THE MAGNIFICENT DISTAL RADIOULNAR JOINT

Emily Altman, PT, DPT, CHT, OCS, CLT, WCC
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Special Issue: Wrist

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

Emily Altman PT, DPT, CHT, CLT, WCC, OCS*
Hand Therapy Department, Hospital for Special Surgery, New York, NY, USA

Some Funny Things Happen When Your Work Gets Published

CURRENT CONCEPTS

The "Four-Leaf Clover" Treatment Algorithm: A Practical Approach to Manage Disorders of the Distal Radioulnar Joint

Sanjeev Kakar, MD,* Marc Garcia-Elias, MD, PhD*†

Continuing Medical Education
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Some Funny Things Happen When Your Work Gets Published

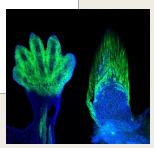
The New York Times http://nyti.ms/2bnFtD7

SCIENCE

From Fins Into Hands: Scientists Discover a Deep Evolutionary Link

Carl Zimmer

MATTER AUG. 17, 2016



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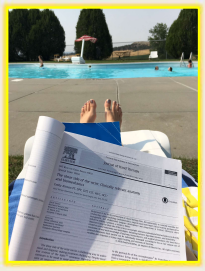

Thank You

- All therapists, surgeons, researchers who have contributed over the years to the progression of our knowledge base.
- Scott Wolfe, MD
  - *Attending Hand Surgeon Hospital For Special Surgery, NYC*
- Aviva Wolff, EdD, OTR/L, CHT
  - *Mentor, Supportive Colleague, Good Friend*
- Jennifer Rosetto
  - *Illustrator Extraordinaire*
- Hospital For Special Surgery
  - *Extraordinary Library*
- American Society of Hand Therapists

Objectives

- Able to describe the bony congruity of the DRUJ
- Able to describe the arthrokinematics of the DRUJ during pronosupination
- Able to list the soft tissue components of the TFCC
- Able to explain to a co-worker what occurs at the TFCC during a Galeazzi Fracture
- Able to measure ulnar variance on an AP xray of the wrist
- Able to openly share your new-found profound respect for the DRUJ

Why This?

- Reputation enhancement
- Respect augmentation
- Increase awareness of recent increases in information available
- Skill enhancing exercise in correlating anatomy with clinical decision making
  - *Scrutinize anatomy and biomechanics*
  - *Apply to what we see in the clinic*
    - How to manage and progress with careful thought

Evolution

The New York Times | http://nyti.ms/2bnFtD7

SCIENCE

From Fins Into Hands: Scientists Discover a Deep Evolutionary Link

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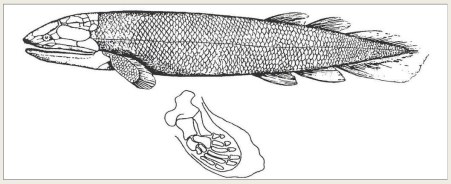
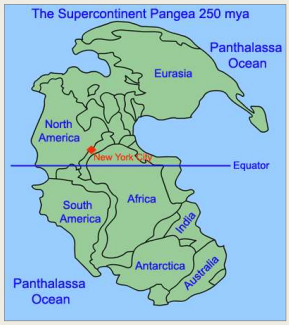
Key Unit

One bone + two bone forearm + intercalary carpus + 5 rays



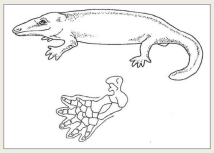
Pectoral fin of the crossopterygia
400 million years ago

Almquist EE. Evolution of the distal radioulnar joint. *Clin Orthop Relat Res. 1992;275:5-13*



Evolution

- Origins of the structural design of present-day 2-bone forearm
- Transformation of purpose with relocation to dry land



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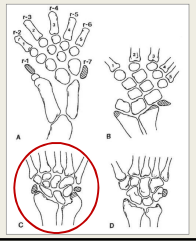
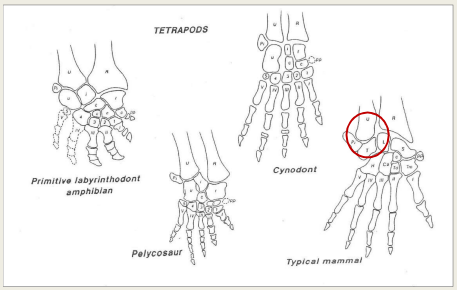




WeinzweigJ, Watson HK. Evolution of the wrist. In: Weinzweig J, Watson HK, eds. *The Wrist*. Philadelphia, PA: Lippincott Williams & Wilkins;2001:1-6.

