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Special Issue: Wrist

The ulnar side of the wrist: Clinically relevant anatomy and biomechanics

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ABSTRACT

Background: In the hectic environment of a hand therapy clinic, the opportunity to carefully consider the relationships among pathology, pathomechanics, surgical repair techniques, tissue healing, postoperative management, and rehabilitation program development and progression is limited. Clinicians often default to seeking a protocol, a recipe to follow.

Objectives: Using the ulnar side of the wrist as an example, relevant anatomy and biomechanics are directly related to several commonly seen pathologies, including fractures, ligament injuries, and instability.

Conclusion: Armed with knowledge of anatomy, biomechanics, and surgical procedures, the need for a protocol disappears. Each patient can be individually managed according to his or her unique set of variables and responses to injury, repair, healing, and recovery of function.

Introduction

The ulnar side of the wrist can be a challenging area to understand and diagnose, making treatment challenging. Despite excellent reviews of the topic,[1,2] consensus regarding management continues to be weak in some areas. The past few decades have seen an impressive increase in the amount of information pertaining to the ulnar side of the wrist and an increase in the respect for the complexity and functional importance of the region.

The goal of this article is to consider the anatomy and biomechanics of the distal radioulnar joint (DRUJ), triangular fibrocartilage complex (TFCC), and interosseous membrane (IOM) and its implications for hand therapy management. Understanding anatomy and biomechanics as they relate to pathology, pain, conservative management, operative procedures, postoperative management, and the progression or rehabilitation is essential to assessment and planning treatment. Anatomy, biomechanics, and physiology (especially tissue response to injury and repair) serve as the basis of rehabilitation program development and progression, intervention prioritization, and outcome optimization.

The evolution of the DRUJ

The origins of the wrist and the structural design of the present-day 2-bone forearm can be traced back 400 million years to the pectoral fin of the crossopterygia.[3] Its transition to tetrapod amphibious living marks a significant change in wrist function from a swimming appendage to a weight-bearing structure.[4] The biomechanical construct of 2 forearm bones, intercalary carpal bones, and 5 rays persisted through the appearance and demise of countless amphibian, reptilian, and mammalian species. As demands shifted from quadriped weight bearing to brachiation (the ability to swing from tree branch to tree branch) to fully upright bipedal ambulation, the morphology of the wrist changed accordingly.[3] Brain size and the opposable thumb have received a great deal of attention in the literature and are often recognized as key features that permitted survival of the species. However, the ability to supinate and pronate the forearm and the development of a synovial DRUJ are also important considerations because stable forearm rotation is necessary for the strong and dexterous use of spears, axes, and knives and for carrying items. These capabilities allowed hominids to evolve from food gatherers to food producers. It gave them the ability to use tools, control their environment, and defend themselves. Three specific evolutionary changes at the DRUJ contributed to these advantageous physical capabilities: (1) recession of the distal ulna from the carpus, (2) development of an ulnocarpal meniscus (the triangular fibrocartilage [TFC]), and (3) development of a formal synovial DRUJ.[5,6] Before the recession of the ulna, the ulnar styloid articulated with the triquetrum and pisiform, significantly limiting rotation. Before the development of a synovial DRUJ, a syndesmosis existed between the distal radius and the ulna, again limiting rotation. The development of an ulnocarpal meniscus facilitates load

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transmission from the carpus to the ulna and supports the ulnar side of the carpus.

Before proceeding with a close examination of the DRUJ, it is important to remember that it is not actually a joint. What is, by convention, called the DRUJ is really half of the forearm joint. Removing the radial and ulnar shafts and approximating the DRUJ and the proximal radioulnar joint (PRUJ) creates a perfect bicondylar joint (Fig. 1).[7,8] The resultant joint contains 2 convex articulating surfaces of equal size (radial head and ulnar head) and 2 concave counterparts of equal size (sigmoid notch of the proximal ulnar and distal radius). The joint's axis of rotation passes through the 2 convex surfaces (the radial and ulnar heads). The proximal condyle (radial head) of this imaginary joint rotates axially within the annular ligament, whereas the distal condyle (ulnar head) is fixed. This unique design results in pronosupination instead of flexion/extension.[9] Thus, the DRUJ cannot be evaluated in isolation. Injury, pathology, and pathomechanics existing at any part of the forearm complex will impact elements of the entire forearm structure.

