Understanding the wrist: Anatomy, function, imaging

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Review Article

Principles of Anatomy and Function in Wrist Imaging

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ABSTRACT

Three-dimensional hand movements combined with high stability of the wrist require precisely coordinated systems. The biomechanics of the carpal bones is based on the dynamic interaction between bone and joint architecture, ligament support, stabilization via extrinsic muscles, fine motor control via intrinsic muscles, and neuromuscular control loops. The proximal carpal row is an intercalated segment through which forces are transmitted from the forearm to the mid-carpus and fingers distally. Depending on the movement, the proximal carpal row must constantly change shape and position while maintaining its height. This review will improve understanding of carpal anatomy and biomechanics. A sound knowledge of these topics is essential for the early detection of wrist diseases, particularly instability patterns.

Keywords anatomy, biomechanics, joints, ligaments, wrist

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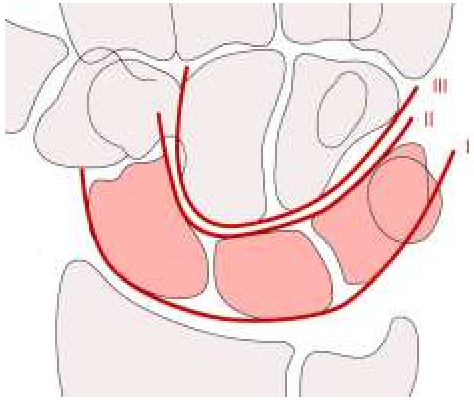
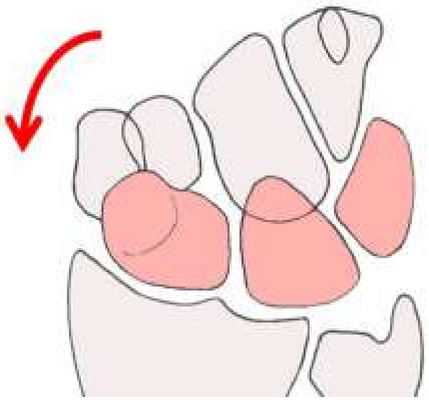
Anatomical and functional basics (1)

Carpal rows

- **proximal carpal row** ➡ intercarpal mobility
  (scaphoid, lunate, triquetrum)
- **distal carpal row** ➡ rigid structure
  (trapezium, trapezoid, capitate, hamate)



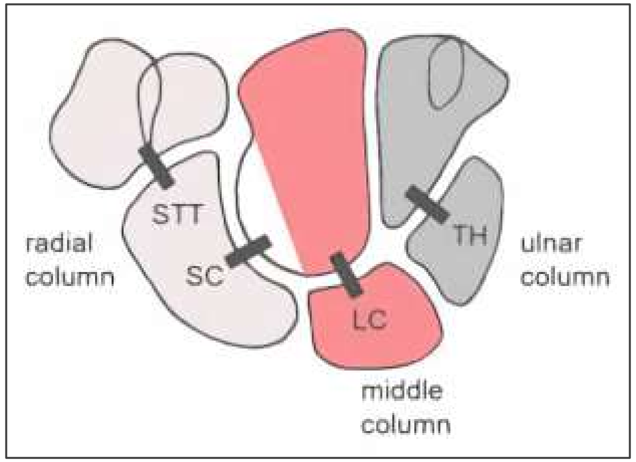
carpal arcs acc. Gilula

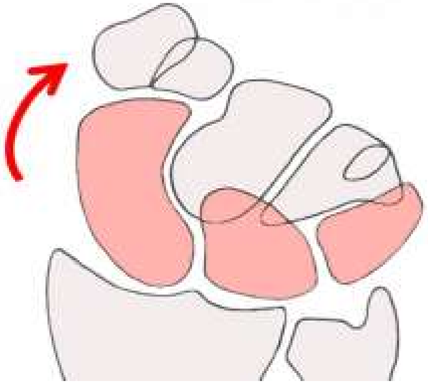


radial deviation

Carpal columns

- **radial column** ➡ 50 % load transfer
  (scaphoid, trapezium, trapezoid)
- **middle column** ➡ 30 % load transfer
  (lunate, capitate)
- **ulnar column** ➡ 20 % load transfer
  (triquetrum, hamate)





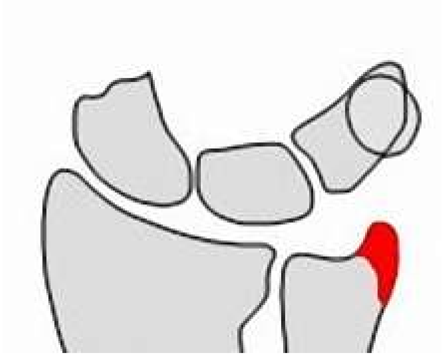
ulnar deviation

Anatomical and functional basics (2)

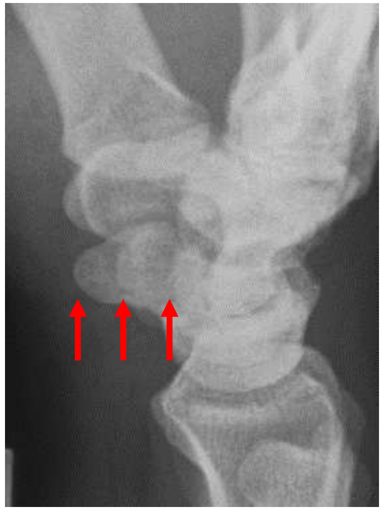
Radiographs in neutral position

- **dorsopalmar view**
  - arm elevated,
    hand in height of the shoulder
  - ulnar styloid process projects
    ulnarly in profile





- **lateral view**
  - arm adducted to the trunc
  - scaphoid-pisiform-capitate ratio (SPC)

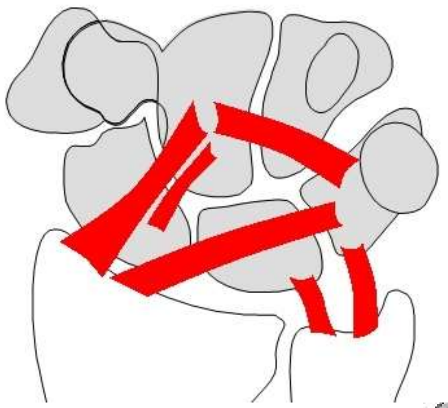

Anatomical and functional basics (3)

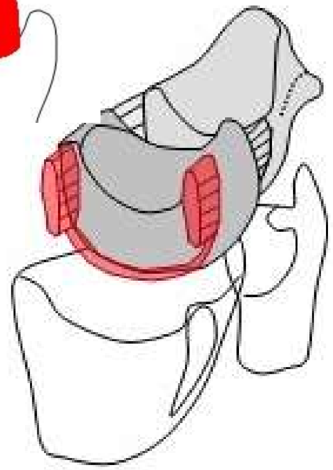
Stability of the wrist by

- **congruence of the joint surfaces** - flat, flat-convex or flat-concave
- **carpal ligaments** - extra-capsular vs. intra-capsular

  - extrinsic vs. intrinsic

  - intra-articular vs. extra-articular





- **current muscle tension** - not destructive,

  - but protective by balancing in sensorimotor control loops

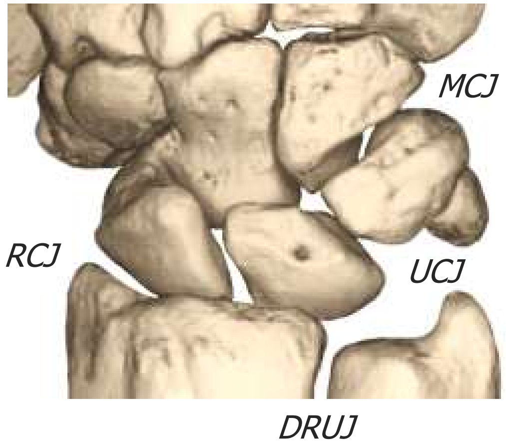
Taleisnik J. J Hand Surg Am 1976;1:110 - Larsen CF, et al. J Hand Surg Am 1995;20:757 – IFSSH. J Hand Surg Am 1999;24:866
Hagert E. J Hand Ther 2010;23:2 - Salva-Coll G, et al. J Hand Surg Eur Vol 2011;36:553 - Ringler MD. J Hand Surg Am 2013;38:2034

Anatomical and functional basics (4)

Joints

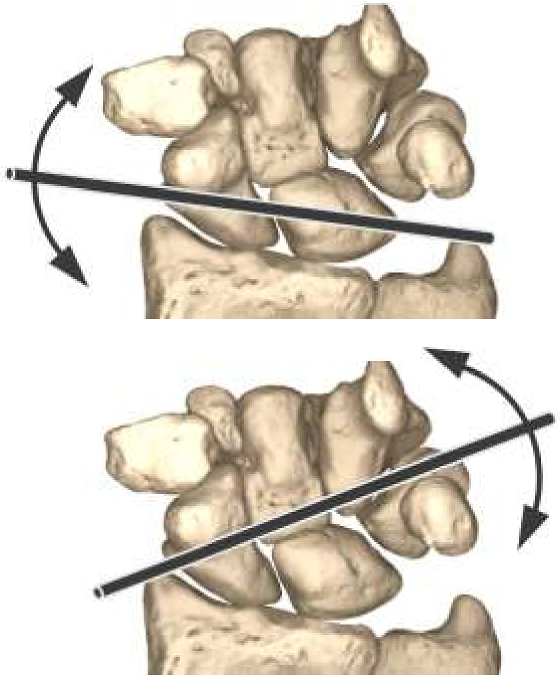
- DRUJ
- RCJ + UCJ
- MCJ

(intercarpal)



Movements

- obliquely
  multiplanar + multiaxial
- interplay of stability, mobility
  and sensorimotor control



Stability

- normal arrangement under everyday loads
- balance between
  external force and internal counterforce

Instability

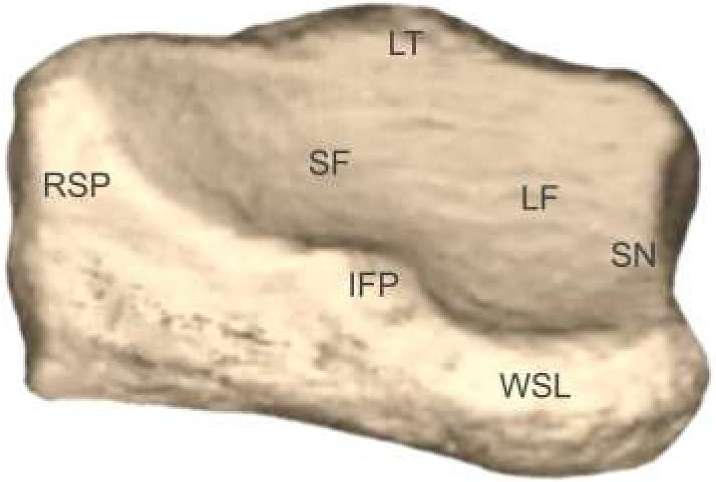
- **dyskinematics** =
  abnormal compensatory movements
- **dyskinesia** =
  abnormal structural arrangement

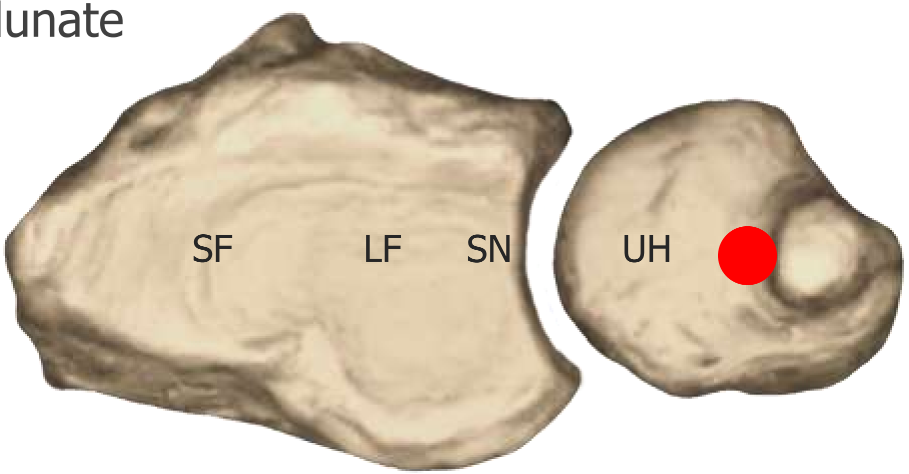
Crisco JJ, et al. J Bone Joint Surg Am 2005;87:2729

Distal forearm - Anatomy (1)

