Wrist Biomechanics

Hand Therapy Training Program 2015

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Acknowledging Julie Rouse

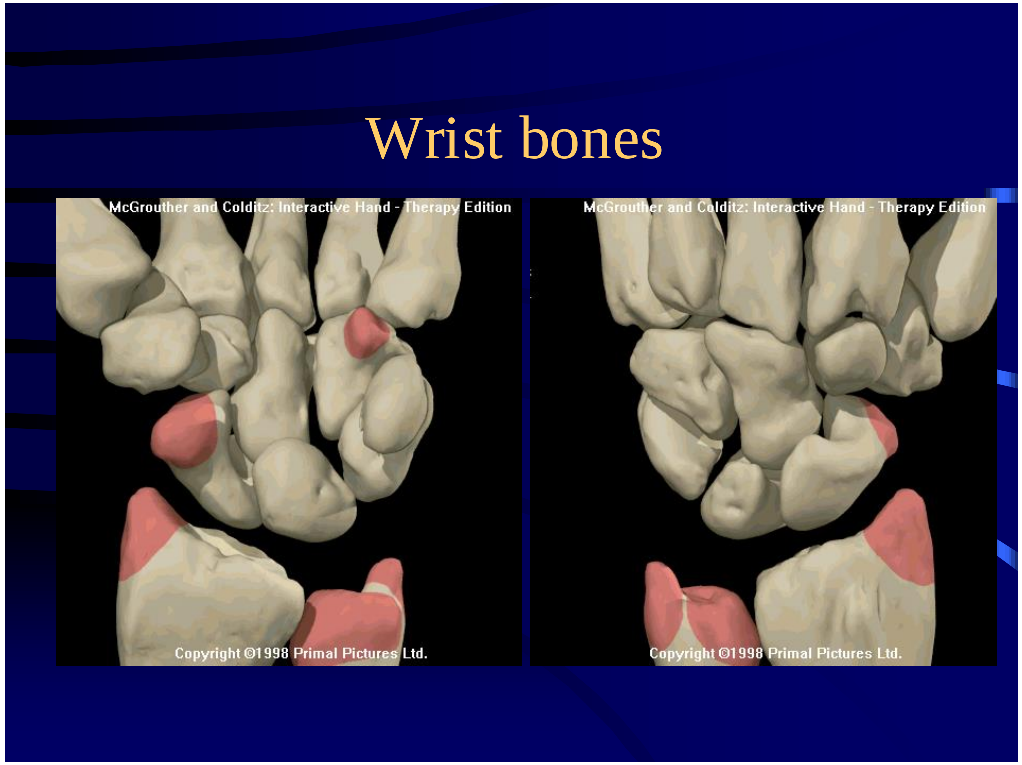
WRIST ANATOMY OVERVIEW

- Wrist **Mobility** is the sum of all movements of an articular complex made up of the
  - ☐radio carpal joint,
  - ☐the midcarpal joint
  - ☐the ulna carpal joint and
  - ☐the radio-ulnar joint.
- Wrist **Stability** is dependent on
  - o the bony morphology of each joint,
  - o the passive resistance of the fibrous skeleton and
  - o the dynamic stability of muscle co-contraction.

The bony features

- Distal radius has double obliquity
- Carpal condyle of prox. row has smaller diameter of curvature than radius,
- Carpal stability largely due to interosseous ligaments and bony config.
- The carpus is a “condyle of variable geometric form”
- Rotation of Scaphoid and lunate in a sagital plane allows persistent adaptation of carpal articular surface
- The scaphoid presents a long axis inclined by **45 degrees**

Anatomy



- Proximal and Distal rows
  - 8 carpal bones

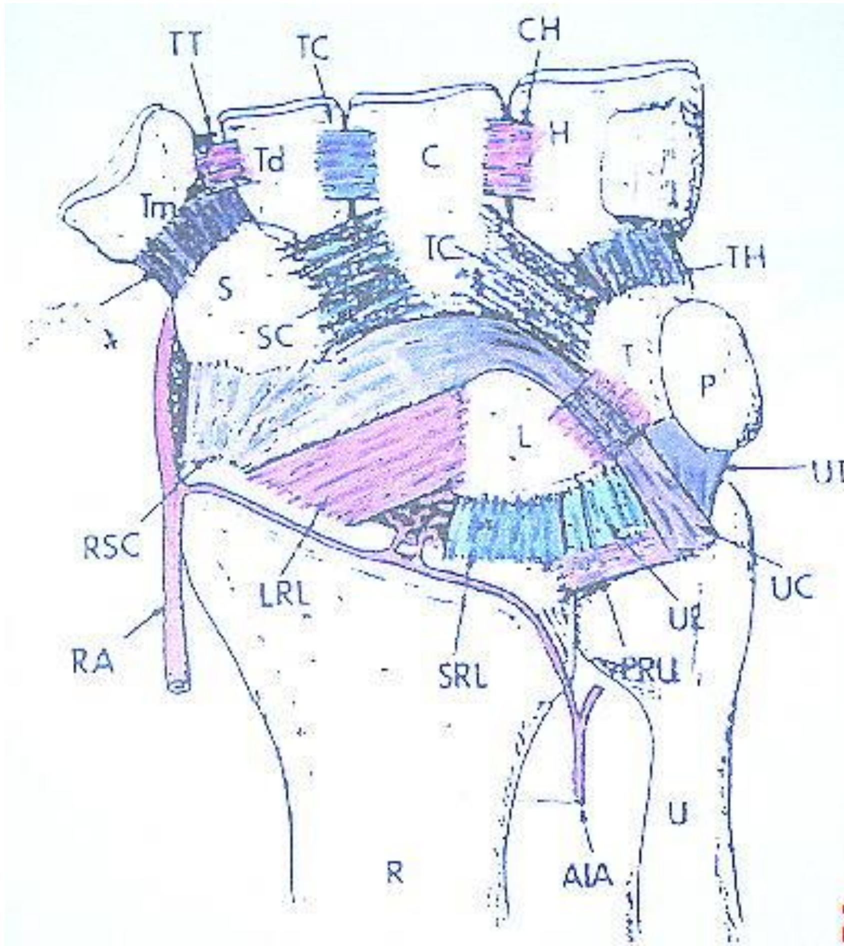
Some Lovers Try Positions That They Cant Handle !!

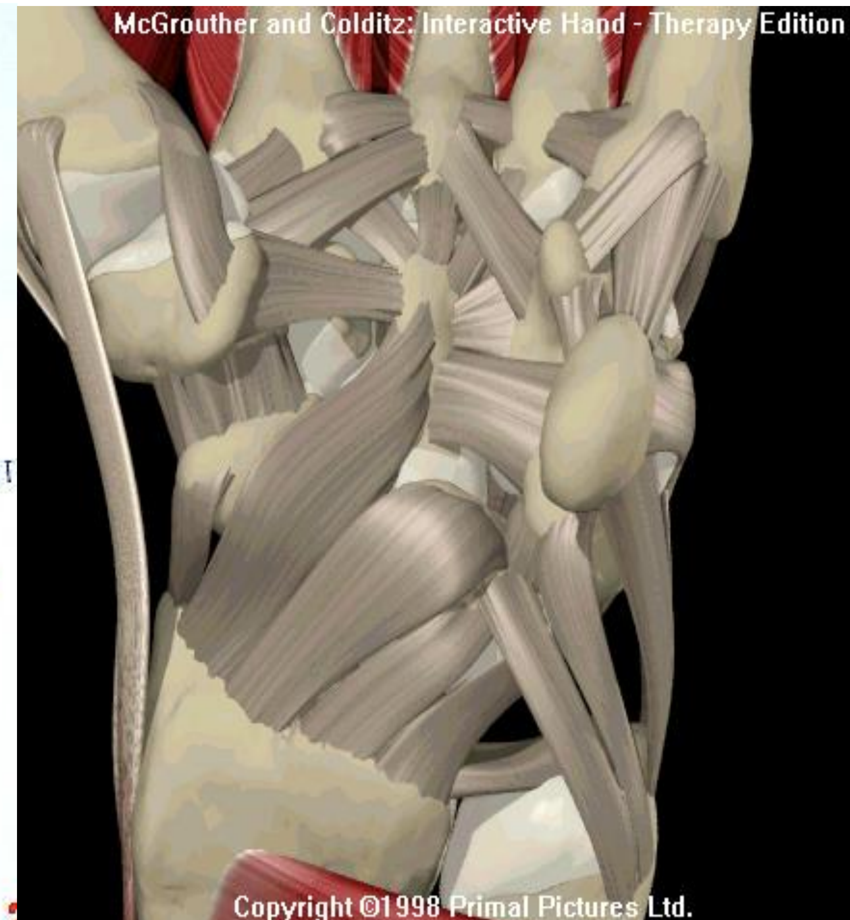
Fibrous joint capsule and extrinsic ligaments

1. Anterior /Palmar ligament: Arcuate

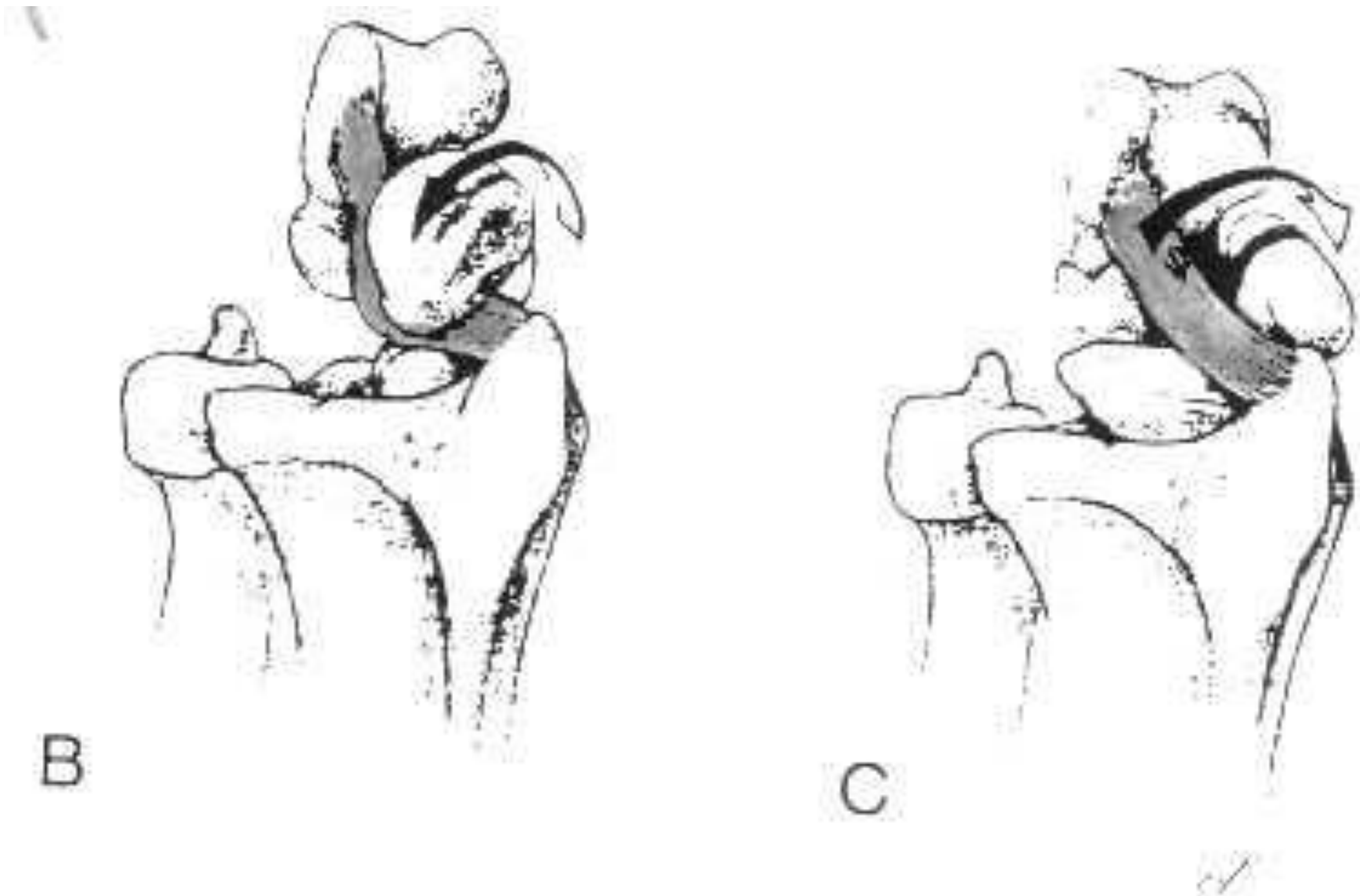
- V shaped or double V, symmetrical limbs from R and U converging on capitate for insertion
- o Radial ligs. much stronger than ulnar designed to resist natural ulnar translocation
- o RSC strong band, acts as pivot for scaphoid flexion. (diag)
- o Space of Poirier found between two bands of RLT and RSC as crosses LC joint, weak spot as no LC lig.

Volar Extrinsic Ligaments





Scaphoid Rotation around RSC



Capsular ligaments

B. • **Dorsal capsule:**

- much weaker transverse V shape ligament, apex on triquetrum, direction oblique and medial, and counters tendency for ulnar subluxation.
- Also resists natural loading forces through clenched fist, resisting natural tendency to Z collapse ie mid carpal stability (ref diag)
- Prox. portion converge on Tqtm as an osteofibrous Knot surrounding ulnar aspect of wrist.

