Carpal Ligaments
&
Wrist Biomechanics

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Wrist Biomechanics

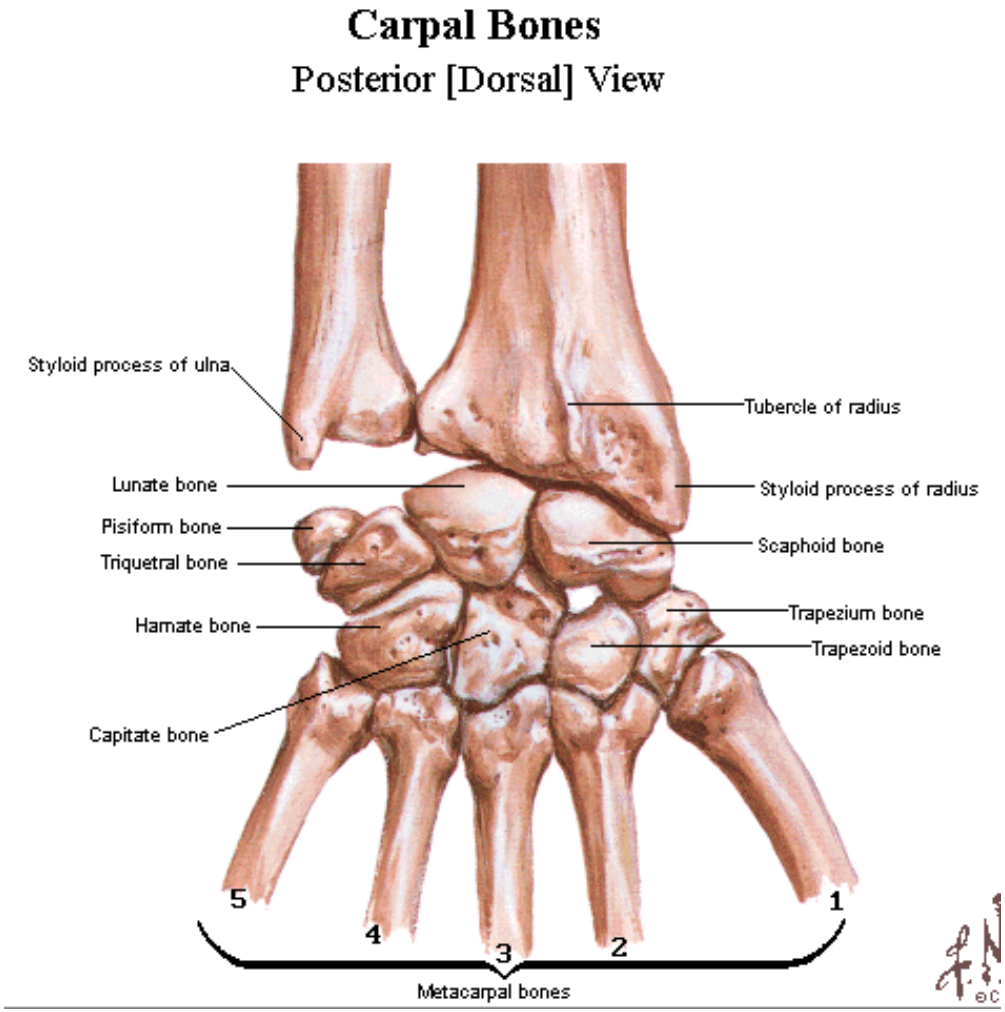
- Anatomy
- Force transmission
- Kinematics

Anatomy

- Carpus – 8 bones

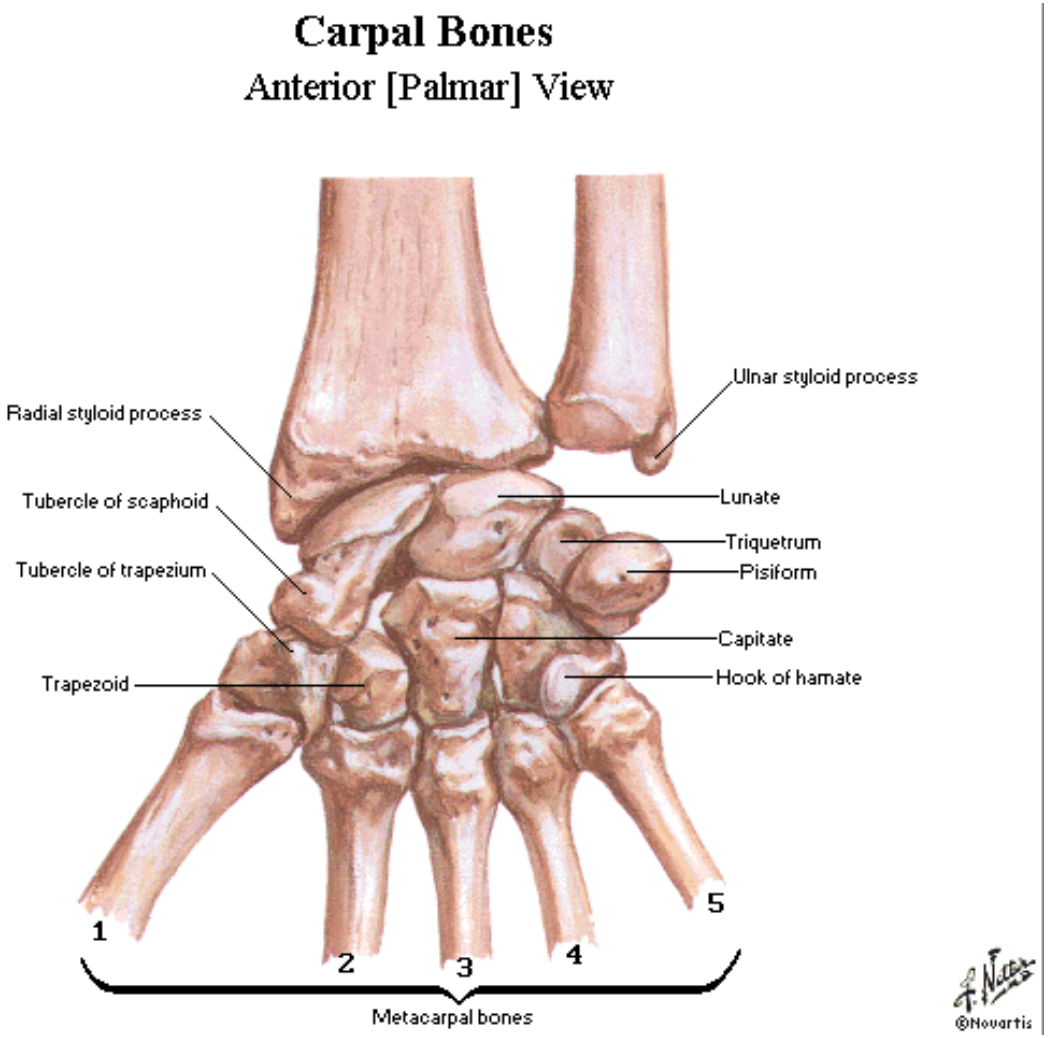
Anatomy

- Complex interlocking shapes
- Intrinsic and extrinsic ligaments



Anatomy

- Proximal surface is an oblong condyle – Radius & TFCC
- Variable geometry to accommodate movements
- Multifaceted articulation meet the need for movement and stability



Ligament Anatomy - Overview

- **Extrinsic or Capsular ligaments**
  - are defined as crossing the radio-carpal joint, the midcarpal joint or both
- **Intrinsic or Interosseous Ligaments**
  - between the bones of either the proximal or distal carpal rows

Ligament Anatomy - Overview

- If more than one ligament connects 2 bones, a modifying term is added **e.g. short, long, dorsal, palmar, deep.**
- **Dorsal ligaments** seen as distinct structures on elevating the extensor retinaculum
- **Palmar ligaments –** better viewed from within the radio-carpal & midcarpal spaces from a dorsal perspective on arthroscopy

Ligament Anatomy - Overview

- Palmar Radio-carpal Ligaments
- Palmar Ulno-carpal
- Dorsal Radio-carpal
- Palmar Midcarpal

- Posterior Row Interosseous
- Distal Row Interosseous
  - » Taleisnik 1976, Berger 1991