Antebrachial carpal joint

- **radioscaphoid compartment**
  - triangular scaphoid fovea
  - proximal scaphoid pole
- **radiolunate compartment**
  - rectangular lunate fovea
  - proximal circumference of the lunate
- **ulnocarpal compartment**
  - TFCC
  - lunate
  - triquetrum





IFP = interfact prominence
LF = lunate fovea
LT = Lister tubercle
RSP = radial styloid process
SF = scaphoid fovea
UH = ulnar head
WSL = water-shed line

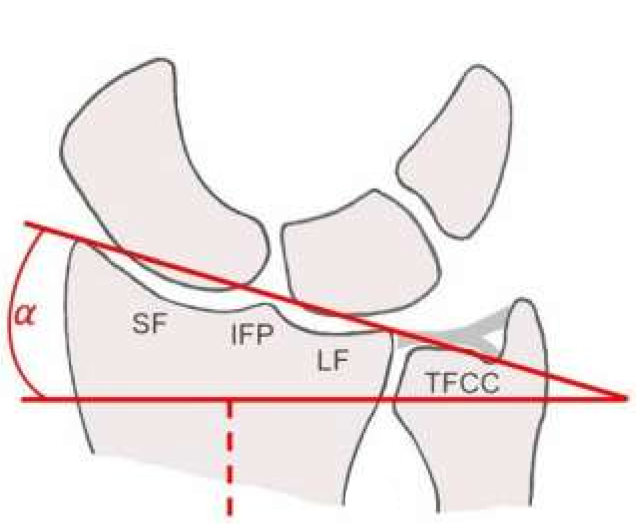
Distal radioulnar joint

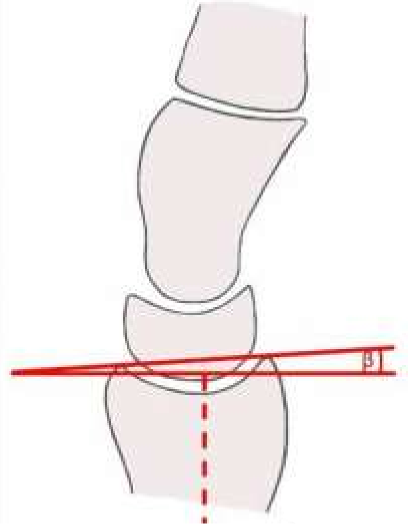
- sigmoid notch = SN
- articular surface of the ulnar head
- pivot joint

Palmer AK, et al. J Hand Surg Am 1981;6:153 - Schuind FA, et al. J Bone Joint Surg Am 1992;74:1418
Linscheid RL. Clin Orthop 1992;275:46 - Hagert E, et al. Hand Clin 2010;26:459

Radius

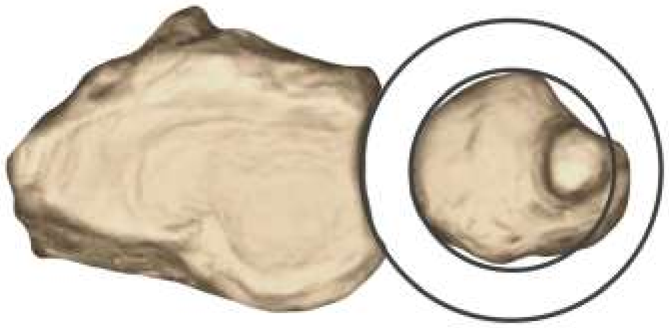
- large radial styloid process
- ulnar inclination 15 – 35 degrees
- palmar inclination 0 – 20 degrees





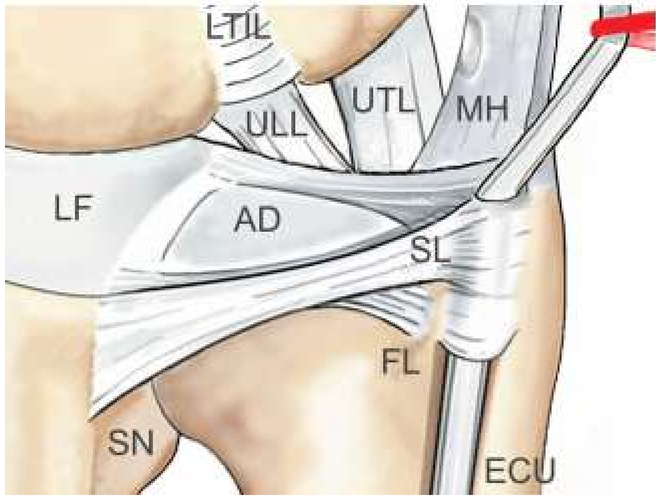
Ulna

- small ulna head: 20 mm (16 – 22 mm)



TFCC

- articular disc
- ulnar insertions
- periphery



Palmer AK, et al. J Hand Surg Am 1981;6:153 - Schuind FA, et al. J Bone Joint Surg Am 1992;74:1418
Linscheid RL. Clin Orthop 1992;275:46 - Hagert E, et al. Hand Clin 2010;26:459

Distal forearm - Function (1)

Ulnar variance = difference in length between the

- – radius (palmar border) and
- – ulna head (distal border)

- **normal** 0 ± 2 mm
- **positive, negative**

- **dynamic**
  - – ulna 0,6 mm longer in the pronated position (i.e. “superman position” in MRI), shorter in the supinated position
  - – ulna functionally longer with forearm muscle contraction (“grip view” or “pencil view” in radiography)


Neutral ulnar variance


Positive ulnar variance


Negative ulnar variance


Superman position

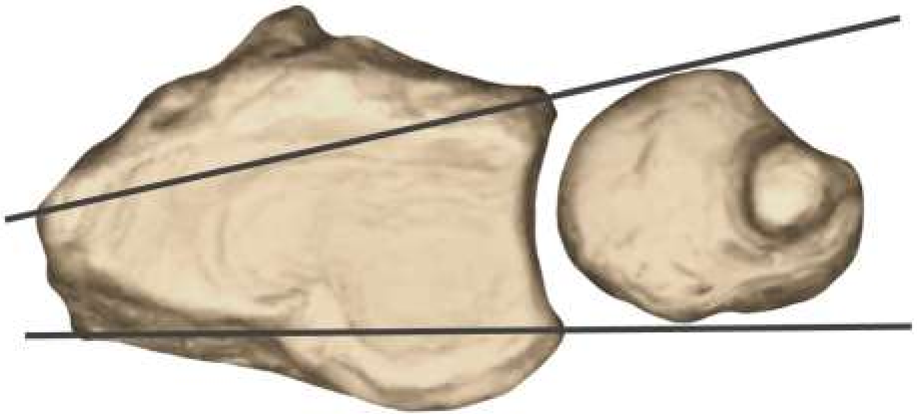

At rest


Grip view

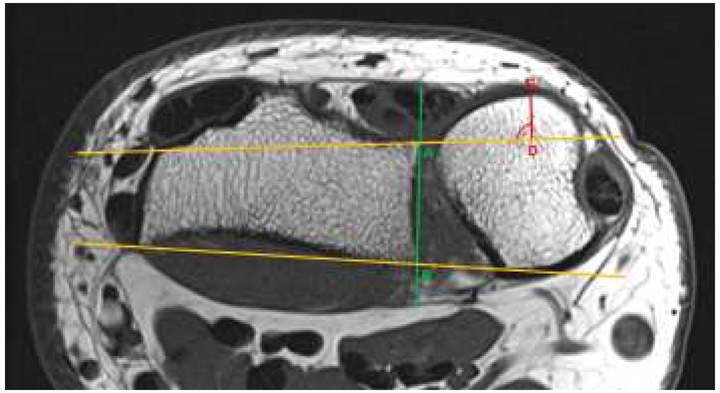
Distal forearm - Function (2)

Distal radioulnar joint (DRUJ)

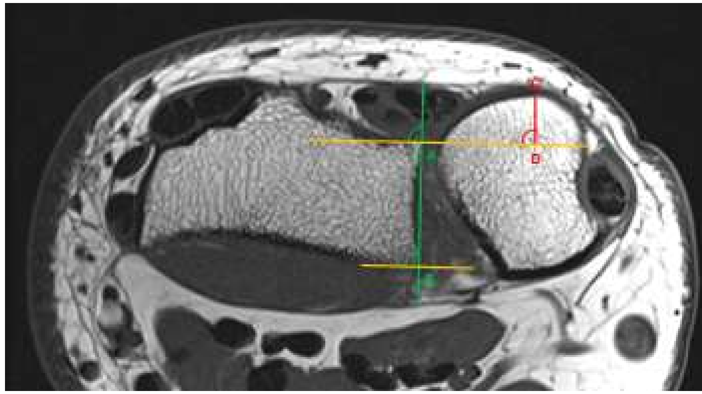
- ulnar head located within a cylinder that diverges ulnarly
- best described by the Mino lines



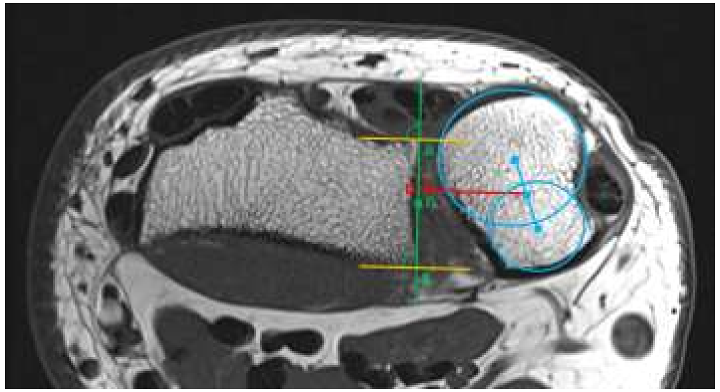
- position depends on pronosupination



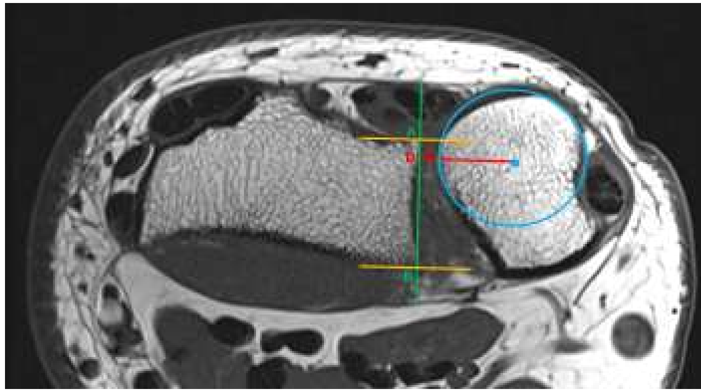
radioulnar line method (Mino)



subluxation ratio method (Park)



epicenter method (Wechsler)



radioulnar ratio method (Lo)

Mino et al. J Hand Surg Am 1983;8:23

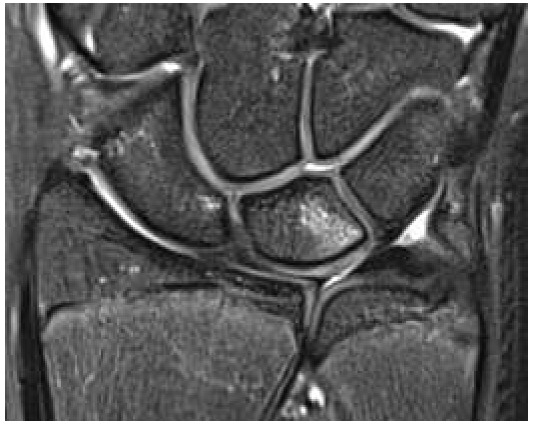
Distal forearm - Pathology (1)

Positive ulnar variance (ulna > 2mm)

- causes
  - post-traumatic most common
  - congenital (e.g. Madelung's disease)

