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Chapter 1

Anatomy of the Distal Radioulnar Joint and Ulnocarpal Complex

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The advent of terrestrial bipedalism saw the phylogenetic evolution of the distal radioulnar joint (DRUJ) from a syndesmotic or fused forearm joint in tetrapods to a joint capable of pronosupination in hominids, creating dexterity and allowing advanced handling of tools.[1] This evolution of the DRUJ, and the simultaneous evolution of the opposable thumb, has been attributed great importance in the development of mankind.

The DRUJ in humans is now a suspension joint where the ulna, with its distal ulnar head, constitutes the fixed and stable point around which the entire forearm and carpus rotates. This suspension construction is dependent on articular congruity of the proximal and distal radioulnar joints, the static stability of the ligaments stabilizing the DRUJ and the ulnocarpal joint, the integrity of the interosseous membrane and the dynamic neuromuscular stability of the DRUJ.[2] In this chapter, we will describe the osseous, ligamentous, and neuromuscular anatomy of the DRUJ and ulnocarpal wrist.

BONY ANATOMY

The DRUJ is a trochoid diarthrodial joint that forms the distal linkage between the radius and the ulna and is involved in pronation and supination of the forearm. The DRUJ should be considered the distal component of the entire forearm joint. The "forearm joint" is composed of the proximal radioulnar joint (PRUJ), the interosseous membrane and the DRUJ.[3] The axis of forearm rotation runs obliquely from the center of the radial head proximally to the foveal attachment of the triangular fibrocartilage complex (TFCC) in the ulnar head distally.[4-10] The ulna, anchored proximally to the humerus, provides a stable base around which the radius and hand move. The motion of the radius around the ulna is a combination of rotation and dorso-palmar translation.[7] This complex motion is delineated by joint shape and multiple soft tissue constraints. We consider the ulna to be the fixed unit of the forearm with the radius rotating around it. The ulnar head, in the uninjured state, serves a crucial role in the forearm joint as the stable weight-bearing component of the forearm, supporting the radius and allowing load bearing through the hand.[2] Thus, removal of the ulnar head, due to surgery or trauma, will have a significant effect on overall DRUJ mechanics.

The ulnar head is cylindrical in shape and covered in cartilage for roughly three quarters of its circumference.[11] The ulnar head contains two articular surfaces: *the pole and the seat*.[12] The ulnar pole articulates with the articular disc of the TFCC forming the *ulnocarpal articulation*; this articulation allows for wrist circumduction and load transfer through the ulnar aspect of the wrist (Fig. 1-1). The ulnar seat articulates with the sigmoid notch, forming the *radioulnar articulation* that allows for forearm rotation.

The ulnar pole is teardrop-shaped and curves proximally and medially before terminating at the ulnar styloid. The ulnar styloid is a continuation of the subcutaneous ridge of the ulna and can vary in length from 2 to 6 mm.[13] Phylogenetic evolution has produced a gradual separation of the ulnar styloid from the ulnar carpus. In tetrapods, the ulnar styloid originally articulated directly with the ulnar carpus. Requirements for primates to travel by means of *brachiation* (moving through the trees with the use of the arms) resulted in the developmental necessity of forearm pronosupination; this resulted in a separation of the ulna from the carpus and regression of the ulnar head and styloid.[14] Despite this

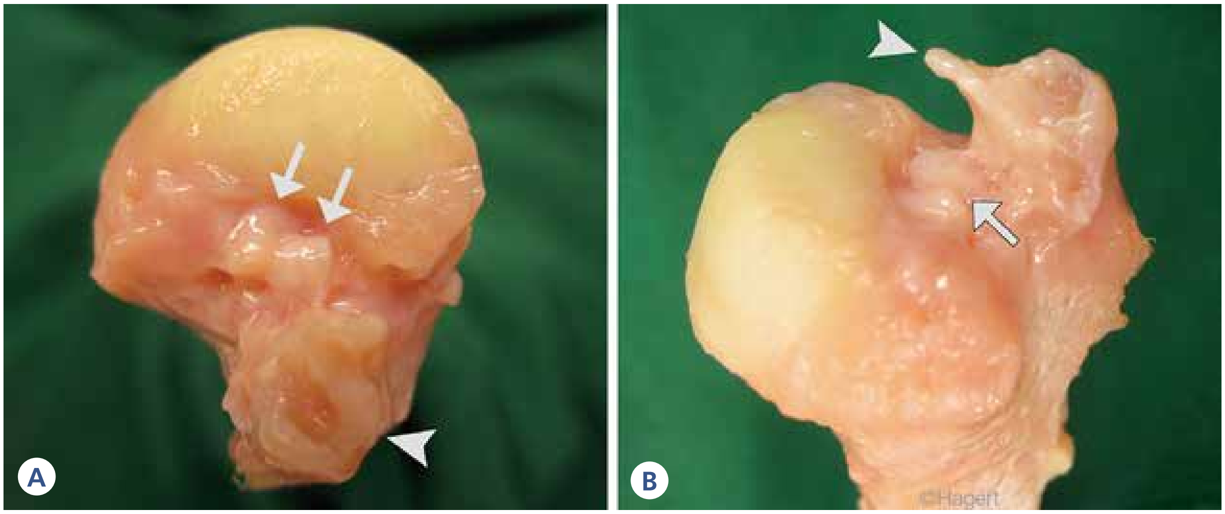

FIGURE 1-1
The ulnar head contains two articular surfaces: *the pole and the seat*. **(A)** The ulnar pole is best visualized in an axial image of the ulnar head. The pole is teardrop shaped and curves proximally and medially before terminating at the ulnar styloid. **(B)** The ulnar seat is best visualized in a coronal image of the ulnar head. The seat articulates with the sigmoid notch of the radius. Central and lateral to the ulnar styloid is a roughened depression within the ulnar pole referred to as the *fovea*. The fovea is the site of attachment for the apex of the triangular fibrocartilage (TFC) and the deep fibers of the radioulnar ligament. The important insertions of the distal radioulnar ligaments are illustrated in both images. The two bundles of the distal radioulnar ligaments are clearly seen inserting into the fovea (*arrows*), with a smaller and superficial portion of the ligaments inserting onto the ulnar styloid (arrowheads). Reproduced with permission from Hagert and Hagert[2].

phylogenetic separation of styloid from the ulnar carpus, one may still encounter great variation between the size and shape of the ulnar styloid between patients. These differences should not necessarily be considered pathologic; however, a large styloid process can impact the ulnar carpus during wrist extension and forearm supination, causing a so-called *ulnar styloid impaction syndrome (USIP)*, and should always be kept within the differential of ulnar-sided wrist pain.[15,16]

Central and lateral to the ulnar styloid is a roughened depression within the ulnar pole referred to as the *fovea* (Fig. 1-1). The fovea is the site of attachment for the apex of the TFCC and the deep fibers of the radioulnar ligament. It also represents the distal central axis for forearm rotation. This is a critical structure to identify during reconstruction of the TFCC and the DRUJ as it allows one to reconstruct the TFCC and distal radioulnar ligaments to their isometric point.