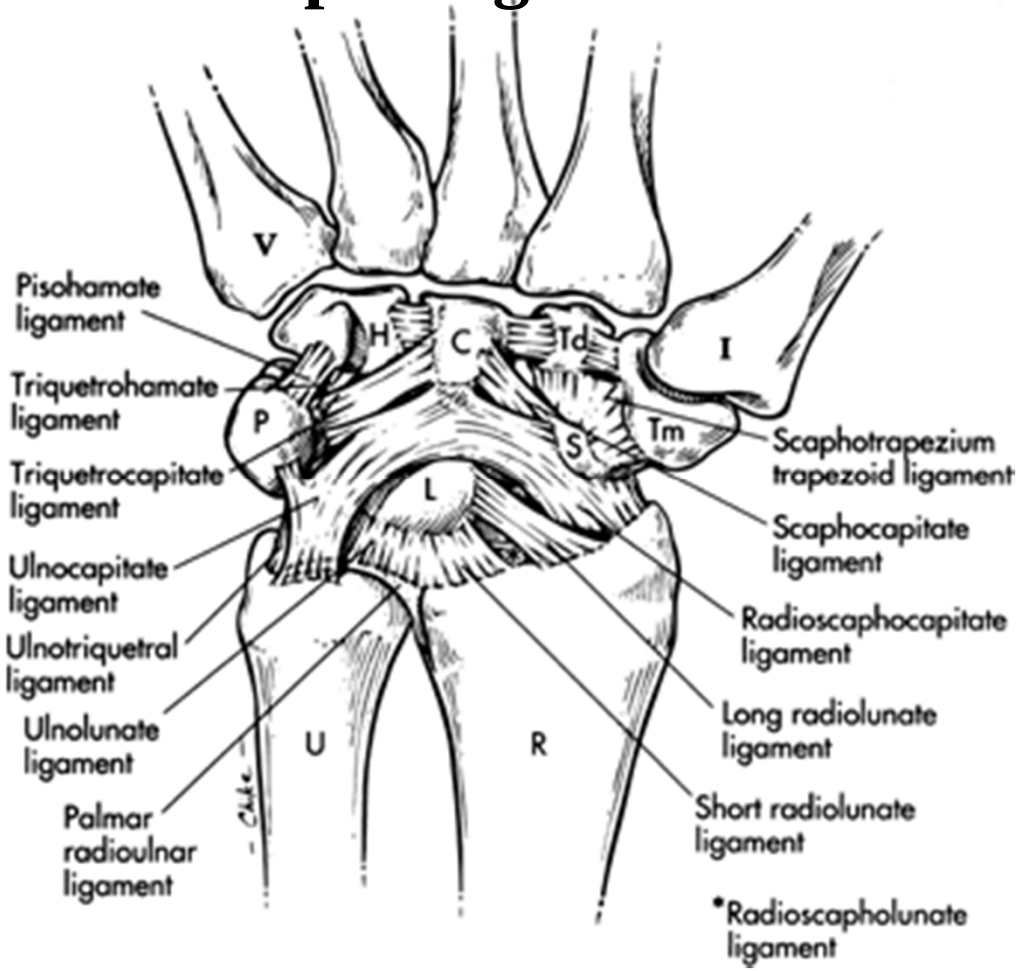
Ligament Anatomy - Overview

Palmar Radio-carpal Ligaments

- Radioscaphocapitate
- Long Radiolunate (radiotriquetral)
- Short Radiolunate
- Radioscapholunate
  - Ligament of Testut---Neurovascular pedicle
    - Br. of Ant. Int Nv + Art. + Radial Art.
      - » Berger J Hand Surg (1996) Gelberman JBJS (2000)

Ligament Anatomy - Overview

- **Palmar Radio-carpal Ligaments**



Ligament Anatomy - Overview

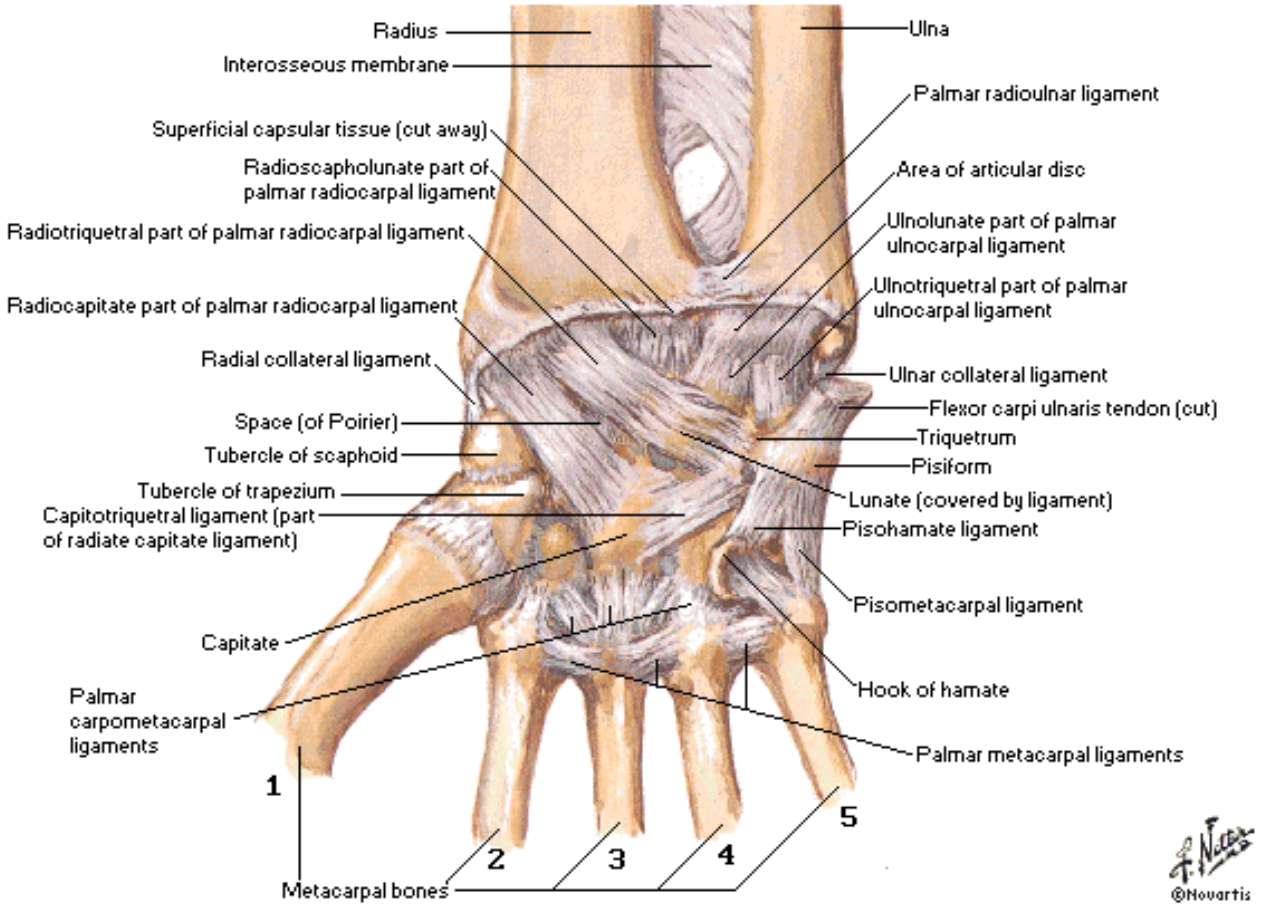
Space of Poirier

- lying between the volar radiocapitate and long radiolunate ligaments
-

  - area expands when wrist is dorsiflexed & disappears in palmar flexion;

  - rent develops during dorsal dislocations, & it is thru this defect that lunate displaces into the carpal canal

Ligament Anatomy - Overview



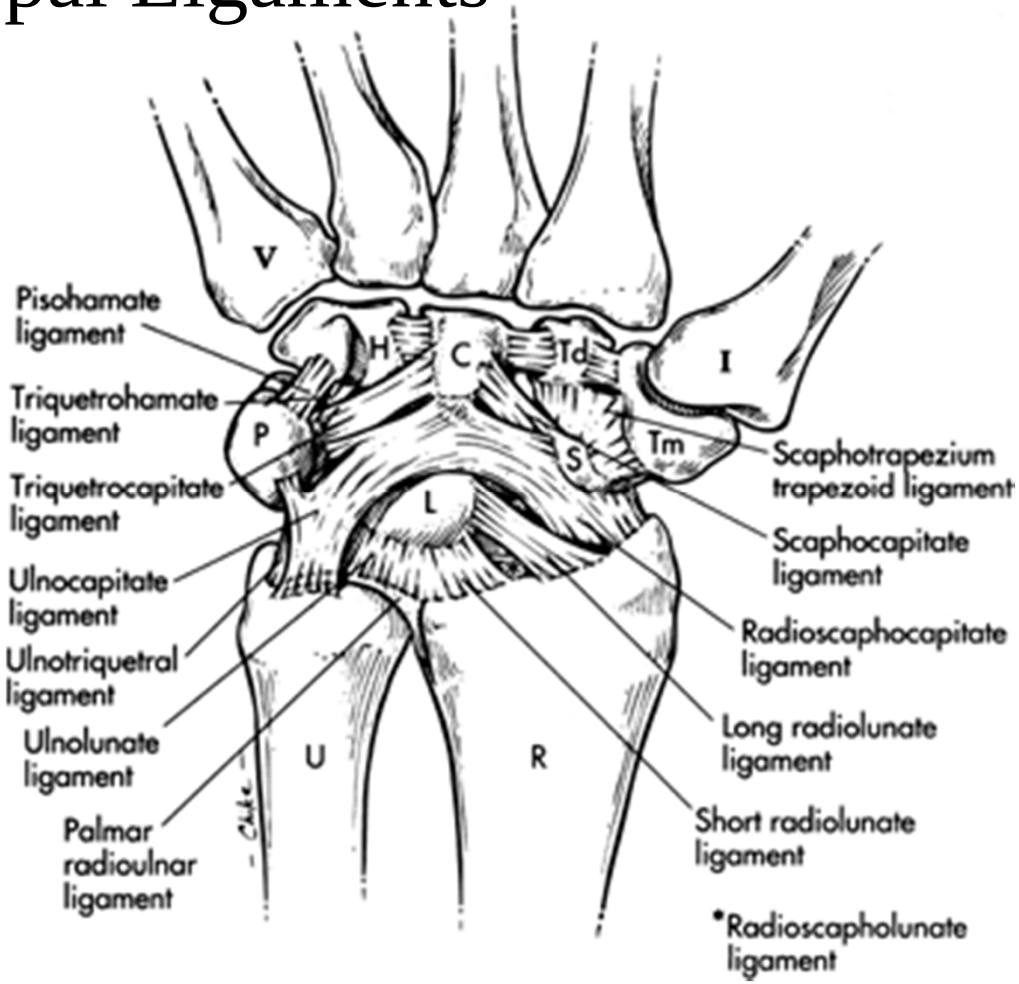
Ligament Anatomy - Overview

Ulnocarpal Ligaments

- Ulnolunate
- Ulnotriquetral
- Ulnocapitate
  - Forms the Arcuate /Deltoid (distal ‘V’) with theRadioscaphocapitate lig.