Evolution in Humans

- Brain size (vs) opposable thumb (vs) forearm rotation…
- Three key features
  - *Recession of the ulna from the carpus*
  - *Development of an ulnocarpal meniscus*
  - *Development of a formal synovial DRUJ*

To help his readers fathom evolution, Charles Darwin asked them to consider their own hands.

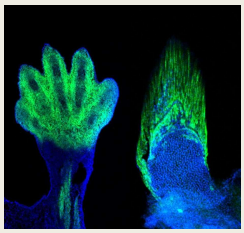
"What can be more curious," he asked, "than that the hand of a man, formed for grasping, that of a mole for digging, the leg of the horse, the paddle of the porpoise, and the wing of the bat, should all be constructed on the same pattern, and should include similar bones, in the same relative positions?"

- All of these animals share a common ancestor that grew limbs with digits
- Descendants of that common ancestor evolved different kinds of limbs adapted for different tasks
- They have never lost the anatomic similarities that revealed their kinship
- Darwin was limited to the tools of the day

- Just now beginning to "see" deep similarities not visible in Darwin's time
- Help us explain the transition from water to land
- How can you compare a human hand to a goldfish fin???
  - *Human hand*
    - Bones develop from cartilage and have blood vessels (endochondral bone)
  - *Goldfish fin*
    - Tiny cluster of endochondral bone at base of fin
    - Rest of fin is long rays of dermal bone that does not start out as cartilage and does not have blood vessels

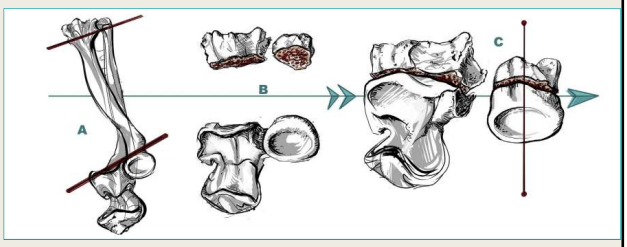
Pathways of Discovery

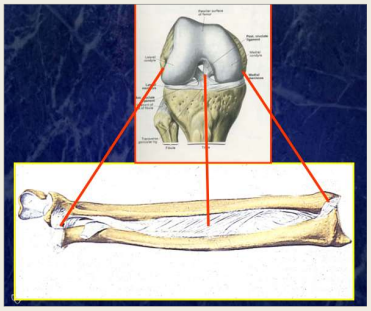
- **Fossils**
  - *Transition from sea to land 370 million years ago*
- **Laboratory**
  - *Compare how tetrapods (mice) and fish develop as embryos*



Composite image of a mouse hand and a fish fin, each labeled with the same molecular markers

Misnomer



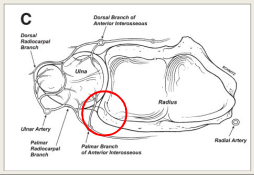


Richard A. Berger, MD, PhD
Mayo Clinic

Osseous Anatomy

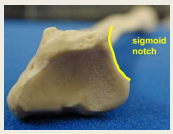
- Trochoid joint
- Resultant motion is rotation or spinning
- Concave sigmoid notch/convex ulnar seat
- Sigmoid notch has an extra-articular osteocartilaginous lip
  - *Buttress to palmar translation*
  - *"Deepens" the sigmoid notch*
- Volar ulnar corner of the distal radius
  - *Volar projection*
  - *Ulnar projection*

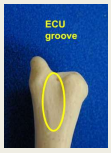
Katolik LI, Trumble T. Distal radioulnar joint dysfunction. J Hand Surg Am. 2005;5(1):587-594