The remaining portion of the ulnar head is comprised of the ulnar seat. The ulnar seat articulates with the *sigmoid notch* of the radius to make the radioulnar articulation of the DRUJ. The sigmoid notch and the ulnar head are not congruent surfaces; the sigmoid notch has a shallow articular surface that allows for dorsal and palmar translation of the radius against ulnar head during rotation.[11] The radius of curvature of the sigmoid notch measures about 15 mm and is centered around the base of the ulnar styloid, while the curvature of the ulnar head has a radius of approximately 10 mm, with its center at the fovea of the ulnar head (Fig. 1-2). The articular cartilage (approximately 2 mm thick) of the ulna seat occupies an area of 90°–135° of the ulnar head circumference, while

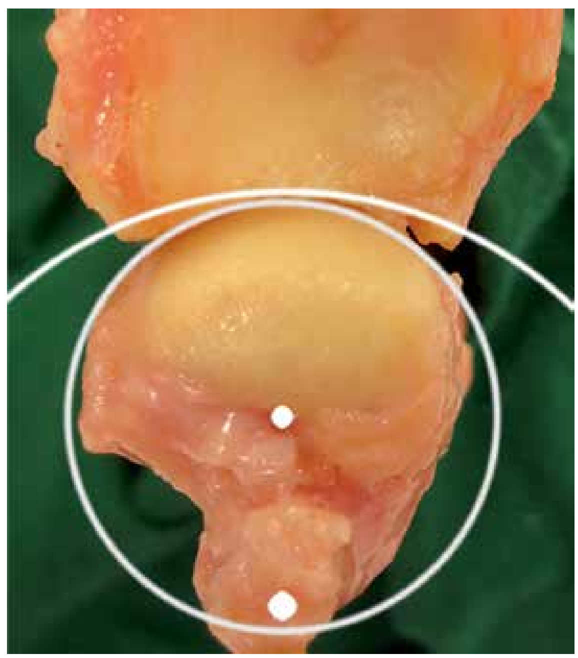

FIGURE 1-2
Transverse view of the articular surfaces of the distal radius and ulna. The smaller, inner circle depicts the curvature of the ulnar head with its center (*small dot*) equivalent to the region of the fovea, where the remnants of the insertions of the deep radioulnar ligaments are seen. The larger, outer circle illustrates the curvature of the semilunar notch on the distal radius and its center (*large dot*) correlates to the ulnar styloid, equivalent to the styloid insertion of the superficial radioulnar ligaments.

the cartilaginous arch of the sigmoid only spans 47°–80°.[11] The distal end of the radius moves in a translational fashion around the fixed ulnar head. In full supination, the ulnar head is in contact with the palmar aspect of the sigmoid notch, while in full pronation it rests against the dorsal lip.[11] As the radius translates against the fixed ulnar head, the resultant movement is a combination of rolling and sliding; during this motion the contact surface area changes with the smallest area of contact occurring at the extremes of pronation and supination.[11,17] With the forearm held in neutral, approximately 60% of the radial and ulnar cartilaginous surfaces are in contact; however at the extremes of pronation and supination, only about 10% of the cartilaginous surfaces, (equivalent to an area of 1–2 mm), are in direct contact (Fig. 1-3).[11,18] Thus the stability of the DRUJ at the extremes of rotation is highly dependent on the surrounding ligaments and muscles to prevent dislocation. Consequently, most closed dislocations of the DRUJ occur when the wrist is placed into hyper-supination or hyper-pronation.

There may be substantial variation in sigmoid notch shape from patient to patient, and this may also impact the inherent stability of the DRUJ. Tolat et al[19] described four variations in sigmoid notch anatomy, based on studies of the bony anatomy of the DRUJ in the axial plane (Fig. 1-4). The four variations were:

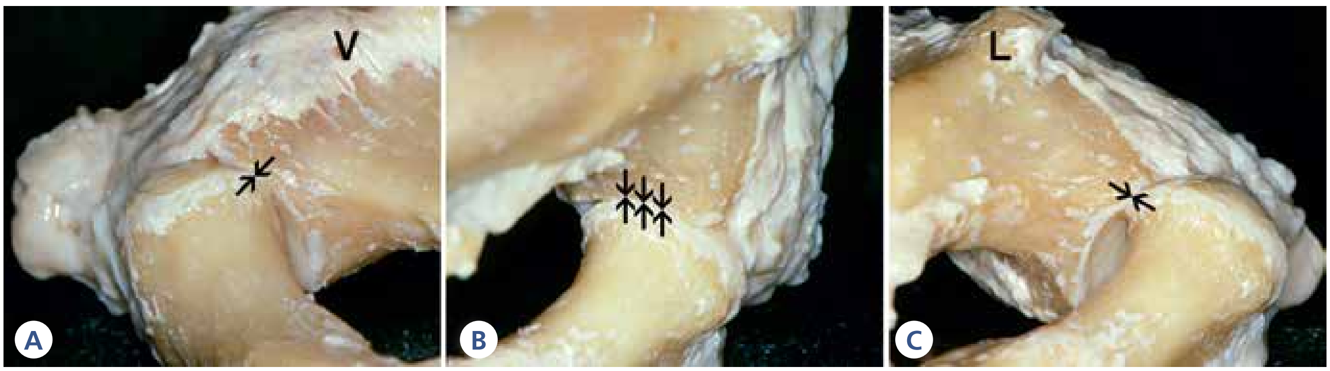

FIGURE 1-3

Illustration of the joint compression of the distal radioulnar joint in **(A)** pronation, **(B)** neutral position, **(C)** supination. Note the greatest joint contact in neutral (*arrows* in B), as opposed to minimal joint contact in pronation and supination (*arrow* in A and C, respectively). L = Lister's tubercle, V = volar edge of the distal radius.

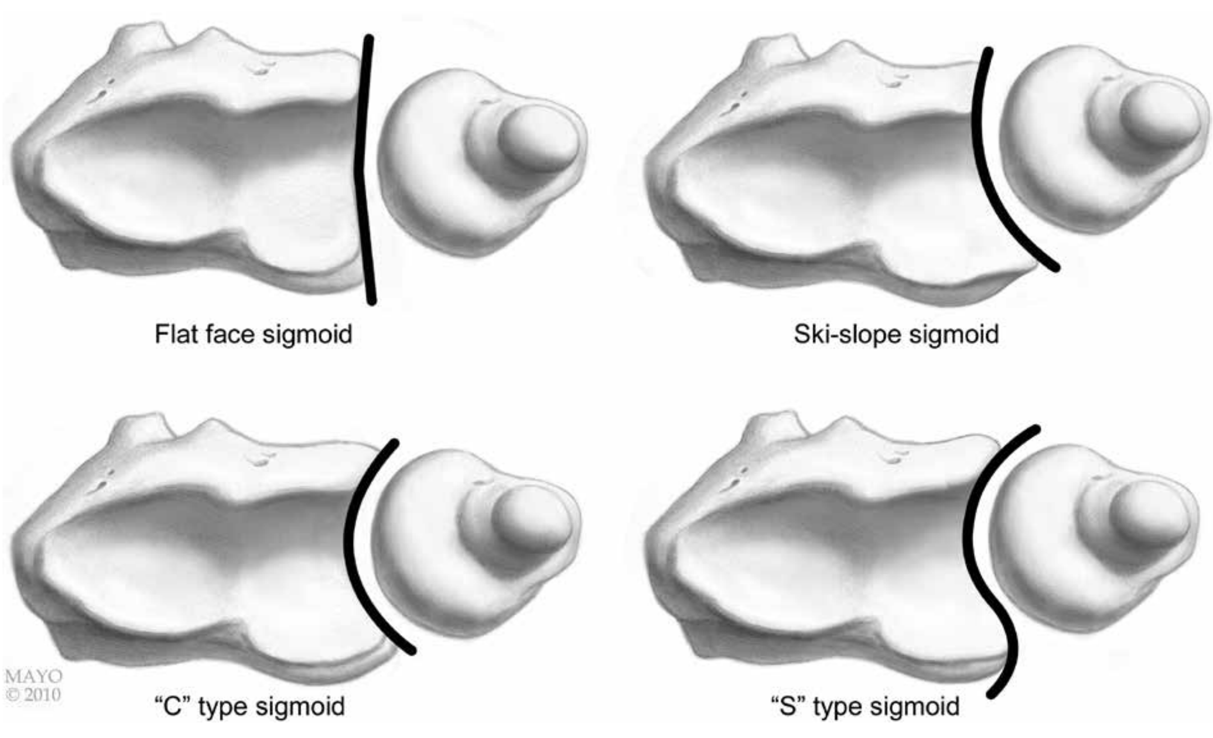

FIGURE 1-4

The sigmoid notch has been shown to have 4 anatomic variations as described by Tolat.[19] Reproduced from Kakar S, Carlsen BT, Moran SL, Berger RA. The management of chronic distal radioulnar instability. *Hand Clin*. 2010;26:518; with permission.