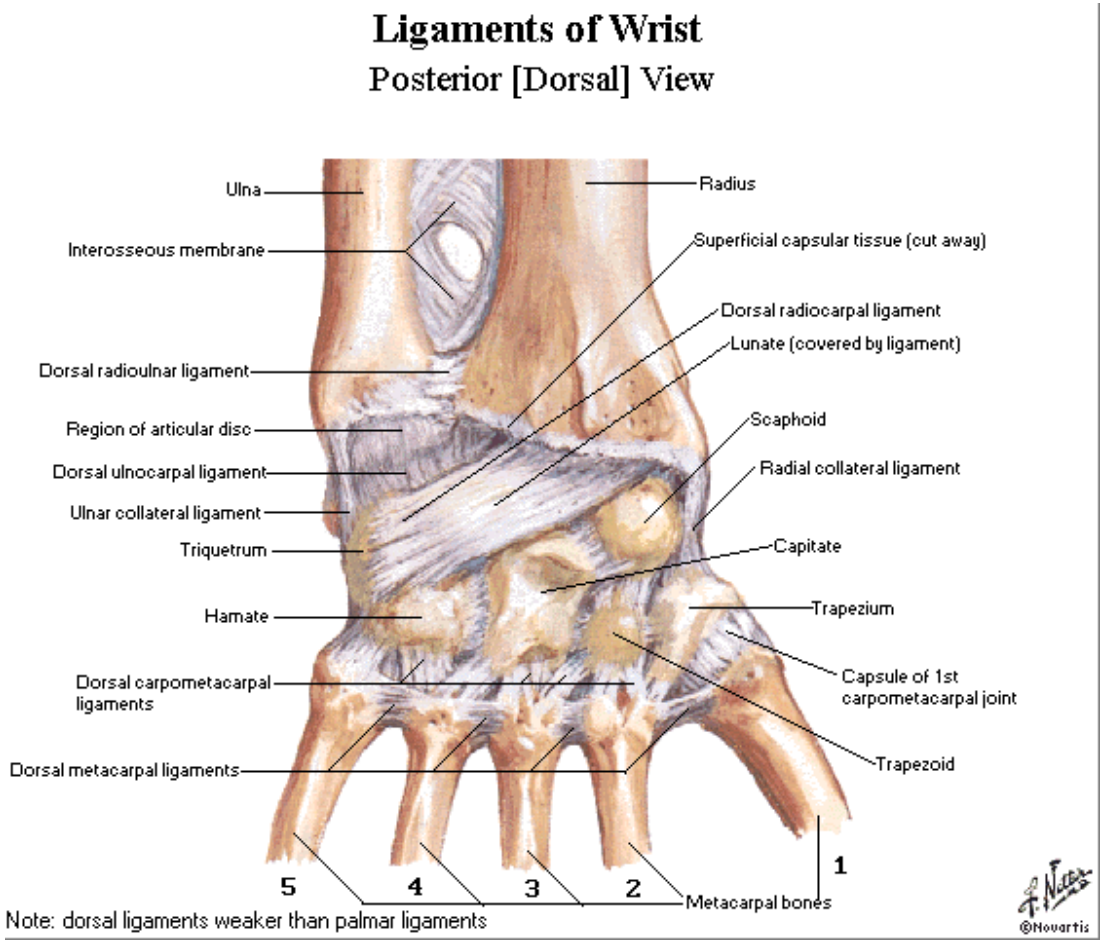
Ligament Anatomy - Overview

- Ulnocarpal Ligaments



Ligament Anatomy - Overview

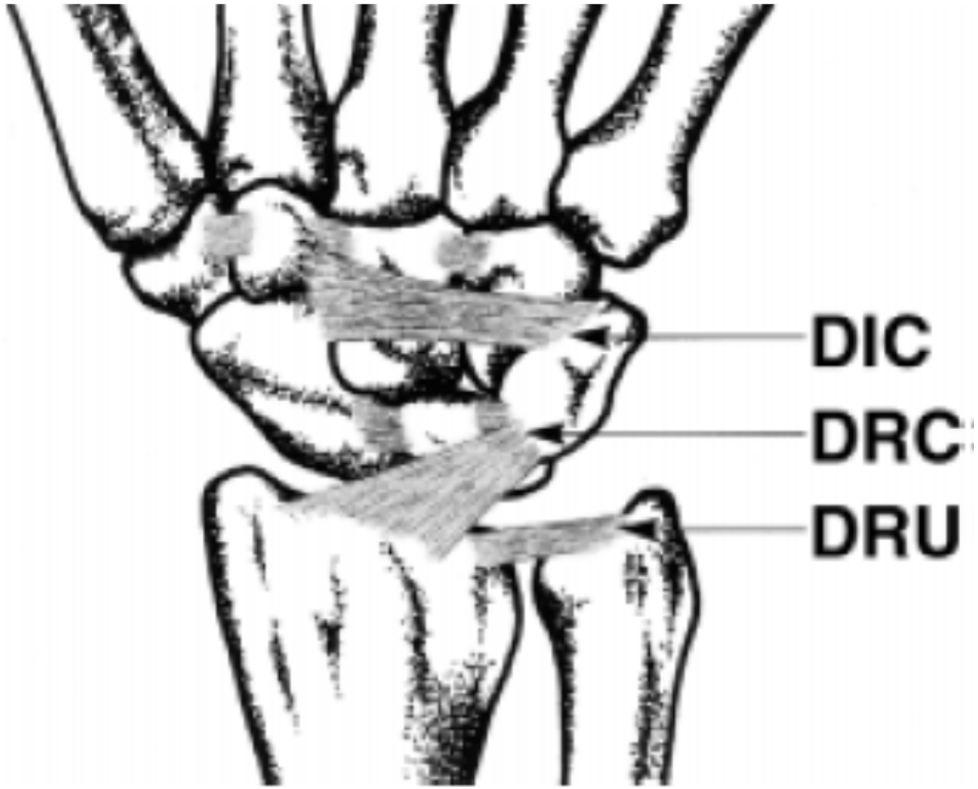
- Dorsal Radiocarpal Ligaments
  - •Also called Dorsal radiotriquetral
  - •Dorsal ulnocarpal
  - •Dorsal radioscaphoid



Ligament Anatomy - Overview

•Dorsal intercarpal Ligament
(Long Intrinsic)

Midcarpal analogue to DRC



Ligament Anatomy - Overview

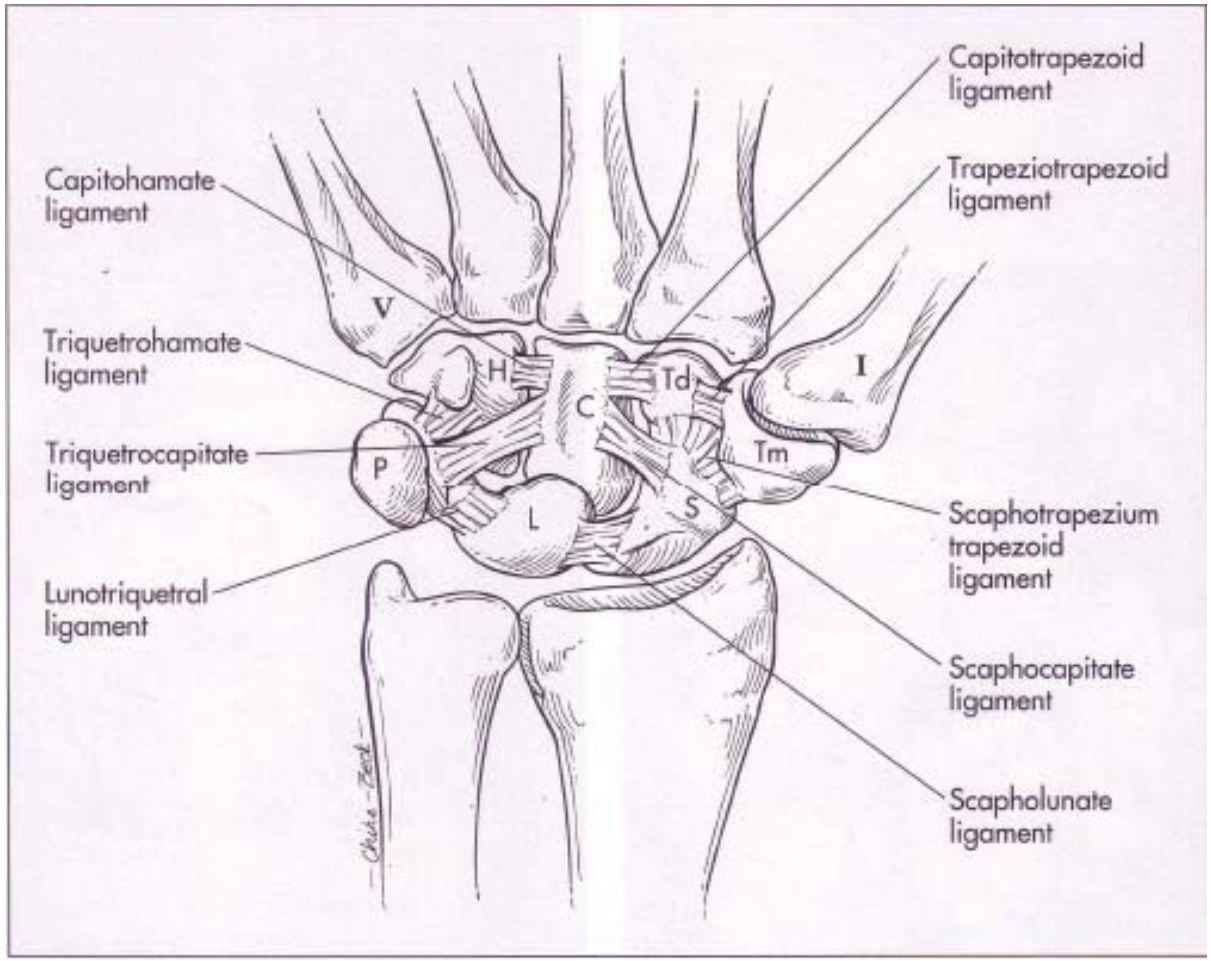
Palmar Midcarpal Ligaments

- Scaphotrapezium trapezoid
- Scaphocapitate
- Triquetrocapitate
- Triquetrohamate
- Pisohamate

