Zancolli (Argentina)

Committee: Carlos Zaidenberg (Argentina)
Diego Piazza (Argentina)
Hernan Iriarte (Argentina)

Report submitted February 2013

Anatomy of the Hand

Knowledge of anatomy of the hand is the basis for understanding pathology and for precise application of surgical techniques.

This committee has selected to write a report on the TFCC anatomy but believing also that it will be extremely useful for hand surgeons to have a brief actualization of the most significant new papers on hand anatomy.

Since the last IFSSH´s Committees Reports (November 2010), a lot of papers on hand anatomy have been published, many confirming what is already known but some adding new knowledge on the already know structures. This last group mainly refers to anatomical variations that need to be known in order to diminish surgical surprises and to imagine how to deal with them.

We are conscious that due to the huge amount of bibliographical sources we might have missed some important papers and we apologize for it.

Committee Report on Anatomy of the TFCC

The Triangular Fibrocartilage was initially described by **Weitbrecht** (1742) as *intermedia triangularis* cartilage. In modern literature were **Palmer and Werner** (1981) that introduced the term Triangular-Fibro Cartilage-Complex (TFCC) to describe these structures.

Anatomical description

The TFCC is a structure running from the medial border of the radius to the styloid area of the ulna and with a distal volar expansion to the carpus. This fibrocartilage-ligament complex stabilizes the distal radio-ulnar and ulno-carpal joints, distributing load between the carpus and ulna, and allowing smooth wrist flexion-extension, radial-ulnar deviation and forearm pronation-supination.

Other structures also intervene in stability: musculotendinous structures, the bony anatomy and the interosseous membrane.

The TFCC different components are:

- **Articular disc**
- **Dorsal and palmar distal radio-ulnar ligaments**
- **Meniscus homologue**
- **Capsule**
- **Extensor carpi ulnaris subsheath**

The **articular disc** is a cartilaginous avascular structure that has two wide insertions in the radius having as functions, load transmission (approximately 20% in normal conditions) and prevention of deformity during rotations of the radio-ulnar ligaments.

Dorsal and palmar radio-ulnar TFCC portions arise from the medial border of the distal radius and insert on the ulna at two separate and distinct sites: the fovea at the base of the ulnar styloid and to the ulna styloid itself. (Figure 1)

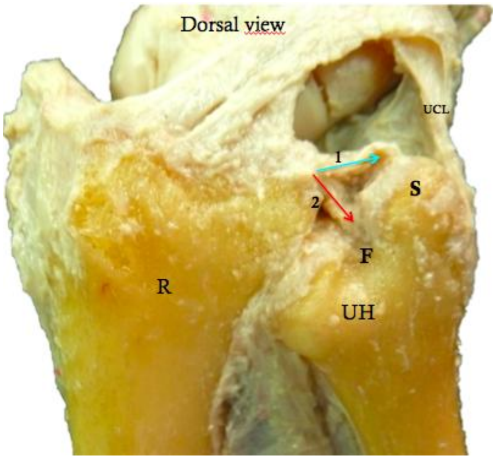


Figure 1. C. Zaidenberg *dissection*
R: radius, UH: ulnar head, S: styloid insertion, F: foveal insertion, UCL: ulnar collateral ligament. 1: Superficial aspect of TFCC (styloid), 2: deep insertion (foveal)

The peripheral portion of the articular disc of the TFCC is thicker than the central part and has longitudinally oriented collagen fibres. This thickening has been described as the **dorsal and palmar distal radio-ulnar ligaments**. Both of them containing a superficial and a deep portion. Dorsal and palmar deep portions inserts on the ulna's fovea (conjoined ligamentous insertion).

Superficial portion of dorsal RU ligament inserts proximally in three different sites, according to Zancolli EA descriptions (2008), A-radial border of ECU groove; B-deep in the ECU groove; C- dorsal aspect of the styloid process. **(Figures 2 A,B,C).**

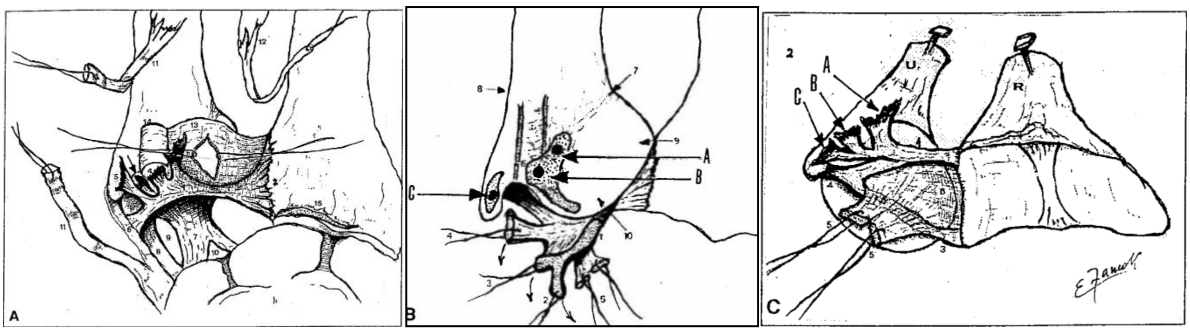
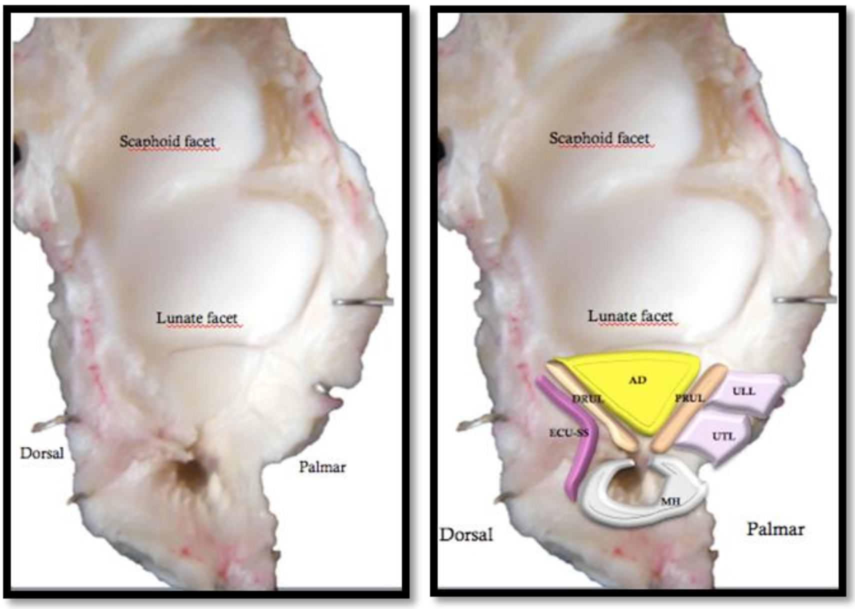