- *Type A. "Flat face" notch*. In this variation, the sigmoid notch is essentially a flat surface.
- *Type B. "Ski slope" notch*. In this variation, there is a flat dorsal segment with a palmar lip.
- *Type C. "C" type notch*. In this variation, dorsal and palmar lips are present, forming a "C" around the ulnar head.
- *Type D. "S" type notch*. In this variation, there is a sharp dorsal lip and a curved convex palmar lip, forming an S–shaped configuration.

The type A sigmoid notch was the most common, seen in 42% of subjects followed by type C (30%), B (14%), and D (14%).

Variation within the coronal plane may also be seen within the *DRUJ inclination*. The DRUJ inclination[19] is defined as the angle formed between 1) a line parallel to the joint surface between the sigmoid notch and the ulnar seat and 2) a line corresponding to the longitudinal axis of the ulna. This line describes the inclination of the ulnar seat in relation to the sigmoid notch, as shown in (Fig. 1-5). Tolat et al[19,20] described three main anatomical variations in the DRUJ inclination based on observations in the coronal plane:

- *Type I. Parallel type*. Apposing joint surfaces at the radioulnar articulation are parallel to the long axis of the radius and ulna.
- *Type II. Oblique type*. Apposing joint surfaces of the radius and ulna are oblique, with the distal aspect of the radioulnar articulation slanting ulnarly.
- *Type III. Reverse oblique type*. Apposing joint surfaces of the radius and ulna are oblique with the distal aspect of the radioulnar articulation slanting radially.

The DRUJ inclination was found to be around the 10°–15° range for Tolat's type II and around 15°–20° for type III. Type I joint configurations have angles that closely approximate parallel to the long axis of the forearm. The type I configuration was found to be the most prevalent form, seen in 55% of subjects, followed by type II in 33% and type III seen in only 12%.[21,22] Ross et al[23] recommended further assessment with MRI as the true inclination of the sigmoid notch might be different compared with that suggested by plain radiographs.

Further findings from Tolat's study found that DRUJ inclination was associated with the shape of the sigmoid notch. A type A (flat) sigmoid notch was observed more frequently with type II DRUJ inclination (60%), while a type C shape sigmoid notch was observed more frequently with type III DRUJ (43%). The authors suggest that a type II DRUJ may have greater translational motion due to its association with a flat sigmoid notch, while a type III DRUJ may have less translational motion due to its association with the more constrained type C sigmoid notch. Clinical correlation has yet to be determined.

In addition to variation in DRUJ shape, there can be wide variability in the length of the ulna in relation to the radius. This relationship between the longitudinal length of the radius and ulna is described radiographically as the *ulnar height* or *ulnar variance*. Ulnar variance can be measured by several radiographic techniques, and while all are satisfactory, we mention the most common method here. Ulnar height is measured by drawing a line parallel to the volar sclerotic rim at the lunate facet of the radius perpendicular to its longitudinal axis (Fig. 1-6). A separate line is drawn

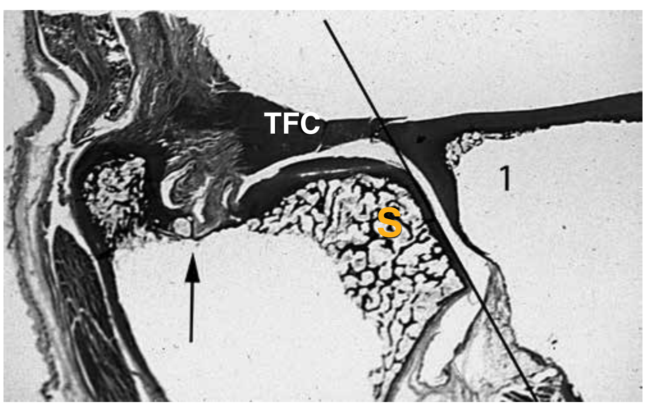

FIGURE 1-5
Anatomy of the DRUJ. A sagittal section of a fetal wrist showing the pertinent anatomy of the DRUJ. The sigmoid notch (1) can be seen to articulate with the ulnar seat (S). The inclination of the ulnar seat is shown by the diagonal line drawn parallel to the joint surface. Inclination of the ulnar seat can vary from patient to patient. The ligamentous attachments of the radioulnar ligaments can be seen attaching to the fovea (*arrow*) and joint capsule. TFC = triangular fibrocartilage.

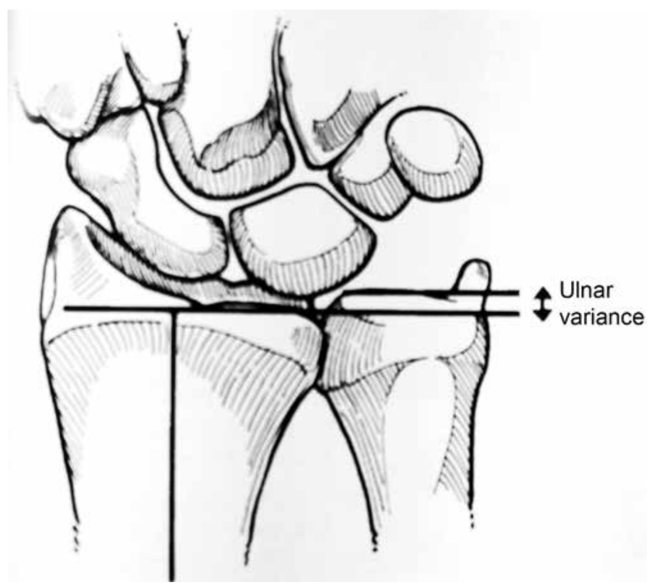

FIGURE 1-6
Ulnar variance is measured by drawing a line through the lunate facet of the distal radius perpendicular to the long axis of the radius. The difference between this line and a line drawn tangent and parallel to the distal rim of the ulnar seat is equivalent to the ulnar height.

parallel to the distal cortical rim of the ulnar dome. The difference between these two lines, as measured on a true posterior-anterior radiograph, represents the ulnar height.[24] In order to obtain a true posterior-anterior radiograph and a true lateral of the DRUJ, the following steps need to be taken by the radiologist:

1. The upper arm is adducted to the trunk.
2. The elbow flexed 90° with the forearm in a neutral position (0° pronation/supination).
3. The fingers of the hand placed in a neutral position and the thumb placed at the side of the second metacarpal.[2,25]

Following patient positioning, the x-ray beams are projected perpendicularly to the flexion-extension plane of the elbow; with this technique a straight posterior-anterior (PA) view of the radius and the ulna is achieved. An alternative to having the upper arm adducted to the trunk is to have the shoulder abducted to 90°, elbow at 90° and hand resting flat on the X-ray detector, a technique commonly used in radiology departments. In a true PA view, the radial styloid will form the radial contour of the radius and the ulnar styloid will form the ulnar border of the ulna and will be in full profile view (Fig. 1-7A). Following a true PA view, the lateral view will retain the profile of the ulnar styloid (Fig. 1-7B). The most common mistake is to take a PA with the hand resting flat on the X-ray detector and the forearm and elbow in extension. This is, in fact, a pronated view of the wrist. In the pronated position, the radius migrates proximally, resulting in an image where the ulnar head and ulnar styloid appear longer (Fig. 1-7C). In this position, there is a risk that the ulnar variance is interpreted as positive (*ulna plus*, see below) or that the patient experiences ulnar styloid impaction syndrome.[26]