  – No attachment between Lunate and Capitate

Ligament Anatomy - Overview

Palmar Midcarpal Ligaments



Ligament Anatomy - Overview

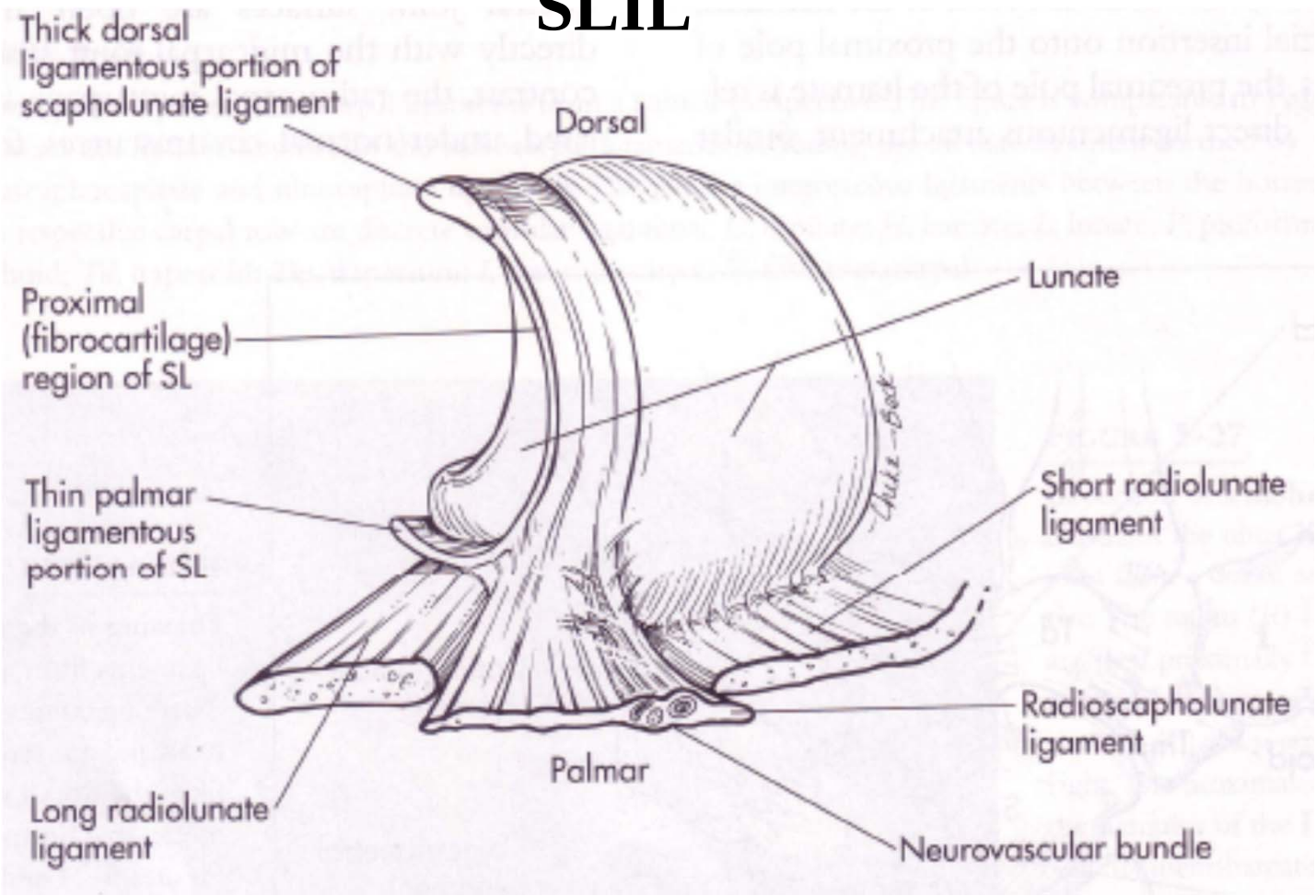
Proximal Row Interosseous (Intrinsic) Ligaments

- Scapholunate (SLIL)
- Lunotriquetral (LTIL)
- Scaphotriquetral
- Pisotriquetral

  – Dorsal, Palmar and Proximal (Membranous)