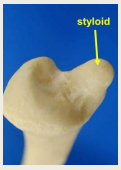


Osseous Anatomy

- Ulnar pole/seat
- Fovea
  - *Well vascularized*
  - *Devoid of cartilage*
  - *Attachment site of deep branches of DRU and PRU ligaments*
  - *Exit site of forearm axis of rotation*
- Ulnar styloid
  - *Attachment site of superficial branches of DRU and PRU ligaments*
- Just dorsal to the ulnar styloid process is the groove for the extensor carpi ulnaris (ECU)
- The distal ulnar does not articulate directly with the carpus







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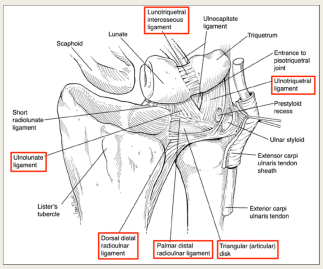
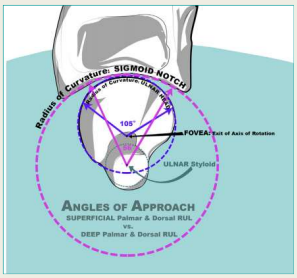
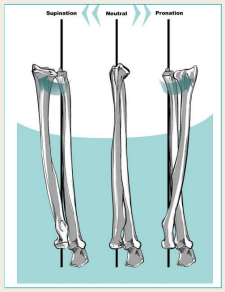


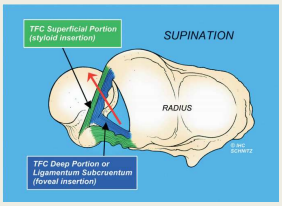
Radius of Curvature

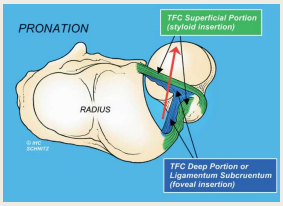


Biomechanics and Structure - DRUJ

- Biomechanical function of the DRUJ is forearm rotation
- Motion about a longitudinal axis
  - *Radial head – fovea of the ulnar seat*
- Third degree of motion to the carpus
- Motion occurs in 3 planes
  - *Rotation*
  - *Proximal – Distal*
  - *Dorsal - Palmar*

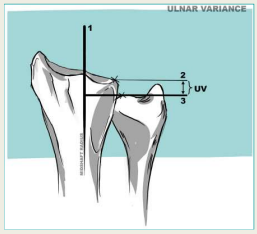




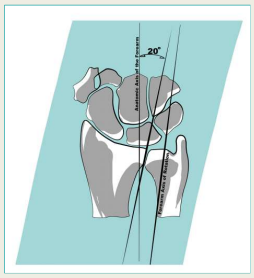


Kleinman WB. Stability of the distal radioulna joint: biomechanics, pathophysiology, physical diagnosis, and restoration of function. What we have learned in 25 years. *J Hand Surg.* 2007;32(7):1086-1106

Anatomic Geometry and Measures
Ulnar Variance



Anatomic Geometry and Measures
Frontal Plane



Joint Reaction Forces

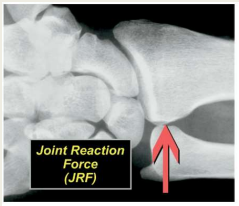


Figure 4. The seat of the ulna is the fulcrum for all distal radioulna joint mechanics. Because most upper limb activities in the bipedal human occur with the radiocarpal unit "on top" of the ulna seat, the joint reaction force (JRF) at the distal radioulna joint can be enormous. The joint reaction force is proportional to the load in the hand, the force of all muscles acting to pull the radius and ulna together for stability, and the force of gravity acting on the hand-forearm unit.

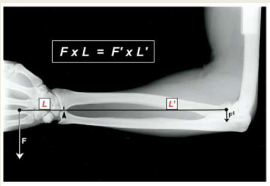
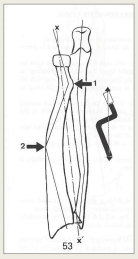
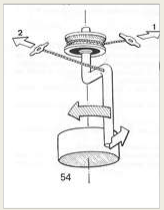


Figure 5. In equilibrium, the moments on the distal and proximal sides of the ulna seat fulcrum must be equal. The load in the hand (F) times the distance of the load from the fulcrum (L) must be equal to the length of the forearm from the fulcrum (L') times the resistance to displacement provided by the annular ligament at the radial head (F'). F x L = F' x L'.