In a study of 120 Caucasian subjects, Schuind[21] noted that the average ulnar variance was 0.9 mm of ulnar minus, with ranges from 4.2 mm of ulnar minus to 2.3 mm of ulnar plus. One may also see a change in ulnar variance based on the position of the forearm bones. The proximal-to-distal translational motion of the radius during pronation and supination can be visualized radiographically as a change in ulnar height and may be as great as 2–4 mm.[7] Variation in ulnar length can have a significant impact on the loads passing through the ulnocarpal articulation. If ulnar variance is neutral or negative, approximately 80% of load and impact during hand grip is transferred between the carpus and radius, and 20% between the carpus and ulna. In ulnar positive variance, the load between carpus and ulna increases. Excessive ulnar height can lead to conditions such as ulnar impaction and lunotriquetral instability. This emphasizes the importance of a true PA view of the forearm to determine accurate resting ulnar height.[21,22]

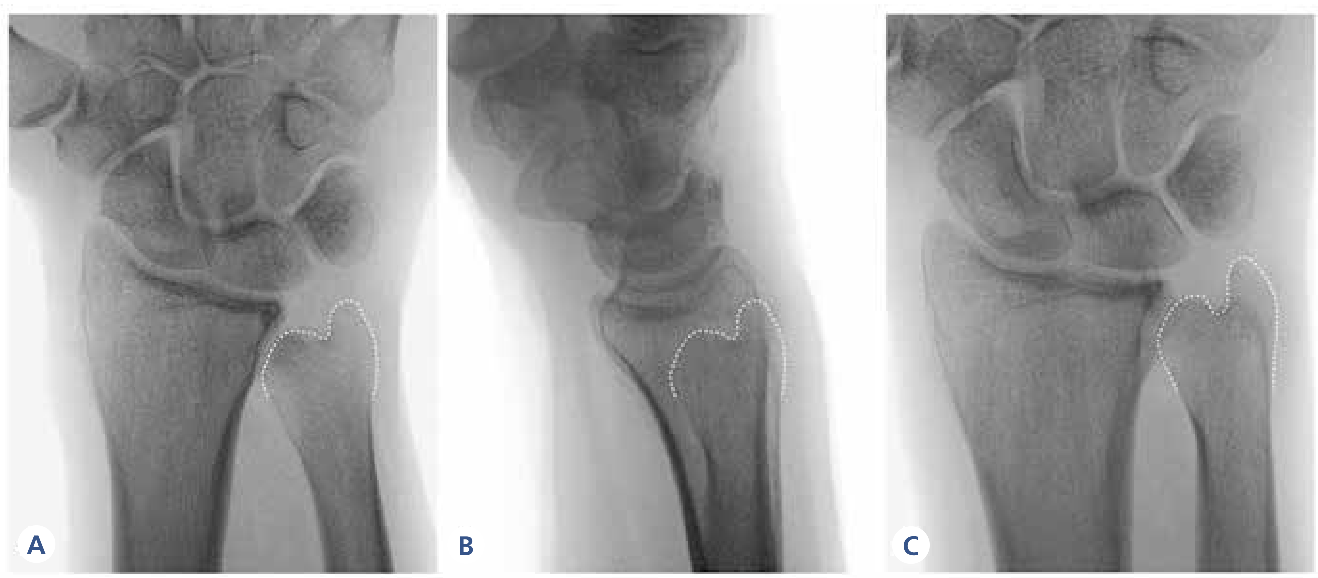

FIGURE 1-7
Radiographic image of the DRUJ. **(A)** True PA provides a lateral profile of the ulnar styloid (*dotted line*). **(B)** If a true PA was taken, the lateral x-ray will show an identical shape and position of the ulnar styloid. **(C)** In the pronated position, the ulnar styloid appears larger and elongated compared to a true PA (see Fig. 1-7A), which may give a false impression of ulna plus or ulnar styloid impaction syndrome.

SOFT TISSUE ANATOMY

Stability of the DRUJ, particularly at the extremes of pronosupination, is dependent upon ligamentous and muscular constraints. The dorsal and volar radioulnar ligaments serve as the most important passive stabilizers of the DRUJ,[11,27] as only 20% of DRUJ constraint is provided through articular contact.[28] The soft tissue structures that contribute to the remainder of DRUJ stability include the components of the triangular fibrocartilage complex (TFCC), extensor carpi ulnaris (ECU) including its subsheath, pronator quadratus (PQ), and interosseous membrane (IOM).[29] The different stabilizing factors of the DRUJ are displayed in (Figs. 1-8 and 1-9).

The foveal insertion of the TFCC is the most important of the stabilizing structures of the DRUJ.[30] Without load, there are no significant differences found for the different portions of the TFCC. Under loaded conditions, the foveal insertion has a greater effect on stability than the styloid insertion and its disruption can produce instability.[30] (Fig. 1-10).

The TFCC was originally named by Palmer and Werner in 1981,[31] and is used to describe the soft tissues that span between the radius and ulnar styloid, namely the radioulnar ligaments and the articular disc (comprising the triangular fibrocartilage, TFC), covering the ulnar dome. At its periphery, this tissue contains the major supporting ligaments for the DRUJ, while the central portion provides a cushion for load distribution between the carpus and ulna. The TFCC is thus a grouping of several anatomic structures, which include: (Figs. 1-8–1-10):

1. Articular disc
2. Dorsal and volar distal radioulnar ligaments
3. Dorsal and volar distal radioulnar joint capsule
4. Ulnocarpal ligaments
5. Ulnocarpal capsule
6. ECU sheath
7. Prestyloid recess
8. Meniscus homologue
9. The interosseous membrane

Articular Disc

The articular disc of the TFC originates from the distal margin of the sigmoid notch and extends to cover the ulnar pole merging at the level of the fovea with the palmar and dorsal distal radioulnar ligaments. The articular disc is a biconcave structure made of Type II collagen; its central portion is relatively avascular with most of the blood supply entering through the periphery. Thus, tears occurring within the center of the disc are unlikely to heal spontaneously.[32,33] The disc is of variable thickness and its thickness is dependent on the relative length of the ulna. Patients with an ulnar negative wrist tend to have a thicker disc than those with an ulnar positive wrist.[22] Degeneration of the disc occurs with