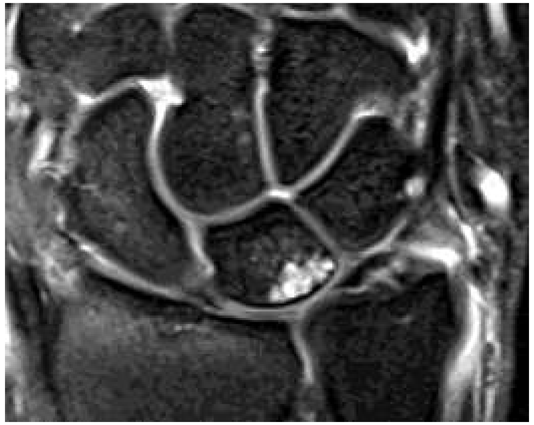
- ulnocarpal impaction syndrome
  - chondropathy
  - perforation of the articular disc (TFC)
  - bone marrow edema (lunate > triquetrum)
  - cystic-sclerosing changes

dynamic positive variance



bone marrow edema

static positive variance

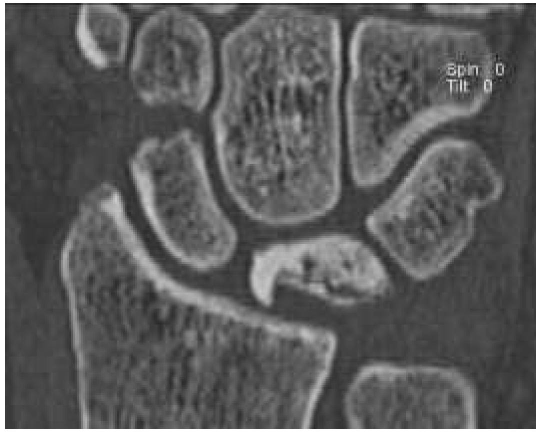


cystic-sclerosing changes

Distal forearm - Pathology (2)

Negative ulnar variance (ulna < 2 mm)

- congenital
- Kienboeck‘s disease
  - increased pressure to the radial segment of the lunate (Hulten‘s theory)
  - avascular osteonecrosis

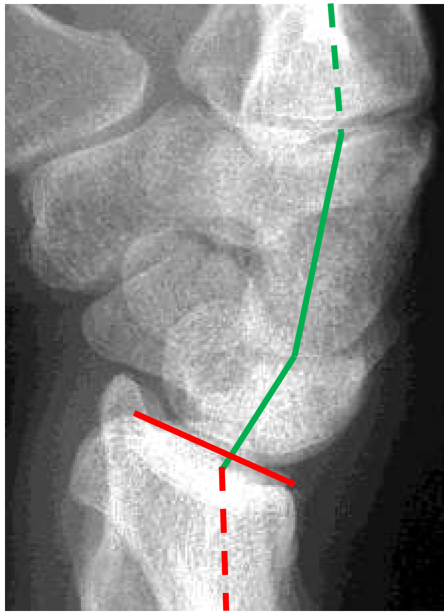


Impingement syndrome

- ulna < 5 mm
- proximal neoarticulation
- bone marrow edema > cystic-sclerosing changes

Carpus adaptive

- dorsal inclination > 10 degrees in malunited DRF
- wrist in zigzack deformity
- early-onset osteoarthritis



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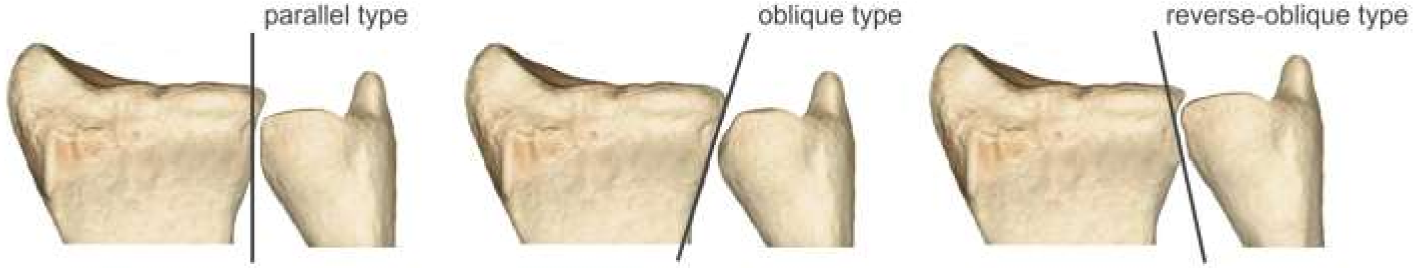
Prommersberger KJ, et al. Handchir Mikrochir Plast Chir 2023;55:211 – Visser D, et al. Eur J Orthop Surg Traumatol 2020;30:1357

DRUJ and TFCC - Anatomy (1)

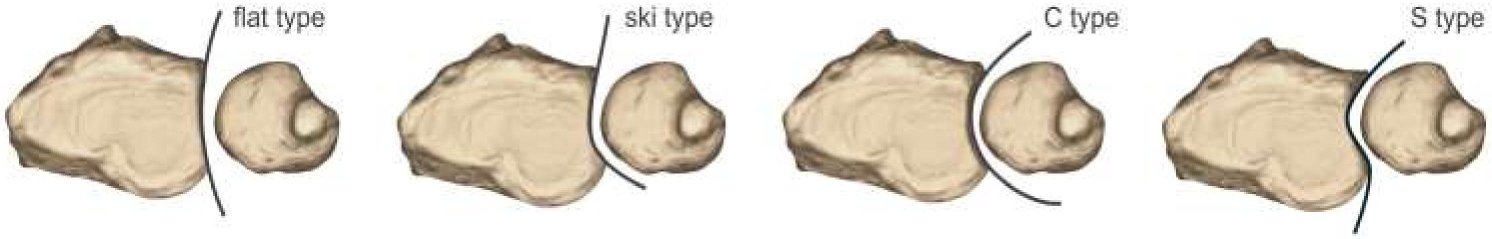
DRUJ articular surfaces

- parallel, oblique, reverse-oblique
- symmetrical vs. asymmetrical



Sigmoid notch

- 30 mm (26 – 35 mm) > ulnar head (20 mm
- flat type, ski type, C type, S type

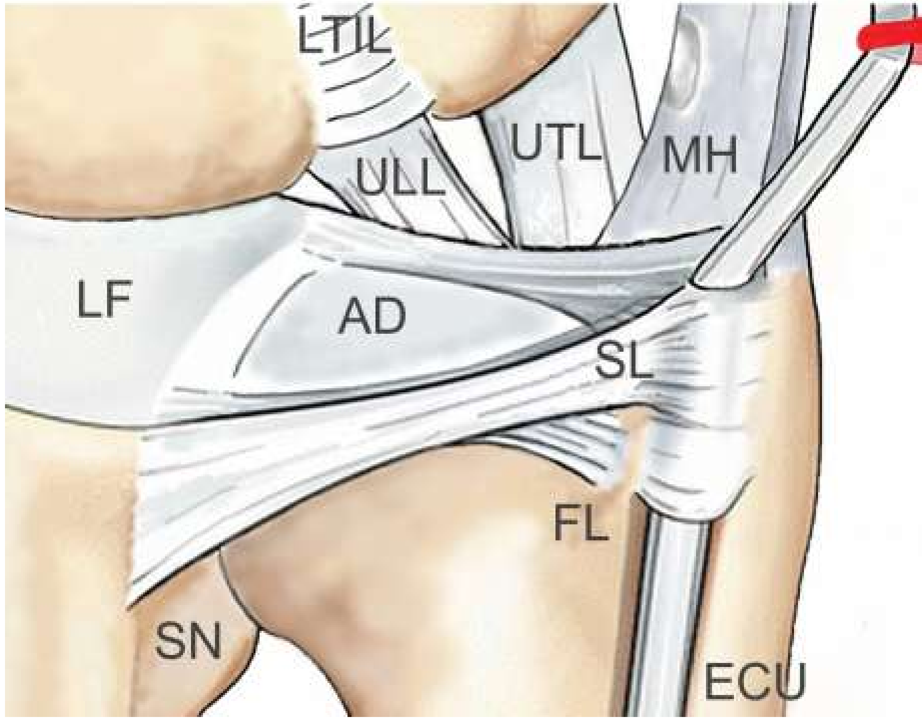


Ulnar head

- radial articular surface ➡ DRUJ
- distal articular surface ➡ TFCC
- fovea capitis ➡ foveal lamina
- ulnar styloid process ➡ styloid lamina, ECU tendon

DRUJ and TFCC - Anatomy (2)

TFCC ensures 70 % of DRUJ stability



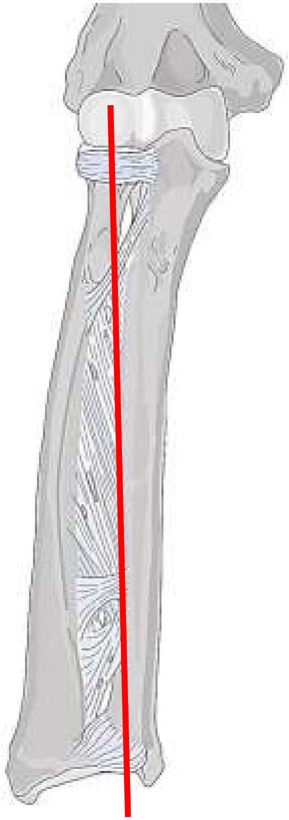
- **articular disc** (AD)
  triangular, biconcave, limbus vascularized, center avascular
- **palmar and dorsal radioulnar ligaments** (PRUL, DRUL)
  cortical origins at the sigmoid notch, foveal and styloid insertions
- **ulnocarpal ligaments** (ULL, UTL)
  palmar intracapsular, stabilize the ulnocarpal compartment
- **ECU tendon sheath** (ECU)
  in a dorsal depression of ulnar head
- **meniscus homologue** (MH)
  tent-like from capsule to triquetrum
- **pronator quadratus muscle**
  palmar in the depth, flat, oblique
- **interosseous membrane**
  chorda obliqua, central liagment, distal oblique bundle
- **joint capsule of the TFCC**
  ulnocarpal ligaments palmar, ECU tendon sheath dorsal

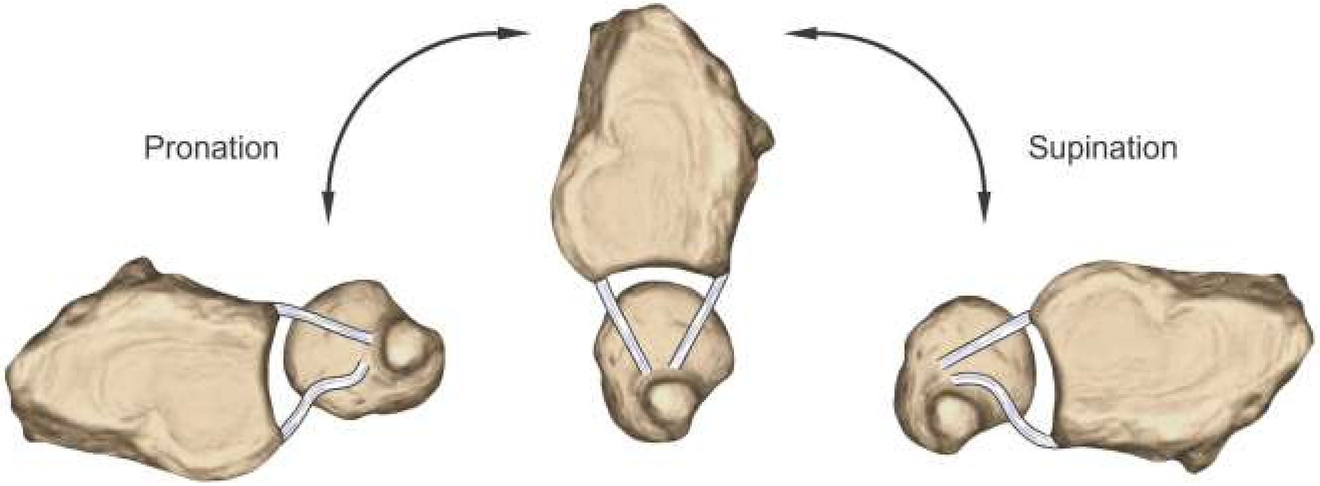
Nakamura T. J Hand Surg Br 2001;26:446 – Atzei A, et al. Hand Clin 2011;27:263
Palmer AK, et al. J Hand Surg Am 1984;9:681 – Noda K, et al. J Hand Surg Am 2009;34:415

DRUJ and TFCC - Function (1)

Pronosupination

- rotational axis between the centers of the
  - radial head proximally and
  - ulnar head distally
- radius rotates around the fixed ulna head
- maximum contact in the neutral position
- rotational ROM
  - 150 – 180 degrees in both radioulnar joints
  - 30 degrees intracarpal





- radioulnar ligaments
  - primary stabilizers of the DRUJ
  - alternately tense or relaxed
- foveal laminae provide most of DRUJ stability

Linscheid RL. Clin Orthop 1992;275:46 – Kleinman WB, et al. J Hand Surg Am 1998;23:588
Atzei A, et al. Hand Clin 2011;27:263 – Haugstvedt JR, et al. J Hand Surg Eur Vol 2017;42:338

DRUJ and TFCC - Function (2)