Figure 2. *Dorsal attachments of the superficial fascicle of the dorsal RU ligament.*
A: dorsal view. B: Oblique view. C: Volar view. From radial to ulnar, its 3 different ulnar insertions A,B,C. (from ***EA Zancolli´s*** *paper)*

Superficial portion of palmar RU ligament inserts distally in the volar surface of lunate and triquetrum bones by two separate fascicles (ulno-lunate and ulno-triquetral ligaments). These ligaments are considered to connect the ulna to the carpus through the palmar foveal origin of the radioulnar ligament. **(Figure 3)**



C. Zaidenberg dissection

Figure 3. *TFCC components: AD: articular disc; DRUL: dorsal radioulnar ligament; PRUL: palmar radioulnar ligament; ECU-SS: extensor carpi ulnaris subsheath; MH: meniscus homologue; UTL: ulnotriquetral ligament; ULL: ulnolunate ligament.*

Anatomical and histological studies have shown that only the proximal ligamentous component of the TFCC connects the radius directly to the ulna (**Nakamura** et al 1995, 1996, 2000).

The deep components of the TFCC have been referred by wrist investigators as the *Ligamentum Subcruentum*. In his landmark 1975 article on the "Articular disc of the hand", **Kauer** gives credit to **Henle** and **Fick** for describing a vascularized fissure between the superficial and deep components of the TFCC, which they called the "ligamentum subcruentum", technically not a ligament at all. Over the past 20 years, however, the term Ligamentum subcruentum has come to represent the deep fibers of the TFCC (inserting into the fovea) and is now used commonly by many investigators as interchangeable with the term "deep TFCC radioulna ligaments".

Nakamura & Makita (2000) suggested that the *ligamentum subcruentum* is merely the expression of a vascular intrusion into this defect between the superficial and deep laminae of the TFCC.

The **meniscus homologue,** a smooth synovium-like membranous structure which extends from the discoid section of the TFC to the triquetrum, was first described by **Lewis** (1970) as a distal-volar expansion that extends from the dorsal-ulnar aspect of the distal radius to the palmar-ulnar aspect of the triquetrum. It works like a hammock supporting the carpal ulnar border, highly vascularized with loose areolar tissue. There is a cavity adjacent to the ulnar styloid that communicates with the ulnocarpal space, called the prestyloid recess.

Garcia Elias, based on histological studies, considered the tissue which continued from the TFCC to the carpal bone as a meniscus homologue which is difficult to separate from the TFCC.

Others authors (**Ishii, Palmer & Werner** 1998) redefined in three configurations of the meniscus homologue and the prestyloid recess, based on how the prestyloid recess communicates with the ulnocarpal space: 1- narrow opening type; 2- wide opening type; 3-no opening type.

Different studies have shown that there are variations in the attachment of the TFCC to the triquetrum. **Hogikyan & Louis** subdivided the patterns of its attachment to the triquetrum into four types: a small, thin structure and focal attachment (group 1: 28%); a small, thick structure and focal attachment (group 2: 39%); a thick structure and broad attachment to between one-third and one-quarter of the triquetrum (group 3: 28%); and a broad attachment covering the entire triquetrum (group 4: 5%).

Nishikawa et al. also performed a study for the meniscus homologue's attachment to the ulnar side of the triquetrum (79 joints) obtaining different results than those from previous studies. They found that the section attached to the triquetrum is smooth and that in almost all cases the site of attachment is on the ulnar articular side of the triquetrum **(Figure 4)**. In about 10% of cases, the meniscal homologue was found attached to the ligament of the lunotriquetral ligament, obscuring the articular surface of the triquetrum.

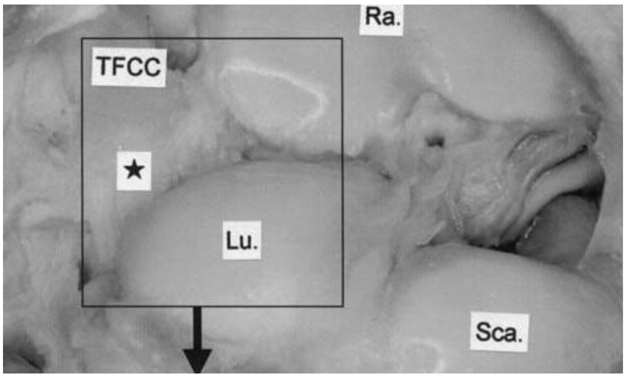


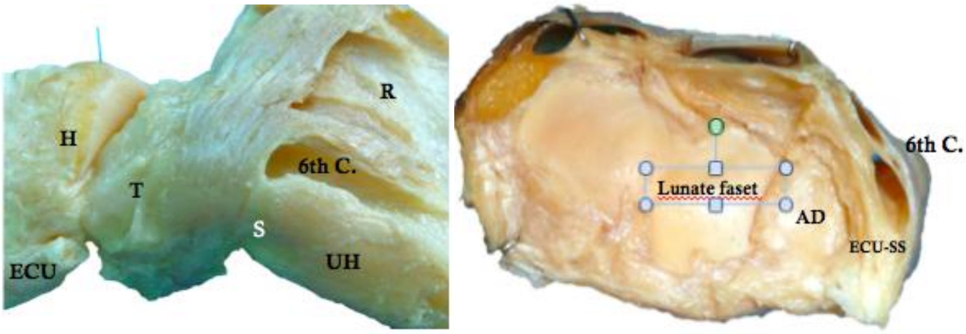
Figure 4: *Photograph showing the TFCC broadly attached to the triquetrum (group 4). The TFCC attached to the lunotriquetral ligament and the joint surface of the triquetrum was covered by the TFCC. (*TFCC broadly attached on the triquetrum). (from* ***Nishikawa´*** *s paper)*