Dorsal Extrinsic ligaments

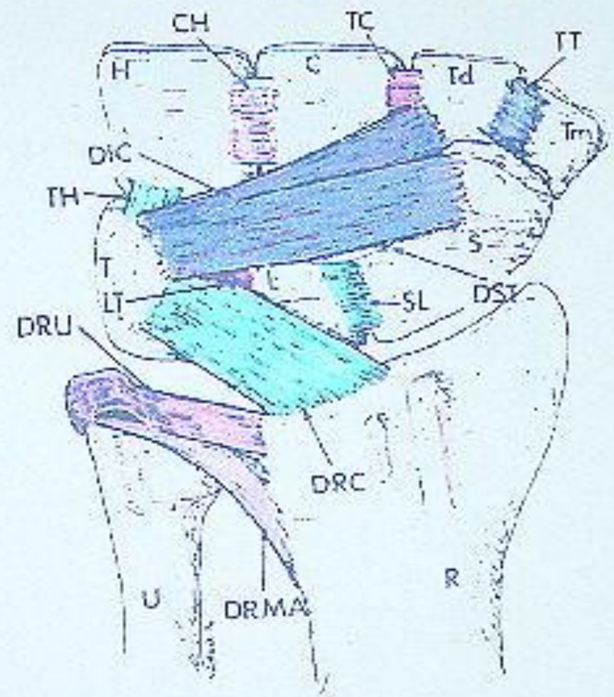
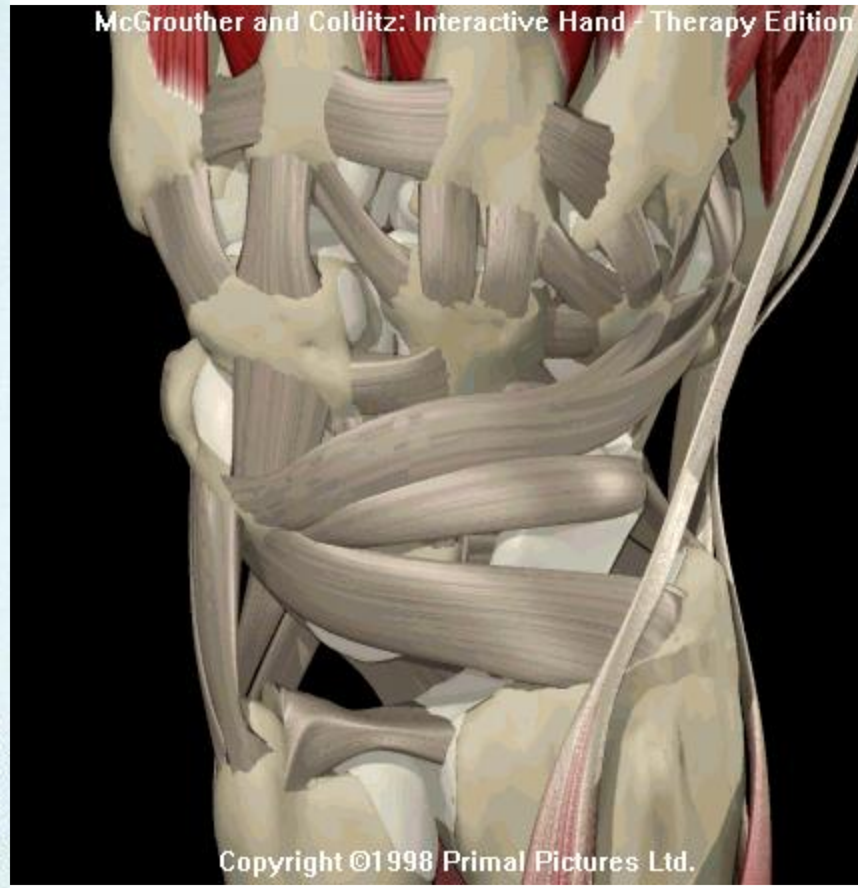
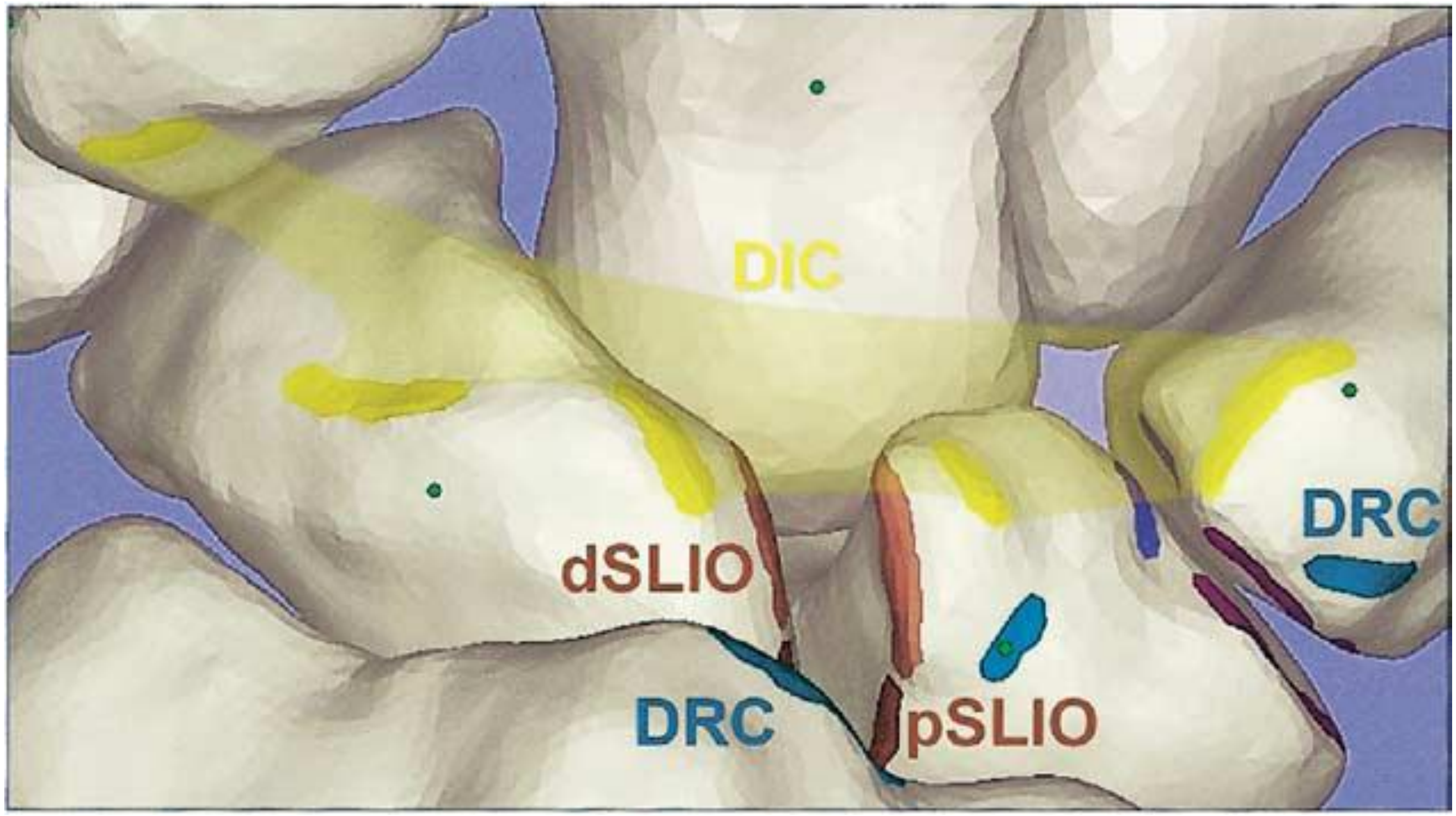


Figure 15. The dorsal carpal ligaments from a dorsal perspective. Ligaments: DRU = dorsal radioulnar; DRMA = dorsal radial metaphyseal arcuate; DRC = dorsal radiocarpal; DIC = dorsal intercarpal; DST = dorsal scaphotriquetral; SL = scapholunate; LT = lunotriquetral; TH = triquetrohamate; TT = trapeziotrapezoid; TC = trapezocapitate; CH = capitohamate. Bones: R = radius; U = ulna; S = scaphoid; L = lunate; T = triquetrum; Tm = trapezium; Td = trapezoid; C = capitate; H = hamate.

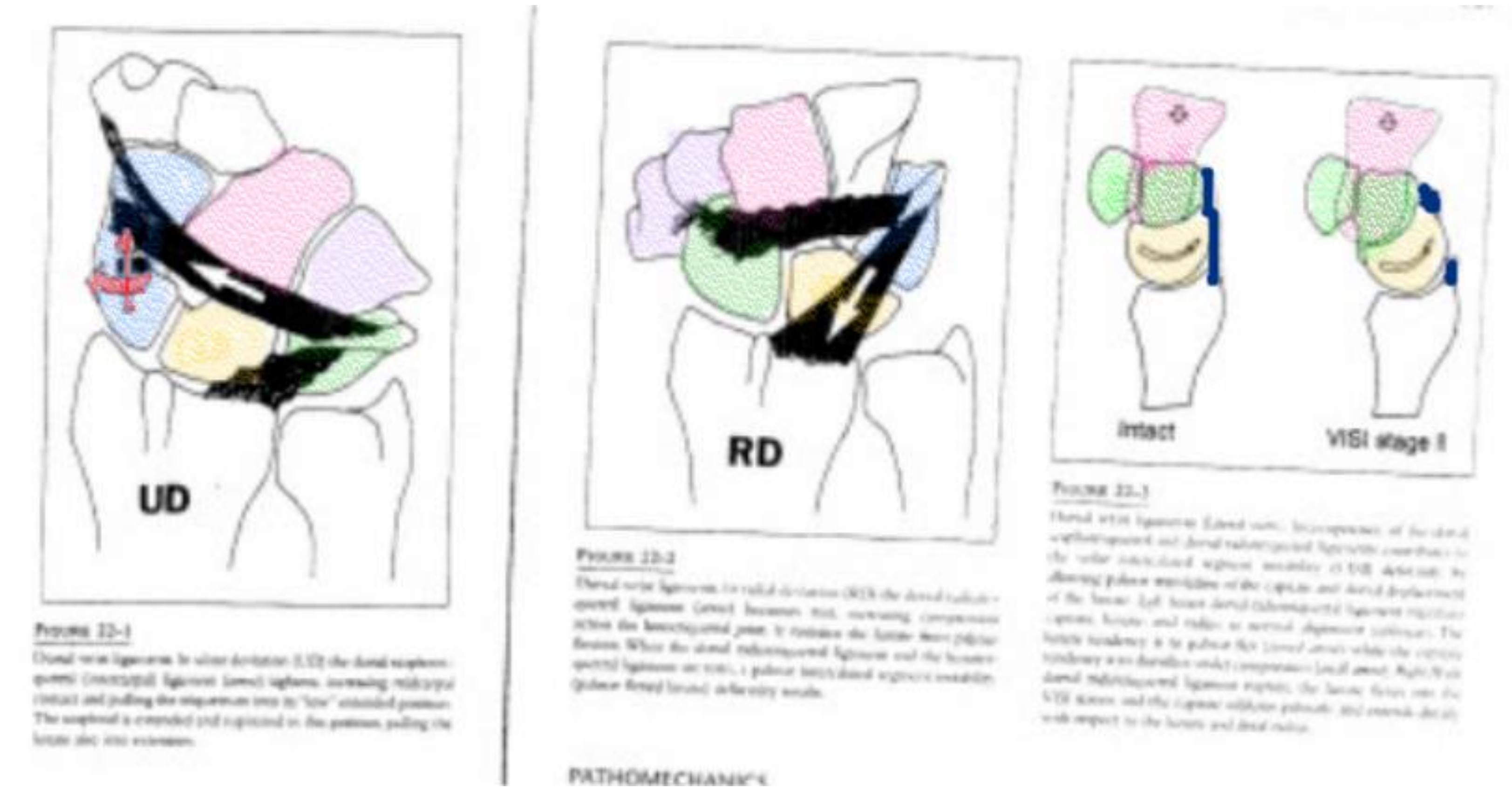


DIC



DIC & RTqL

- Picture of tension on DIC in deviation



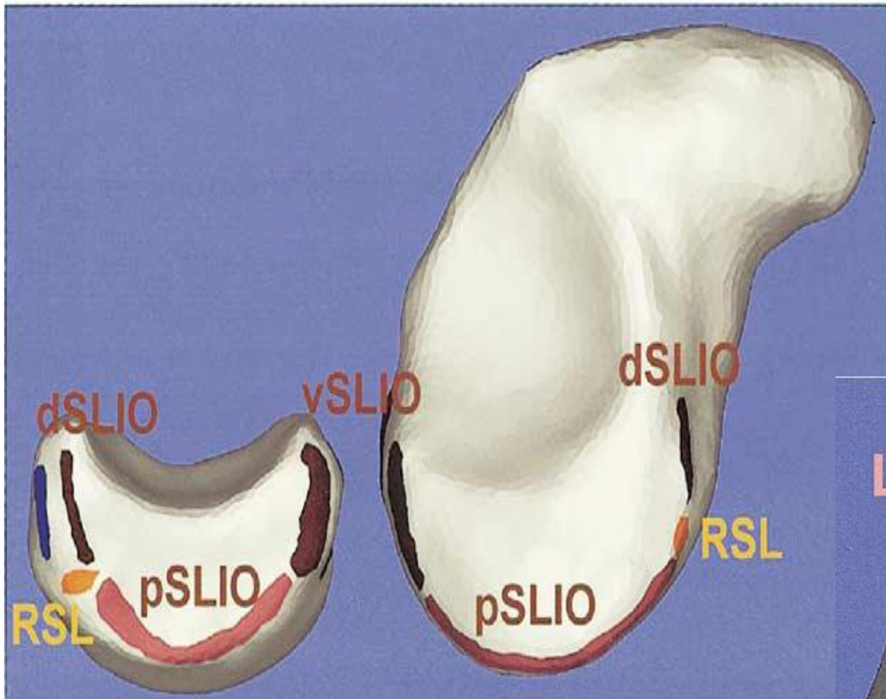
The intra -articular ligaments

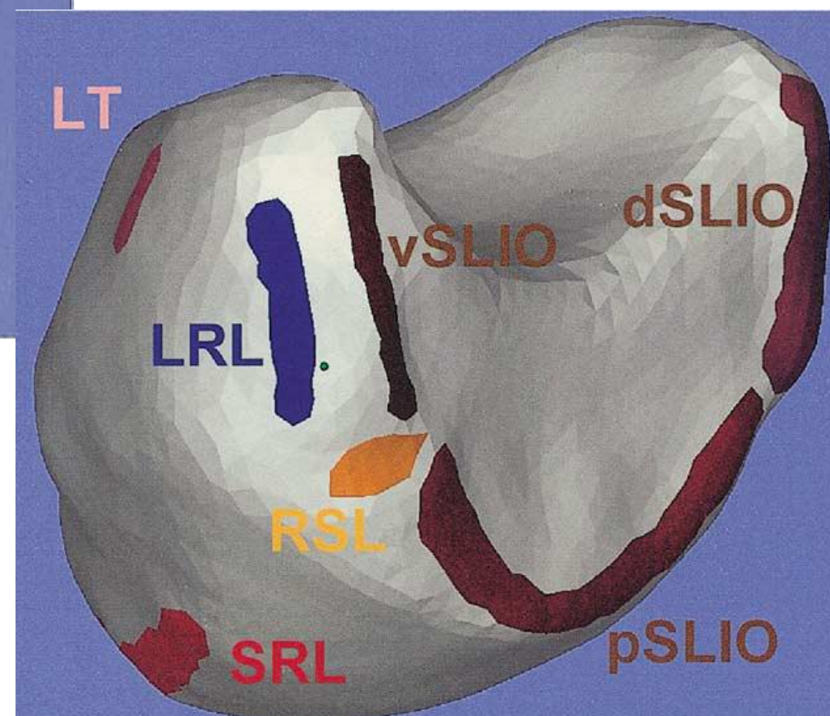
Intrinsic ligaments Connecting the carpal bones.