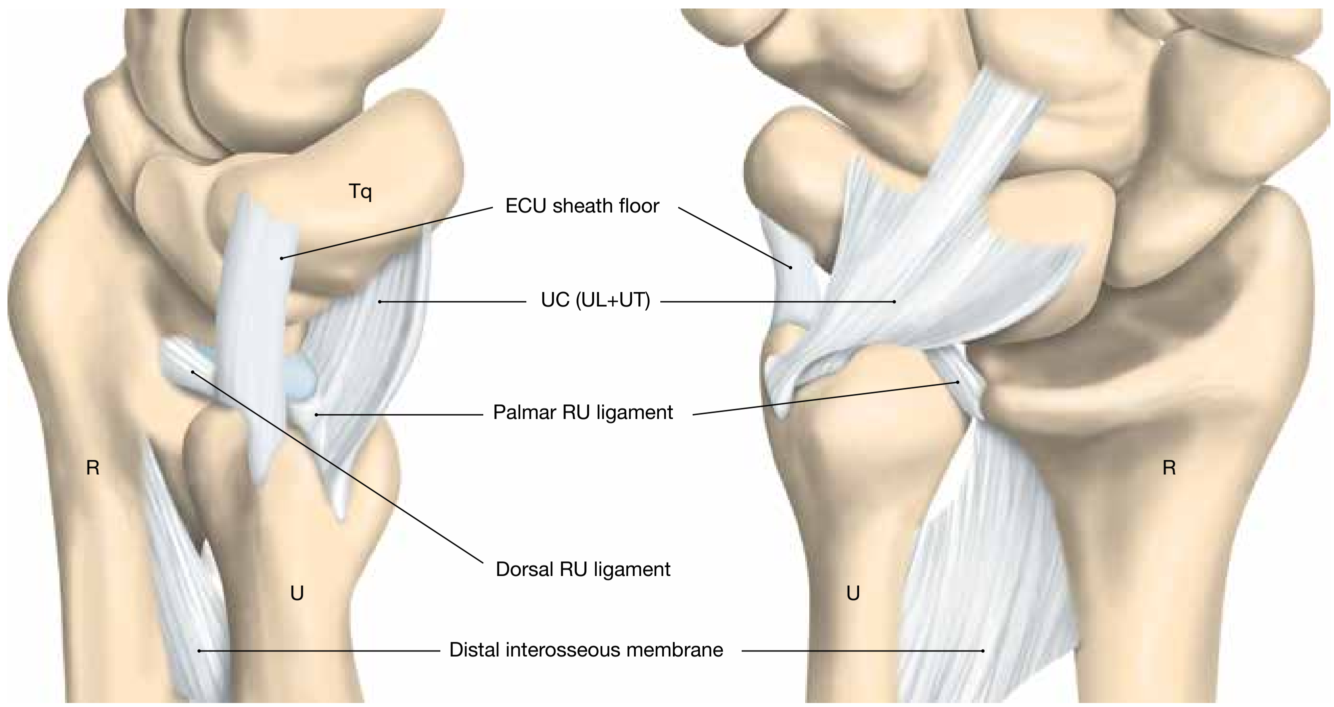

FIGURE 1-8
Schematic drawing of stabilizing factors of the DRUJ (R = radius, U = ulna, RU = radioulnar, Tq = triquetrum). Reprinted with permission from Andersson J. Clinical and arthroscopic assessment of wrist ligament injuries and instability. Gothenburg: Sahlgrenska Academy, Institute of clinical sciences. Dissertation. 2016.

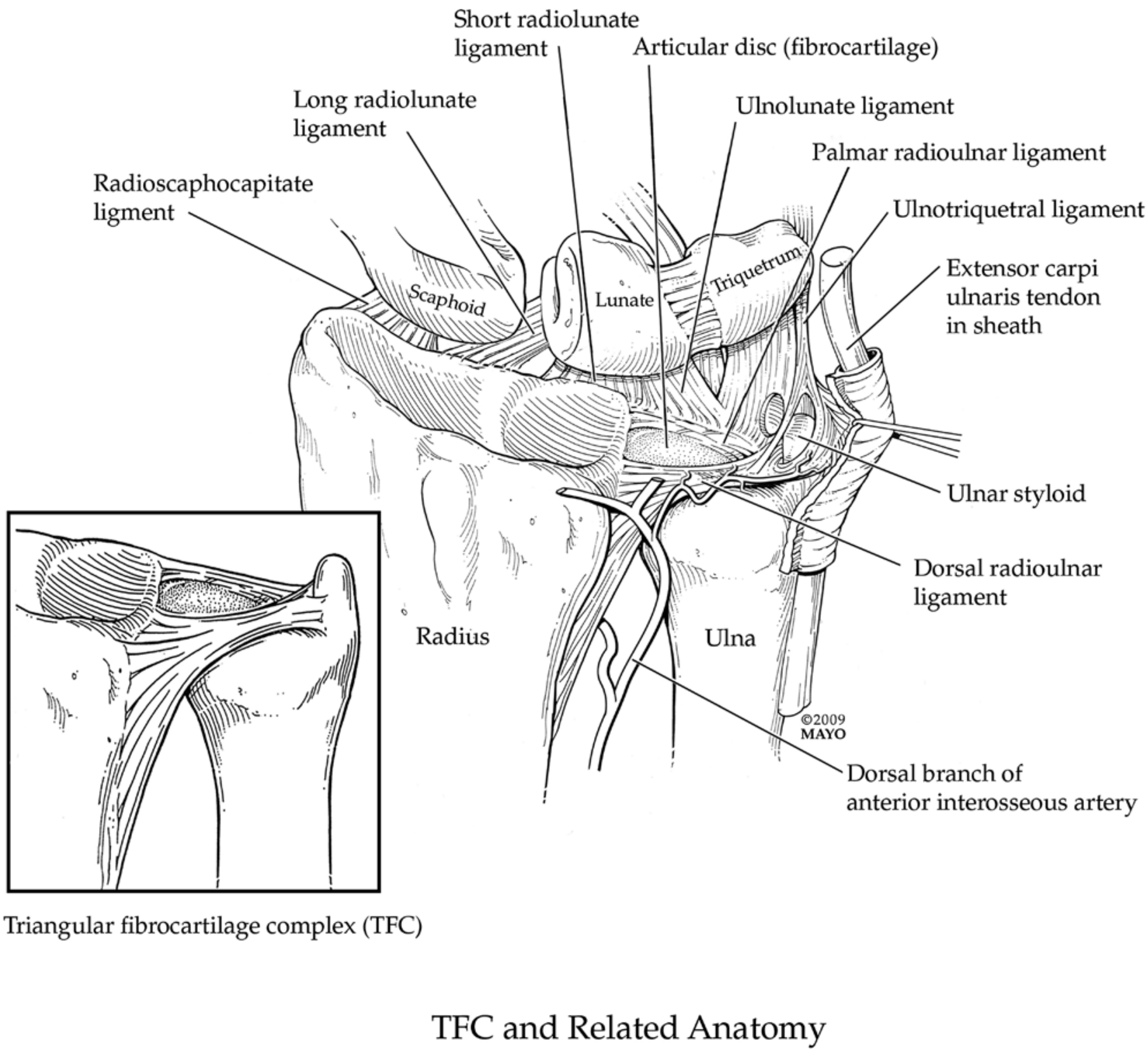

FIGURE 1-9
Primary and secondary stabilizers of the DRUJ. The image displays the major stabilizing components of the TFCC including the articular disc, dorsal and volar radioulnar ligaments, ulnocarpal ligaments (which include the ulnotriquetral and ulnolunate ligament) as well as the extensor carpi ulnaris sheath. Reproduced from Carlsen B, Rizzo M, Moran SL, Soft tissue injuries associated with distal radius fractures. *Operat Tech Orthop.* 2009;19(2):108; with permission.

senescence and is likely the cause of higher occurrence of disc tears in the elderly.[34] The primary purpose of the disc is to serve as a cushion or shock absorber for the ulnar aspect of the carpus, as it transfers load from the carpus to the ulna. Work by Adams and Holley suggests that it may also stabilize the ulnar carpus to the ulna during pronation.[35]

Dorsal and Volar Distal Radioulnar Ligaments

From the volar and dorsal edges of the articular disc arise the volar and dorsal radioulnar ligaments. These are densely organized bundles of cartilage that begin at the ulnar margin of the radius at the sigmoid notch and run toward the ulnar styloid. Each ligament is composed of an inner and outer fiber bundle. The inner portion, or deep fibers, of both the volar and dorsal radioulnar ligaments attach to the fovea while the remaining superficial fibers of the volar and dorsal radioulnar ligament attach to the midportion and base of the ulnar styloid (Fig. 1-1).[36] Since the superficial fibers of the distal radioulnar ligaments insert onto the ulnar styloid, fractures at the base of the ulnar styloid can potentially lead to instability of the DRUJ, as the foveal attachment of the deep DRUL maybe be disrupted.