The **capsule** attaches to the ulna along the anterior and posterior margins of the styloid process, and to the radius along the anterior and posterior borders of the sigmoid notch. Distally the DRUJ capsule is incorporated into the TFCC.

The thickened ulnar joint capsule originates from hyaline-like fibrocartilage on the tip and middle portion of the ulnar styloid, and coalesces with the meniscus homologue to constitute the ulnar wall of the TFCC. (**Nakamura & Yabe**, 2000). The ulnar collateral ligament is composed of the floor of the extensor carpi ulnaris sheath and the thickened joint capsule.

The **Extensor Carpi Ulnaris** (ECU) tendon courses through the sixth dorsal compartment of the wrist, passing dorsal on the lower end of the ulna through a small fibro-osseous tunnel. The tendon is held tightly in the ulnar groove by a thin **subsheath**, a proper relatively rigid retinaculum, attached on the margins of the ulnar groove and ensuring its stability during pronation-supination. It is a pulley described by Bourgery et al as "*petit arcade fibrose*" which prevents ECU tendon subluxation. The ECU retinaculum is separate from the dorsal or extensor retinaculum and covered by expansions of the extensor retinaculum, which plays no stabilizing role with regard to the ECU tendon.

The extensor carpi ulnaris (ECU) subsheath has a firm connection to the dorsal edge of the ulnar fovea through Sharpey's fibers. Based on its histological composition, it is considered that the ECU subsheath is an important ulnocarpal stabilizer. **(Figure 5)**



C.Zaidenberg *dissection*

Figure 5: *Photograph showing cadaveric wrist dissection. R: radius; 6th Compartment; UH: ulnar head; S: Styloid; T: triquetrum; H: hamate; ECU: extensor carpi ulnaris. ECU-SS: subsheath; AD: articular disc.*

Vascular supply of the TFCC

There are two clearly defined areas, 1) the central is avascular nourished by synovial fluid, 2) the periphery of the TFCC is supplied by branches of the ulnar artery and also from the anterior and posterior interosseous arteries. This has important implicance in the healing potential of future repairs. **(Figure 6)**

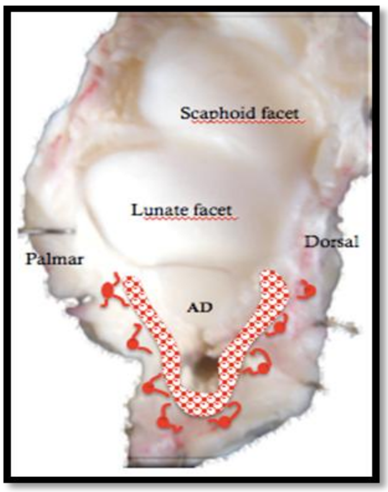


Figure 6. *Vascular supply patterns* ***(C. Zaidenberg*** *dissection)*

Innervation of the TFCC

Gupta et al (2001) studied the innervation of the TFCC. Central and radial aspects of the TFCC do not have any nerve fascicles or fibers present.

The volar portion of the TFCC is innervated by a branch of the ulnar nerve and the dorsal sensory branch of the ulnar nerve.

The ulnar and dorsal aspects of the TFCC are more variable in their patterns of innervation. Branches of the ulnar nerve and the dorsal sensory branch of the ulnar nerve innervate the ulnar aspect of the complex. Branches of the posterior interosseous nerve and the dorsal sensory branch of the ulnar nerve innervate the dorsal aspect of the TFCC. **(Figure 7)**

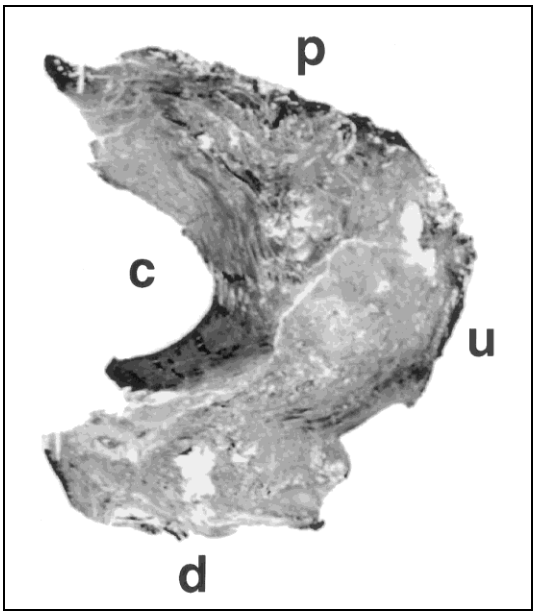


Figure 7*. Low-power view of preserved and sectioned TFCC showing sampled regions including central/radial (c), palmar (p), ulnar (u), and dorsal (d). (from* ***Gupta´s*** *paper)*

Cavalcante ML, Rodrigues CJ, R. Mattar Jr (2004) went futher and studied mechanoreceptors and nerve endings. The free nerve endings, **(Figure 8)** responsible for sensing pain, predominate in the ulnar and dorsal areas. The Vater-Pacini corpuscles predominate in the radial and dorsal area, promoting perception of the onset or cessation of movement and mechanical stress change. The Golgi-Mazzoni corpuscles were more frequent in the ulnar and ventral areas, linking these areas to function of slow adaptation and sensation of extreme movements. The propioceptive function receptors were found in all areas of TFCC because Ruffini corpuscles have homogeneous distribution in its fibrocartilaginous tissue.