Carpal interosseous ligs. (SL ,LT etc) Radio-scapholunate ligament and TFC

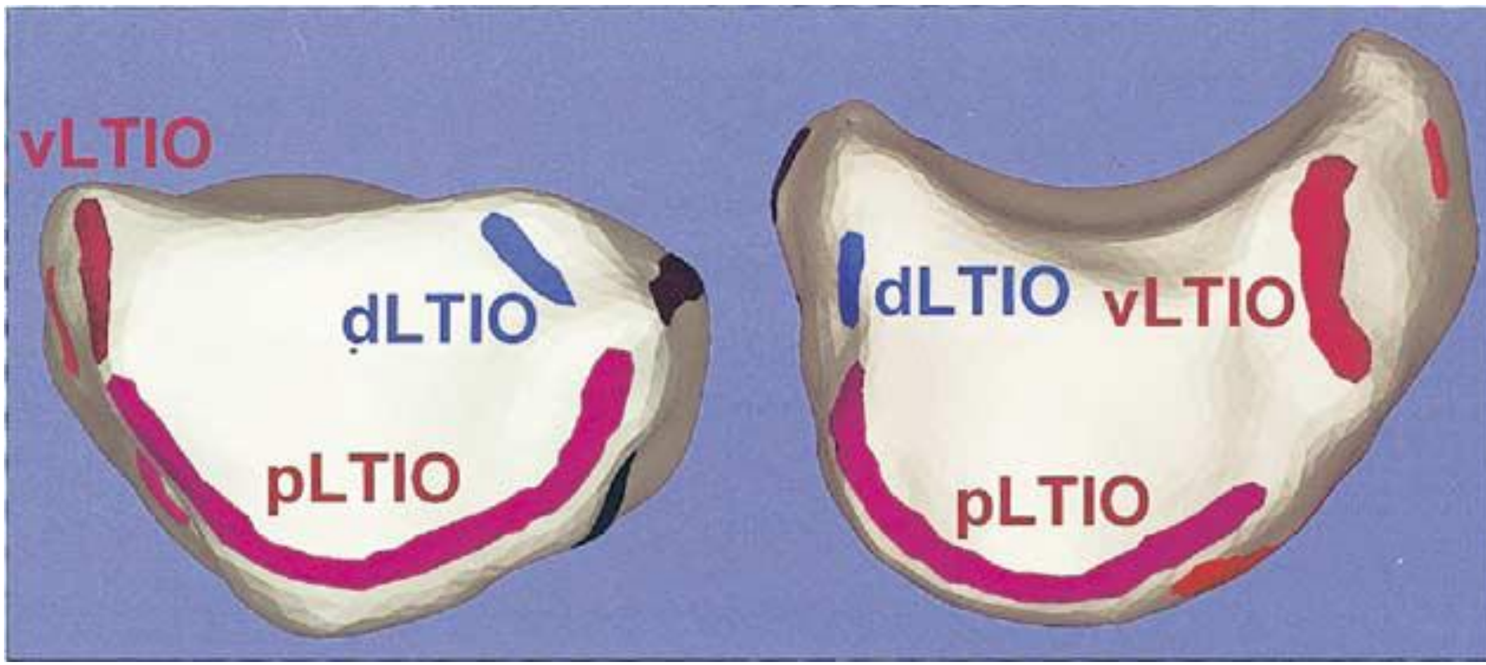
- Proximal row: strong interosseous, proximal to joint and Ant, post, deficient distally. (Cf diag scaphoid)
- Distal row strongly bound to form one unit. NB. no intrinsic ligament between capitate and lunate.
- On radial side of mid carpal joint, Scaphoid attached by distal pole to tpzm, tpzd and capitate.
- On ulnar side, Tqtm attached to capitate and Hamate
- RSL ligament. Ligament of Testut. Vascular channel

SLIO ligament

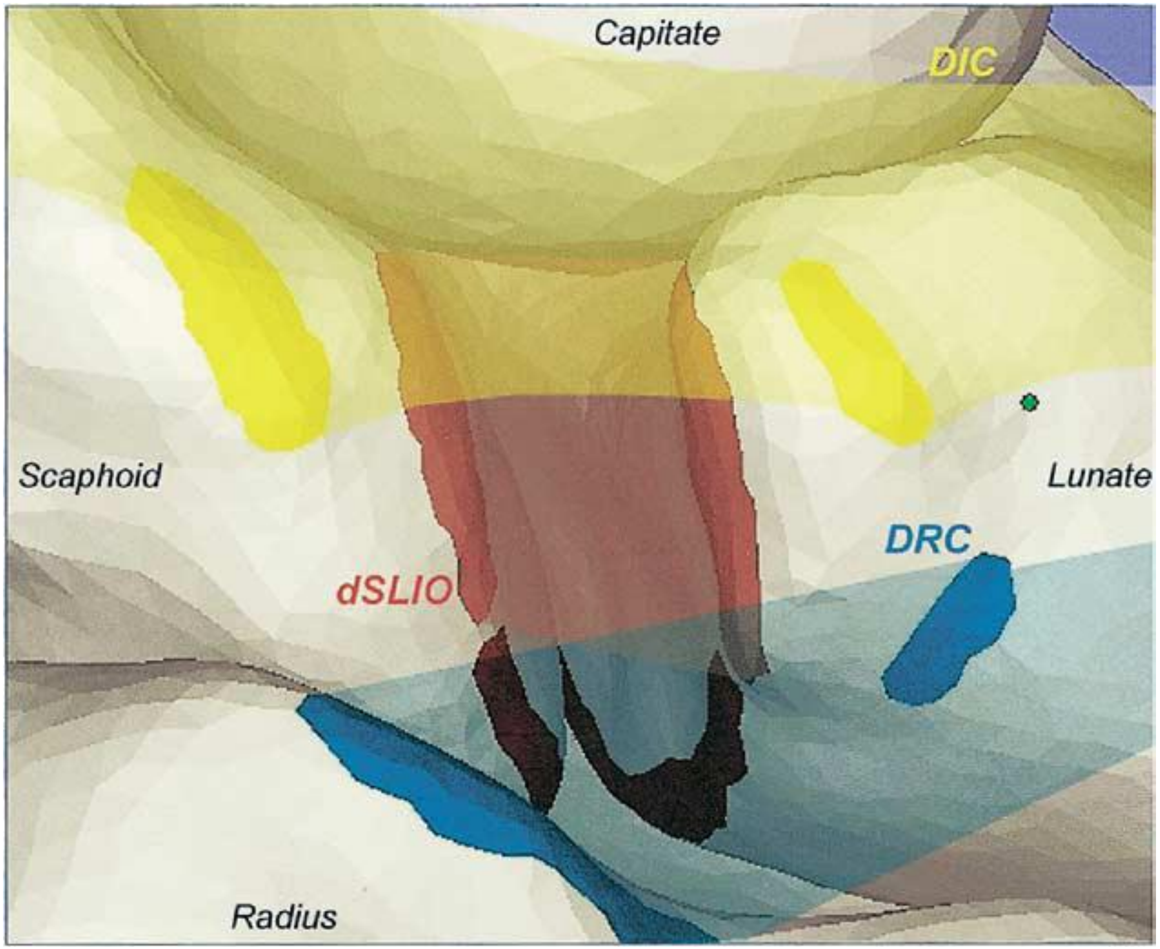




LTIO



SLIO in vivo



SLL

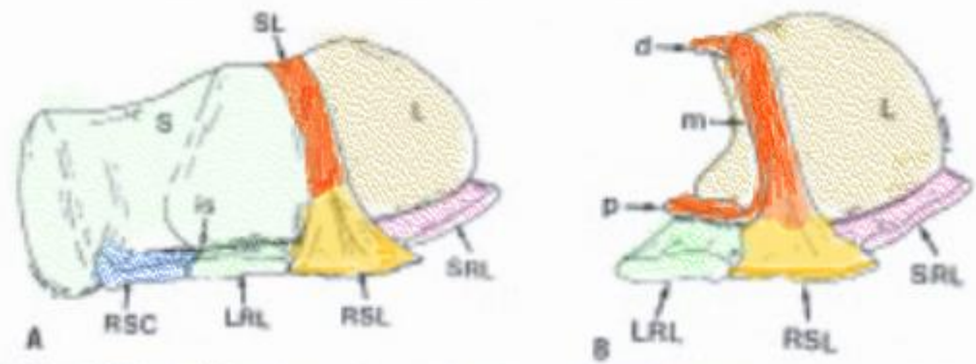


FIGURE 5. Drawings of the scapholunate complex and the palmar radiocarpal ligaments. (A) Bones: S = scaphoid, L = lunate. Ligaments: RSC = radioscaphocapitate, LRL = long radiolunate, SRL = short radiolunate, RSL = radioscapholunate, SL = scapholunate interosseous, is = interligamentous sulcus. (B) Bones: L = lunate (scaphoid is removed). Ligaments: LRL = long radiolunate, RSL = radioscapholunate, SRL = short radiolunate, d, m, and p = dorsal, proximal membranous, and palmar regions of the scapholunate interosseous, respectively. Reproduced with permission from: Berger RA, Garcia-Elias M: General anatomy of the wrist. In An K-N, Berger RA, Cooney WP (eds): Biomechanics of the Wrist Joint. New York, Springer-Verlag, 1991, pp 8, 14.

Scapholunate ligament

April–June 1996 87

Extra articular ligaments of the wrist

- Transverse carpal ligament:
  - attached to scaphoid, trapezium, hamate, and pisiform.
  - Pulley for strong flexor tendons, contributes to volar carpal stability and CMC joint.
- Posterior (Extensor) retinaculum
  - transverse portion forms six osteo- fibrous tunnels for extensor tendons.
  - Oblique portion turns around the ulnar carpus and ECU and inserts onto pisiform and triquetrum, i.e. extra articular sling.

Ulnar fibrous structures

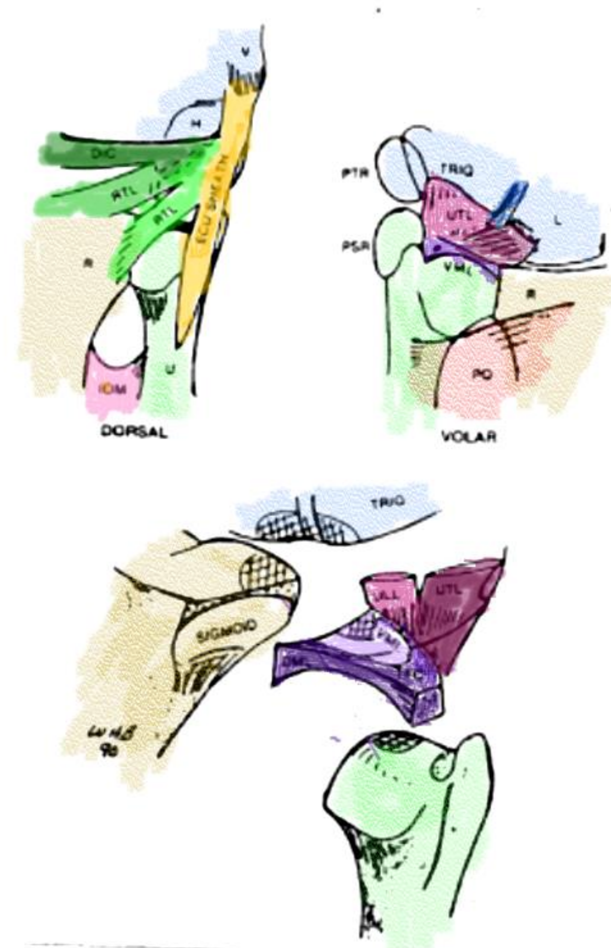
Includes

- dorsal and palmar RUL,
- TFC (disc),
- UCL.
- Ant and post RTq,
- ECU sheath.

- o Carpus essentially suspended on ulna side from the radius by 2 oblique ligament systems, anterior RLT, post RT.
- Carpal attachment to ulnar by VUCL arising off TFC and fovea: and ECU sheath dorsally.
- Taleisnik describes a meniscus between radius and Tqtm (aka meniscus homologue)

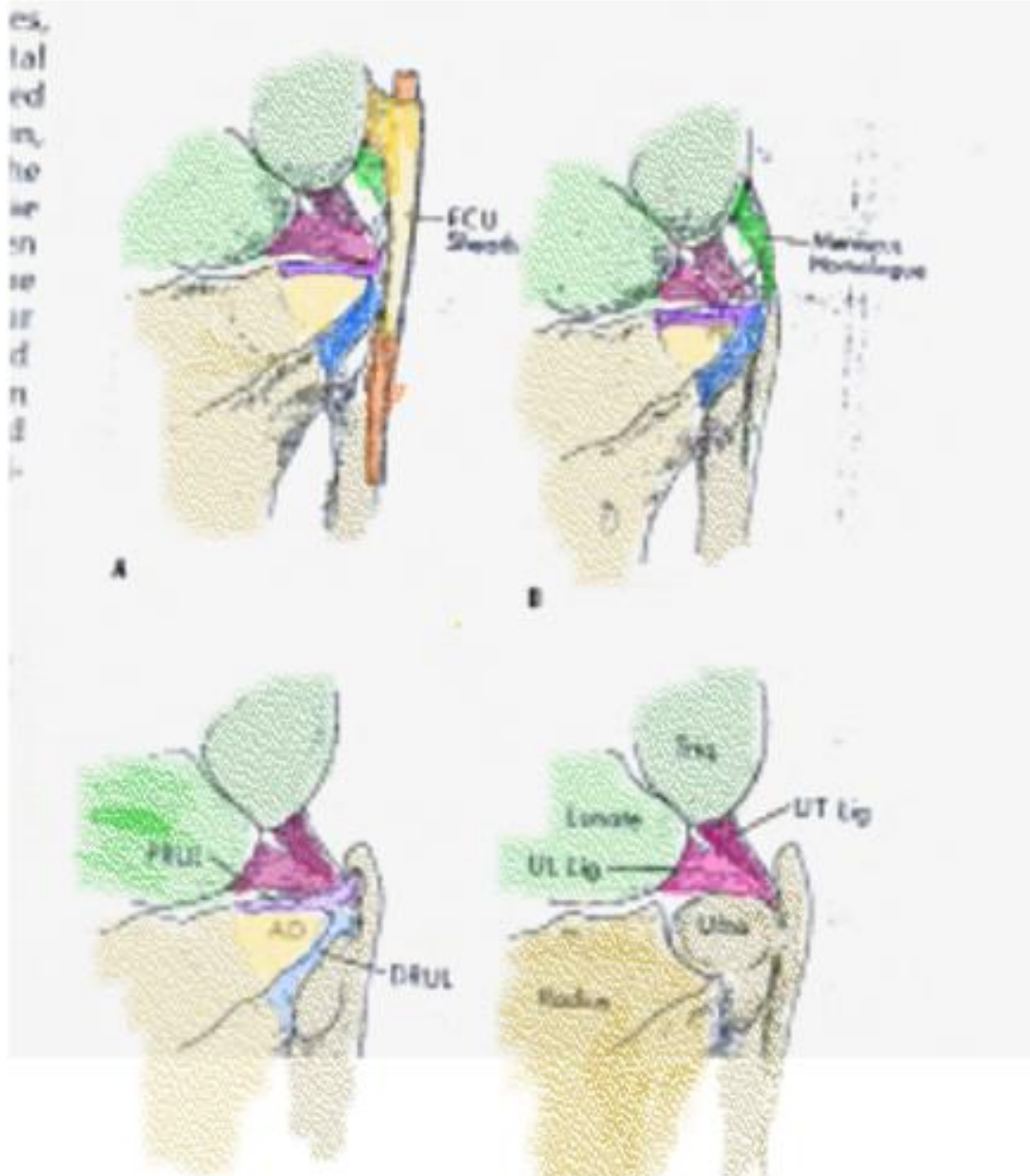
TFCC

- Central disc avascular cartilage, synovial.
- Peripheral bands, fibrous vascular, RU ligaments
- Deep fibres RUL attached to fovea
- Superficial RUL attached to base of styloid.
- Ref Kleinman W.B JHS 2007 32:7,1086-1106