Ulnocarpal buffer

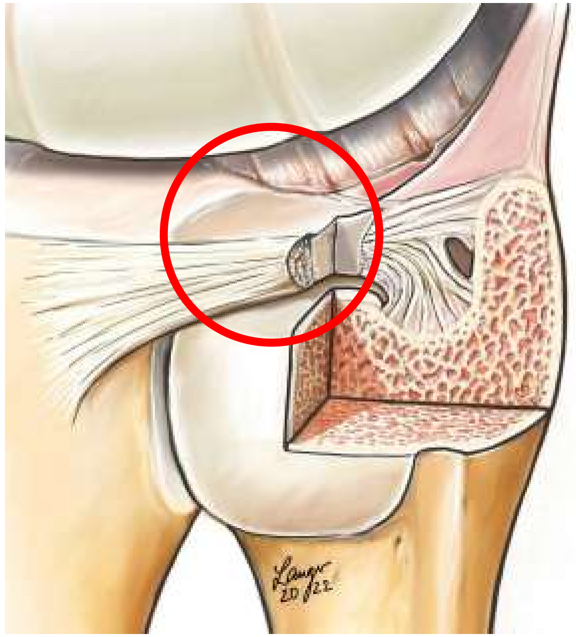
- articular disc (TFC) absorbs 20 % of the axial load
- compression strengthens the PRUL and DRUL

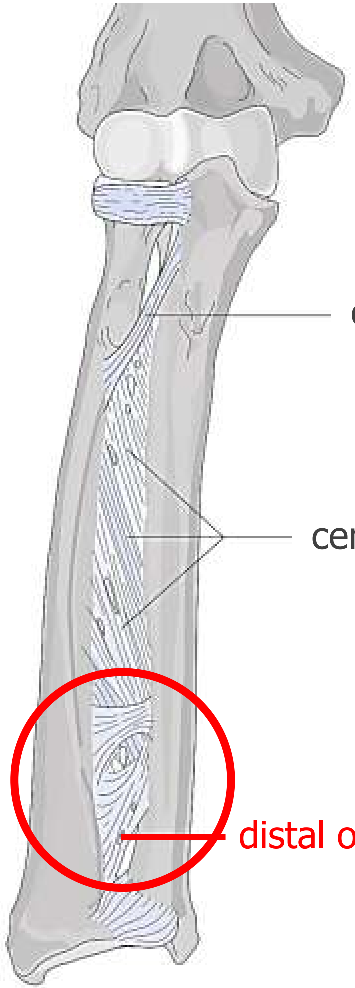
Secondary DRUJ stabilizers

- pronator quadratus muscle + interosseous membrane

Longitudinal stability

- central ligament counteracts proximalization of the radius
- distal oblique bundle prevents dorsopalmar translation of the radius

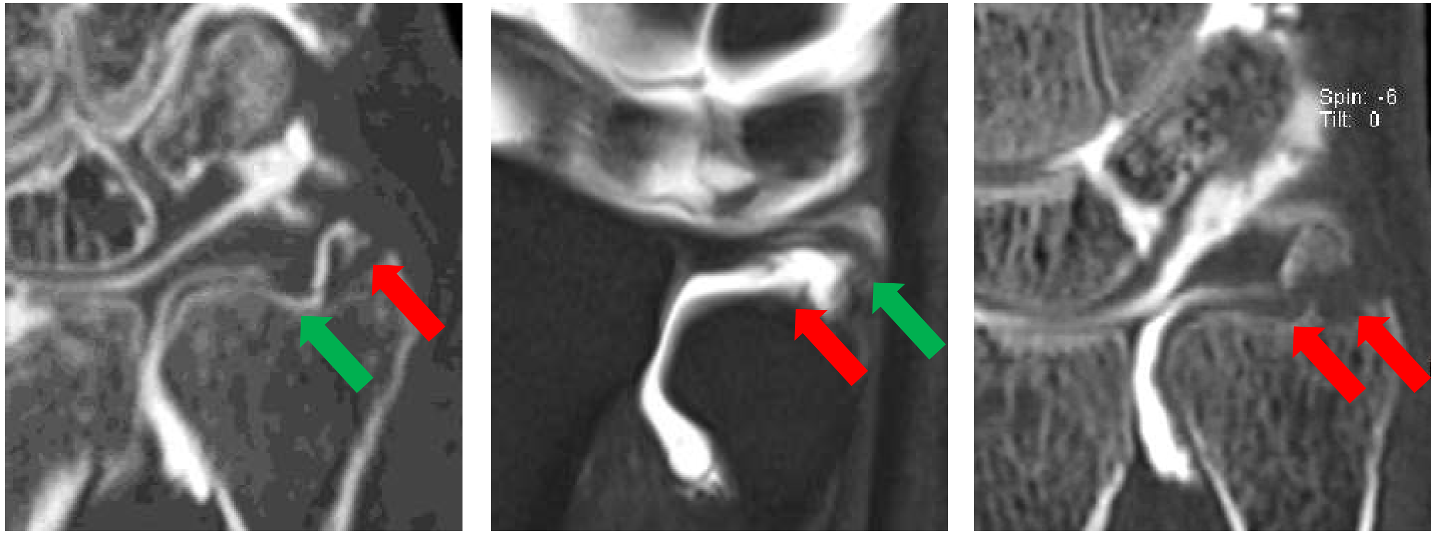




DRUJ and TFCC - Pathology (1)

Instability factors

- large ROM, flat sigmoid notch, partner sizes, asymmetrical geometry, lax ligaments
- insufficient ligaments (PRUL, DRUL)
  - ligament tears (traumatic, inflammatory, …)
  - PSU fractures



Unidirectional DRUJ instability

- partial rupture of the foveal lamina
  ➡ during pronosupination
- complete rupture of the foveal lamina
  ➡ at rest

Bidirectional DRUJ instability

- unidirectional instability + IOM dysfunction
- displaced DRF, Essex-Lopresti injury,
  ulnar shortening osteotomy, Madelung's deformity

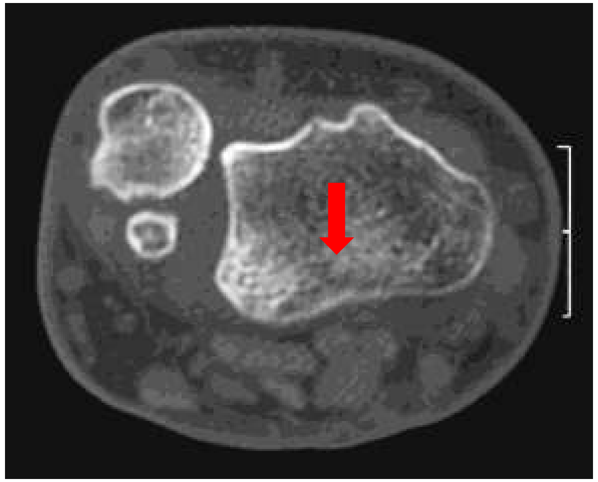
DRUJ and TFCC - Pathology (2)

DRUJ instability in radiography

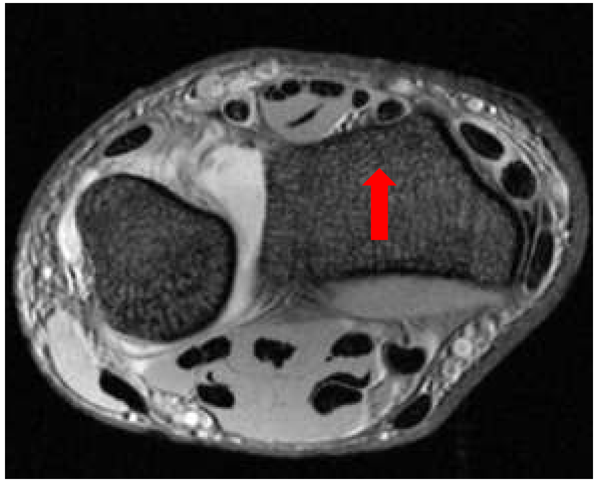
- dorsopalmar view
  - joint space > 3 mm (at rest or under load)
- lateral view
  - radius malaligned relative to the ulna

DRUJ instability in CT / MRI

- more sensitive than X-ray
- 4 measurement methods (acc. Mino, Park, Wechsler, Lo)
- ulna is fixed, radius is dislocated



palmar dislocation



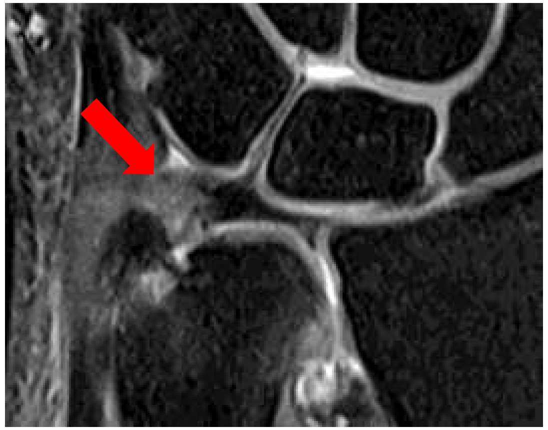
dorsal dislocation

Mino et al. J Hand Surg Am 1983;8:23 – Iida A, et al. J Hand Surg Am 2012;37:968
Gillet R, et al. Semin Musculoskelet Radiol 2025;29:827

DRUJ and TFCC - Pathology (3)

Healing of TFCC injuries

- positive at the ligaments
- negative at the articular disc



DRUJ osteoarthritis

- in chronic DRUJ instability
- predisposing factors
  - asymmetrical DRUJ
  - ulnar shortening osteotomy

Rheumatoid arthritis

- beginning at the PSU
- spreading via the ULL and UTL to the ulnar side of the wrist

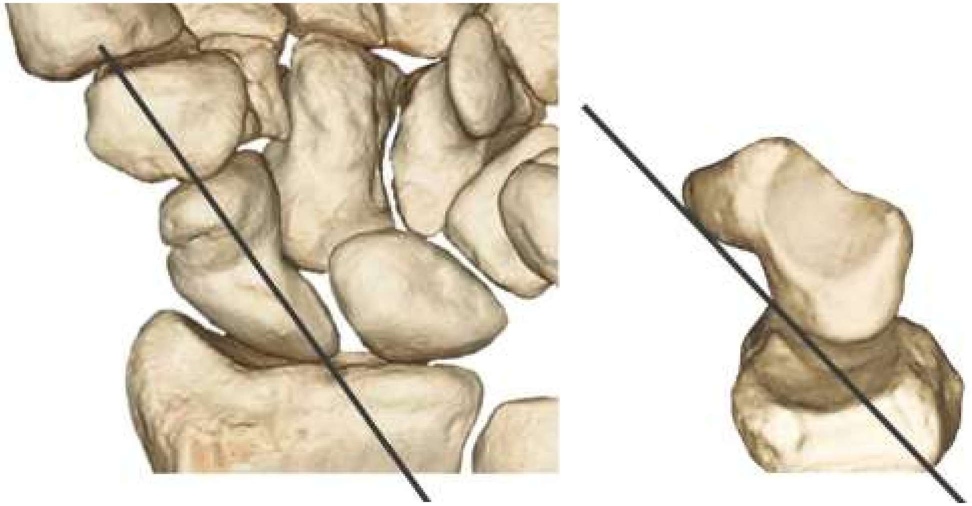
Ulnocarpal instability

- ULL and/or UTL ruptured (traumatic, degenerative, inflammatory)
- dorsal tilt of the triquetrum and lunate

Tolat AR, et al. J Hand Surg Br 1996;21:587-594 – Atzei A, et al. Hand Clin 2011;27:263
Bednar MS, et al. J Hand Surg Am 1991;16:110 – Moritomo H. J Wrist Surg 2013;2:186

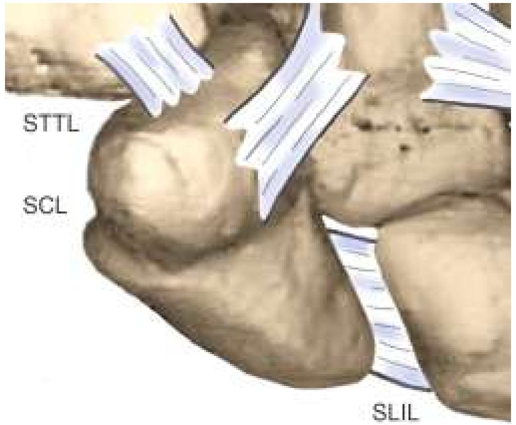
Proximal carpal row - Anatomy (1)