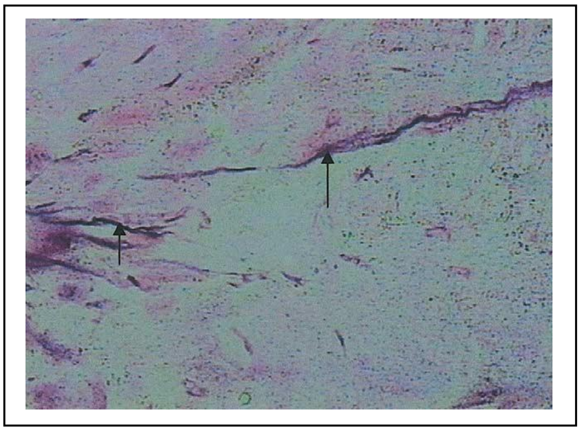


Figure 8*. Free nerve endings (arrows) in the fibrocartilaginous tissue at the peripheral area of the TFCC. (from* ***R. Matta Jr****´s paper)*

Biomechanics in short

The distal radioulnar joint (DRUJ) has been defined as a diarthrodial trochoid articulation formed by the head of the ulna and the shallow sigmoid cavity of the lower end of the radius. The curvatures of the two articulating surfaces are not equal. The radius of the ulna is about two thirds the length of the sigmoid notch concavity. This results in a relatively unstable articulation with reduced area of contact between the two bones. To overcome this, different stabilizing structures exist: (a) the TFCC, composed of the discus articularis, the palmar and dorsal radioulnar ligaments, the ulnocarpal ligaments, and the ECU sheath; (b) the pronator quadratus muscle; and (c) the interosseous membrane.

The concave radius-of-curvature of the sigmoid notch is greater than that of the ulna head **(Figure 9)**.

Full congruity of two articulating surfaces is therefore not possible. This incongruity of articular surfaces creates a geometrically non-constrained articulation at the DRUJ, subject to translational dorsal and palmar instability. In the extremes of forearm rotation, <10% of the ulnar head may be in contact with the sigmoid notch.

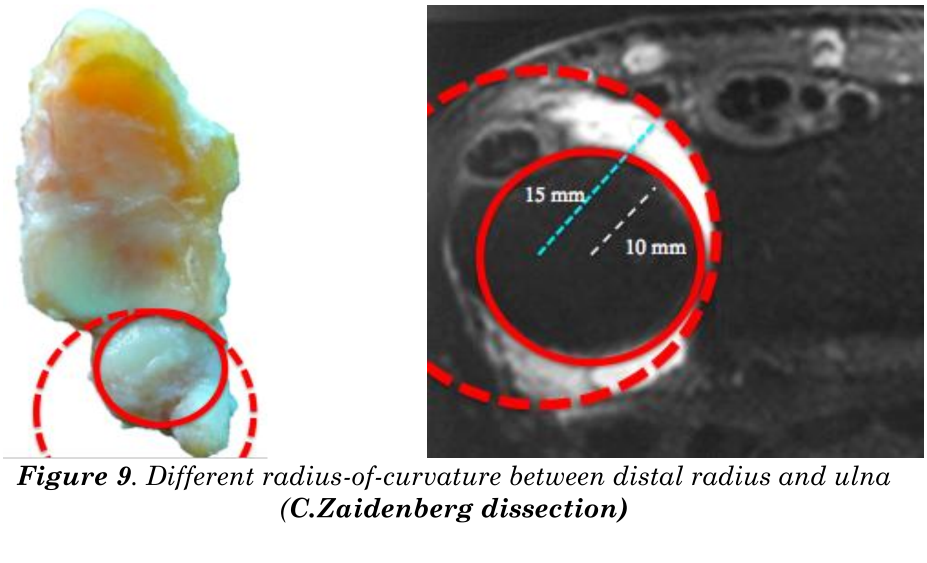


Figure 9*. Different radius-of-curvature between distal radius and ulna*
(C.Zaidenberg dissection)

Thus for complete function in pronosupination, a longitudinal axis that passes through the center of the radial head proximally and through the foveal sulcus distally. **(Figure 10)**

The radioulnar ligaments arise from a broad area in the ulnar fovea and from a rather narrow area at the ulnar styloid. Considering the larger area of origin and the close relationship of the fovea to the rotation axis of the forearm, it is likely that the foveal origin is the more important. (**Nakamura** 2001)

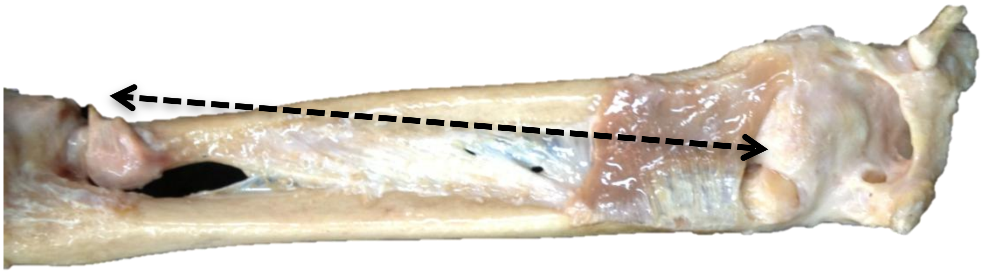


Figure 10. *Longitudinal axis that passes through the center of the radial head proximally and through the foveal sulcus distally.* ***(C. Zaidenberg*** *dissection)*

DRUJ Stability

With inherently unstable, non-constrained articular surfaces, anatomic stability of the DRUJ is also achieved through extrinsic extracapsular structures.