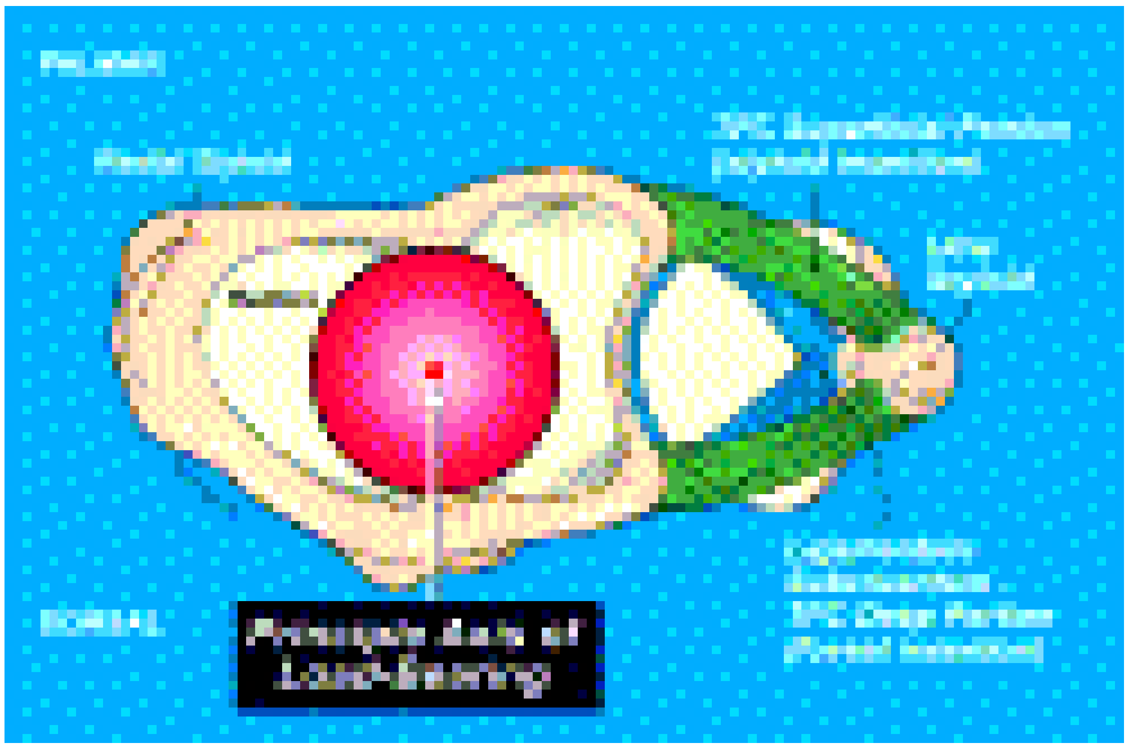


TFC

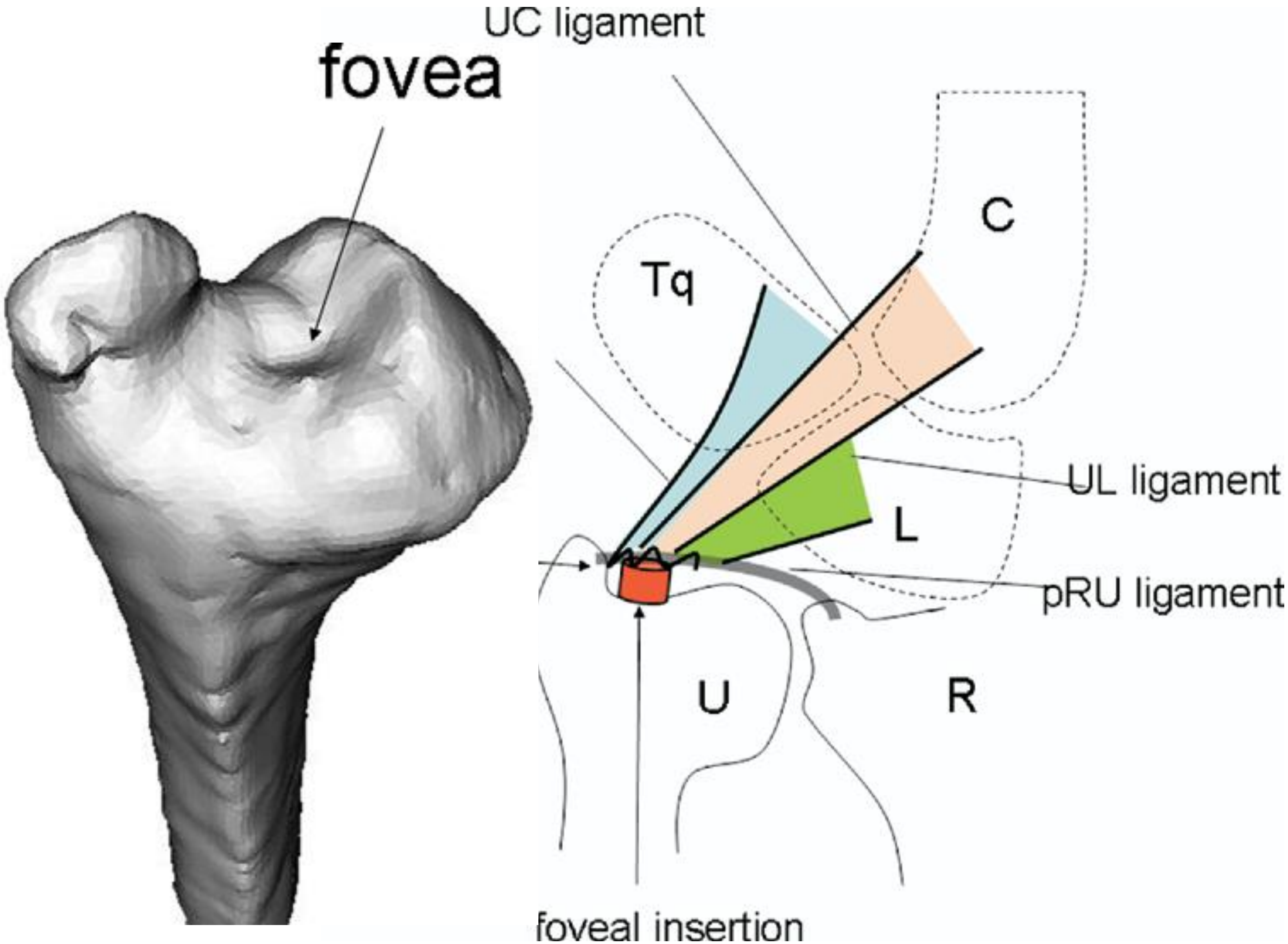
(Palmer 1989)



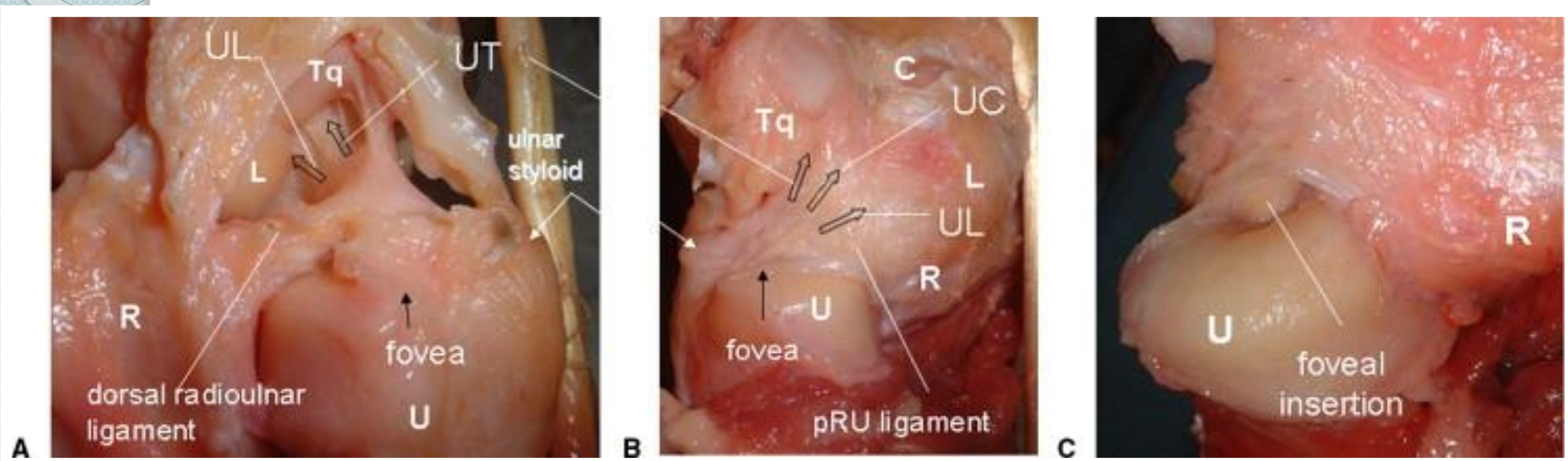
DRUL (Kleinman)



Ulnar carpal ligaments (Moritomo)



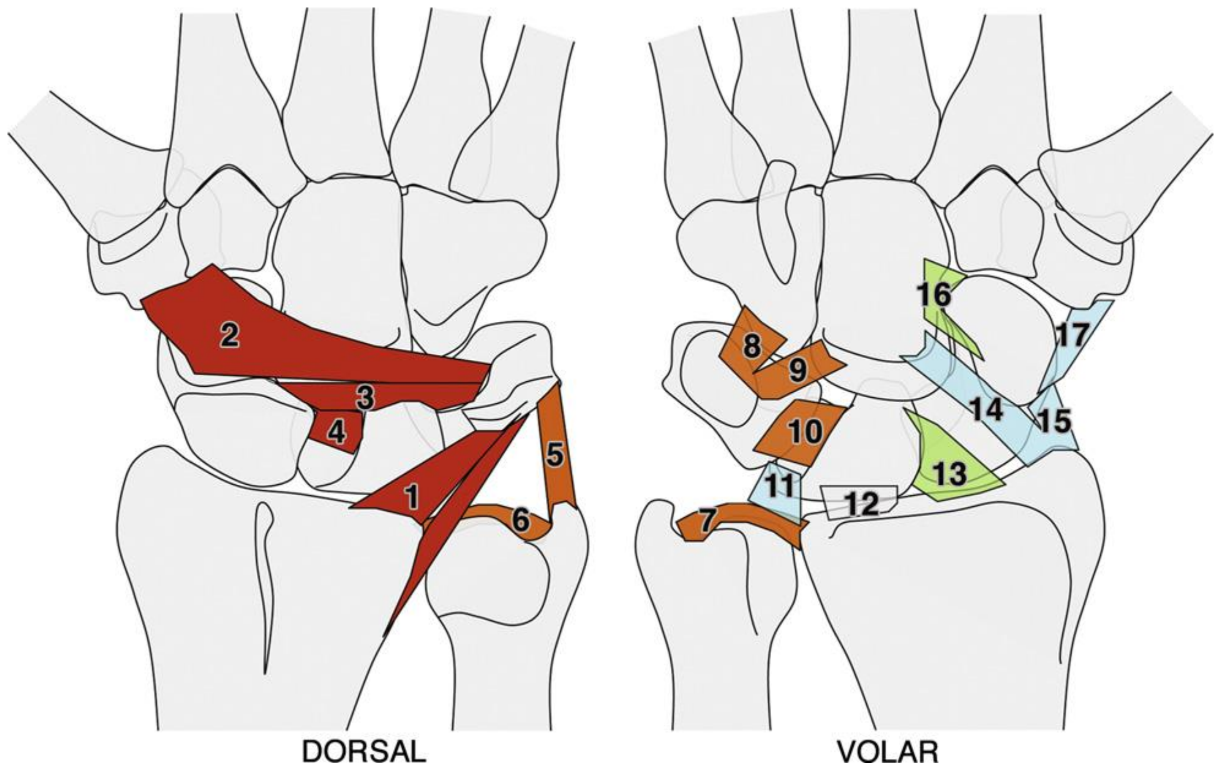
Volar ulnar carpal ligs.



Journal of Hand Surgery 2008; 33:1278-1286

Innervation patterns of wrist ligaments

- Hagert thesis 2008



BIOMECHANICS

- KINEMATICS: mechanics of motion.
- KINETICS: mechanics of stability

Carpal mechanics.

Eight bones schematically arranged into proximal and distal ROWS. Scaphoid articulates with both rows.

Extensive carpal mobility would be impossible without SL inter action. Mutual displacement of S&L indispensable in allowing prox. row to articulate with distal radius .

Lunate and capitate are "intercalary" bones between radius and third MC. Mechanical this joint would "collapse in zig zag fashion with force. The scaphoid acts as brace across the joint. Cf diag

Carpal Kinematics-
"a work in progress "

1. Column theory
2. Row theory
3. Oval ring
4. Dart throwing motion.

Who's in charge scaphoid or triquetrum??

Column Theory .

Navarro 1921 columnar:

Central:L C H - flexion extension

Lateral: S T T –load bearing and thumb

Medial: Tq P – roation.