Ligament Anatomy - Overview

SLIL



Ligament Anatomy - Overview

Distal Row Interosseous (Intrinsic) Ligaments

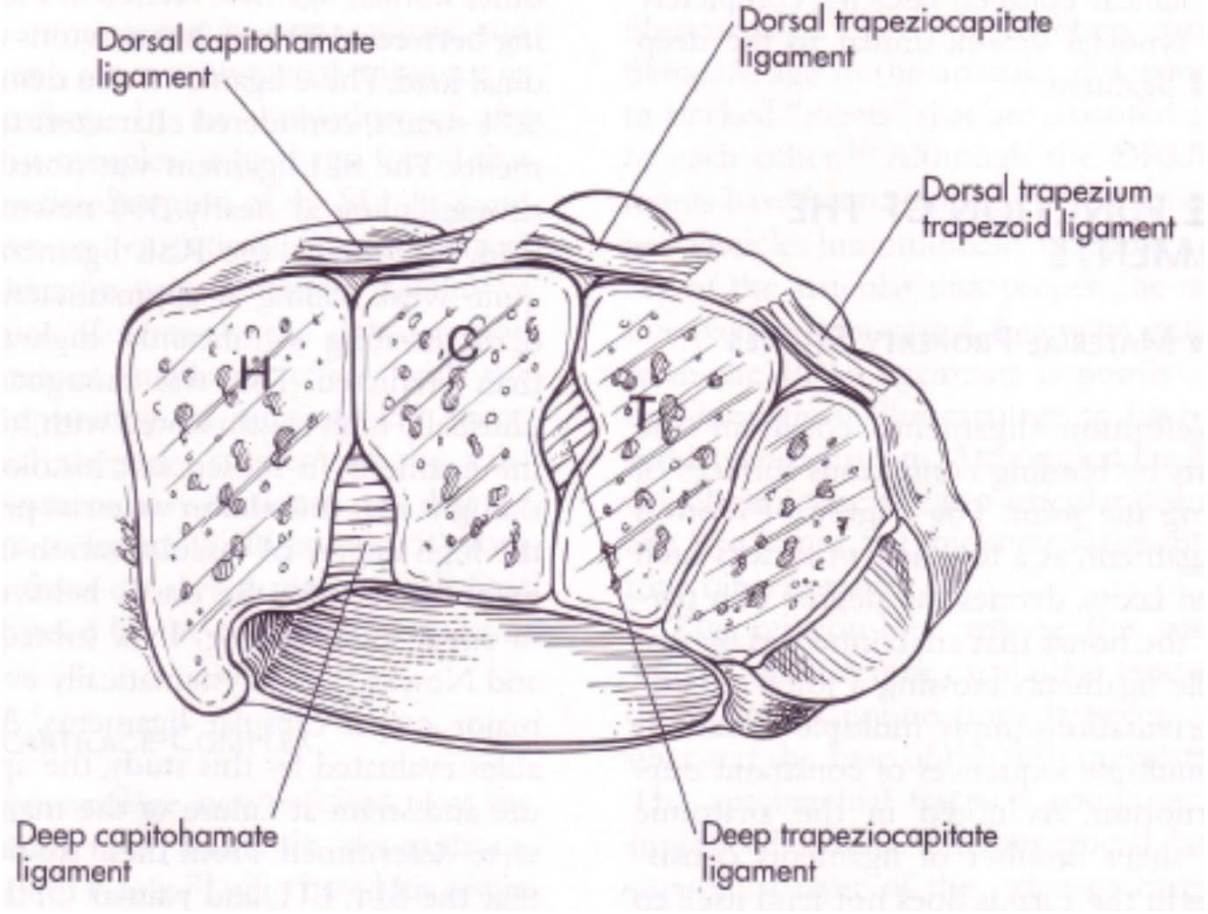
- Trapezium trapezoid – Dorsal & Palmar

- Trapeziocapitate
- Capitohamate

} Dorsal, Palmar & Deep

Ligament Anatomy - Overview

Distal Row Interosseous (Intrinsic) Ligaments



Ligament Anatomy - Overview

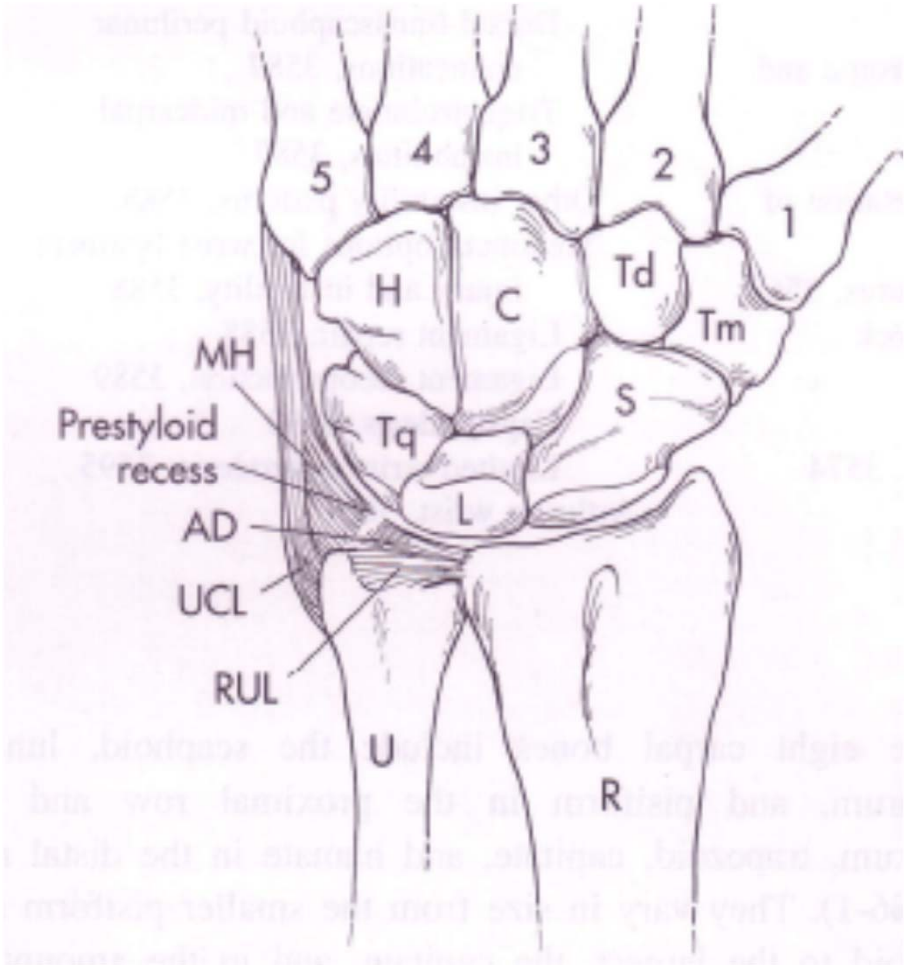
Triangular Fibrocartilage complex – TFCC

Chondroligamentous support attaching distal radius/ulna to carpus

- Ulnar collateral ligaments
- Dorsal and volar radioulnar ligaments
- Articular disc
- Meniscal homologue
- ECU sheath
- Ulnolunate and Ulnotriquetral Ligaments
  - » Palmar & Werner J Hand Surg (1981)

Ligament Anatomy - Overview

Triangular Fibrocartilage complex – TFCC



Wrist ligaments

- Dorsal ligaments tend to converge on triquetrum
- Volar stronger than dorsal
- Weak area - space of Poirier
- Important intrinsic ligaments are SLIL and LTIL

» Short et al J Hand Surg (2005)

Force Transmission

Forces measured using

- Fuji Film
  - » Viegas et al (J Hand Surg 1989)
- Pressure sensitive Conductive Rubber
  - » Hara et al (J Hand Surg 1982)
- Strain gauges
  - » Trumble et al (J Hand Surg 1987) Masear et al (J Hand Surg 1992)
- Load Cell
  - » Werner et al(J Hand Surg 1992) Trumble et al (J Hand Surg 1987)

Force Transmission

- 80-90% through Radius & 10-20% - Ulna
- Peak pressures are higher through Scaphoid fossa than lunate fossa
- 50% of load applied through distal Carpus is transmitted through the Capitate to the scaphoid & lunate

Force Transmission

Force Transmission (%)

STT	Scaphoid / Capitate	Capitate/ Lunate	Triquetrum/ Hamate	Authors
30	19	30	21	Horii et al
17	22	39	22	Viegas et al

» Horii et al (J Hand Surg 1990)

» Viegas et al (J Hand Surg 1989)

Force Transmission

Pattern of force transmittal depends on:

- Wrist position
- Capsuloligamentous integrity
- Articular surface
- Congruity

Force Transmission

	Force Distribution (%)	
Wrist Position	**Radius**	**Ulna**
Neutral	81.6	18.4
Radial Deviation	87.2	12.8
Ulnar Deviation	71.6	28.4
Supination	86.0	14.0
Pronation	63.0	37.0

Data from Werner et al (J Hand Surg 1992)

Force Transmission

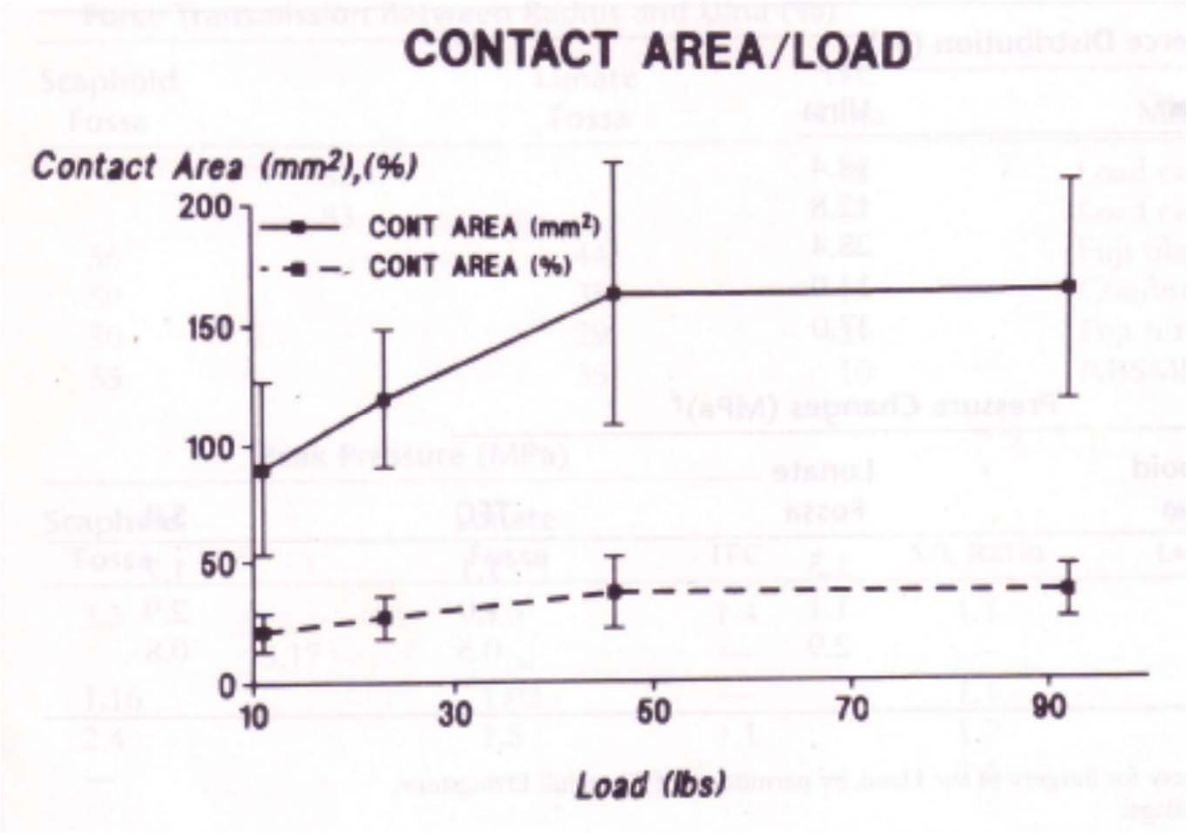
Role of TFCC:

- 10% of force transmitted through
  - » Schuind et al J Biomech (1995)
- Difference in Ulnar variance borne out by thickness of TFCC
  - » Palmer et al (J Hand Surg 1988) Werner et al(J Hand Surg 1992)
- Effect of resection of TFCC on Load Transfer
  - 1/3 – not significant
  - >2/3 – Increased Load through Radius
    - » Palmer et al (J Hand Surg 1988)

Force Transmission

- Due to difference in congruency of the joint surfaces, loads tend to concentrate on relatively small surface areas
- Maximum 40% of Radio-carpal joint surface

» Viegas et al (J Hand Surg 1989)



Kinematics

Bryce 1896 described carpal bone motion based on radiographs of his own wrist

Kinematics

- Direct visualization of dissected specimens
- Uniplanar radiographs » Von Bonin (1919)
- Measurement of displacement of inserted wires in carpal bones » Cyriax (1923)
- Fluoroscopy » Wright (1935)
- Cineradiography » Arkless (1966)
- Stereoscopic measurement » Erdman (1979)
- Light emitting diodes attached to the carpal bones
  - » Berger Clin Orthop (1982
- 3-D CT imaging
  - » Neu et al J Biomech (2001)