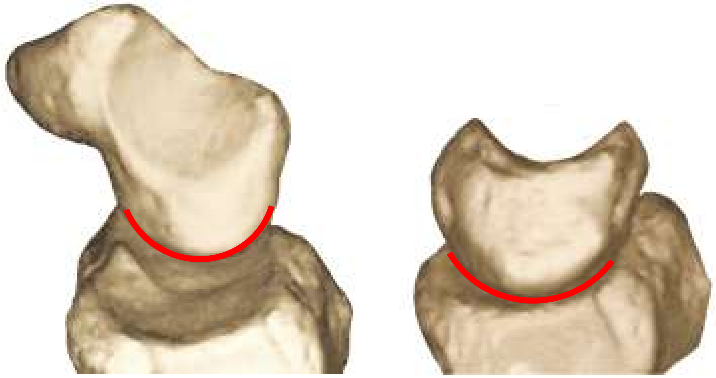
Carpal condyle articulates with the glenoid of the forearm



Scaphoid

- 45 degrees double-angled to the coronal and sagittal planes
- extends distally beyond the midcarpal joint
  - stabilizing bridge ("slider crank")
- proximal connection via
  - scapholunate interosseous ligament (SLIL)
- distal connections via
  - scaphocapitate ligament (SCL)
  - scaphotrapeziotrapezoidal ligaments (STTL)
- small proximal curvature





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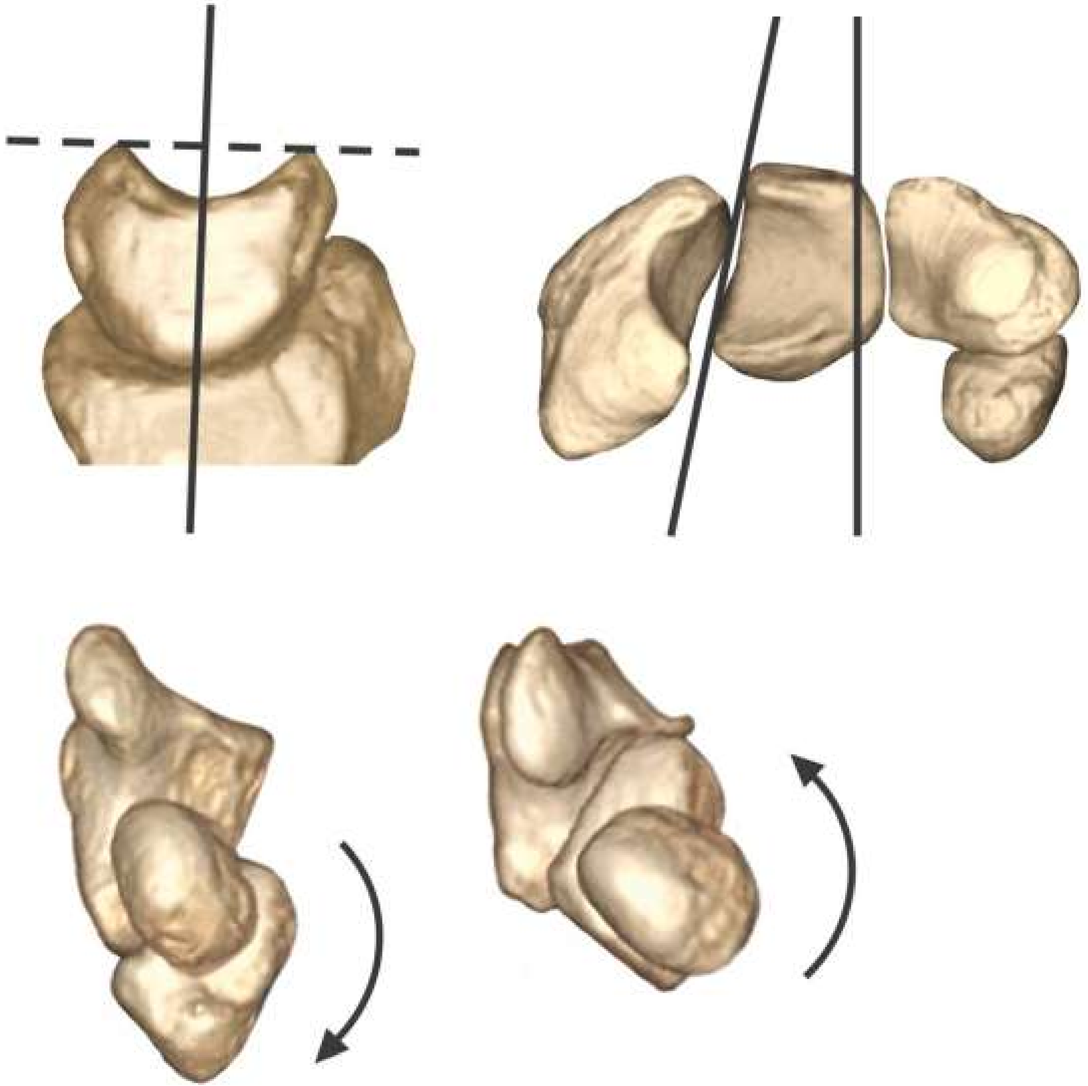
Proximal carpal row - Anatomy (2)

Lunate

- central element of the wrist
- wedge-shaped with a smaller dorsal extension
  - ➡ tendency to rotate into extension

Triquetrum

- pyramid-shaped with a proximal tip
- articulations
  - – to the hamate on a spiral-shaped joint surface
    - ➡ “high position” vs. “low position”
  - – to the pisiform on a flat joint surface



Proximal carpal row - Anatomy (3)

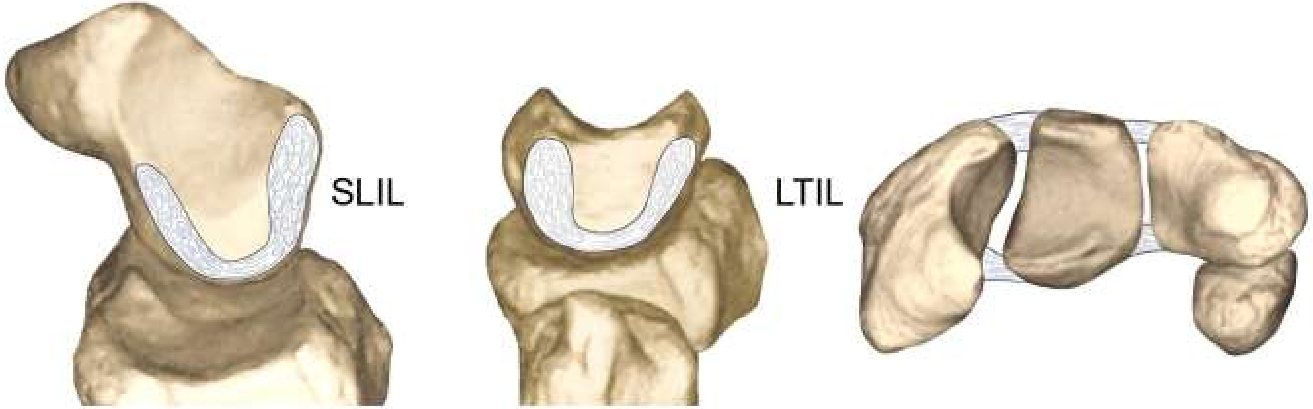
Scapholunate interosseous ligament (SLIL)

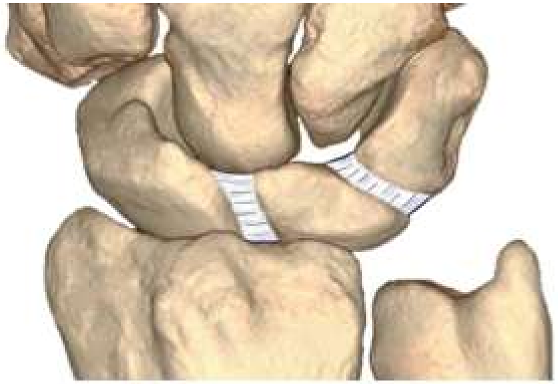
horseshoe-shaped with 3 segments

- **dorsal SLIL segment**
  - strong, horizontally running
  - most important for stability
- **middle SLIL segment**
  - thin membrane without stabilzing function
- **palmar SLIL segment**
  - diagonally running, end-stage stabilzer

Lunotriquetral interosseous ligament (LTIL)

- horseshoe-shaped with 3 segments
- **palmar LTIL** thick and most important for stability

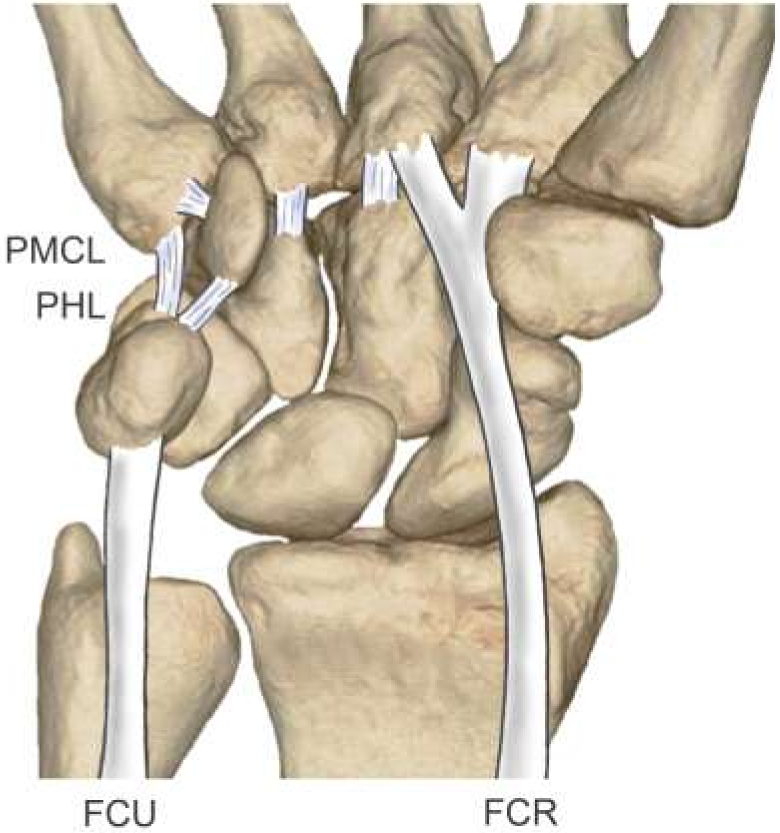


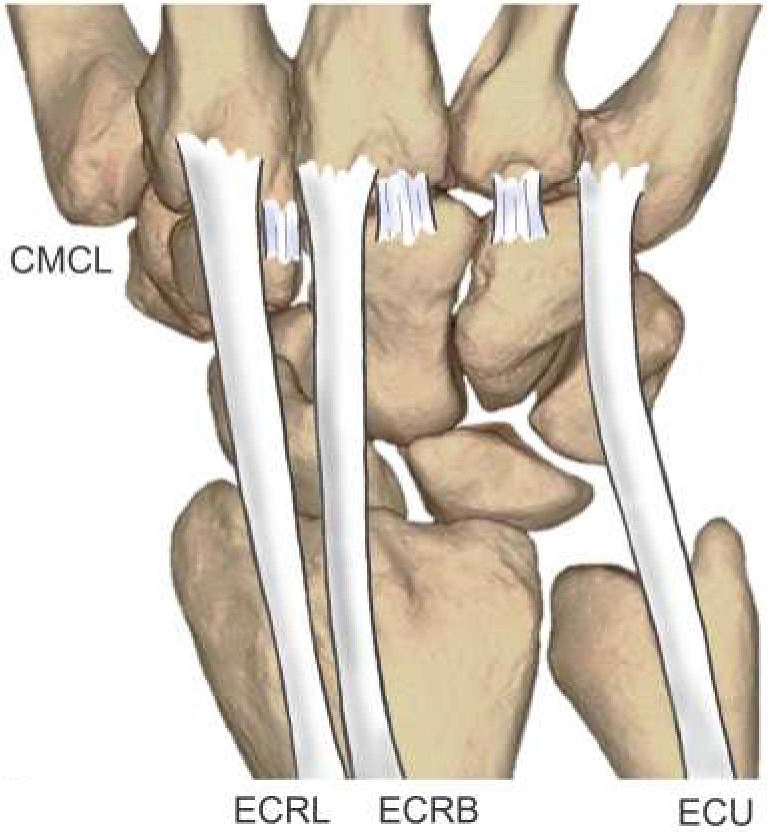


Proximal carpal row - Function (1)

Intercalated segment

- tendons of the extrinsic forearm muscles insert at the metacarpal bases
- proximal carpal row
  - intercalated between the forearm and midcarpus
  - specific movements
  - dynamic ligament cohesion
  - carpal height constant