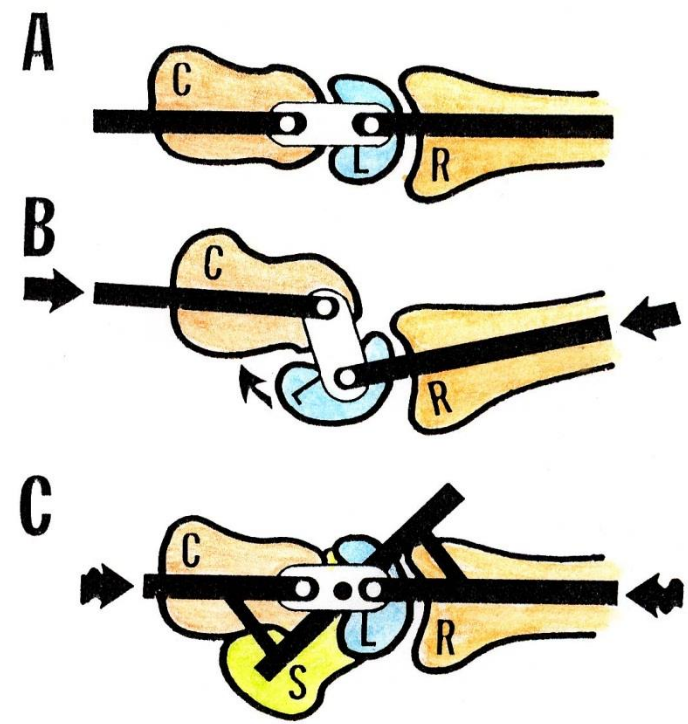
Taleisnik (1976,) describes .

central columns of lunate with distal row

- and two lateral columns.
  - scaphoid(mobile) and
  - triquetrum(rotatory)

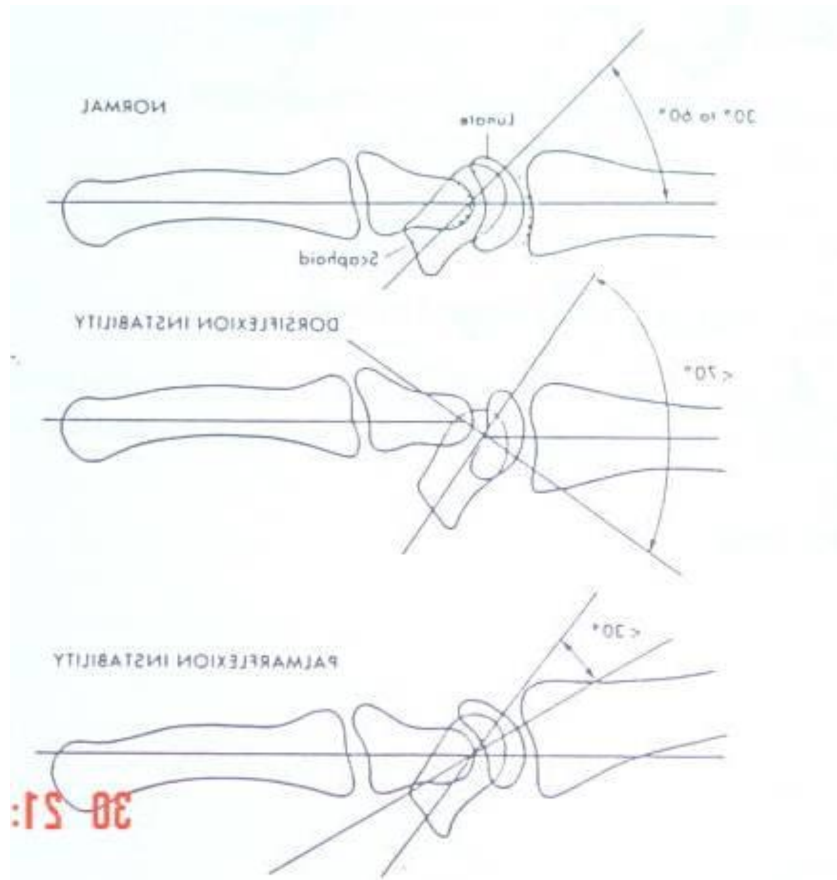
Theories of carpal motion
Row concept.

- Gifford 1943 link mechansism: intercalated segment
- Linscheid 1972; furthered intercalated segment with scaphoid as bridge.



Row theory- DISI and VISI

- Landsmeer, (1968,1976 and Kauer (1964) compared mechanism of carpals to that of longitudinal parallel chains / Rows. Describe collapse paterns or DISI and VISI



Oval Ring theory

Lichtman(1981)

- defined the oval ring concept.
- Complex relationship between the two Rows,
- radial link of STT
- ulnar link of TqH

Weber:(1981.84)

Controlling influence of Tq / Hamate joint

Craigen & Stanley (1985)

- Plain xray study of 52 wrists in vivo
- Described two kinematic patterns of the scaphoid.
- One pattern for FE
- Another pattern for RUD
- Influenced by joint ligament laxity.

DTM (Dart throwing motion)

Moritomo (2004)

Plane in which wrist functional oblique motion occurs. ie radio-dorsal, ulnar- palmar, through MCJ.

- Most commonly used plane of rotation in ADL.
- Can occur with minimal MM force (tenodesis effect), less scapho–lunate motion.
- Oblique ridge on distal scaphoid, guides STT motion.
- Helicoid configuartion of Tq H articulation favours DTM.
- STT lig. configuration help control guide DTM
- Dynamic control by ECR and FCU (consider also functional forearm rotation mid pronation)
- Suggest could be most stable and controlled wrist motion.

Gardener et al (2006)

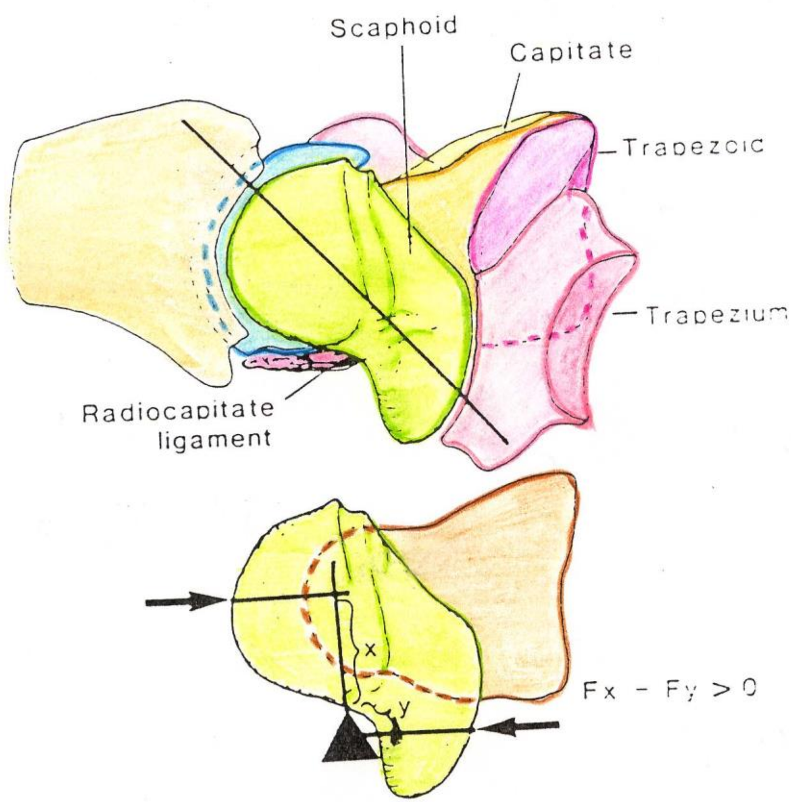
Despite many studies of carpal mechanics over past 100years , no unanimous theory or model fully explains wrist anatomy and function

Proximal row mechanics

Proximal row as the intercalated segment of the wrist, is where the majority of motion occurs.

- Motion is complex and determined by shape of articular surface and the tension in the restraining structures
- Motor arms pass over the carpal region and attach to base of metacarpals, movement of distal row as one unit, tenses up MC ligaments and moves proximal row
- Scaphoid has a natural tendency to flex and the triquetrum to extend. As long as SL and LT ligaments are intact the proximal row is balanced (Berger2000)
- Prox. row bones rotate synchronously in flexion and RD, but rotation of Scaphoid greater than lunate and Tqtm

Scaphoid angle



Kinematics: flexion-extension

FLEXION:

- TPZM pressure down on scaphoid cause this to flex around pivot of RSCL. This unlocks mid carpal joint.
- Movement occurs at midcarpal joint with capitate flexing on lunate.
- Dorsal ligaments are stretched TQTM moves distally to radial articular surface of HMT

Kinematics: flexion extension

EXTENSION:

- Palmar ligs. tensioned through ECR ECU action on MC and distal row.
- Tension in STT and RSC lig across neck of scaphoid cause extension of scaphoid
- Extn of scaphoid translates through SLL to extend Lunate
- Extension of scaphoid stops before extension of lunate continues further , Capitate extends with lunate.
- Triquetrum moves proximally on Hamate

Kinematics : deviation

RADIAL DEVIATION

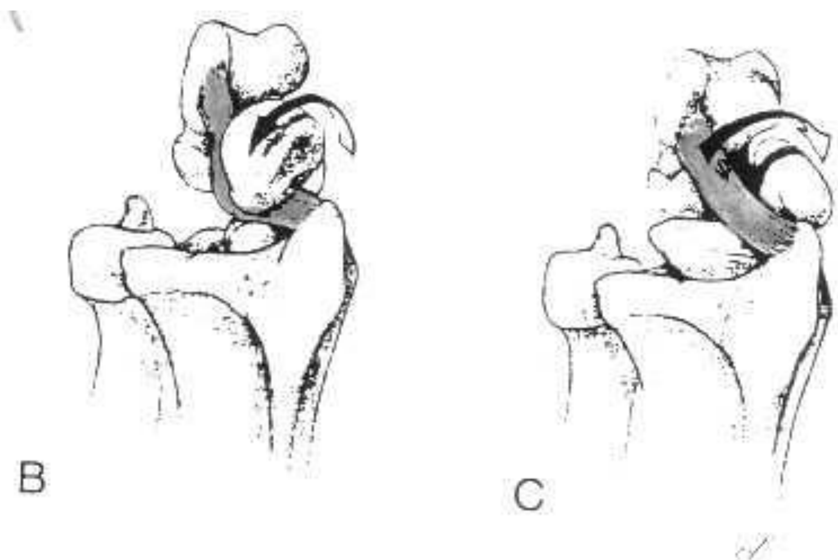
- FCR ECR pull on 2nd MC, push on TPZM, pushes SCPD to flex over RSC to neutral
- Hamate translates as part of DR, TQTM translates radial/ proximally and dorsally on the slope of Hamate
- LUN: flexes with scaphoid through SLL also pulled by TQTm Ligs. , dorsal to axis of capitate , compressive forces cause slight palmar flexion of LNT.
- Ulnar translation of carpus is checked by DRT lig.

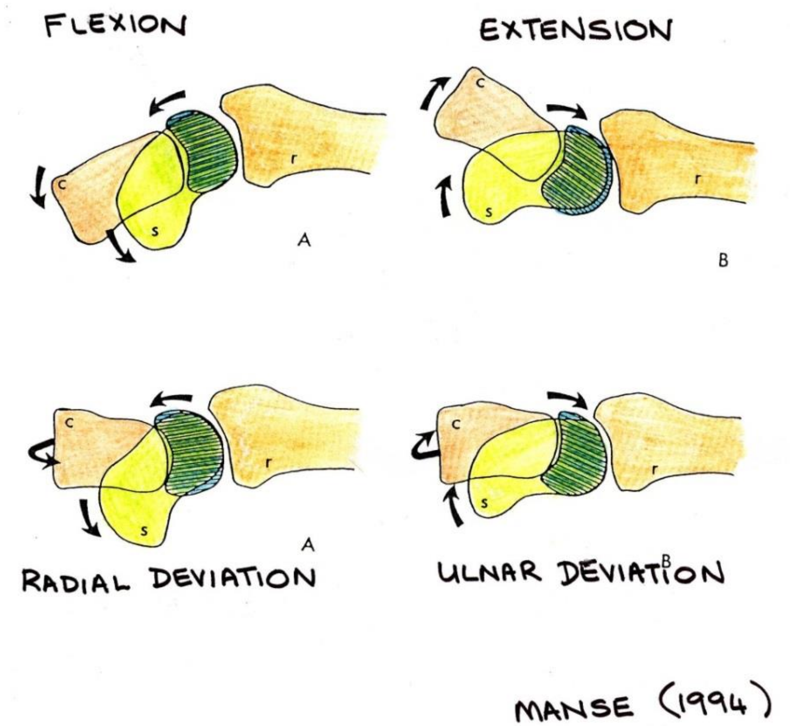
Kinematics : deviation (2)

ULNAR DEVIATION

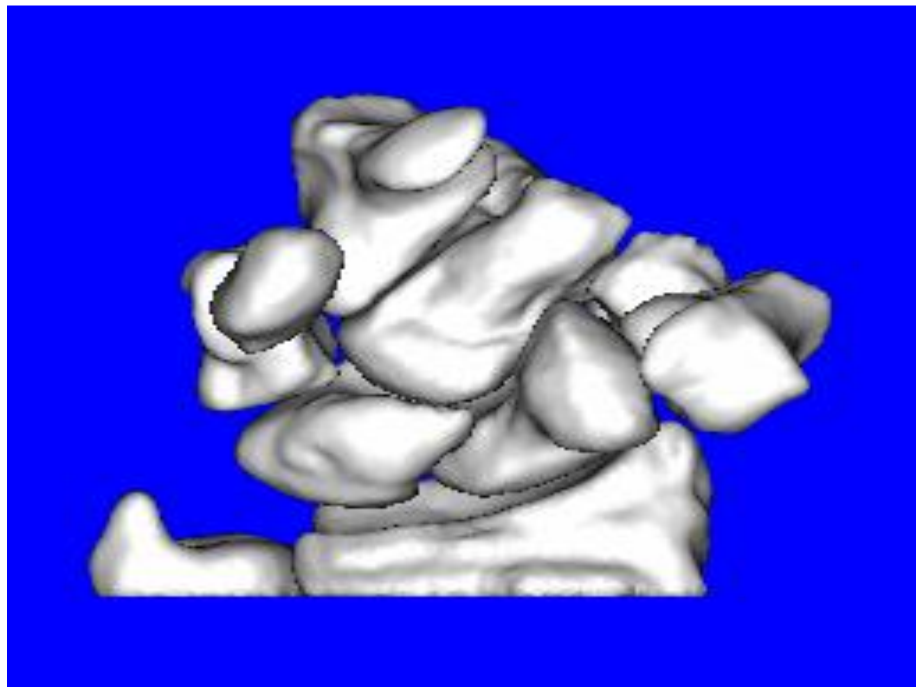
- ECU AND FCU :TQTM translates ulnarly/ distally on HmT also forced palmarly
- Palmar translocation of TQTm forces lunate axis palmar to capitate and Lunate extends.
- EXTn of lunate elevates distal pole of SCPHD into extn.
- TPZM moves distally checked by RST ligs, pulls scaphoid into EXTN,
- TQTM limited by UH, compresses Lunate which dorsiflexes.