Kleinman WB. Stability of the distal radioulna joint: biomechanics, pathophysiology, physical diagnosis, and restoration of function. What we have learned in 25 years. *J Hand Surg.* 2007;32(7):1086-1106

Anatomic Geometry and Measures
Radius Bone Frontal and Sagittal Plane

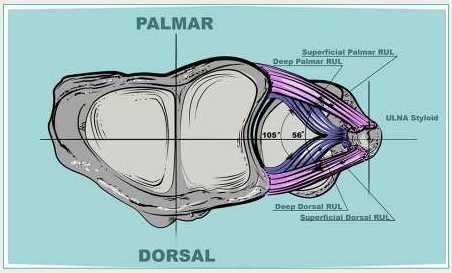


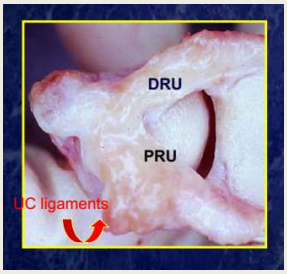


Kapandji IA. *The Physiology of the Joints.* 5th ed. Vol. 1. New York: Churchill Livingston: 1982:98-128.

Ligamentous Restraints - DRUJ

- Ligaments of the TFCC provide the primary intrinsic stability of the DRUJ.
- Supplemental stability
  - *IOM*
  - *Extensor retinaculum*
  - *Muscle/tendons that cross the longitudinal axis of rotation of the forearm*





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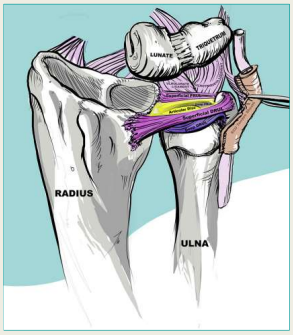
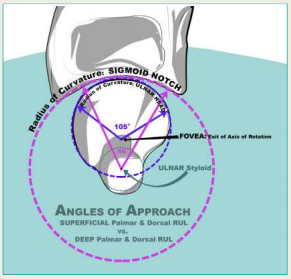
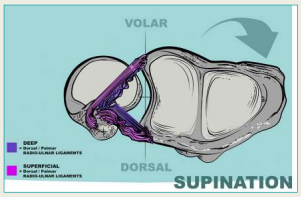
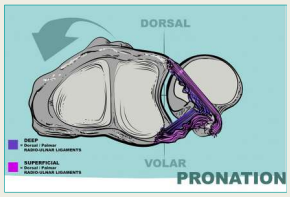


PRUL/DRUL Controlling Motion



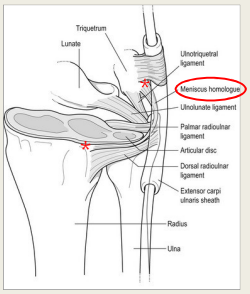
PRUL/DRUL Controlling Motion





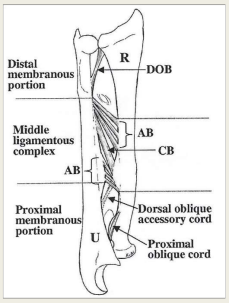
TFCC

- Complex 3-D structure
  - *Restraint*
  - *Control*
  - *Load transmission*
- Articular disc, PRUL, DRUL, ECU subsheath, UT ligament, UL ligament, meniscus homologue



The IOM

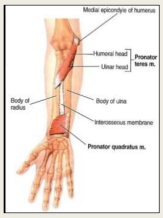
- Broad ligamentous structure that connects the radius and ulna along entire length
- Stabilize the relationship of the radius and ulna through the arc of pronosupination



Noda K, et al. Interosseous membrane of the forearm: an anatomical study of ligament attachment locations. *J Hand Surg. 2009*;34:415-422.