Extrinsic stability is provided principally by dynamic tensioning of the ECU as its tendon crosses the distal head of the ulna, the semirigid sixth dorsal compartment itself, constraining the ECU tendon, dynamic support provided by the superficial and particularly the deep heads of the pronator quadratus and the interosseous membrane. These extrinsic DRUJ stabilizers are of relatively minor consequence to rotational forearm stability, compared with the more biomechanically effective intrinsic radioulnar components of the TFCC.

Classification of TFCC ruptures

Palmer (1989) divides TFCC lesions in two groups according to etiology (traumatic or degenerative) and location. He describes four main traumatic ruptures. **(Figure 11)**

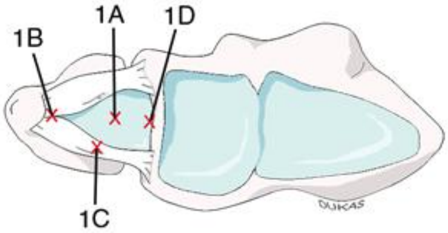


Figure 11: *Palmer Classification. I: Traumatic TFCC injuries. 1A: central tear. 1B: peripheral avulsion from ulnar styloid. 1C: volar ulnocarpal ligaments tear. 1D: radial attachment tears.*

A different rupture was also described by **Zancolli EA** (2008), who added a fifth injury: superficial dorsal avulsion, referring mainly to the two more radial insertions of the superficial fascicle of the dorsal radioulnar ligament, **(Figure 12)** which he considers is the main cause of dorsal ulnar instability.

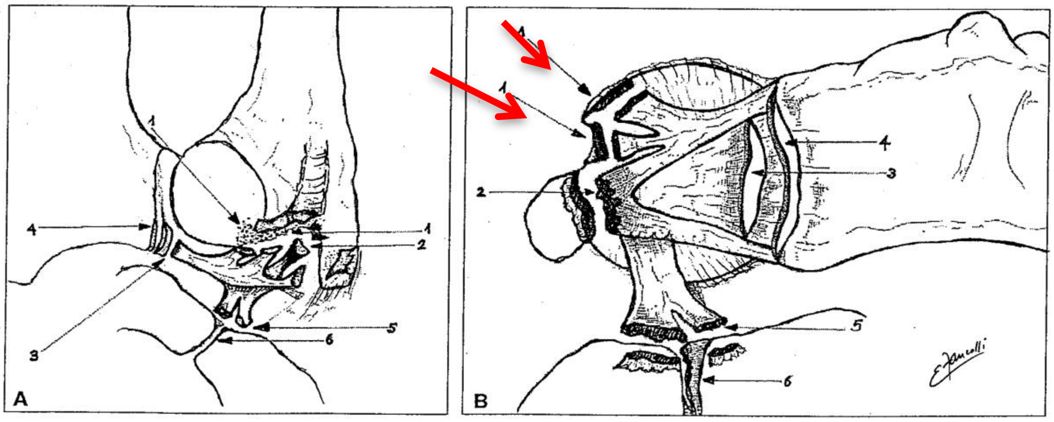
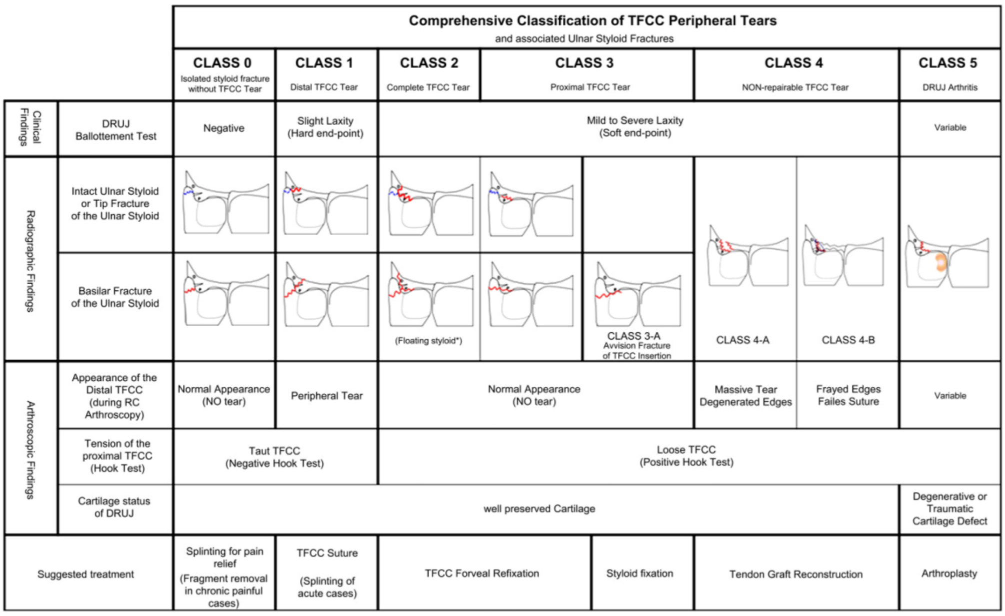


Figure 12A,B: *Traumatic injuries of the TFCC: 1.superficial dorsal avulsion (arrows); 2.deep ulnar avulsion (foveal); 3. Central perforation; 4. Radial avulsion; 5. distal avulsion: frequently associated with lunotriquetral interosseous ligament tear (6). (from* ***EA Zancolli´s*** *paper)*

Based on clinical, radiographic, and arthroscopic findings, **Atzei** et al (2011) defined a comprehensive classification that refers to the different types of peripheral (Palmer class IB) TFCC lesions with a guideline for specific treatment modalities. He defined six different classes. **(Figure 13)**



Comprehensive Classification of TFCC Peripheral Tears
and associated Ulnar Styloid Fractures