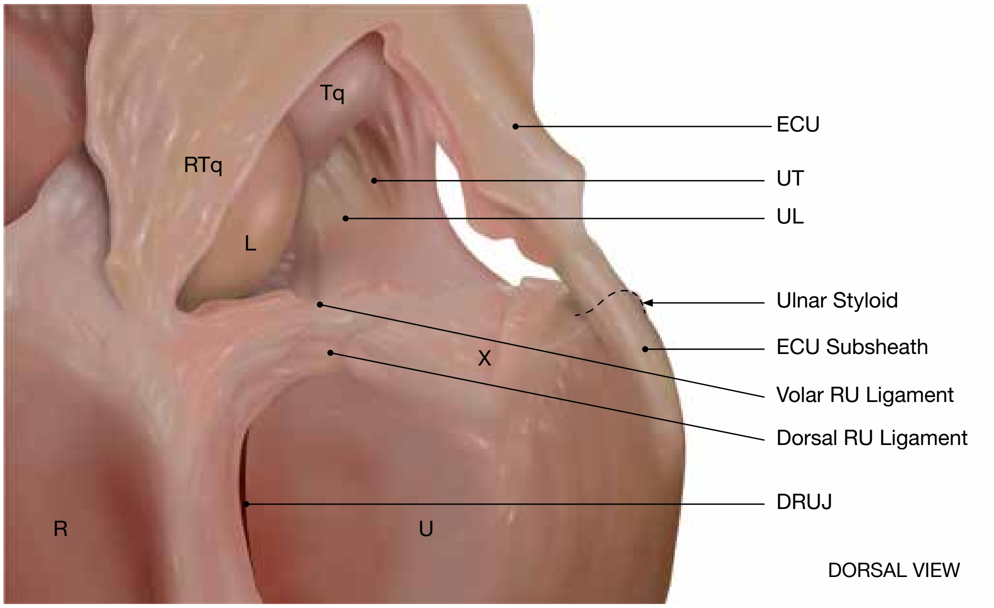

FIGURE 1-10
TFCC anatomy. Palmar and dorsal radio-ulnar (RU) ligaments, ulnocarpal ligaments (UL, UT) are displayed. (ECU = extensor carpi ulnaris, DRUJ = distal radio-ulnar joint, R = radius, U = ulna, L = lunate, Tq = triquetrum, RTq = radiotriquetral ligament, X = ulnar fovea, site of attachment of the deep fibers of TFCC. Reprinted with permission from Andersson J. Clinical and arthroscopic assessment of wrist ligament injuries and instability. Gothenburg: Sahlgrenska Academy, Institute of clinical sciences. Dissertation. 2016.

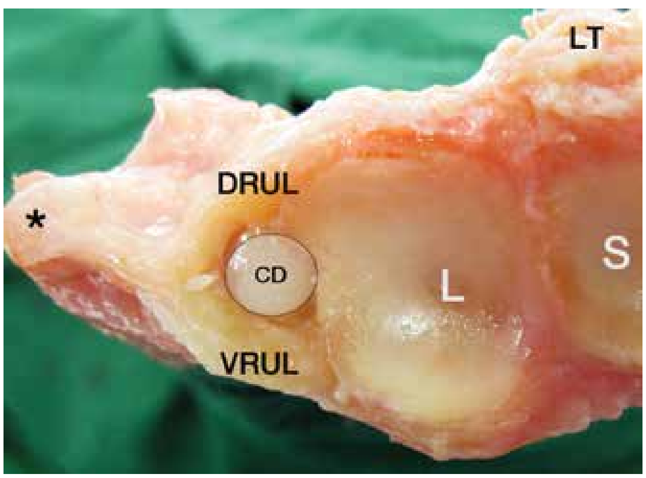

FIGURE 1-11
Distal view of the DRUJ, with the fibrocartilaginous portion of the central disc illustrated in light grey (CD). The dorsal radioulnar (DRUL) and volar radioulnar ligaments (VRUL) are seen emanating from the dorsal and volar ulnar corners of the distal radius, inserting onto the distal ulna. Also seen is the lunate facet (L), the scaphoid facet (S), Lister's tubercle (LT), and the ulnar styloid (*).

The volar and dorsal distal radioulnar ligaments, with their deep and superficial fibers, make up the major stabilizers of the DRUJ (Fig. 1-11). With the forearm in neutral position, both ligaments are lax, with stability provided by congruency of the articulating surfaces of the sigmoid notch and the ulnar seat. As the forearm pronates, the superficial fibers of the dorsal ligament become taut, while the superficial fibers of the palmar ligament gradually relax. However, in the same pronated position, the deep fibers of the dorsal and volar radioulnar ligaments will act in the opposite manner, being lax and taut, respectively.[2] The reverse ligament tightness and laxity occurs during supination.[12,37,38] Tensioning of the radioulnar ligaments leads to compression of the seat of the ulnar head against the dorsal lip of the sigmoid notch during pronation, while the ulnar head is compressed against the volar lip of the sigmoid notch during supination.[11,18,21]

The stabilizing role of the distal radioulnar ligaments are also influenced by load. Without load, there are no significant differences within the different portions of the TFCC in maintaining DRUJ stability. Dynamic loading, on the other hand, is an important component of joint stability and injuries to the radioulnar ligaments result in instabilities during dynamic load.[30] Injury to the foveal insertion and dynamic loading result in greater joint displacement than injury to the styloid insertion alone.

Dorsal and Volar Distal Radioulnar Capsules

The distal radioulnar joint capsule consists of the dorsal and volar DRUJ capsules and may be considered passive stabilizers of the joint. In a recent study on the volar DRUJ capsule, it was found to be reinforced by fibrocartilaginous attachments to the volar ulnar rim of the distal radius, with fibers running as far as the dorsal edge of the ulnar styloid.[39] The volar capsule will thus serve as a passive stabilizer in supination. The dorsal DRUJ capsule is generally thicker, with important integration into the dorsal DRUL, rendering it a passive stabilizer of the DRUJ in pronation.[40]

Ulnocarpal Ligaments

The ulnocarpal ligaments (UCL) are a group of three ligaments that originate from the palmar anterior edge of the TFC and insert into the ulnar carpal bones. There are two vertically oriented ligaments that form a portion of the volar radiocarpal ligament. The *ulnotriquetral ligament* inserts into the palmar aspect of the triquetrum, and the *ulnolunate ligament* courses obliquely to insert on the lunate (Fig. 1-12).[33] Superficial to these ligaments is the ulnocapitate ligament (Fig. 1-13). The ulnocapitate fibers originate from the fovea and course obliquely and anteriorly toward the capitate. The ligament expands distally and fans out to attach to the hamate, capitate, and portions of the radioscaphocapitate ligament.[15] In clinical practice it is difficult to distinguish these three ligaments anatomically as they blend together. The UCL plays a major role in stabilizing the DRUJ in maximal pronation as it stabilizes the ulnar carpus relative to the ulna. During supination the UCL helps to push the ulnar head into the sigmoid notch.[41]

Therefore, an ulnocarpal sag in the axial plane can be explained by disruption of the UCL complex.

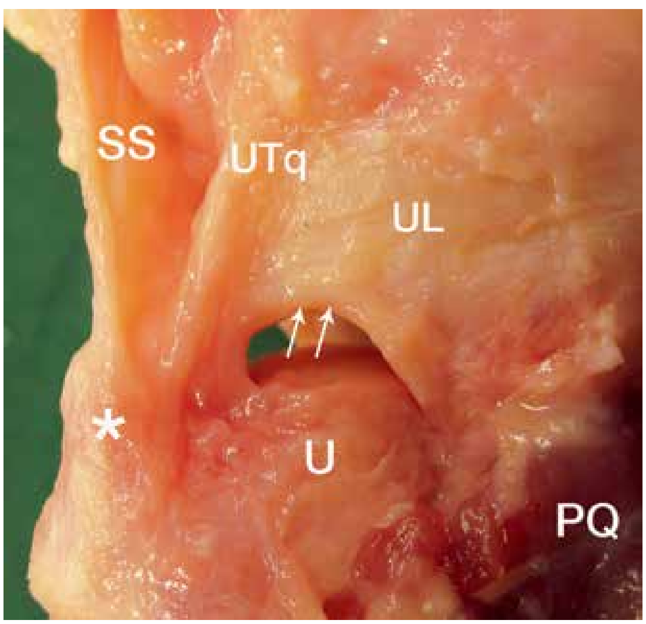

FIGURE 1-12
The ulnotriquetral (UTq) and ulnolunate (UL) ligaments emanate from the volar radioulnar ligament (*arrows*) and insert onto the volar edge of the triquetrum and lunate, respectively. * = ulnar styloid, U = ulnar head, SS = ECU subsheath, PQ = pronator quadratus muscle.