Scaphoid motion

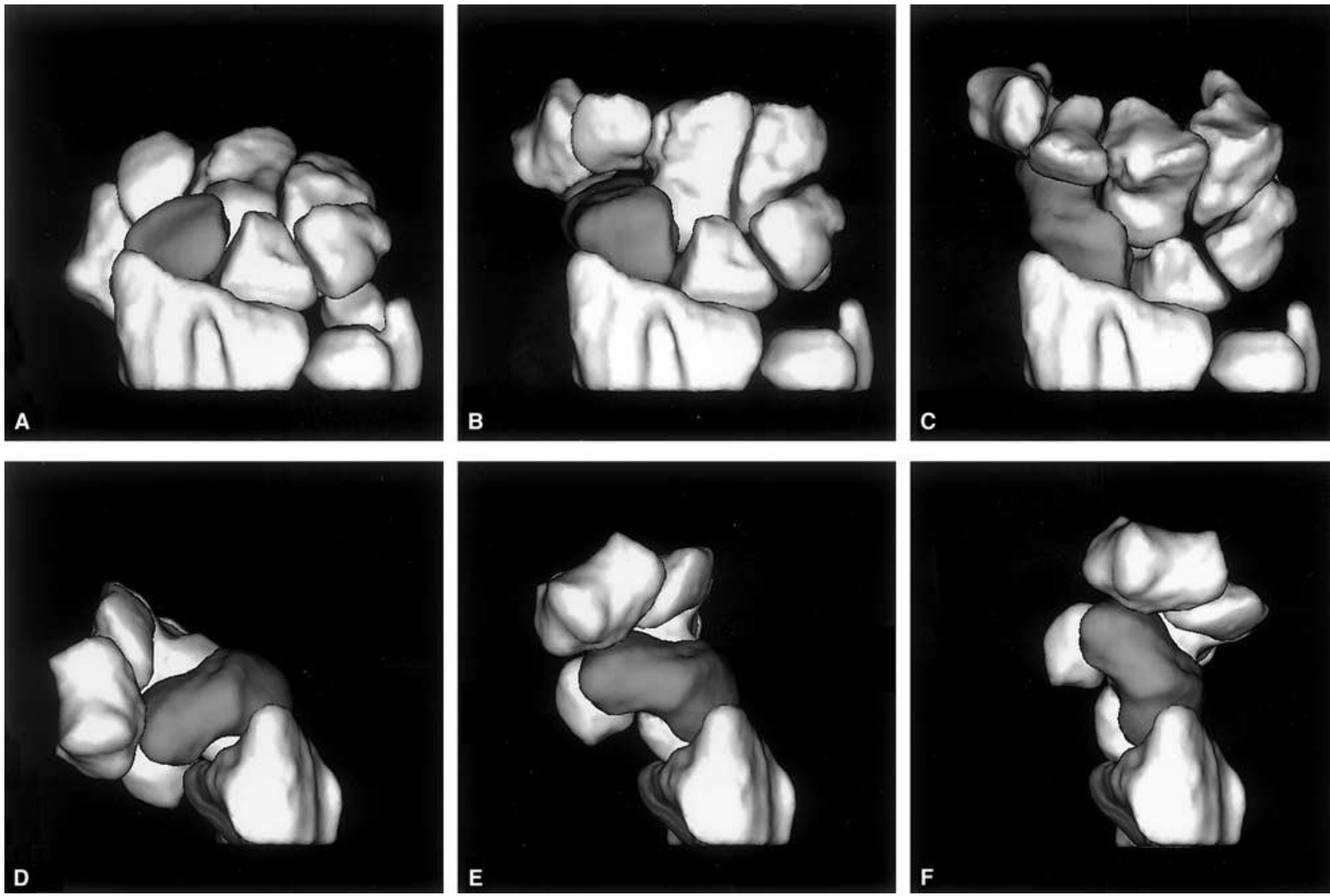




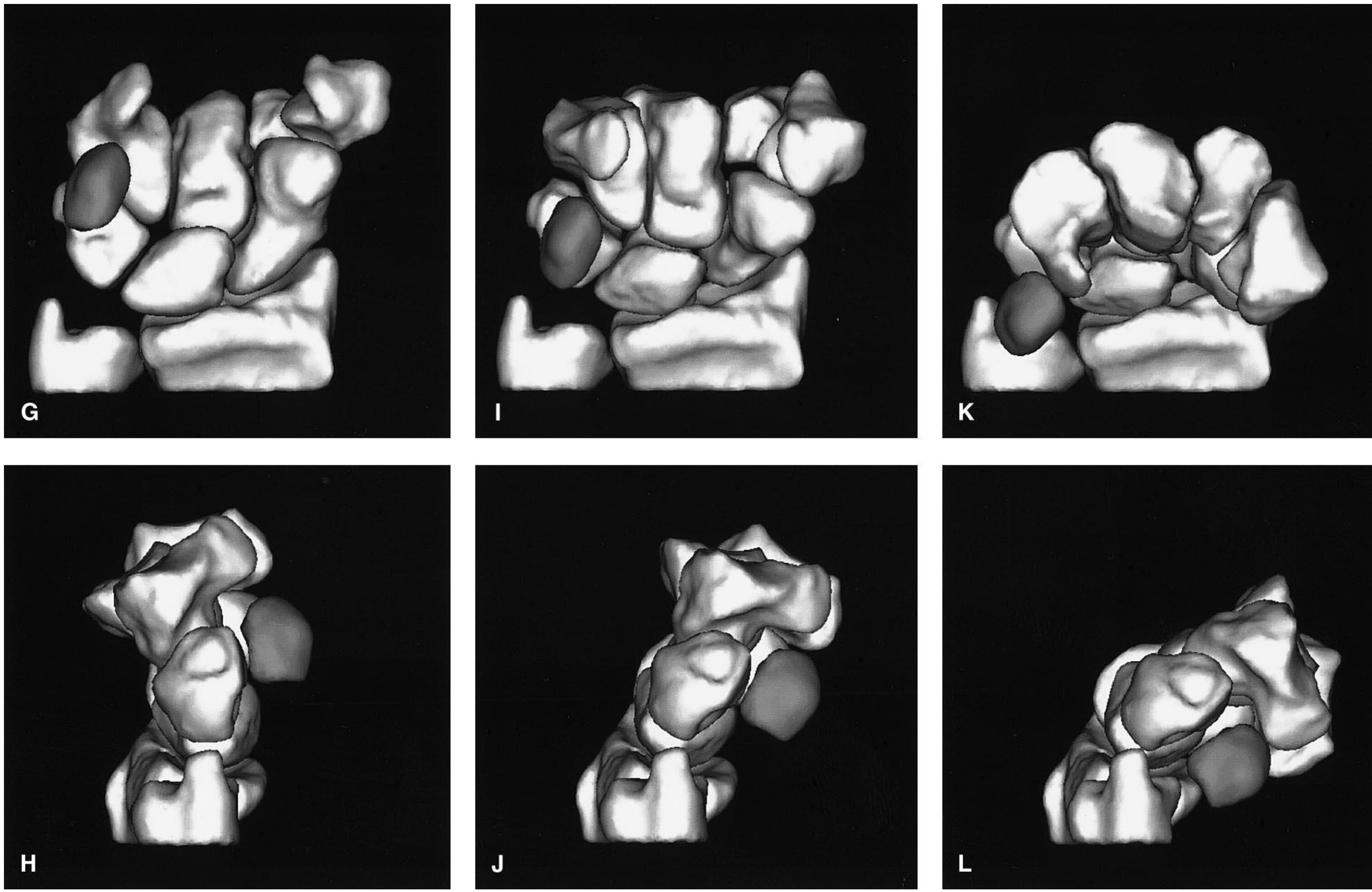
In vivo carpal motion Moojen et al 2003 (www.jhandsurg.org) http://www.uba.uva.nl/nl/publicaties/snel/animaties.html)



