IFSSH Scientific Committee on Anatomy and Biomechanics

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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](image)

*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.](image)


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](image)

**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)

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 impilcance in the healing potential of future repairs. (Figure 6)
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)

Cavalcante ML, Rodrigues CJ, R. Mattar Jr (2004) went further 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 proprioceptive function receptors were found in all areas of TFCC because Ruffini corpuscles have homogeneous distribution in its fibrocartilaginous tissue.
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.
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)](image)

**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.](image)
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 intersosseous 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)

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


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


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


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.

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


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.


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.

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.


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.


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.


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)

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.


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.


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.


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).
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.


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.


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


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.