FIGURE 1-13
The palmar ulnocarpal ligaments as viewed from the dorsal side of the wrist. The ulnolunate (UL) and ulnotriquetral (UT) ligaments originate from the edge of the triangular fibrocartilage (TFC) and the distal palmar volar radioulnar ligament. The ulnocapitate (UC) ligament, not shown in this image, has its origin on the fovea and runs palmar to the UT and UL ligament. The UC is thought to reinforce the palmar portion of the lunotriquetral (LT) ligament distally. TH = triquetrohamate ligament. Courtesy of Steven Moran, MD.

Ulnocarpal Capsule

The ulnocarpal capsule has also been described as the *ulnar collateral ligament*; however, its biomechanical[42] and histological[43] properties do not classify it as a true ligamentous structure, as it consists of loose disorganized connective tissue and not the parallel collagen bundles associated with true ligaments. The capsule begins at the ulnar margin of the of the ulnotriquetral ligament and extends dorsally to the ECU tendon sheath. It surrounds the ulnar styloid and attaches distally to the triquetrum. This structure may become fibrotic following joint injury or ulnar fracture and limit rotation.[44]

The ECU Sheath

The final stabilizing component of the TFCC is the ECU sheath. The ECU is held in close proximity to the ulna head by the fibrous tunnel of the sixth extensor compartment.

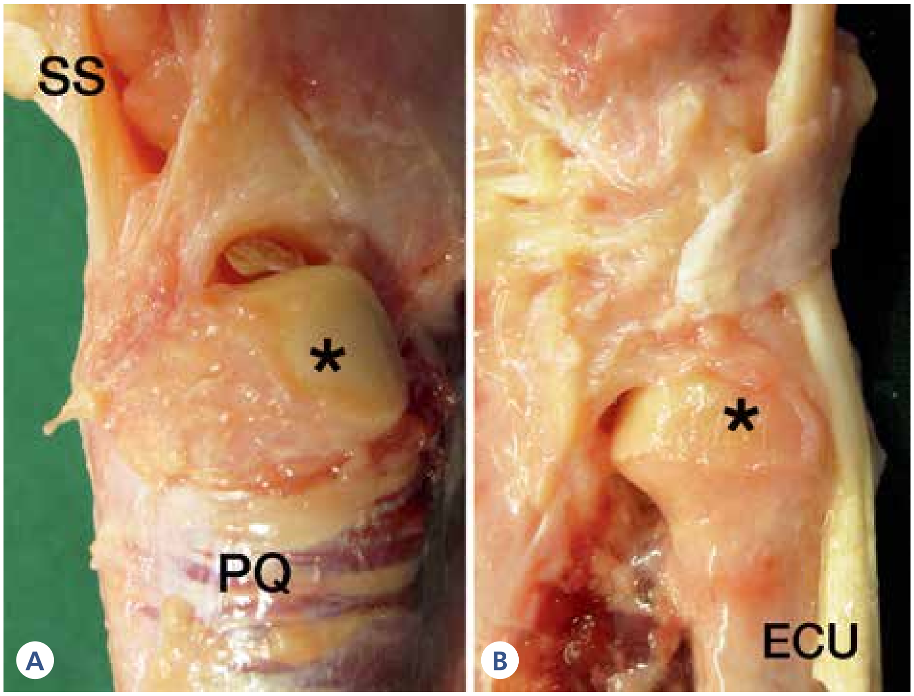

FIGURE 1-14
The neuromuscular stability of the DRUJ is primarily determined by **(A)** the pronator quadratus (PQ), in particular the deep head, which wraps around the volar forearm just proximal to the DRUJ. **(B)** The extensor carpi ulnaris (ECU) with its subsheath (SS) similarly plays a role in the dynamic stability of both the DRUJ and the carpus as a whole. * = ulnar head.

The ECU sheath augments the dorsal capsule and imparts stability to the DRUJ, separate from the effects of the ECU tendon proper (Fig. 1-8).

The ECU and PQ muscle make up the two major muscular supports of the DRUJ and have important roles in the dynamic neuromuscular stability of the DRUJ. The ECU, including the ECU subsheath, is an important stabilizer of the DRUJ in forearm supination (Fig. 1-14), as the relationship of the tendon sheath to the groove of the ulnar head may resist abnormal displacement of the ulnar head.[15] The ECU has been shown to have a slight torque effect on the DRUJ, with potential pronation torque in maximal supination and vice versa in pronation.[45] Studies on the stabilizing function of the ECU have shown that this muscle, in addition to DRUJ stability, has an important role in carpal stability, particularly acting as a powerful pronator of the triquetrum and distal carpal row.[46] The ECU has been shown to completely dislocate from its sheath in cases of complete DRUJ dislocation and can potentially become interposed in the joint preventing closed reduction. The ECU is enclosed in an independent fibrous tunnel consisting of the supra – and infra-tendinous extensor retinaculum, the 6th septum and the linea jugata (longitudinal fibers (ulnar insertion of the extensor retinaculum)).

The PQ muscle provides the final major stabilizing structure of the DRUJ. This muscle arises from the palmar crest of the ulna and then courses obliquely across to insert on the metaphysis of the radius. The PQ is consistently found to consist of a superficial and a deep head, which span the distal volar surface of the radius and ulna, just proximal to the DRUJ (Fig. 1-15).[47] In pronation the superficial head is lax; however, in supination the muscle acts to stabilize the ulna by constraining the sigmoid notch and increasing ulnar head sigmoid notch articulation and preventing lateral displacement. The superficial head depresses the ulna during pronation while the deep head opposes the ulna to the radius. Anatomical studies have suggested that the deep head helps in compressing the ulnar head into the sigmoid notch and stabilizing the joint.[48] In vivo electromyographic analysis of the stabilizing function of the PQ similarly shows that the deep head is active during both pronation and supination of the forearm, suggesting that this muscle has a primary function as a dynamic stabilizer of the DRUJ.[49] The PQ may thus be important in neuromuscular therapy for patients with hyperlaxity or subclinical instabilities of the DRUJ, as well as following surgical reconstructions of the TFCC.[50]

Meniscus Homologue

The meniscus homologue refers to the tissue that lies between the superficial portion of the distal radioulnar ligament and the ulnar capsule (Fig. 1-16). This area contains the prestyloid recess, which can be visualized arthroscopically.[42] This tissue has been shown to be richly vascularized as well

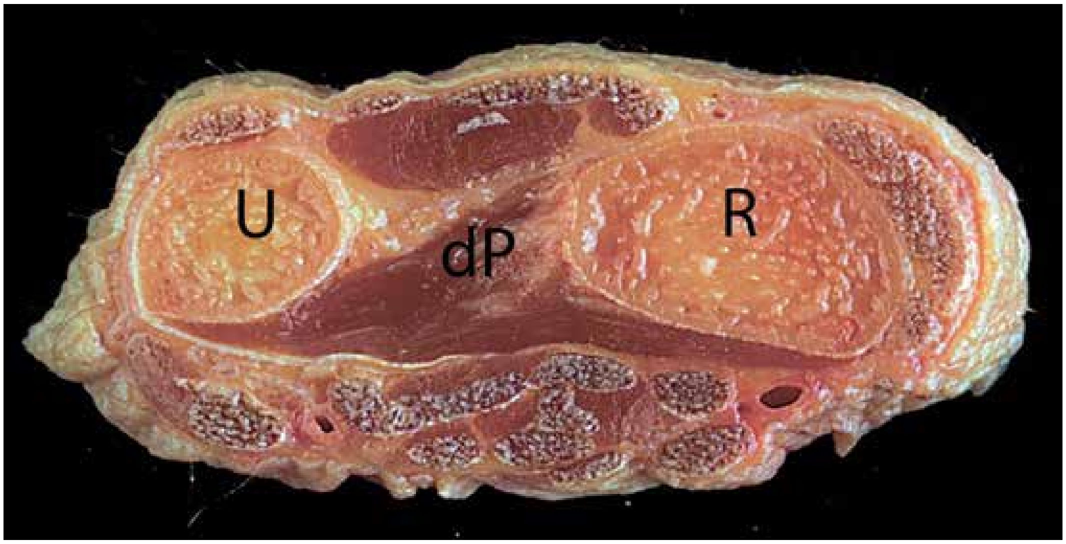

FIGURE 1-15
Deep head of the pronator quadratus muscle (dP) is visualized attaching to the ulnar aspect of the radial metaphysis. U = ulna, R = radius.