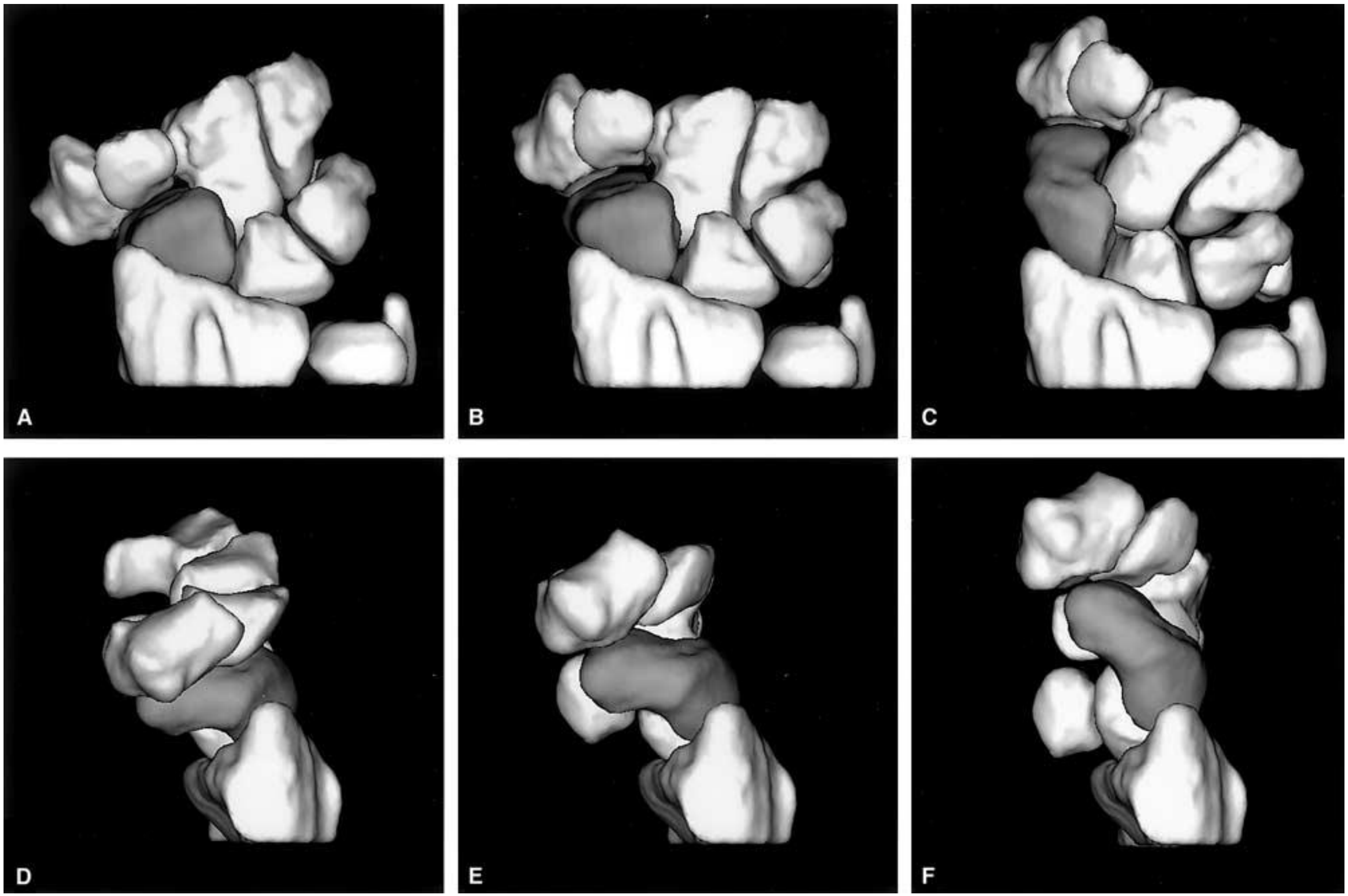
Scaphoid motion F-E in vivo



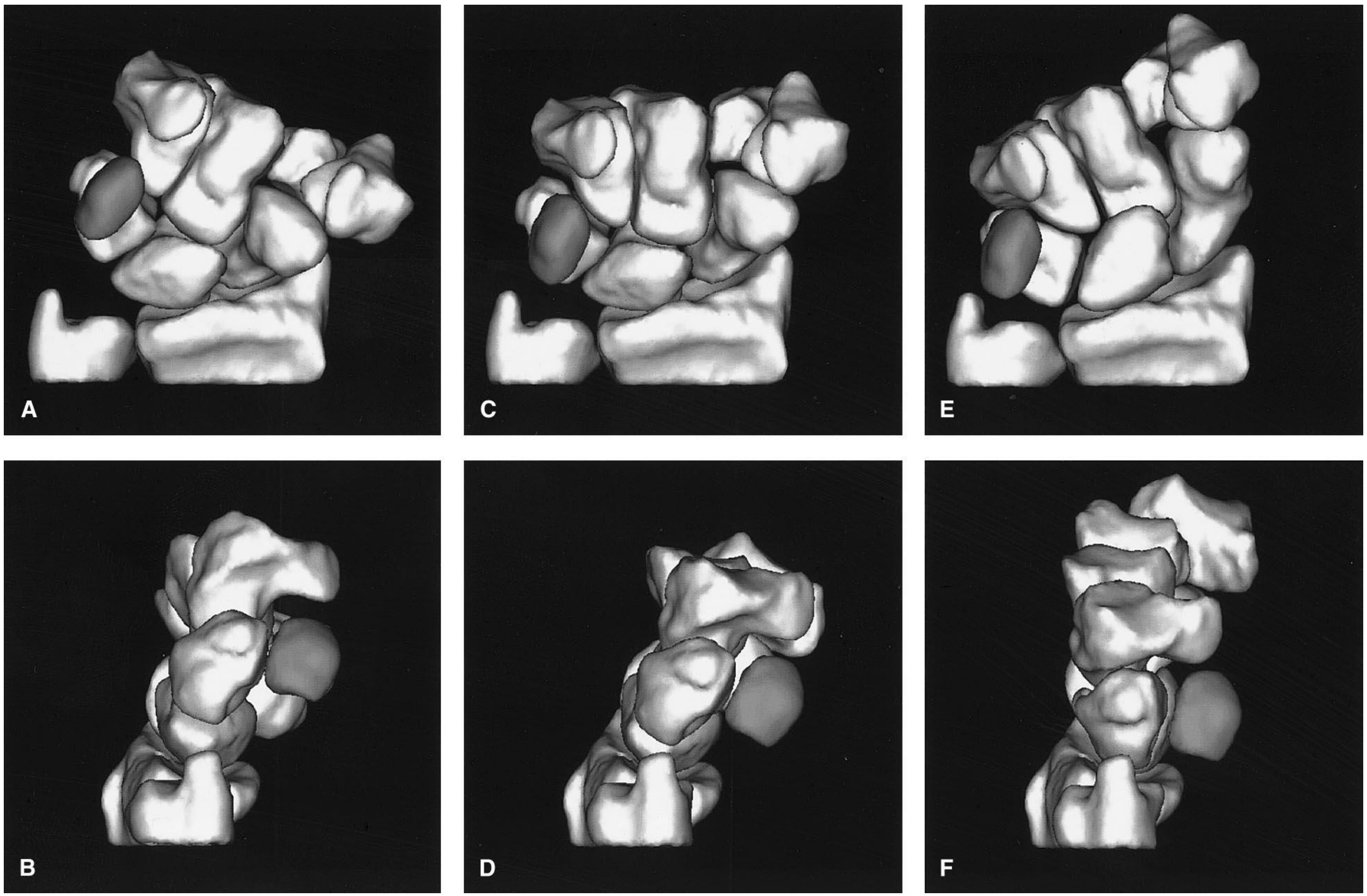
Pisiform motion F-E in vivo



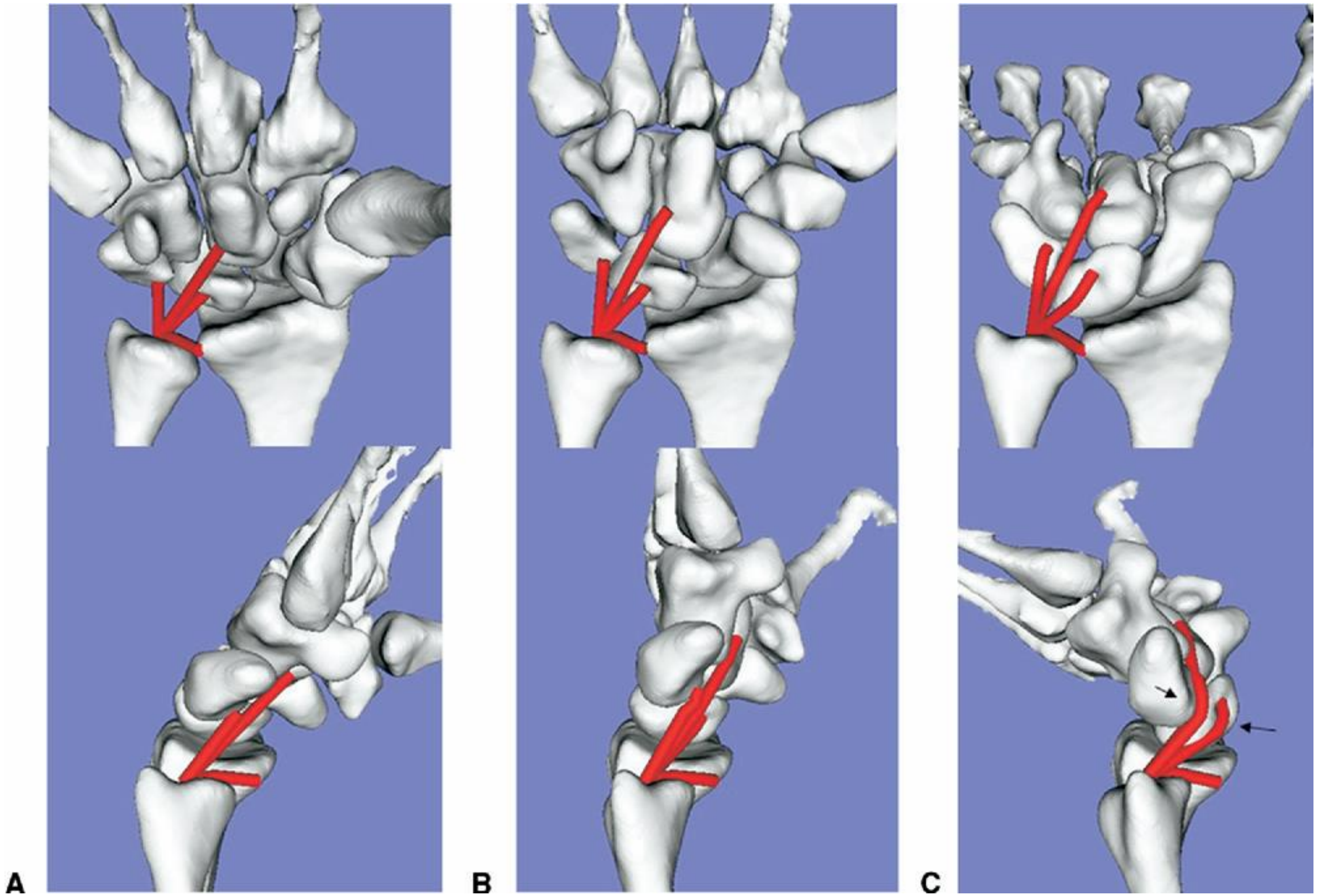
Scaphoid motion R-UD in vivo



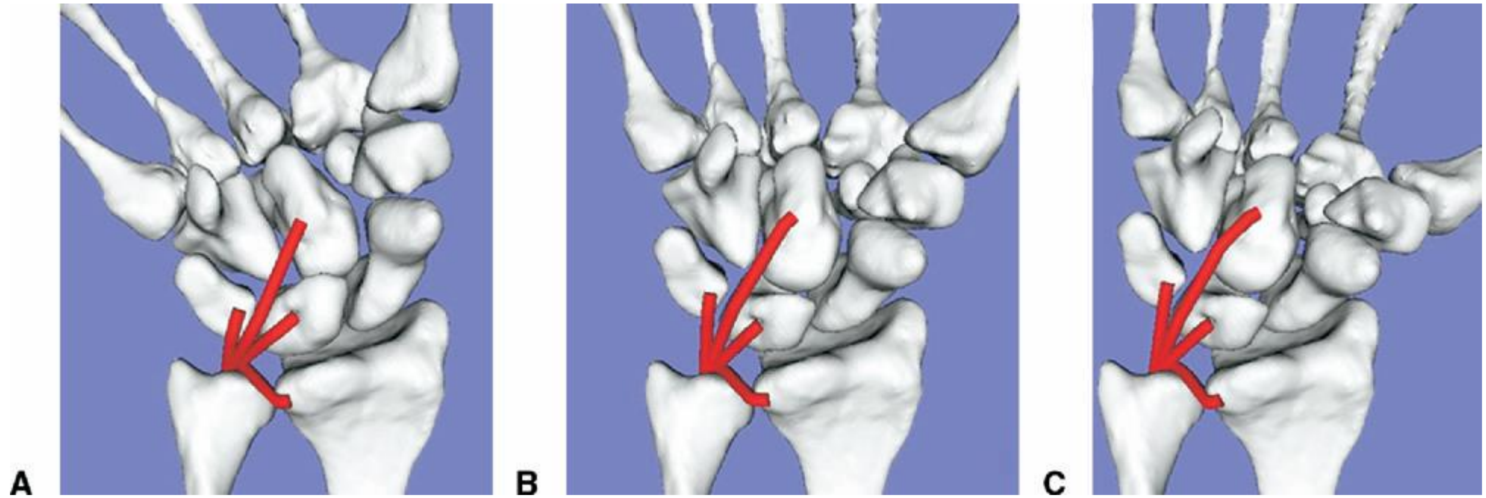
Pisiform motion R-UD in vivo

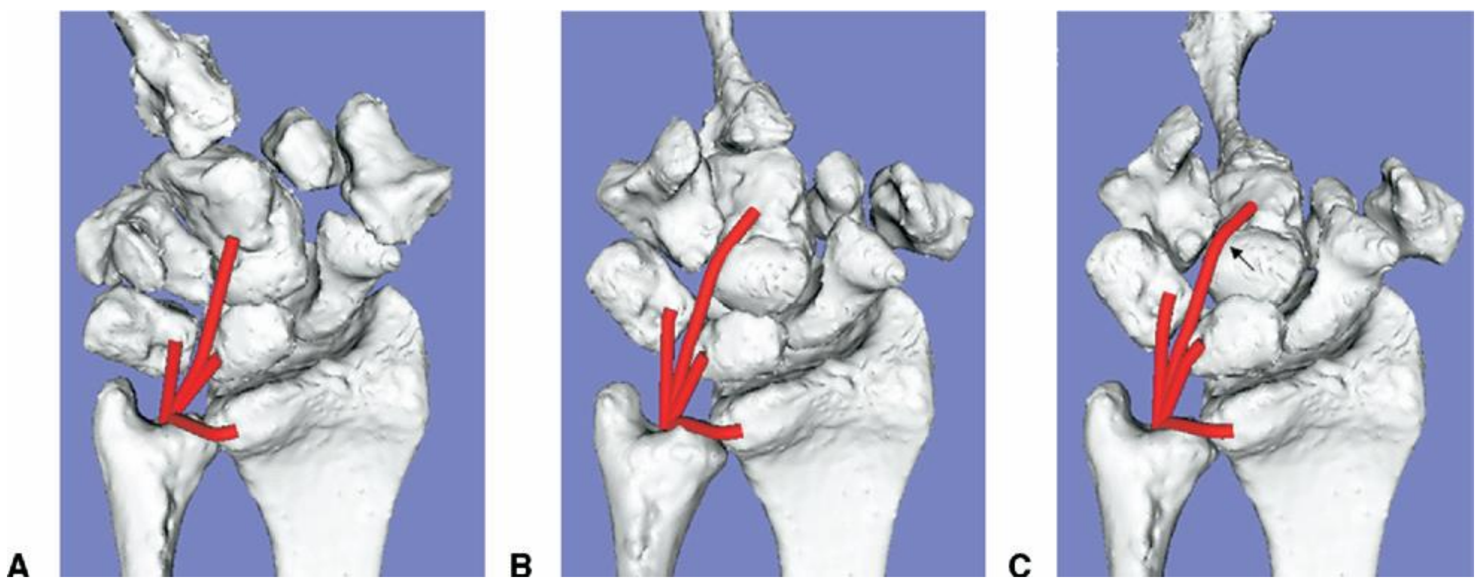


Moritomo: JHS 2008
(a) F (b) N (c) E



3D ligament paths (Moritomo)



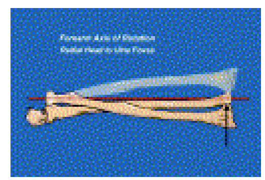


Pronation - Supination

- DRUJ .IOM and PRUJ form one forearm joint. (Hagert 1992).
- Curved radius with hand attached rotates around the ulnar.
- Ulnar head a/s much greater than shallow sigmoid notch

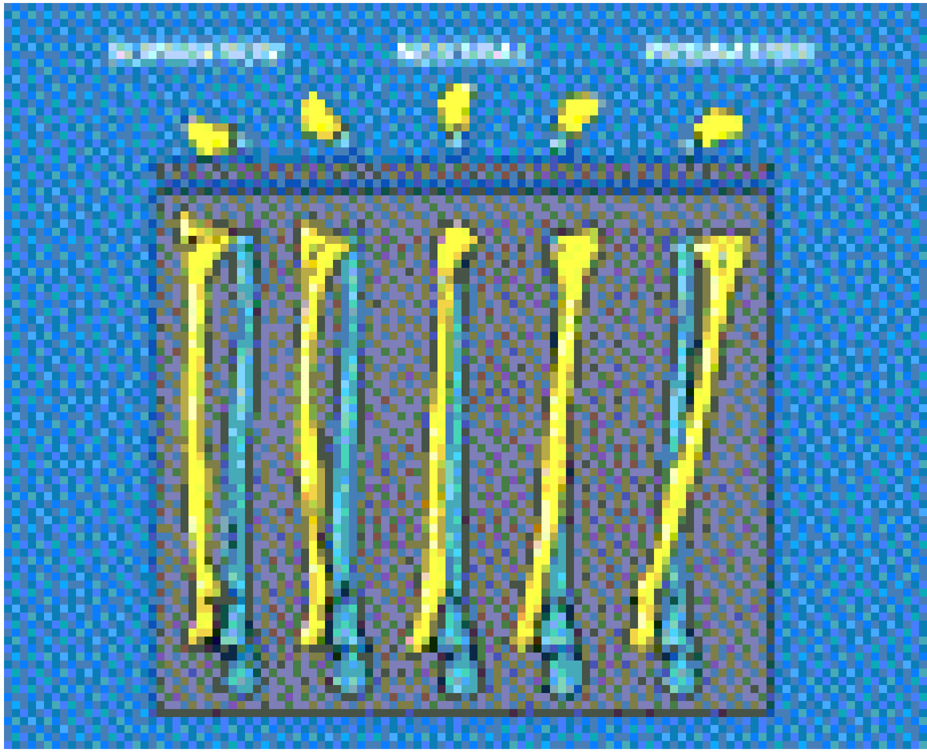
Axis of rotation: importance of ulnar fovea

- Long axis of rotation from centre of RH to Ulnar Foveal sulcus.
- Ulnar fovea: recess between cartilage of ulnar pole and styloid
- Richly vascular
- Attachment of ligs.
- Position critical to rotational and translational stability.



Prono-supination (Kleinman)

- At DRUJ, ulna head serves as fixed keystone for DR to rotate around
- Stability and function depend on length of the 2 bones, change in length of ulna by 2mm changes transmission of forces from 5-40% (Palmer 1987)
- Nb DRUJ frequently displaced by DR #.



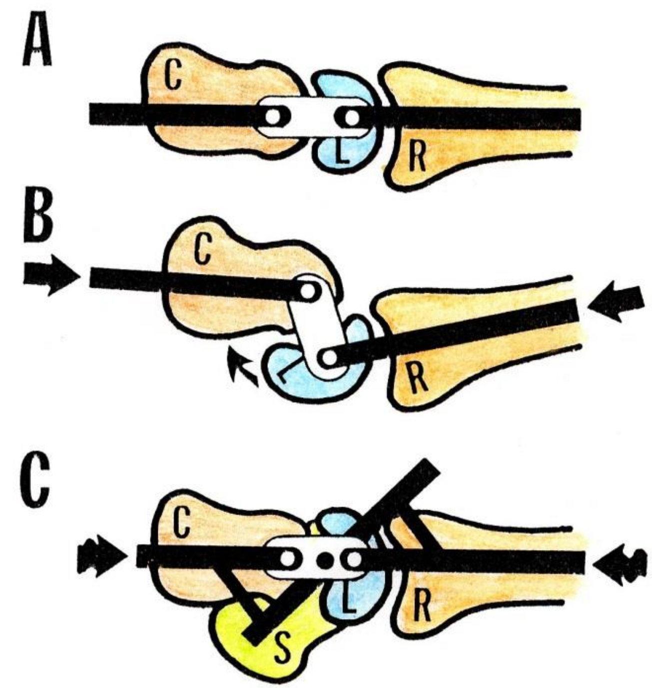
Wrist Kinetics (stability)

- Stability in any given joint is a combination of bony shape and joint congruity and compressive forces provided by static capsular /ligamentous restraints and dynamic forces of co contracting muscles.
- Joint Stability influenced by proprioceptive feedback loop.

THEORIES OF STABILITY (1)

RADIO CARPAL JOINT

- **Gifford et al :** intercalated bridge
- **Landsmeer:** Opposing motion of Prox row . (practical demo)



Theories of Stability (2) RCJ

- **Mayo clinic**

  - Distal row tendency to divergence countered by strong interosseous bands.
  - MICJ: under axial load tendency to collapse across MICJ, with prox row flexion, distal row extension. Arcuate ligament, SC and TqH very important. (if torn or lax tendency for VISI). Also DIC important stabiliser
  - Proximal row: under axial load, scaphoid greater rotation than others, increased torque at SLL , increased co-aption of joints.
  - Radio carpal. Tendency to slide ulnarly and palmarly, resisted by palmar and dorsal radiocarpal ligaments.