Osseous anatomy of the DRUJ

The DRUJ is a trochoid joint, which is created when a section of a cylinder of 1 bone (ulnar head) fits into a corresponding concavity in another bone (sigmoid notch).[6] The resultant motion is rotation or spinning. The DRUJ is formed by the concave *sigmoid notch* of the distal radius and the convex *seat* of the ulnar head. In approximately 80% of wrists, the volar side of the sigmoid notch has an extra-articular osteocartilaginous lip that creates a buttress to palmar translation of the ulna.[10,11] The volar ulnar corner of the distal radius is a keystone of both the radioulnar and radiocarpal joints. Its precise shape, with a volar projection and an ulnar projection, buttresses against both palmar translation of the carpus and distal ulna. Covered by hyaline cartilage, the *ulnar pole* is the rounded portion of the ulnar head that articulates with the TFCC distally.[2] The *fovea* is a small area that separates the ulnar styloid from the ulnar pole. The fovea is well vascularized,[12,13] devoid of cartilage, and is the insertion site of the deep branches of the dorsal radioulnar ligament (DRUL) and palmar radioulnar ligament (PRUL).[2] The distal end of the axis of rotation of the forearm passes through the fovea.[2] The *ulnar styloid process* extends from the dorsoulnar aspect of the distal end of the ulna, serving as the insertion site of the superficial branches of the DRUL and PRUL. Just dorsal to the ulnar styloid process is a groove for extensor carpi ulnaris (ECU) tendon. The radius of curvature of the sigmoid notch is considerably larger than that of the ulnar seat so that the DRUJ does not derive stability through bony congruity (Fig. 2).[2,14] It depends heavily on soft tissue stabilizers. The maximum possible joint surface contact between the sigmoid notch and the ulnar seat is 60% and that occurs in neutral rotation.[14] At the extremes of pronation and supination, there is only 10% bony contact.[14,15] Bony anatomy alone accounts for an estimated 30% of joint stability.[16] The distal end of the radius contains 2 concave facets, which articulate with the scaphoid and lunate of the proximal carpal row. The distal radius supports the carpus and hand. When the forearm pronates and supinates, the hand travels with the radius, moving from a palm down to a palm up/palm down position. The distal ulna does not directly articulate with the carpus.

Biomechanics and structure of the DRUJ

The mechanical function of the DRUJ is forearm rotation. This rotation movement, also known as pronation and supination, is a movement of the forearm about a longitudinal axis, which runs from the center of the radial head to the fovea of the ulnar head. Because the DRUJ and PRUJ are mechanically linked, effective forearm rotation does not occur without both joints working in synchrony. Forearm rotation elegantly provides a third degree of freedom to the wrist complex.[17,18] Placing the third degree of motion extrinsic to the carpus allows the hand to be placed in infinite positions to grasp objects with predictable and dependable stability. A theoretical alternate design that includes a synovial joint with 3 degrees of freedom at the wrist would require a bulky system of extrinsic muscles, and hand function would be compromised.[17]

Motion occurs in 3 planes at the DRUJ: (1) rotation about the longitudinal axis of the forearm, (2) dorsal–palmar translation, and (3) proximal–distal translation. *Rotational motion* is easy to identify because the palm of the hand moves 180° from palm up to palm down. There is, however, some noteworthy complexity. The axis of rotation is a line drawn from the center of the radial head to the center of the ulnar head. The radial head spins in place around the proximal end of the axis of rotation (attached to the lateral side of the proximal ulna by the annular ligament), whereas the entire distal end of the radius rotates around the fixed round head of the ulna, which contains the distal end of the axis of rotation. Distally, the axis of rotation is outside the moving distal radius. The position of the radius relative to the axis of rotation is always changing through the arc of pronosupination (Fig. 3). *Dorsal–palmar*

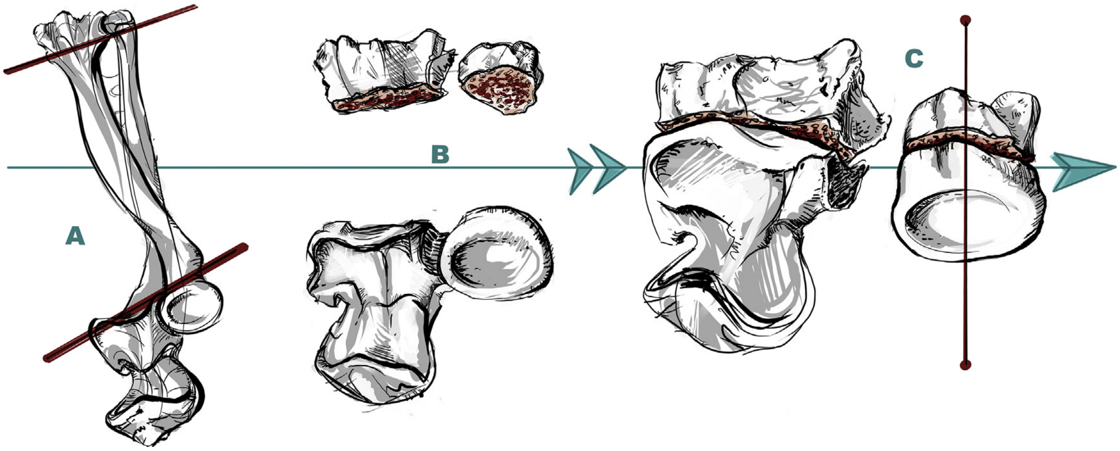

Fig. 1. With the approximation of the proximal and distal radioulnar joints, a bicondylar joint is created. The axis of rotation goes through the radial and ulnar heads, the convex side of the joint. Redrawn with permission from the Wolters Kluwer.[9] (A) The forearm bones are seen in full pronation. The two lines indicate the sites of osteotomy. (B) The radial and ulnar shafts are removed and the two distal and two proximal segments are approximated. (C) The distal radial segment is brought close to the proximal ulnar segment and the ulnar head close to the radial head.