		CLASS 0 Isolated styloid fracture without TFCC Tear	CLASS 1 Distal TFCC Tear	CLASS 2 Complete TFCC Tear	CLASS 3 Proximal TFCC Tear	CLASS 4 NON-repairable TFCC Tear	CLASS 5 DRUJ Arthritis
Clinical Findings	DRUJ Ballottement Test	Negative	Slight Laxity (Hard end-point)	Mild to Severe Laxity (Soft end-point)			Variable
Radiographic Findings	Intact Ulnar Styloid or Tip Fracture of the Ulnar Styloid					CLASS 4-A / CLASS 4-B	
	Basilar Fracture of the Ulnar Styloid			(Floating styloid*)	CLASS 3-A Avvision Fracture of TFCC Insertion		
Arthroscopic Findings	Appearance of the Distal TFCC (during RC Arthroscopy)	Normal Appearance (NO tear)	Peripheral Tear	Normal Appearance (NO tear)		Massive Tear Degenerated Edges / Frayed Edges Failes Suture	Variable
	Tension of the proximal TFCC (Hook Test)	Taut TFCC (Negative Hook Test)		Loose TFCC (Positive Hook Test)			
	Cartilage status of DRUJ	well preserved Cartilage					Degenerative or Traumatic Cartilage Defect
Suggested treatment		Splinting for pain relief (Fragment removal in chronic painful cases)	TFCC Suture (Splinting of acute cases)	TFCC Forveal Refixation	Styloid fixation	Tendon Graft Reconstruction	Arthroplasty

Figure 13: *Atzei Classification. He defined 6 different classes of peripheral TFCC tears.*

References

1. **Adams BD, Berger RA.** An anatomic reconstruction of the distal radioulnar ligaments for posttraumatic distal radioulnar joint instability. *J Hand Surg* 2002;27A:243–251.

2. **Af Ekenstam F, Hagert CG**. Anatomical studies on the geometry and stability of the distal radio ulnar joint. *Scand J Plast Reconstr Surg* 1985;19:17–25.

3. **Af Ekenstam FW, Palmer AK, Glisson RR**. The load on the radius and ulna in different positions of the wrist and forearm: a cadaver study. *Acta Orthop Scand* 1984;55:363–365.

4. **Atzei A, Luchetti R**. Foveal TFCC tear classification and treatment. *Hand Clin* 2011 263-272

5. **Bednar MS, Arnoczky SP, Weiland AJ.** The microvasculature of the triangular fibrocartilage complex: its clinical significance. *J Hand Surg*1991;16A:1101–1105.

6. **Bourgery JM, Bernard C, Jakob NH.** Traite complet d´Anatomie de l´homme. Vol.2. Paris, 1852 m

7. **Cavalcante ML, Rodrigues CJ, R. Mattar Jr**. Mechanoreceptors and nerve endings of the triangular fibrocartilage in the human wrist. *J Hand Surg* (Am) 2004 *29:* 432–435; discussion 436–438.

8. **Fick RA.**Handbuch der anatomie und mechanik der gelenke unter bercksichtigung der bewegenden muskeln. Vol 1. *Anatomie der gelenke*. Jena: Fischer, 1904.

9. **Garcia Elias M.** Anatomy of the wrist. The Wrist, edited by HK Watson. Philadelphia 2001

10. **Garcia Elias M.** Soft tissue anatomy and relationships about the distal ulna. *Hand Clinic*1998;14:165-76

11. **Gupta R, Nelson SD, Baker J, Jones NF, Meals RA.** The Innervation of the Triangular Fibrocartilage Complex. *Plast Reconstr Surg* 2001; 107: 135-9.

12. **Hogikyan JV, Louis DS.** Embryologic development and variations in the anatomy of the ulnocarpal ligamentous complex. *J Hand Surg*1992;17A:719-23.

13. **Henle J.** Handbuch der bänderlehre des menschen. Braunschweig: Friedrich Vieweg, 1856.

14. **Hagert CG.** Distal radius fracture and the distal radioulnar joint – anatomical considerations. *Handchir Mikrochir Plast Chir* 1994;26:22–26.

15. **Ishi S, Palmer AK, Werner FW, Short WH, Fortino MD**. An anatomic study of the ligamentous structure of the triangular fibrocartilage complex. *J Hand Surg Am*. 1998;23(6):977-85.

16. **Kauer JMG**. The articular disc of the hand. Acta Anat 1975;93:590 – 605.

17. **Kleinman WB, GrahamTJ**. Distal ulnar injury and dysfunction. In: Peimer CA, ed. Surgery of the hand and upper extremity. New York: McGraw-Hill, 1996:667–709.

18. **Kleinman WB, Graham TJ.** The distal radioulnar joint capsule: clinical anatomy and role in posttraumatic limitation of forearm rotation. *J Hand Surg* 1998; 23A:588–599.

19. **Lewis OJ, Hamshere RJ, Bucknill TM.** The anatomy of the wrist joint. *J Anat* 1970;106:539-552.

20. **Lewis OJ, Hamshere RJ, Bucknill TM.** The anatomy of the wrist joint. *J Anat* 1969;106:539-52.

21. **Nakamura T, Yabe Y, Horiuchi Y**. Functional Anatomy of the Triangular Fibrocartilage Complex. *Journal of Hand Surgery* 1996. 21B. 5: 581-586.

22. **Ono H, Gilula LA, Marzke MW, Obermann WR.** Bicompartmentalization of the radiocarpal joint. *J Hand Surg*1996;21A:788-93.

23. **Palmer AK, Werner FW.** The triangular fibrocartilage complex of the wrist: anatomy and function. *J Hand Surg*1981;6:153-62.

24. **Palmer AK, Werner FW**. Biomechanics of the distal radioulnar joint. *Clin Orthop Relat Res* 1984;187:26–35.

25. **Palmer AK**. Triangular fibrocartilage complex lesions: A classification. *J Hand Surg*(*Am.*) 14: 594, 1989.