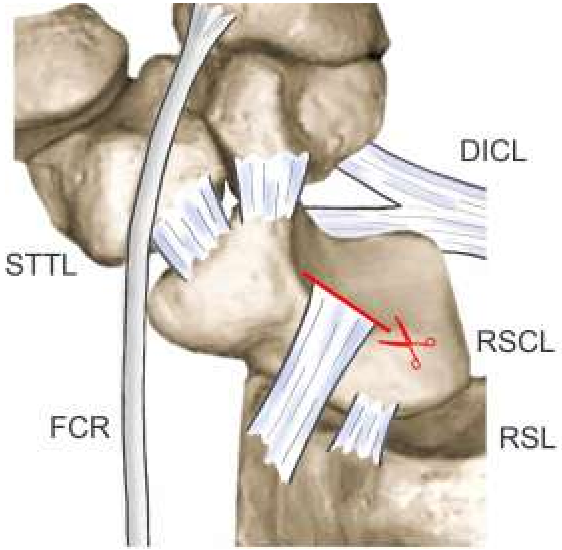


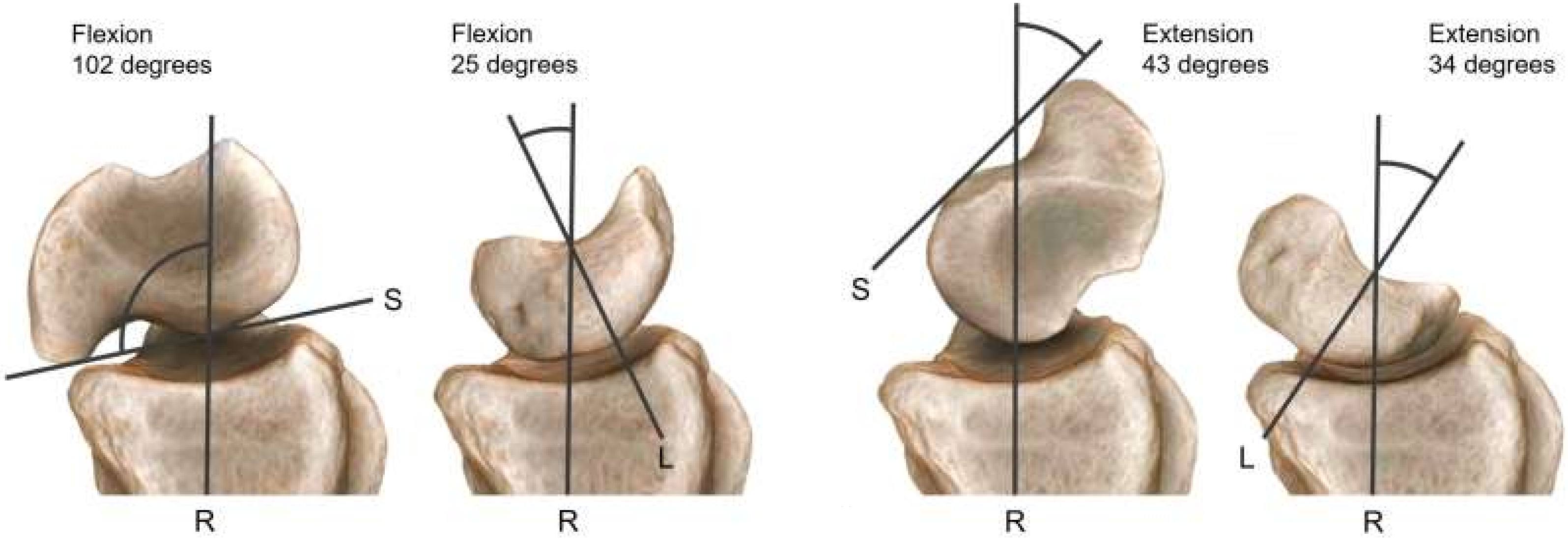
Ruby LK, et al. J Hand Surg Am 1988;13:1 – Hara T, et al. J Hand Surg Am 1992;17:504
Crisco JJ, et al. J Bone Joint Surg Am 2011;93:169 – Wessel LE, et al. J Hand Surg Am 2023;48:1139

Proximal carpal row - Function (2)

Scaphoid

- approx. 30 degrees more of rotation than the lunate
  - smaller proximal curvature
  - SLIL design



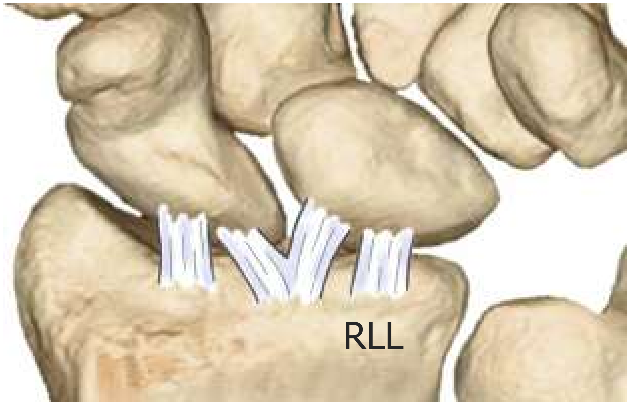


- oblique load transfer is resisted
  - horizontally, by the palmar tilted fovea scaphoidea, the DICL and the RSL
  - longitudinally, by the SLIL, RSCL, STTL and the FCR tendon

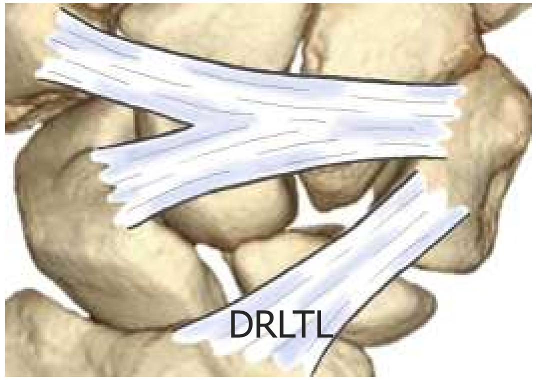
Proximal carpal row - Function (3)

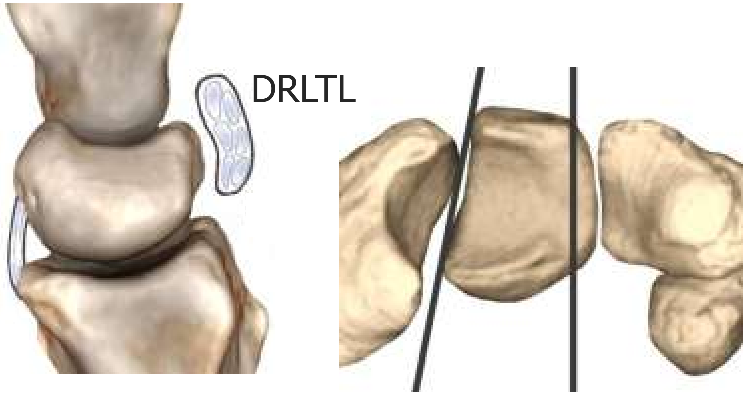
Lunate

- central component of the wrist connected
  - laterally via the SLIL and LTIL
  - palmarly via the RLL
  - dorsally via the DRLTL (no insertion)



- intercalated in the middle carpal column
  - tendency to rotate in extension when detached from the scaphoid
  - due to its wedge shape (dorsal smaller)



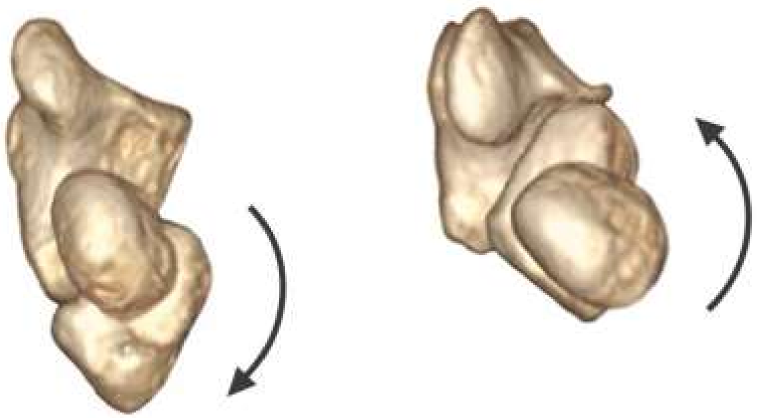


Kauer JMG. Acta Anat 1974;88:481 – Elsaidi GA, et al. Clin Orthop Rel Res 2004;425:152
Dobyns JH, et al. In: Berger RA, Weiss AP (eds). Hand Surgery. Vol. 1, 2004:461

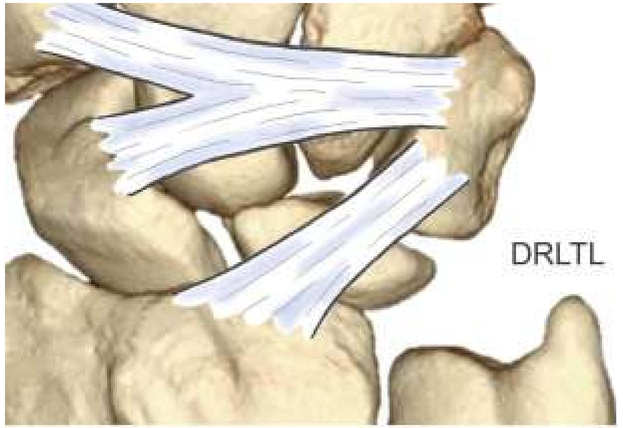
Proximal carpal row - Function (4)

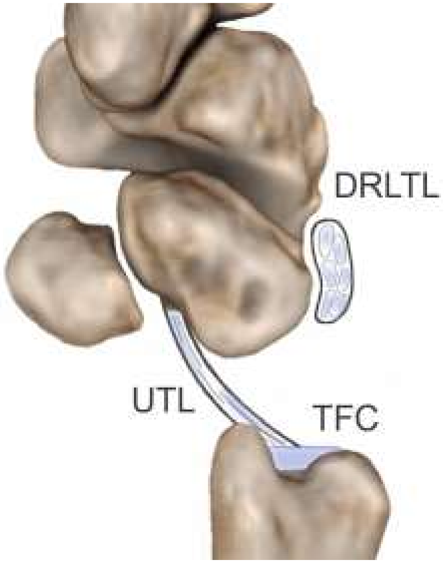
Triquetrum

- lunotriquetral joint
  - 12 – 18 degrees movement during flexion-extension
  - restricted by the LTIL
- hamatotriquetral joint with the triqeutrum
  - in a proximal (“high”) position during radial deviation
  - in distal (“low”) positionduring ulnar deviation



- tilting prevented by
  - the UTL palmarly
  - the DRLTL dorsally

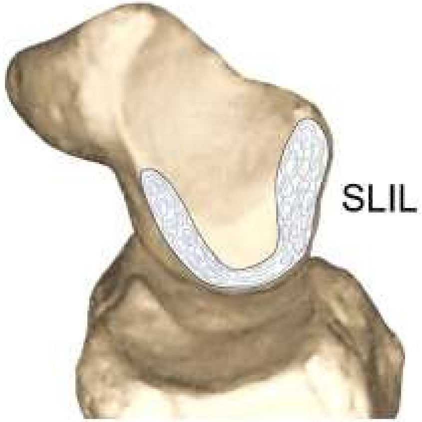


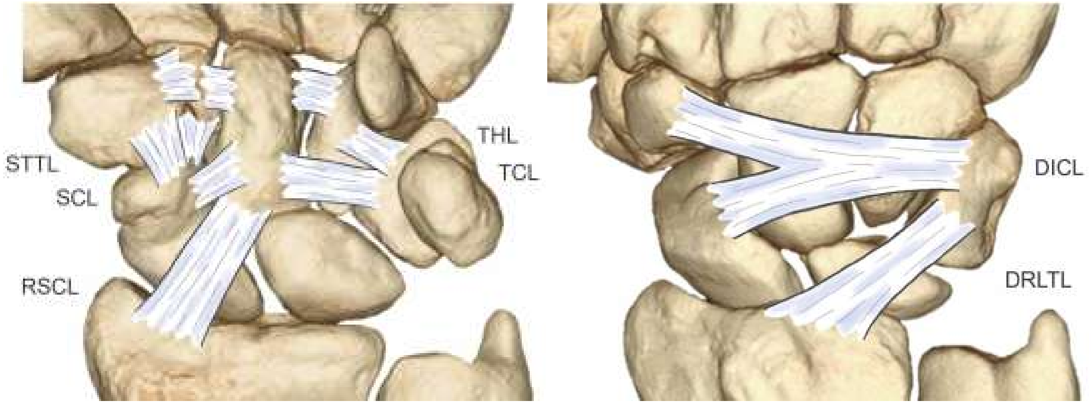


Proximal carpal row - Function (5)