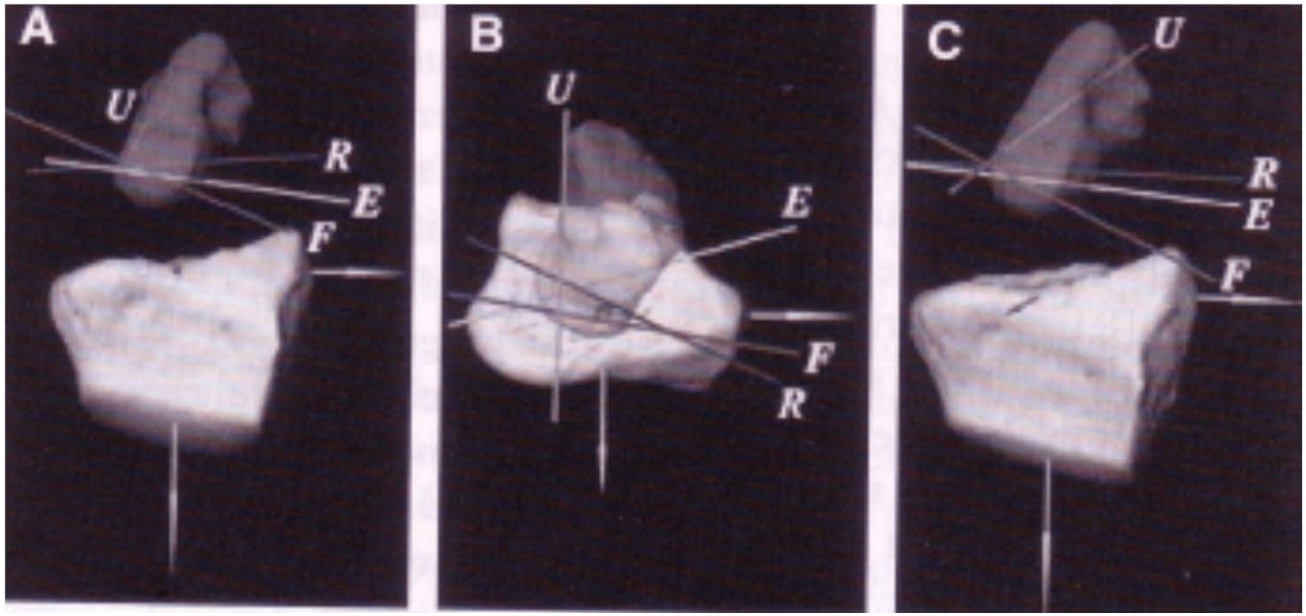
Kinematics

Center of rotation : Head of Capitate

» An et al (1991), Smith at al (1989)

- Center of Capitate axes is not constant and moves about by 4mm
  - Not much, so a single pivot point is reasonable

» Neu at al J Biomech (2001) using 3-D CT Imaging



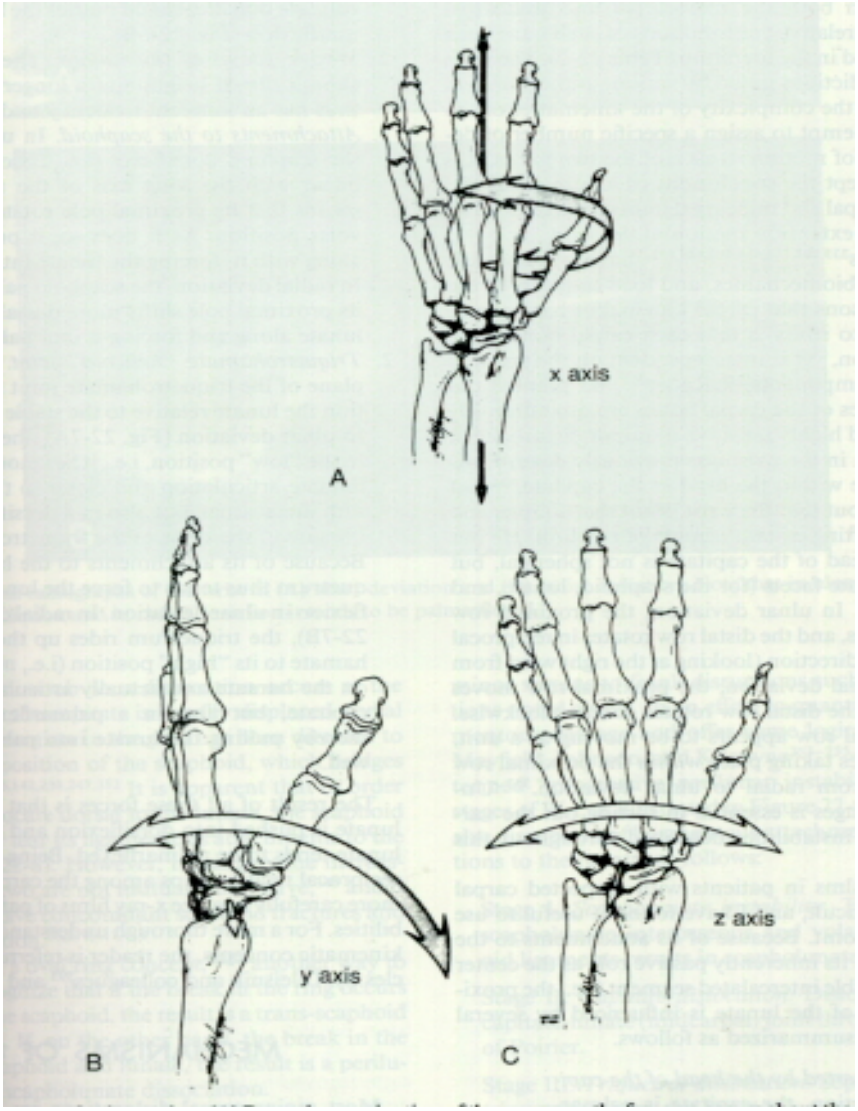
Kinematics

- FCU inserted into Pisiform & linked to Hamate by Pisohamate Ligament
- FCR, ECRL,ECRB & ECU all are attached to base of Metacarpals
- Proximal row completely devoid of tendinous attachment. Intercalated segment.
- Muscle contraction acts on distal carpal row which through its ligamentous attachments moves the proximal carpal row.

Kinematics

- Axes of motion
  - Flexion – Extension Motion
    - **90 – 70 degrees**
  - Radial – Ulnar Deviation
    - **20 – 50 degrees**
  - Pronation Supination Movement
    - 90 – 90 degrees

Axes of Motion



Kinematics

Proposed Models for wrist:

- Column Theory Navarro (1921)
- Modified by Taleisnik (1976)
- Link Joint Theory
  - Gilford (1943)
- Oval Ring
  - Lichtman et al J Hand Surg (1981)
  - Linschfield Clin Orthop. (1986)

Kinematics

Navarro 3 Column Theory

Lateral – Scaphoid, Trapezium & Trapezoid **– Mobile Column**

Central – Lunate, Capitate & Hamate **– Flexion/Extension**

Medial - Triquetral & Pisiform **– Rotational column**

Kinematics

Modified by Taleisnik

•Trapezium & Trapezoid included in the Central column

•Pisiform eliminated from medial column

•**Force bearing Column Theory**

»**Weber (1988)**

1st Column – Load bearing

2nd - configuration of hamate /Triquetrum help rotation stability

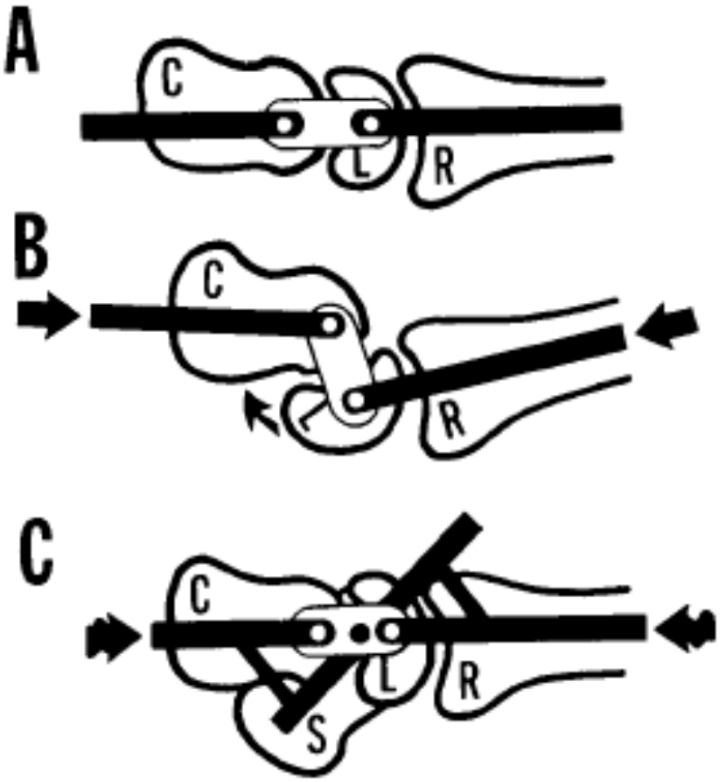
3rd – supports thumb for independent action

Kinematics

Link Theory

- Gilford (1943)

- Described the wrist as a link joint.
- Scaphoid links the radius to the distal carpus & provides stability against compression forces in Flex/Ext



Kinematics

Oval Ring

Allows reciprocal motion between the proximal and distal rows of the carpus during motion i.e. in opposite directions