26. **Pogue DJ, Viegas SF, Patterson RM, Peterson PD, Jenkins DK, Sweo TD, Hokanson JA**. Effects of distal radius fracture malunion on wrist joint mechanics. *J Hand Surg* 1990; 15A:721–727.

27. **Schuind F, An KN, Berglund L, Rey R, Cooney WP, Linscheid RL, Chao EYS**. The distal radioulnar ligaments: a biomechanical study. *J Hand Surg* 1991;16A:1106 –1114.

28. **Schuind F, An KN, Berglund L, Rey R, Cooney WP, Linscheid RL, Chao EYS**. The distal radioulnar ligaments: a biomechanical study. *J Hand Surg* 1991;16A:1106 –1114.

29. **Stuard P, Berger R, Linscheid R, An K.** Dorso Palmar Stability of the Distal Radio Ulnar Joint. *J Hand Surg* 2000, 25A : 689-6

30. **Spinner M, Kaplan EB**. Extensor carpi ulnaris: its relationship to stability of the distal radioulnar joint. *Clin Orthop Relat Res* 1970;68:124–128.

31. **Thiru-Pathi RG, Ferlic DC, Clayton ML, McClure DC**. Arterial anatomy of the triangular fibrocartilage of the wrist and its clinical significance. *J Hand Surg* 1986;11A:258– 263.

32. **Viegas SF, Pogue DJ, Patterson RM, Peterson PD**. Effects of radioulnar instability on the radiocarpal joint: a biomechanical study. *J Hand Surg*

1990;15A:728–732.

33. **Weitbrecht J**. Syndesmologia sive Historia Ligamentarum corporis Humani, quam secundum observations Anatomicas Concinnavit, et Figuris and Objecta Recentia Adumbratis Illustravit. Academy of Sciences, Petropoli, 1742.

34. **Zancolli EA**. Etiopatogenia y tratamiento de la inestabilidad dorsal del extremo distal del cúbito consecutiva a la rotura traumática del fibrocartílago triangular. *Rev Asoc Argent OrtopTraumatol*2008; 73(3):2-23.

Latest Papers on Hand Anatomy

I. Ligaments

The insertion points of the thumb`s MP joint collateral ligaments has been described with some precision. The **ulnar collateral ligament** (UCL) has a metacarpal origin 4.2 mm from the dorsal surface and 5.3 mm from the articular surface. The center of the phalangeal insertion of the UCL was 2.8 mm from the volar surface and 3.4 mm from the articular surface. The volar aspect of the phalangeal insertion extended up to 0.7 mm from the volar edge of the phalanx.

The **radial collateral ligament** (RCL) inserts at the metacarpal, having its center at 3.5 mm from the dorsal surface and 3.3 mm from the articular surface, the dorsal aspect being 1.5 mm from the dorsal edge of the metacarpal. The RCL`s center at phalangeal insertion was 2.8 mm from the volar surface and 2.6 mm from the articular surface, being its volar aspect 0.5 mm from the volar edge of the phalanx. This data is relevant for successful repair and reconstruction.

- Carlson MG, Warner KK, Meyers KN, Hearns KA, Kok PL. **Anatomy of the Thumb Metacarpophalangeal Ulnar and Radial Collateral Ligaments.** *J Hand Surg Am.* 2012 Oct; 37(10): 2021-6.

II. Nerves

The TMC joint has been described as innervated by the radial nerve (main innervation), the lateral antebrachial nerve innervation and the median nerve. Even though denervation's based on these structures not always lead to good results. A new study on 19 cadaveric specimens shows that 58% had superficial radial nerve, 47% had median nerve innervation from the motor branch and 47% had ulnar nerve innervation from the motor branch. This paper supposed to speak for the first time that ulnar innervation may also be present for the TMC joint.

- Miki RA, Kam CC, Gennis ER, Barkin JA, Riel RU, Robinson PG, Owens PW. **Ulnar nerve component to innervation of thumb carpometacarpal joint.** *Iowa Orthop J.* 2011; 31:225-30.

Deep palmar communications between the ulnar and median nerves have continued to be studied. (50 hands, 25 cadavers). In 16% of the hands communicating branches were found

- Marios Loukas, Sharath S Bellary, R Shane Tubbs, Mohammadali M Shoja, Aaron A Cohen Gadol. **Deep palmar communications between the ulnar and median nerves.** *Clin Anat.* 2011 Mar; 24 (2): 197-201.

Another paper also describes that a connecting third common palmar digital branch of the median nerve with the fourth common palmar and proper palmar digital branches of the median nerve presented a plexiform nature.

- Sirasanagandla SR, Patil J, Potu BK, Nayak BS, Shetty SD, Bhat KM. **A rare anatomical variation of the Berrettini anastomosis and third common palmar digital branch of the median nerve.** *Anat Sci Int.* 2013 Jan 17.

The **median nerve** branches for the pronator teres have been studied in one paper. All specimens (20 upper limbs) showed to have a branch from the median nerve long enough to reach the radial nerve in the cubital fossa in potential for neurotization cases.

- Tubbs RS, Beckman JM, Loukas M, Shoja MM, Cohen-Gadol AA. **Median nerve branches to the pronator teres: cadaveric study with potential use in neurotization procedures to the radial nerve at the elbow.** *J Neurosurg.* 2011 Jan; 114(1): 253-5.

The **sublime bridge** is the tendinous arch connecting the radial and humeral heads of the flexorum digitorum superficialis muscle. Located at the mean distance of 8.1 mm from the medial epicondyle, it was found to be tendinous in 75% and muscular in 25% of the specimens. As known, it is a potential factor for median nerve compression at the proximal forearm.

- Tubbs RS, Marshall T, Loukas M, Shoja MM, Cohen-Gadol AA. **The sublime bridge: anatomy and implications in median nerve entrapment.** *J Neurosurg.* 2010 Jul; 113(1): 110-2.