Primary stabilizers
horse-shoe shaped

	SLIL	LTIL
dorsal	▪ strong, horizontal ▪ primary stabilizer	▪ weak, oblique ▪ end-stage stabilzer
palmar	▪ weak, oblique ▪ end-stage stabilizer	▪ strong, horizontal ▪ primary stabilizer

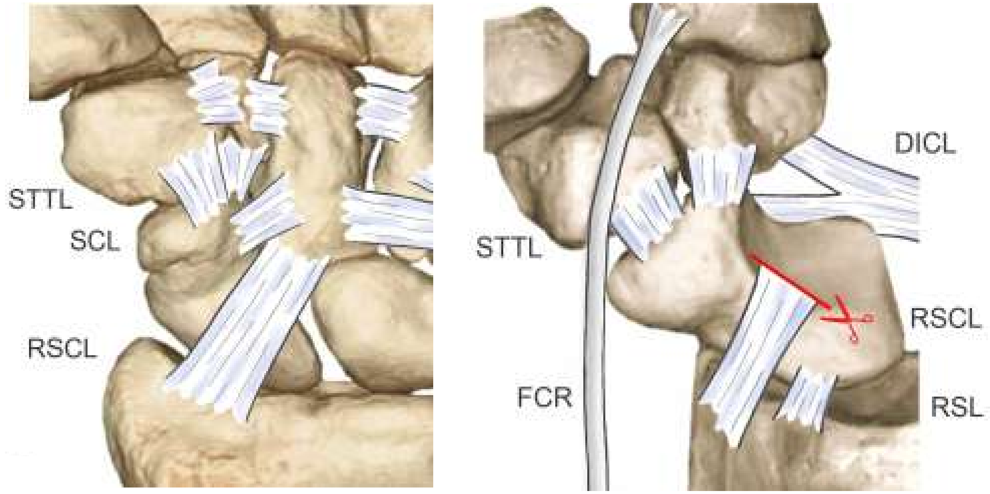




Secondary stabilizers
with mechanoreceptors for neuromuscular control

	SLIL	LTIL
dorsal	▪ DICL, DRLTL	▪ DRLTL
palmar	▪ PRLTL, RSCL ▪ STTL, FCR tendon	▪ PRLTL ▪ UTL

Proximal carpal row - Function (6)

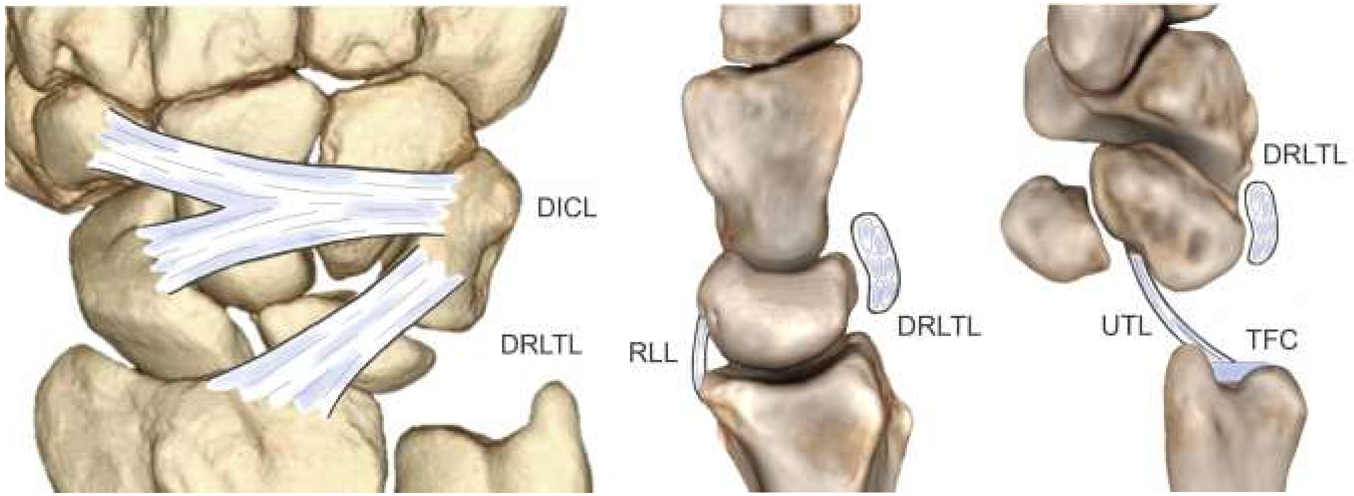


RSCL = palmar support ligament

- crosses the scaphoid waist
- acts as a fulcrum
  (holding the scaphoid in a sling)

Dorsal capsulo-scapholunate septum (DCSS)

- connects the extrinsic capsule and the intrinsic SLIL
- maintains carpal alignment in SLD stage II



Dorsal extrinsic ligaments

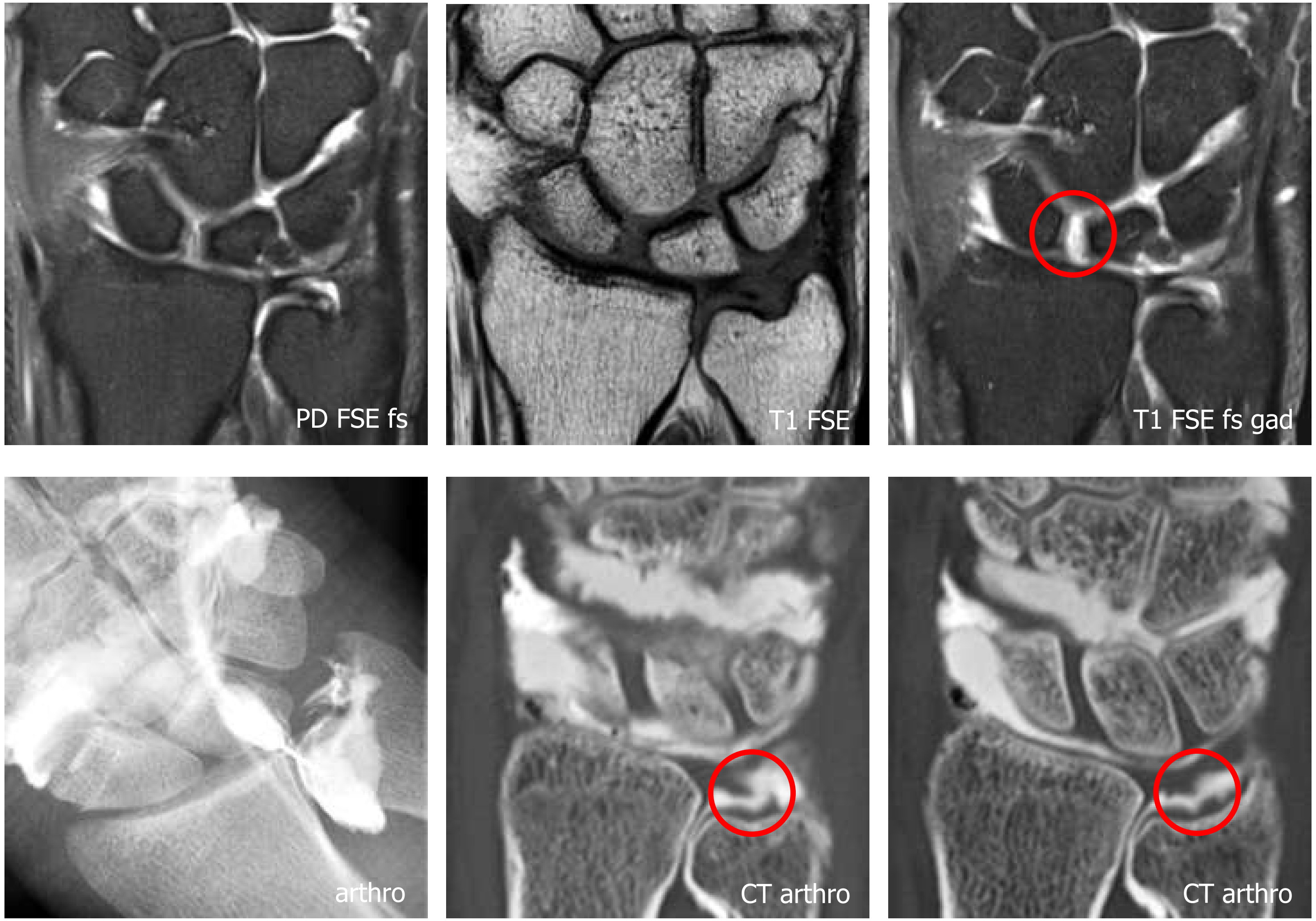
- DICL prevents subluxation of the scaphoid
- DRLTL counteracts rotation of the lunate and scaphoid

Taleisnik J. J Hand Surg Am 1976;1:110 – Salva-Coll G, et al. J Hand Surg Eur Vol 2011;36:553
Van Overstraeten L, et al. J Wrist Surg 2013;2:149 – Wessel LE, et al. J Hand Surg Am 2023;48:1139

Proximal carpal row - Function (7)

Ligament imaging

- **Plain MRI**
  - PD FSE fs, T2 FSE fs, T2* GRE
  - accuracy ~ 60 %
- **Contrast-enhanced MRI**
  - T1 FSE fs following intravenous gadolinium
  - accuracy 90 – 95 %
- **MR arthrography, CT arthrography**
  - T1 FSE, T1 FSE fs, T2 FSE fs
  - accuracy > 95 %



Cerezal L, et al. Sem Musculoskelet Radiol 2012 – Luetkens KS, et al. Eur J Radiol 2021; doi: 10.1007/s00330-021

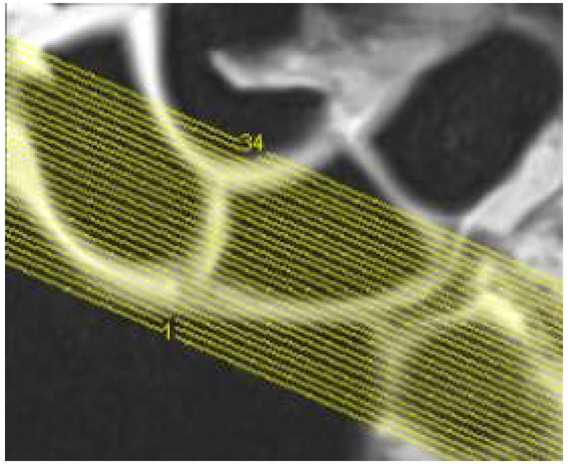
Proximal carpal row - Function (8)