Dynamic Stabilizers - DRUJ

- Extensor Carpi Ulnaris (ECU)
- Pronator Quadratus (PQ)
  - *Superficial Head – transverse fibers*
  - *Deep Head – oblique fibers*

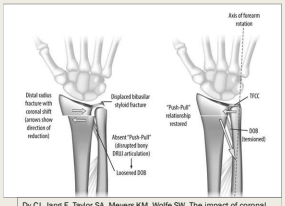


Dynamic Force - DRUJ

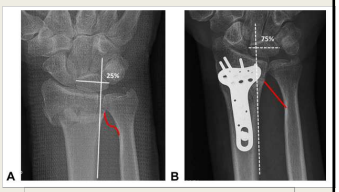
- Four muscles drive motion at the DRUJ
  - *Two pronators*
    - PQ and PT, median innervated, 1 intrinsic, 1 extrinsic
  - *Two supinators*
    - Bicep Brachii and Supinator
      - *Biceps: musculocutaneous nerve, extrinsic*
      - *Supinator: radial nerve, intrinsic*

Distal Radius Fractures

- Multiple ways to impact the DRUJ
  - *Extension into the articular surface of the sigmoid notch*
    - Joint function compromised, at risk for arthrosis (PTOA)
    - 55% of intraarticular distal radius fractures have fracture lines extending into the sigmoid notch (Sammer DM, 2012)
  - *Fracture causes a change in the position of the distal end of the radius*
    - DRUJ congruency and function will be compromised
      - *Radial shortening*
      - *Dorsal angulation of the distal radius*
      - *Coronal shift*
    - Ulnar styloid fracture
      - *Compromise of DRUJ stability*
- TFCC injury occurs in 40-85% of unstable distal radius fractures (Lindau T, 2000)
- 11%-19% of patients sustain TFCC problems after distal radius fractures (May MM, 2002)



Dy CJ, Jang E, Taylor SA, Meyers KM, Wolfe SW. The impact of coronal alignment on distal radioulnar joint stability following distal radius fracture. *J Hand Surg.* 2014;39:1264-1272



Trehan SK, Orbay JL, Wolfe SW. Coronal shift of distal radius fractures: Influence of the distal interosseous membrane on distal radioulnar joint instability. *J Hand Surg.* 2015;40:159-162

Radial Head Fractures

- PRUJ and DRUJ are mechanically linked
  - *Shape of radial head*
  - *Angle of union*
  - *Length*
- Persistent clicking

Radial Head Replacement

- Inexact replacement
- Too large:
  - *Limit rotation and flexion*
- Incorrect angle relative to long axis of the radius
  - *Clicking, clunking*
  - *Subluxation at radiocapitellar joint (Van Glabbeek F. 2005)*

Radial Head Resection

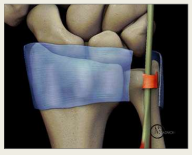
- Load transfer from carpus to forearm
  - *80% to the radius; 20% to the ulna (Palmar AK 1981)*
- Force transferred via the central band of the IOM to ulna and proximally to axial skeleton
  - *Radial head/capitellum articulation prevents proximal migration of radius*
  - *Radial head excision → increased reliance on the intact IOM to prevent proximal migration of the radius with load*
    - No need to overdo gripping and strengthening in therapy!
    - Proximal migration of radius→ulnar positive variance→increased pressure on TFCC and ulnar abutment
      - *May see loss of supination: radius can no longer get around lengthened ulna*

Ulnar Impaction Syndrome
Ulnar Abutment Syndrome

- Ulnar head impinging of the ulnar carpus
- Increased loads seen across the TFC
  - *Degeneration or damage to the articular disc*
- Symptoms more pronounced in pronation than supination

ECU Subluxation

- Incompetence of the ECU subsheath
  - *Tendon subluxates or dislocates out of its groove*
  - *Supination*
  - *Painful snap over the ulnar/dorsal aspect of the wrist with supination*
  - *Immobilization that restricts supination and ulnar deviation*
  - *Confusion with clicking experienced during pronosupination of an unstable DRUJ*



ECU Subsheath Repair/Reconstruction

- Supination and ulnar deviation will stress the repair
- Acknowledge the ECU's dynamic stabilization role
  - *Depression of the ulnar head*
  - *Elevation of the ulnar carpus*
  - *Tensioning of the TFCC via the subsheath's interaction with the DRUL*
- Postoperative findings may include
  - *Prominent ulnar head*
  - *Relative volar posturing of the distal radius and carpus*
  - *C/O increased pressure on their pisiform during writing*
  - *Consider a soft orthotic device to address volar/dorsal posturing of the radius on the ulna*