III. Muscles

The **flexor carpi radialis brevis** muscle is a muscular variant that can be present as much as 3.95 % in cadaveric studies. On volar approaches for distal radius fractures it may be found as a separate tendon running between the FCR and the radial vessels (inserting distally at the FCR tunnel) and superficial to the pronator quadratus.

- Ho SY, Yeo CJ, Sebastin SJ, Tan TC, Lim AY. **The flexor carpi radialis brevis muscle - an anomaly in forearm musculature: a review article.** *Hand Surg*. 2011; 16(3): 245-9.

The **Palmaris Profundus** variant when present (incidence 1/530 limbs) may prohibit endoscopic carpal tunnel release. It was found inserting onto the undersurface of the transverse carpal ligament.

- McClelland WB Jr, Means KR Jr. **Palmaris profundus tendon prohibiting endoscopic carpal tunnel release: case report.** J Hand Surg Am. 2012 Apr; 37(4): 695-8.

IV. Tendons

A new study of the flexor tendon sheaths shows high incidence of variations (33% in 12 cadavers), which have communication between the radial and ulnar bursae. This might explain variations to the classical presentation of spread of infection through the digital flexor sheaths.

- Fussey JM, Chin KF, Gogi N, Gella S, Deshmukh SC. **An anatomic study of flexor tendon sheaths: a cadaveric study.** *J Hand Surg Eur Vol.* 2009 Dec; 34(6): 762-5.

The **extensor pollicis brevis** (EPB) tendon has been determined to run through a separate sheath in the first dorsal compartment in 28% (50 wrists, 25 cadavers)

- Mirzanli C, Ozturk K, Esenyel CZ, Ayanoglu S, Imren Y, Aliustaoglu S. **Accuracy of intrasheath injection techniques for de Quervain's disease: a cadaveric study.** *J Hand Surg Eur Vol.* 2012 Feb; 37(2): 155-60.

Accessory **abductor pollicis longus** tendons have been studied once more (78 cadaveric upper limbs) with a presence of 85%. This paper speaks of the potentiality of the tendons as a graft source for TMC osteoarthritis.

- Bravo E, Barco R, Bullón A. **Anatomic study of the abductor pollicis longus: a source for grafting material of the hand.** *Clin Orthop Relat Res*. 2010 May; 468(5): 1305-9.

The sheaths and tendons of the first dorsal compartment were also studied in 124 cadavers. A unique compartment was found in 63.4%. In 32.1% two complete or partial separate compartments were observed, while 4.5% specimens showed no **extensor pollicis brevis** in the first dorsal compartment.

- Motoura H, Shiozaki K, Kawasaki K. **Anatomical variations in the tendon sheath of the first compartment.** *Anat Sci Int*. 2010 Sep; 85(3): 145-51.

The accessory tendon slip from the **extensor carpi ulnaris** (ECU) has also been studied in 54 specimens with an incidence of 5.6 %. Originating from the ECU, they ended in the extensor apparatus of the fifth finger, running ulnar side of **extensor digiti minimi tendon**.

The mean width was 1.4 $^{+}$/- 0.01 mm. This slip must be considered in cases of ECU tenosynovitis and MRI images of longitudinal split of ECU.

- Pınar Y, Gövsa F, Bilge O, Celik S. **Accessory tendon slip arising from the extensor carpi ulnaris and its importance for wrist pain.** Acta Orthop Traumatol Turc. 2012; 46(2): 132-5.

V. Myotomes

In brachial plexus dissections (38 arms, 19 cadavers), branches from the lateral cord to the ulnar nerve or medial cord have been identified in 13.1%. **Flexor carpi ulnaris** (FCU) in electrodiagnostic studies (in cases of C6, C7 and C8 radiculopathies) showed abnormal findings in 46.2% of C7 radiculopathies, 76.5% in C8 radiculopathies and 0% in C6 radiculopathies.

This study shows that the FCU can also be affected in C7 neuropathies (not only in C8 cases as classically mentioned).

- Pyun SB, Kang S, Kwon HK. **Anatomical and electrophysiological myotomes corresponding to the flexor carpi ulnaris muscle.** *J Korean Med Sci.* 2010 Mar; 25(3): 454-7.

VI. Vascular

The persistent **median artery** has been addressed in three papers. In one of them giving an incidence of 4%. It´s relations, superficial to the third common digital nerve and the extraligamentous recurrent thenar motor branch of the median nerve have been determined.

- Eid N, Ito Y, Shibata MA, Otsuki Y. **Persistent median artery: Cadaveric study and review of the literature.** *Clin Anat.* 2011 Jan 12.

The other addresses the palmar type of the persistent median artery (PMA) with an incidence of 15.4% (42 cadavers, 84 limbs). In 11.9% of the 15.4 % the PMA took part in the formation of the superficial palmar arch.

- Nayak SR, Krishnamurthy A, Kumar SM, Prabhu LV, Potu BK, D'Costa S, Ranade AV. **Palmar type of median artery as a source of superficial palmar arch: a cadaveric study with its clinical significance.** *Hand (N Y).* 2010 Mar; 5(1): 31-6.

Another study on 60 upper limbs demonstrated a 6.6 % persistent median artery.

- Singla RK, Kaur N, Dhiraj GS. **Prevalence of the persistant median artery.** *J Clin Diagn Res.* 2012 Nov; 6(9): 1454-7.

A study about the arteries of the thumb (30 hands) showed that the **princeps pollicis artery** was present in all specimens and was the origin of the radial and ulnar digital arteries in 73.3 %. The dorsal ulnar artery was present in all cases and also originated in the princeps pollicis artery in 73.3%. The dorsal radial artery was present only in 66.7% of dissections as a direct branch of the radial artery. Several anastomoses were found between the radial and ulnar digital arteries and between dorsal and palmar systems.

- Ramírez AR, Gonzalez SM. **Arteries of the thumb: description of anatomical variations and review of the literature.** *Plast Reconstr Surg.* 2012 Mar; 129(3): 468e-476e.