–Lichtman et al J Hand Surg (1981)

–Linschfield Clin Orthop. (1986)

Kinematics

Distal Carpal Row

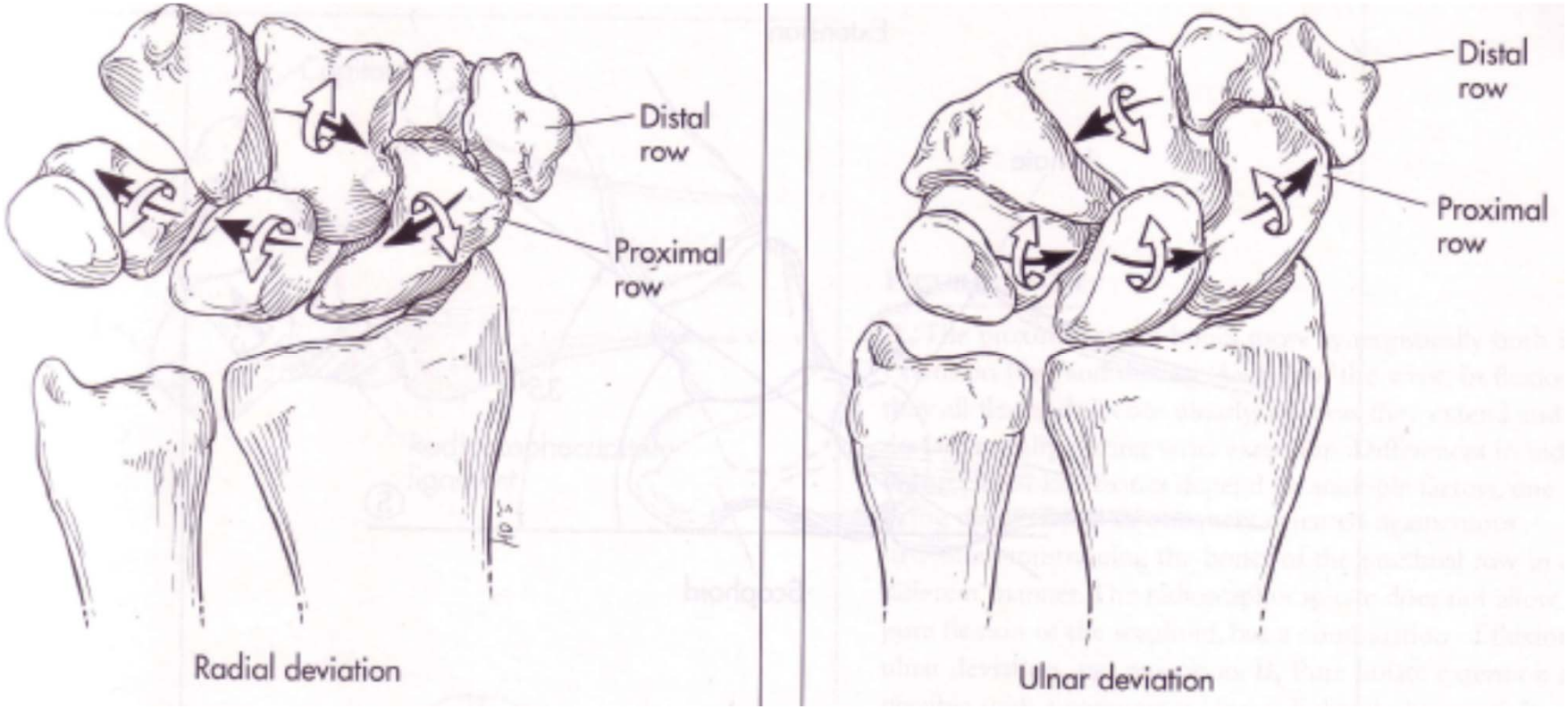
- Bones move synergistically
- Little intercarpal motion
  - 6-12º of angular motion in Flex/Ext
- Act as a single functional unit
    - » Berger Clin Orthop (1982), De Lange et al J Orthop Res (1985), Ruby et al J Hand Surg (1988)
- Extended in Radial deviation to Flexed in Ulnar deviation

Kinematics

Proximal Carpal Row

- Bones move synergistically
- Increased intercarpal motion
  - Scaphoid rotates 80º/111º, Lunate 58º/76º & Triquetral 71º/88º from full flexion to extension
    - » Ruby et al (1988) / Horii et al (1991) J Hand Surg
- Rotations of the intercalated segment ---- RUD
- Flexed in Radial deviation to extended in Ulnar deviation

Kinematics



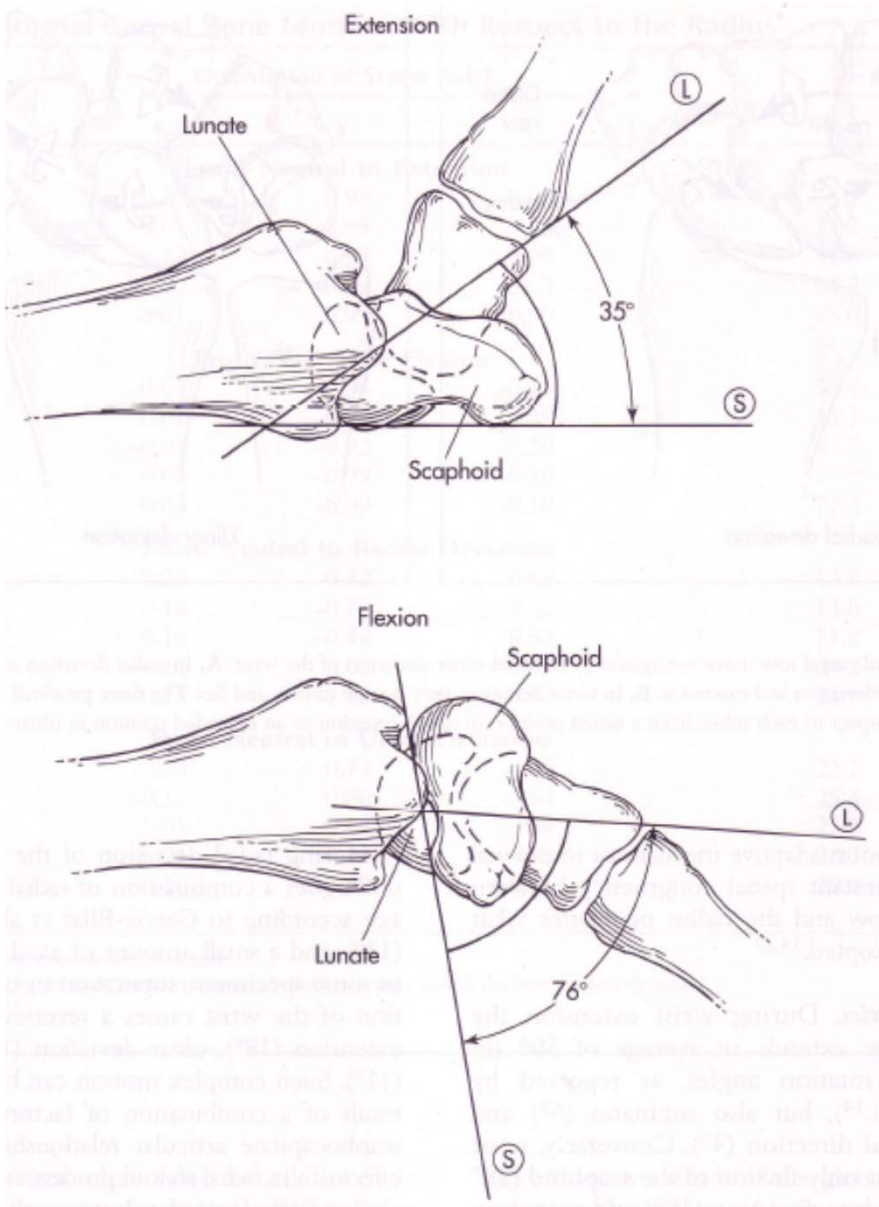
Palmar view

Kinematics

•**Larger rotation of Scaphoid** than the lunate is determined by the ScaphoLunate angle (axes of the scaphoid and lunate)

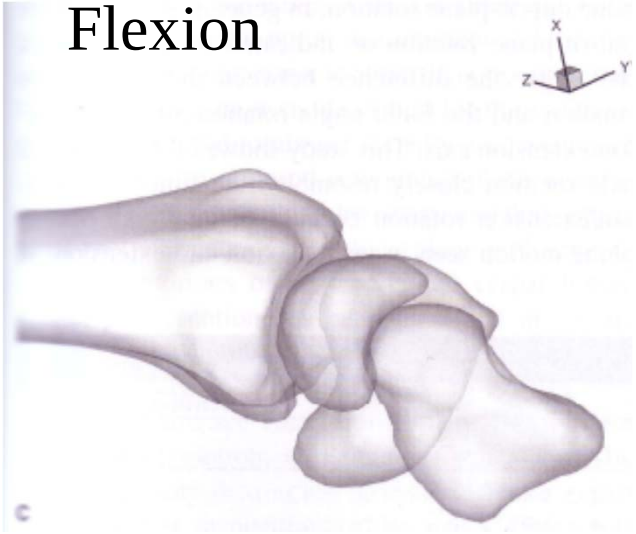
•Varies from 76º with wrist flexion to 35º in extension

»Nakamura et al J Hand Surg(1989)