Forearm Contracture

- Multiple potential contributors to motion loss of the forearm
- PRUJ and DRUJ are mechanically linked
- Manual techniques to address the roll and glide of the radial head in the lesser sigmoid notch of the ulna
  - Pronation: Radial head translates posteriorly on the ulna
  - Supination: Radial head translates anteriorly on the ulna
- Soft tissue structures of the forearm

Ulnar Shortening Osteotomy

- Treat ulnar impaction syndrome
- Reduce load across the TFCC
- Correct relative length relationship
- Tensioning of the UT and UL ligament and the DOB of the IOM
  - *Increasing TFCC stability*
  - *Increasing joint reaction force across the DRUJ*
- Risk of delayed or non-union
- Removal of hardware
- **Leaves the DRUJ and TFCC intact**
- Osteotomy is in diaphyseal bone: time to heal
- No need to rush load application
- Up to 16 weeks to return to full activity

Galeazzi Fracture

- Junction of distal third and middle third of the radius
- +DRUJ dislocation
  - *Significant damage to all TFCC structures*
- Surgical fixation required
- Often positioned in supination postoperatively for maximum DRUJ stability
- Restoration and protection of DRUJ stability is mandatory

Monteggia Fracture

- Shaft fracture of the ulna
- Radial head dislocation
- DRUJ usually not involved
- Lateral collateral ligament complex typically preserved
- Bado 1
  - *Apex anterior*
  - *Anterolateral dislocation of radial head*

Essex-Lopresti Lesion

- High energy fracture dislocation of the forearm
  - *Radial head fracture*
  - *Complete IOM disruption*
  - *DRUJ dislocation*
- Complete longitudinal dissociation of the forearm
- Must not excise the radial head
- Significant elbow and forearm ROM deficits

(Trousdale RT. 1992)

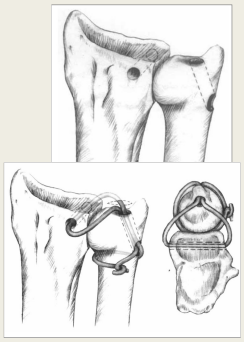
(Trousdale RT. 1992)

Chronic DRUJ Instability
No associated arthrosis

- Ligamentous restraints of the DRUJ are not able to control dorsopalmar translation
- Forces are not effectively transmitted from the hand to the forearm
- History of an unrecognized TFCC traumatic injury
- Pain, weakness, clicking, loss of forearm rotation
- Most common presentation:
  - *Dorsal displacement of the ulna with respect to the radius*
  - *Loss of congruity most pronounced in pronation*
- Circumferential bracing

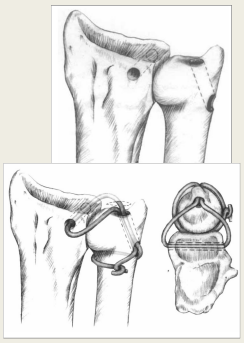
Chronic DRUJ Instability
No associated arthrosis

- Surgical reconstruction
  - *Several soft tissue reconstruction procedures exist*
  - *Adams-Berger procedure attempts to reconstruct the palmar and dorsal ligaments with a tendon graft*
    - Most anatomic reconstruction
- Reconstruction is contraindicated in the presence of
  - *DRUJ arthrosis*
  - *Length discrepancies*
  - *Ulnocarpal impaction*
  - *Malunions of DRFs*
  - *Collagen disorders*
  - *RA*



Chronic DRUJ Instability
No associated arthrosis

- Postsurgical management
  - *Prolonged period of strict limitations of forearm rotation in a sugartong style orthosis*
  - *Permit soft tissue reconstruction to heal*
  - *Aggressive forearm PROM is contraindicated*
  - *6 weeks: long arm cast*
  - *4 weeks: custom forearm ulnar gutter orthosis*
  - *ROM recaptured gradually over 4-6 months (Adams BD, 2000)*



DRUJ Instability/Pain
With arthrosis

- Presence of joint destruction or degeneration limits surgical interventions to salvage procedures
  - *Darrach resection*
  - *Fusion*
  - *Sauve-Kapandji reconstruction*
  - *Arthroplasty*
- Consider after prolonged conservative management
  - *Orthotic immobilization*
  - *Nonsteroidal anti-inflammatory medications*
  - *Corticosteroid injections*