DRUJ and TFCC STABILITY

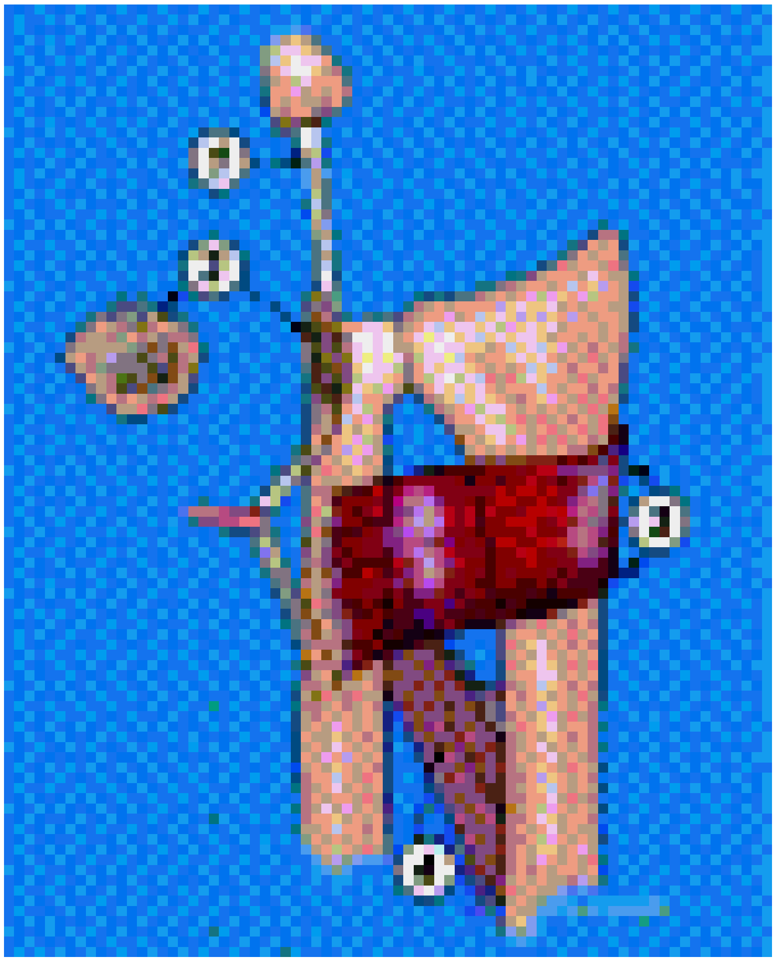
Motion: Sigmoid notch curve of radius greater than curve of ulna,

- **head of ulnar does not just rotate but slides and rotates**.
- Neutral in optimal contact position (70%), diminished at extremes (11 %). (a factor in instability).

Stability of DRUJ accomplished by

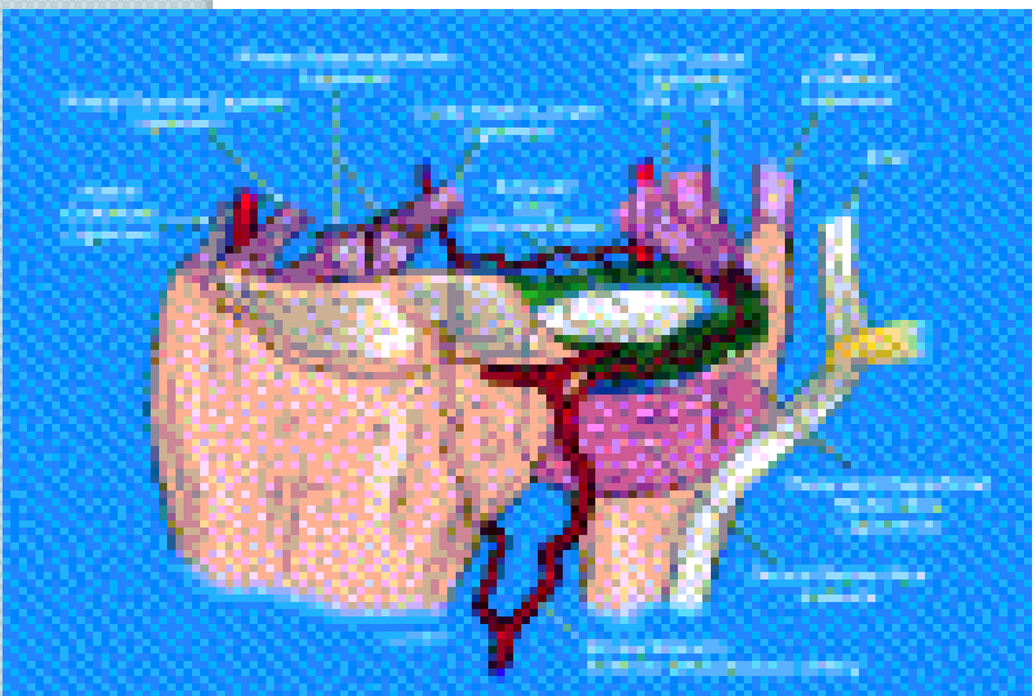
- joint congruity (small),
- **TFC(disc)** provides intrinsic stability with fibrous attachments. And transmits forces
- tension in capsule /ligaments: **DRUL,VUCL**
- dynamic muscle control **PQ /ECU**
- **IOM**

Extrinsic stabilisers-DRUJ



1. Dynamic tension of ECU
2. Semi rigid 6th dorsal compartment.
3. Superficial and deep heads of PQ
4. Interosseous ligaments.

Intrinsic stabilisers- DRUJ



- TFCC
- Dorsal and Palmar RU ligs.arise form medial borders of sigmoid notch
  - Deep insert into fovea
  - Superficial into styloid. (vascular)
- Ulnar/disc lunate ligs
- Ulnar/disc triquetral ligs
- Central disc (avascular)

Theories DRUJ stability
"Conflict/confusion"

Ekstrom & Hagert (1985, 1992)

- Deep fibres principle stabilisers.
- **SUPIN: Dorsal** fibres tight.
- **PRON: Palmar** fibres tight.

Schuind et al (1985)

- SUPIN: Palmar fibres tight.
- PRON: Dorsal fibres tight

Hagert 1994 "Illumination"

Reviewed conflicting papers ,concluded researchers looking at different components.

- 1985: **Hagert** assessed **deep** fibres (superficial dissected)
- 1991; Schuind used markers picked up superficial fibres.

SUPIN: palmar superficial: dorsal deep

PRON: dorsal superficial: palmar deep

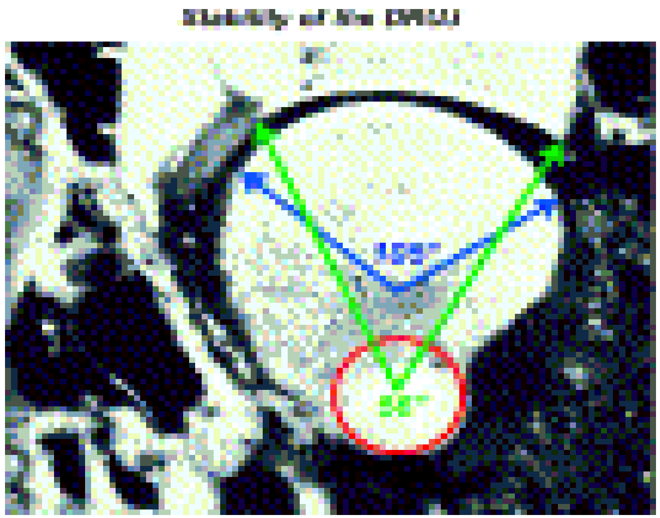
Kleinman 2007 “clarity”

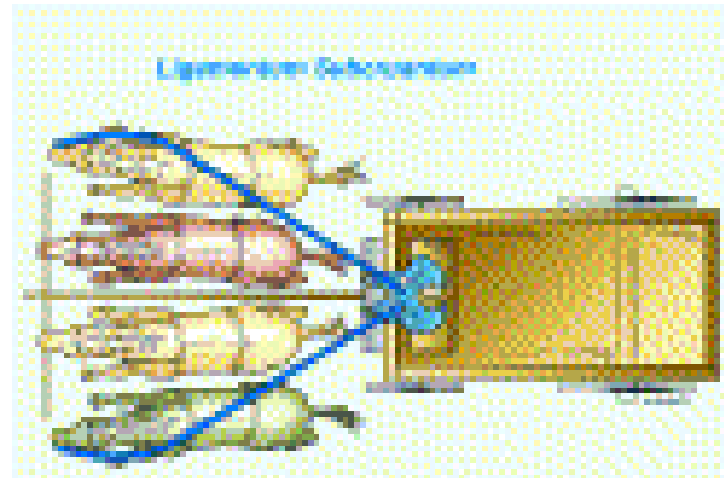
Believes the Deep Foveal fibres (ligamnetum subcruentum) are the principle stabilisers.

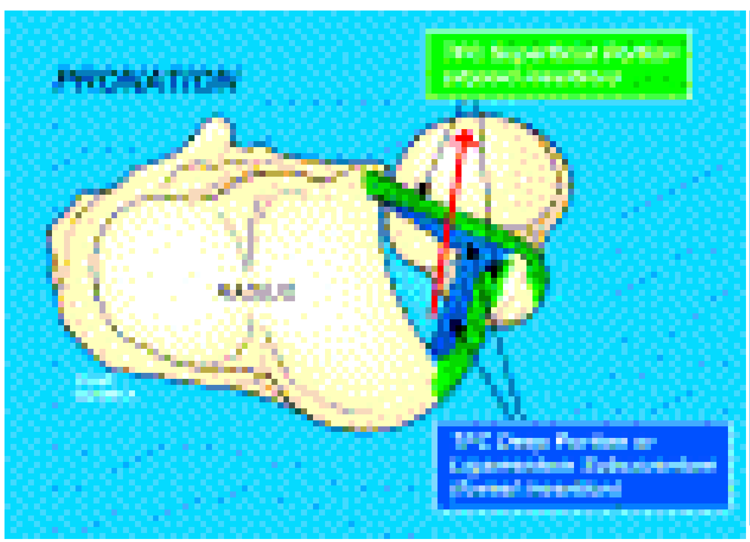
Due to;

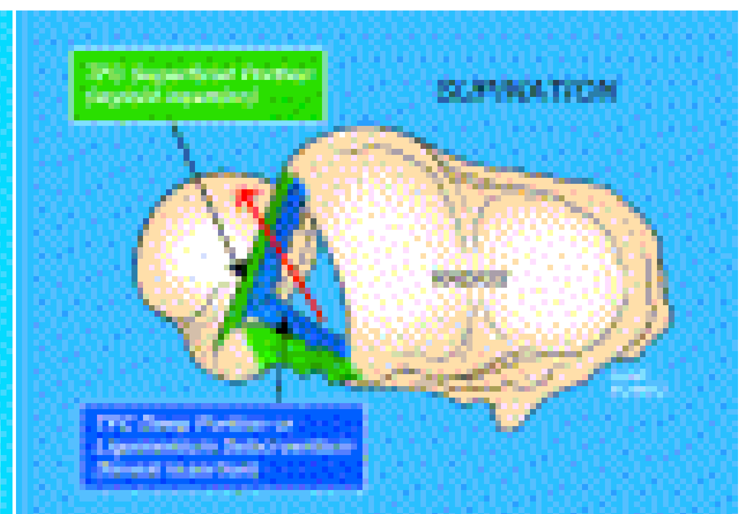
- Translation of ulnar head in extremes rotation renders superficial fibres ineffective stabilsers
- Angle of the deep fibres mechanical advantaged to restrain radius.(ref diags)

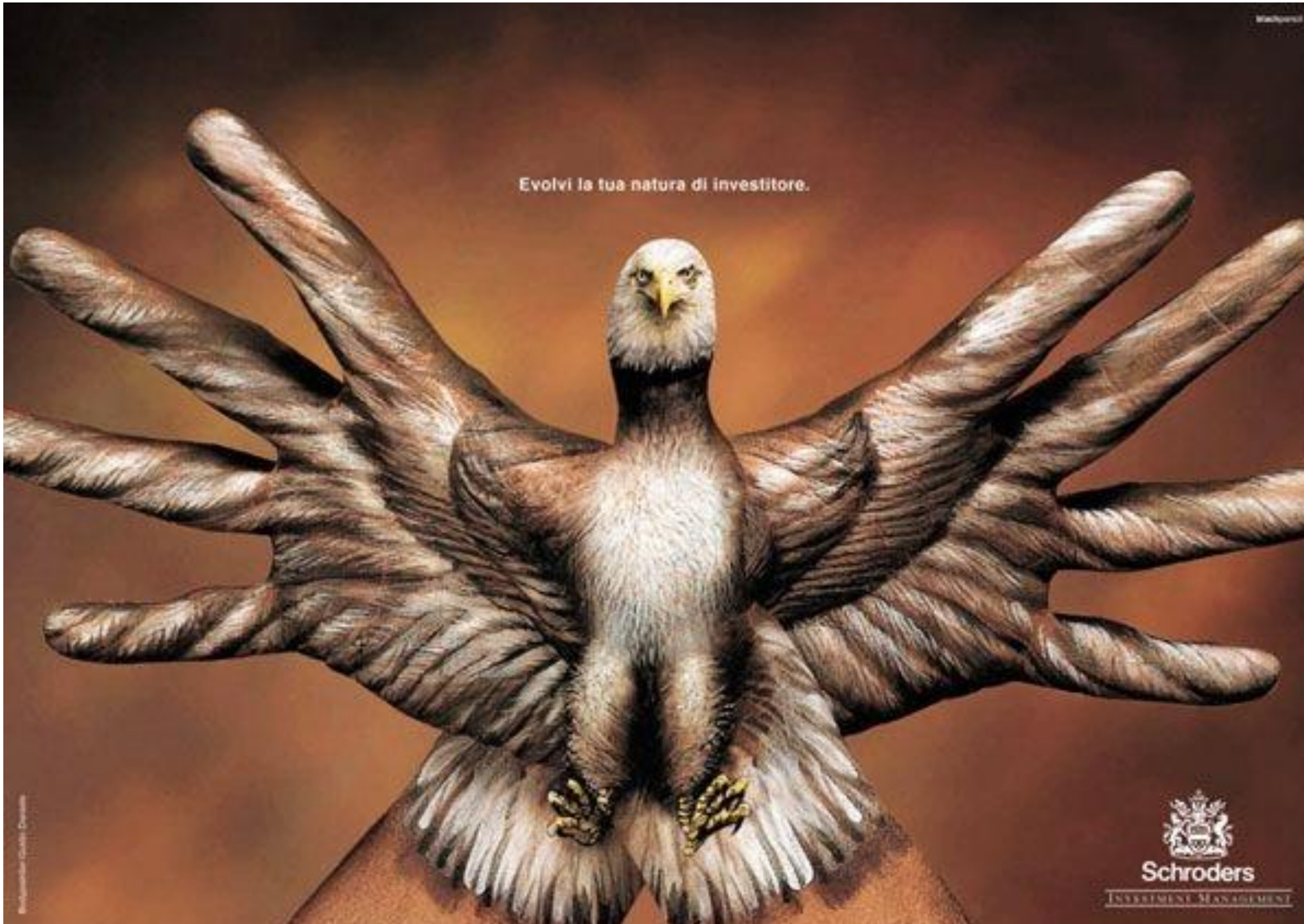
DRUJ stability (Kleinman)







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