Kinematics

Flexion

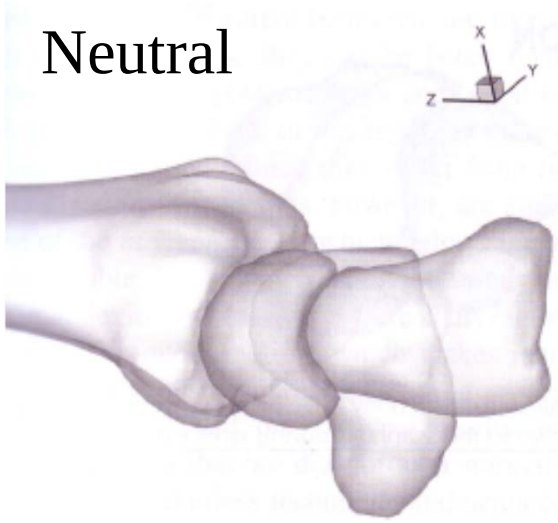


Flexion – shared b/w Radio Carpal and mid carpal

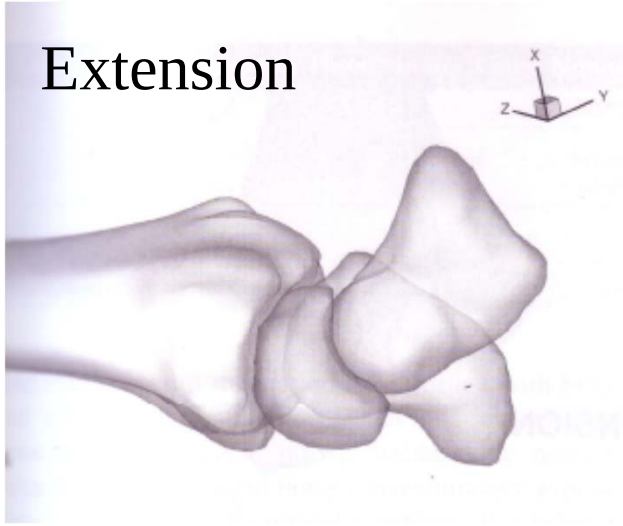
Extension – primarily Radiocarpal (92%)

Kaufmann et al J Hand Surg (2006)

Neutral



Extension

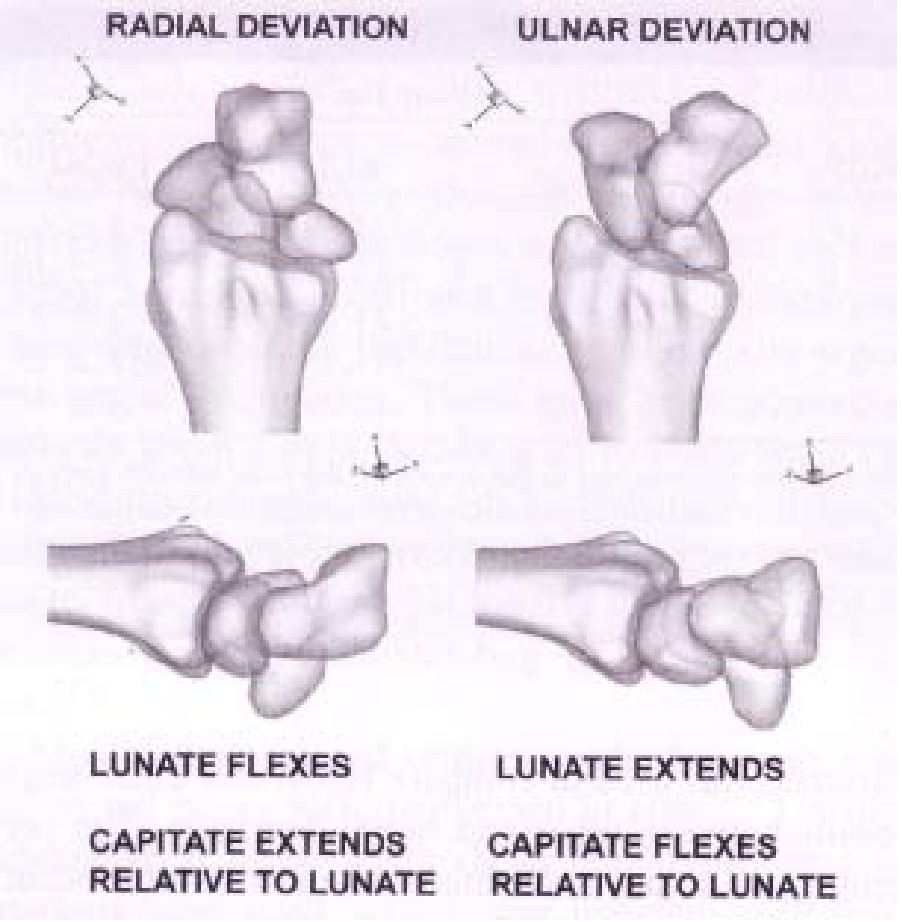


Kinematics

Lunate & Scaphoid flex and Capitate extends in Radial deviation

Lunate & Scaphoid Extend and Capitate flexes in Ulnar deviation

Kaufmann et al J Hand Surg (2005)



Kinematics

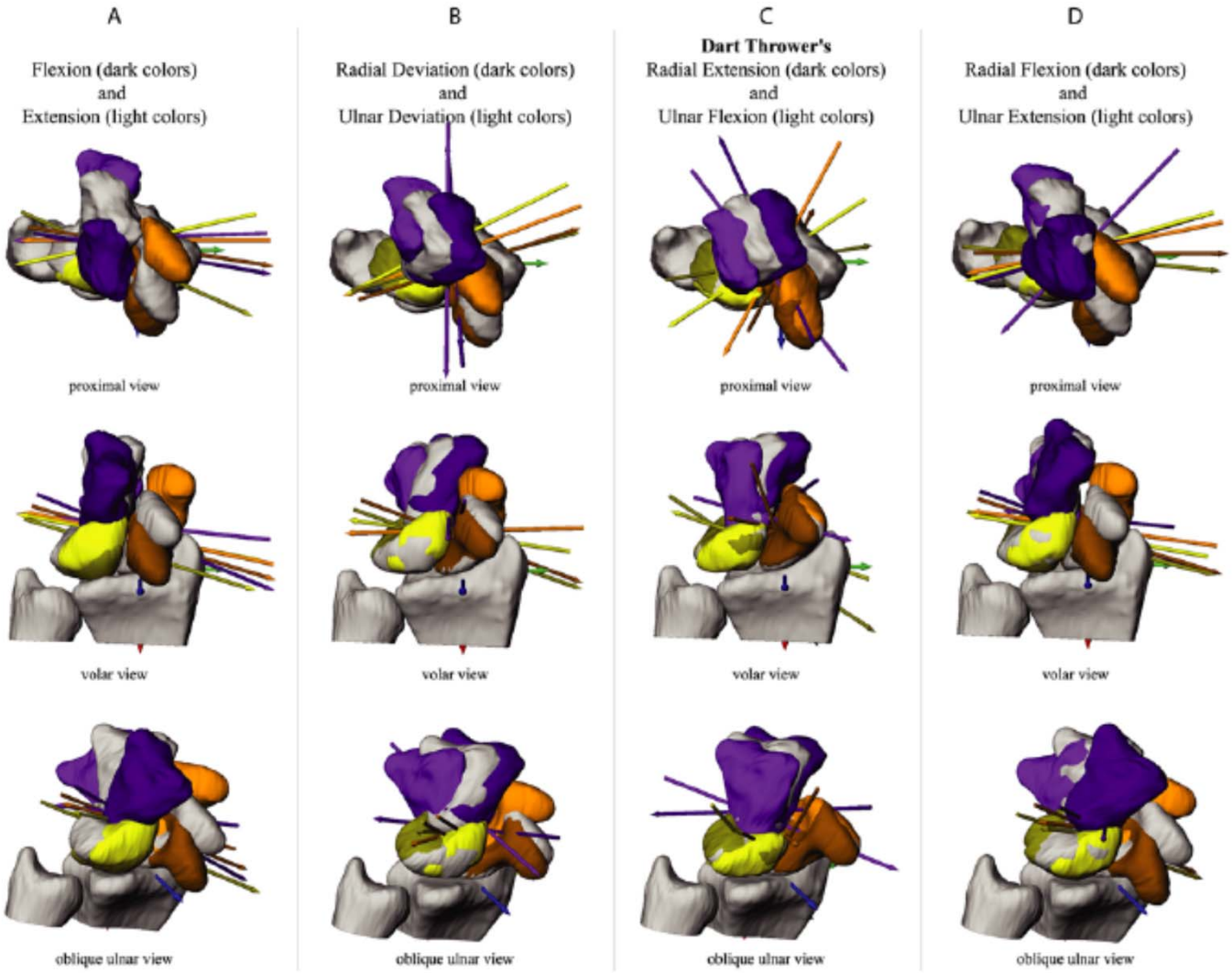
Axes of motion

- **Traditional Planes**
  - Flexion – Extension Motion
  - Radial – Ulnar Deviation
- **“Dart Thrower’s Plane” of motion**
  - Obliquely oriented plane of wrist motion that ranges from a position of combined radial deviation and extension to positions of combined ulnar deviation and flexion
    - » Palmer et al J Hand Surg (1985), Ishikawa et al J Hand Surg (1999), Werner et al J Hand Surg (2004), Crisco et al JBJS (2005)

Kinematics

Kinematics

3-D CT Imaging – The way forward



»Crisco et al JBJS (2005)