Darrach Resection

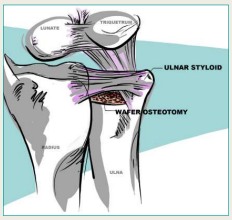
- Removal of the ulnar head to relieve severe pain and instability at the DRUJ
- Commonly used in the treatment of RA
- Most successful in the less active patient
- Risk for painful convergence of the distal stump of the ulna against the radius (McKee MD 1996)
- Complete loss of the ulnocarpal buttress
  - *Ulnar translocation of the entire carpus*
- Complete destruction of the DRUJ and the forearm axis of rotation
  - *Requisite increased demand on soft tissue for structural support*
- Rehabilitation should respect the significantly altered mechanics and functional capacity

Darrach Resection

- Postoperatively
  - *Long arm orthosis in neutral rotation x 6 weeks*
  - *Allow soft tissue to heal*
  - *Then initiation of gentle ROM and recovery of function*
    (Grawe B, 2012)

Wafer Resection Osteotomy

- Address limitations of the Darrach resection
- Removes only 2-4 mm of the distal ulna
- Treatment of
  - *Ulnar impaction syndrome*
  - *Symptomatic tears of the TFCC*
- TFCC and ulnar styloid remain intact
- Contraindicated in the presence of DRUJ instability

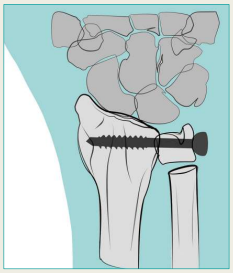


Wafer Resection Osteotomy
Postoperative

- Forearm immobilized in neutral rotation x 3 weeks
- Gentle motion at 3 weeks postop
- 3-6 months for maximal pain relief
  (Feldon P, 1992)

Sauve-Kapandji Procedure

- Damaged, painful, post-traumatic DRUJ WITH arthrosis
- RA
- DRUJ is surgically fused
- Pseudarthrosis is created: ulnar osteotomy
- Ulnocarpal buttress is preserved
- Preserves TFCC
- Preserves ulnocarpal ligaments
- ECU remains in its compartment

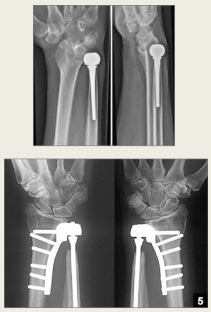


Sauve-Kapandji Procedure

- Postop strict immobilization is not indicated
  - *Custom wrist orthosis to support wrist as fusion heals/local tissue recovers*
- Consider an emphasis on PROM over excessive AROM for recovery of pronosupination
  - *Inflammatory response at osteotomy site →scar formation →limited ROM*
    (Lluch A, 2010)
- Convergence of proximal ulnar stump into radius
- Does not restore normal DRU mechanics
- Can take a long time for postoperative discomfort to resolve and function restored

DRUJ Arthroplasty

- Joint replacement is gaining popularity
- Few options for revision of a failed arthroplasty
- Two groups:
  - *Partial or total ulnar head replacements*
  - *Total DRUJ arthroplasties*



Ulnar Head Replacement
(Garcia-Elias, M. 2007)

- Unconstrained
- Indicated for arthritic DRUJs with minimal instability
- Degenerative, posttraumatic, and inflammatory DRUJ arthritis
- Contraindicated for DRF malunion and in the presence of infection
- Rely on good quality native supporting soft tissue
- Careful soft tissue reconstruction is critical for stability
- Postoperatively
  - *6 weeks immobilization—soft tissue envelope to form and heal*

Total DRUJ Prosthesis
(Scheker LR. 2008)

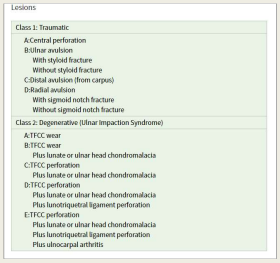
- Constrained implants
- Suitable for unstable DRUJs
- Do not require soft tissue support
- Self stabilizing. Do not require native soft tissue support
- Permit normal proximal-distal translation of radius during forearm rotation
- Provide ulnar column support for the carpus
- Replaces function of ulnar head, sigmoid notch, TFCC ligaments
- No postop range of motion limitations
  - *AROM started immediately*
  - *No protection*