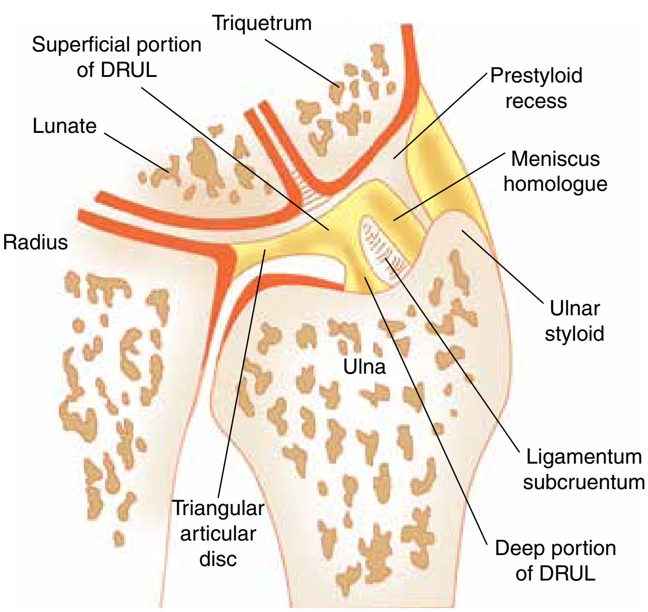

FIGURE 1-16
Illustration of a cross section of the triangular fibrocartilage complex showing the position of the ligamentum subcruentum, meniscus homologue, and prestyloid recess and their relationship to the ulnar styloid.

as richly innervated, in particular with free nerve endings, indicating an importance in providing nociceptive and sensory information from the ulnocarpal joint.[51]

Ligamentum Subcruentum

The space between the two limbs of the distal radioulnar ligament near the ulnar styloid contains richly vascularized tissue, named the *ligamentum subcruentum* (Fig. 1-16). Despite the fact that this tissue is called a ligament, it does not appear to provide any significant stability to the DRUJ. Histologic studies have shown it does not contain true ligamentous tissue, even though the first description of this structure was that the *ligamentum subcruentum* was a vascularized space between the proximal deep and distal superficial portions of the TFCC.

The Interosseous Membrane

Although the interosseous membrane is not considered part of the distal radioulnar joint, TFCC and ulnocarpal wrist, it needs to be mentioned in this chapter as it is of importance in understanding the stability of the DRUJ. Spanning from the proximal to distal forearm, the bundles of the interosseous membrane provide stability to the entire forearm joint. The central bundles of the interosseous membrane primarily consist of tight parallel collagen bundles, indicating an importance in forearm stability. The proximal and distal oblique bundles (DOB), on the other hand, have a predominance of elastic fibers to facilitate rotation.[52] The DOB is of particular interest to the stability of the distal forearm and DRUJ. It consists of obliquely oriented collagen bundles originating from the distal ulna, 40-45 mm proximal to the DRUJ, and inserting onto the dorsal inferior rim of the sigmoid notch.[53] The DOB has also been found to have the highest density of Pacinian corpuscles and free nerve endings of all of the components of the interosseous membrane, indicating both an importance with regard to stability in rotation as well as proprioceptive function of the distal forearm.[54] There is, however, a paucity of evidence for the role of the DOB in DRUJ stability, in particular as the structure is found to vary in size and prevalence.[55]

JOINT INNERVATION

Anatomical studies on the innervation of the DRUJ[56,57] have shown three distinct areas of innervation (Fig. 1-17):

1. The dorsal region – including the dorsal radioulnar and ulnocarpal joint capsule and the dorsal radioulnar ligament – is primarily innervated by the terminal branch of the posterior interosseous nerve;
2. The ulnar region – with the meniscus homologue, ulnotriquetral ligament, and the foveal attachment – is primarily innervated by the dorsal sensory branch of the ulnar nerve;
3. The volar region – including the volar radioulnar joint capsule, volar radioulnar and ulnolunate ligaments – is innervated by branches from the ulnar nerve proper.

Although branches of the anterior interosseous nerve have been shown in the vicinity of the volar DRUJ capsule,[58,59] detailed microscopic studies have not been able to show anterior interosseous nerve afferents in the DRUJ ligaments.[56] Similarly, the medial antebrachial cutaneous nerve has an extraarticular course in the DRUJ[59,60] but lacks intraarticular contributions.[56,61]

The microscopic innervation of the distal radioulnar ligaments was first studied by Cavalcante et al,[62] identifying mechanoreceptors using a gold-choride technique. In a later and more detailed microscopic analysis of all of the regions of the TFCC, Rein et al[51] found a significant distribution of sensory nerve endings in all components of the TFCC, except for the articular disc and the ulnolunate ligament. The most common sensory nerve ending found overall was the free nerve ending which may explain why ulnar sided wrist pain is so commonly encountered in clinical practice.

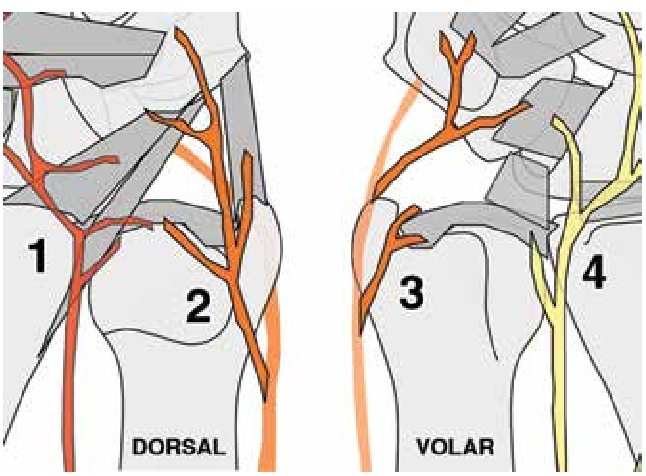

FIGURE 1-17
The DRUJ is innervated dorsally by terminal branches from the posterior interosseous nerve (1), ulnarly by dorsal sensory branches from the ulnar nerve (2), and volarly, by branches from the ulnar nerve (3). In addition, branches from the anterior interosseous nerve (4) contribute to the volar joint capsule, but not to any of the ligaments of the DRUJ or ulnocarpal complex.

CONCLUSION

The DRUJ is an intricate suspension joint where the osseous congruity of the distal radius and ulna, the ligamentous integrity of the distal radioulnar and ulnocarpal ligaments, the sensory function of the ligaments and capsule, and the dynamic neuromuscular action of the PQ and ECU create a balanced joint allowing full rotation of the forearm and placement of the hand for advanced dexterity.

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KEY POINTS

- The DRUJ constitutes the distal component of the forearm joint. The forearm joint includes the DRUJ, PRUJ, and IOM.
- The ulnar head is involved in 2 articulations: (1) the radioulnar articulation at the sigmoid notch, and (2) the ulnocarpal articulation through the ulnar pole, TFC, and ulnar aspect of the carpus.
- The bony relationship between the sigmoid notch and ulnar seat can vary with regards to inclination, ulnar height, and sigmoid shape.
- Bony constraints at the sigmoid notch make up only 20% of DRUJ stability, and this percentage is further reduced at the extremes of rotation. Thus, the majority of DRUJ stability is provided by soft tissue constraints.
- The dorsal and volar radioulnar ligaments – particularly the foveal attachment of the TFCC – are the most important soft tissue stabilizers of the DRUJ.
- The deep fibers of the radioulnar ligaments insert at the fovea, and the superficial fibers insert around the base of the ulnar styloid.
- The predominant nerve ending in the TFCC is the free nerve ending, which may explain the common finding of ulnar sided wrist pain.