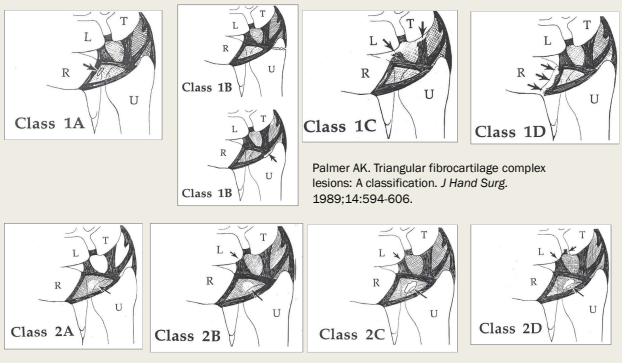
One-Bone Forearm

- Surgical creation of a 1-bone forearm is the ultimate and last resort salvage procedure for DRUJ and forearm pain and instability
- At the midshaft level, a fusion of the distal radius and the proximal ulna is created using a plate
- Digit, radiocarpal, ulnohumeral motion are preserved, but function is severely compromised and pain often persists

TFCC Tear

- Symptoms related to degenerative TFCC tears often resolve with immobilization (wrist or ulnar gutter orthosis) & activity modification
- Acute tears may be candidates for surgical repair or debridement
- Palmar classification describes location and type of tear
- Post surgery
  - *Restore functional forearm and radiocarpal motion without provoking repeated inflammatory responses*

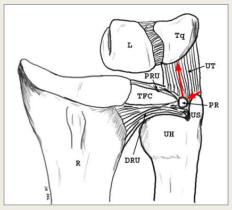




Palmer AK. Triangular fibrocartilage complex lesions: A classification. *J Hand Surg.* 1989;14:594-606.

Longitudinal Split Tears of the UT Ligament

- Do not cause instability or the DRUJ or the ulnocarpal articulation
- Significant ulnar wrist pain
- Traumatic event
  - *Wrist extension*
  - *Supination*
  - *Radial deviation*
- It is an injury of the TFCC
- Key clinical test: Ulnar Foveal Sign
- Require surgical repair
- Immobilized 6 weeks in neutral rotation



Tay SC, Berger RA, Parker WL. Longitudinal split tears of the ulnotriquetral ligament. *Hand Clin. 2010;26:495-501.*

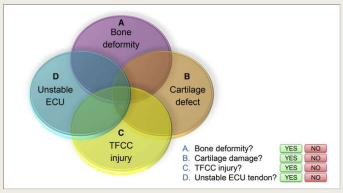
Foveal disruptions and UT ligament split tears.
- Foveal tears: unstable DRUJ
- UT tears: stable DRUJ

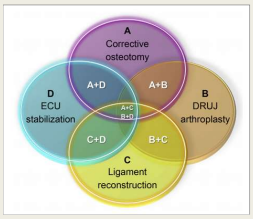
Organizing DRUJ Pathology

Pain without Instability	• TFCC Tear
	  • Repair, Debridement
	• Ulnocarpal Impaction
	  • USO, Wafer procedure
	• ECU subsheath injury
	• UT ligament injury

Pain with Instability	• Acute with fracture
	  • Galeazzi, Essex Lopresti, DRF
	• Acute foveal tear
	• Chronic
	  • Unrecognized acute injury, attritional wear, RA

Pain due to Arthritis	• Related to
	  • Unrecognized injury, Ineffectively treated injury, Inflammatory condition
	• Presence of DRUJ arthrosis impacts treatment options significantly
	  • Darrach, Sauve-Kapandji, Arthroplasty, One bone forearm





Kakar S, Garcia-Elias M. The "four-leaf clover" treatment algorithm: A practical approach to manage disrorders of the distal radioulnar joint. *J Hand Surg. 2016;41:* 551-564

Summary

- The DRUJ is a function multiplier for the human upper limb
- DRUJ delivers the significant evolutionary advantage of forearm rotation
  - *Hand in infinite positions in space*
  - *Predictably transmits forces to the axial skeleton*
- Go forth and love the DRUJ

Thank You!

Contact : altmane@hss.edu

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