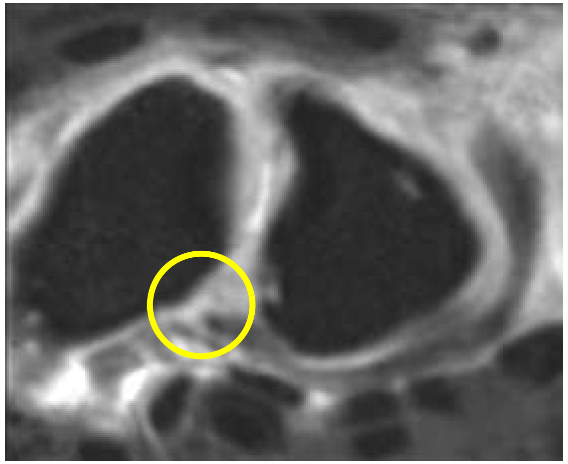
Imaging of the SLIL and LTIL

- palmar segments run obliquely

  ➡ oblique plane corresponding to the anatomy

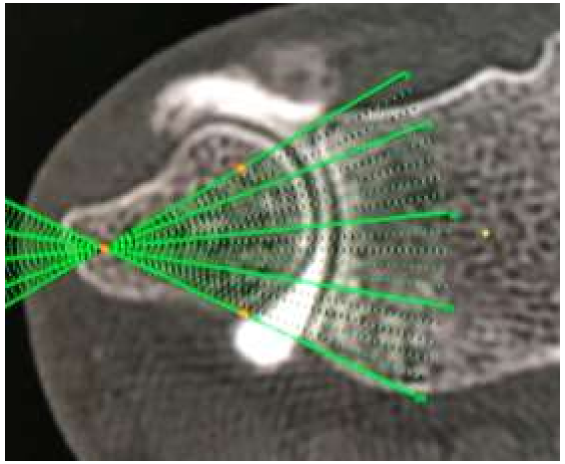
- cave: partial-volume effect





Imaging of the TFCC

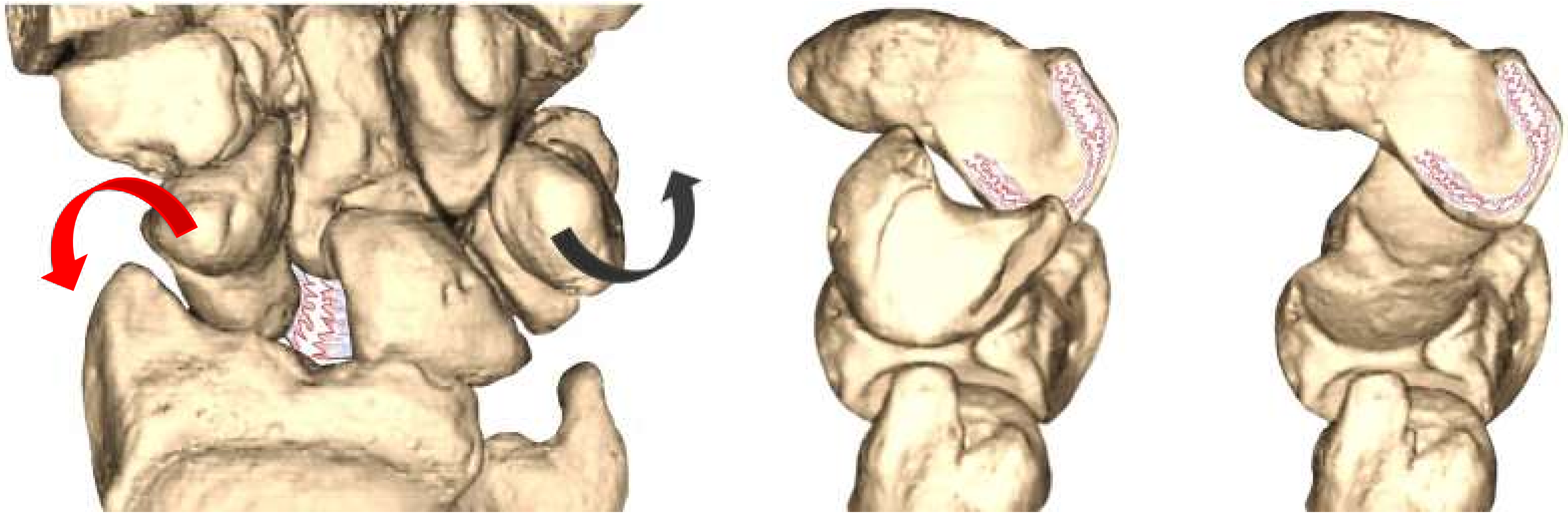
- articular disk, PRUL and DRUL converting ulnarly
- PSU is the pivot center in radial reformatting




Proximal carpal row - Pathology (1)

Scapholunate function as a „spring coil"

- **intact SLIL** ➡ - dorsal segment preventing scaphoid flexion
  - palmar segment preventing triquetrum extension
- **ruptured SLIL** ➡ axial loads lead to SL dissociation
  - scaphoid flexed
  - triquetrum extended



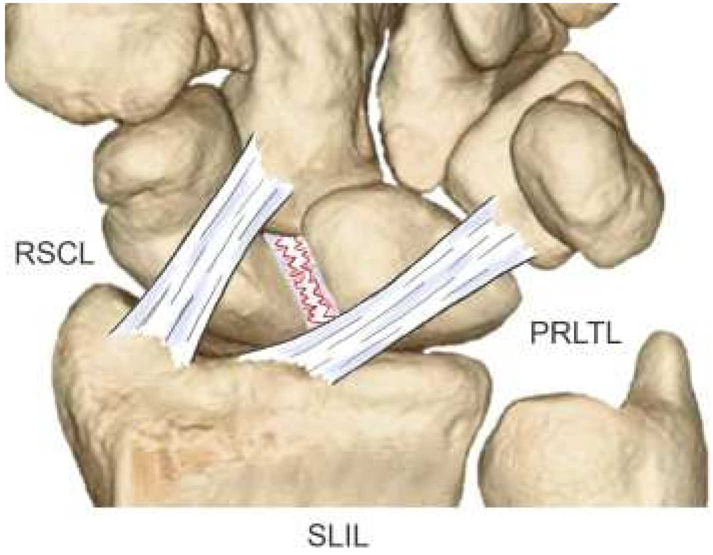
Linscheid RL, et al. J Bone Joint Surg Am 1972;54:1612 – Amadio PC. Clin Anat 1991;4:1
Berger RA, et al. J Hand Surg Am 1999;24:953 - Garcia-Elias M, et al Hand Clin 2001;17:687

Proximal carpal row - Pathology (2)

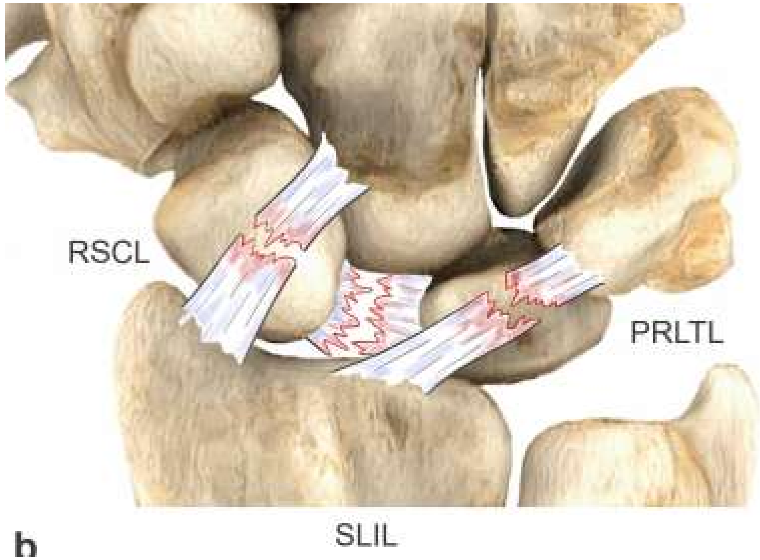
Scapholunate dissociation (SLD)

- by hyperextension injuries (SLIL tear, scaphoid fracture),
  by inflammatory diseases (RA, CPPD), Kienböck's disease, …

- **Dynamic SL instability**
  - SLIL ruptured separately
  - alignment lossed under load (= dyskinematics)



- **Static SL instability**
  - SLIL + secondary stabilizers ruptured
  - alignment lossed already at rest (= dykinesia)

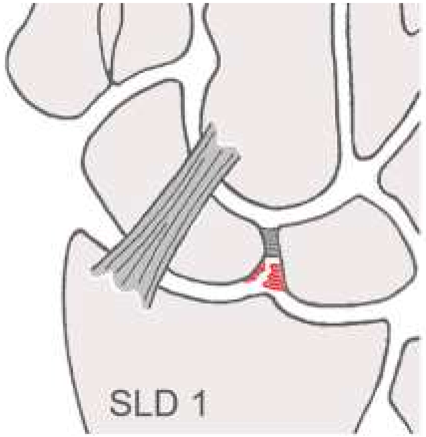


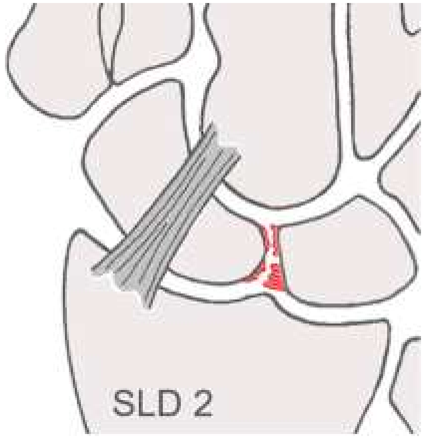
Linscheid RL, et al. J Bone Joint Surg Am 1972;54:1612 – Resnick D, et al. Ann Rheum Dis 1977;36:311
Horii E, et al. J Hand Surg Am 1991;16:355 – Short WH, J Hand Surg Am 2007;32:297

Uniklinikum Würzburg

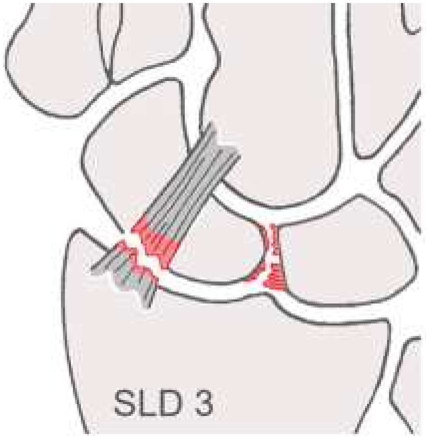
LMU

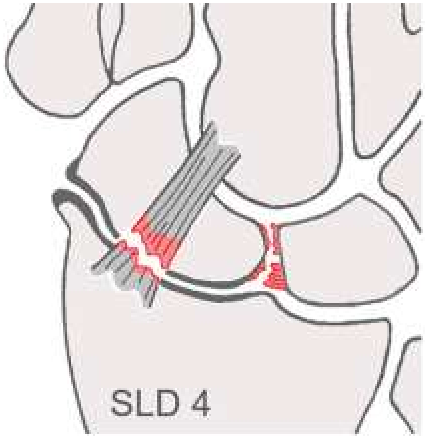
Stages of scapholunate dissociation (SLD)



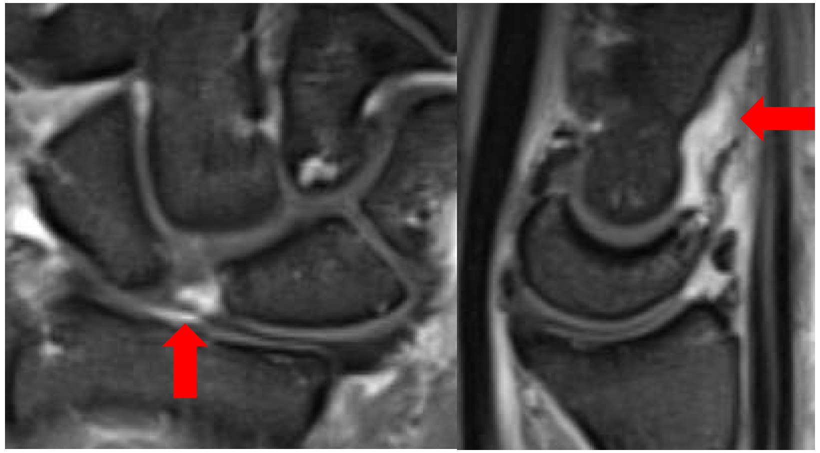


dynamic

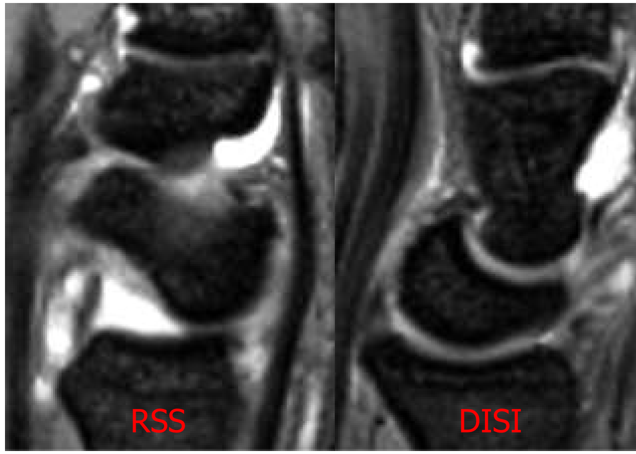




static



„concertina effect"



Pliefke J, et al. Skeletal Radiol 2008;37:139 – Berdia S, et al. Hand Clin 2001;17:533
Mayfield JK, et al. J Hand Surg Am 1980;5:226

Proximal carpal row - Pathology (4)




Dorsopalmar stress view

- ball grip
- pencil grip
- under load, the carpal ring is prone to widening at the level of the weak ligament

The carpus is an oval ring
(Lichtman 1993)

Dorsopalmar cinematography

- radial and ulnar deviations
- temporary widening of the SL gap due to SLIL insufficiency


Video

- Terry-Thomas sign is facultative !

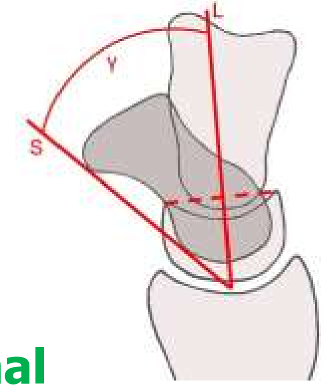
Larsen CF, et al. J Hand Surg Am 1995;20:757 – Berdia S, et al. Hand Clin 2001;17:533
Schmitt R, et al. Semin Musculoskelet Radiol 2021;25:191

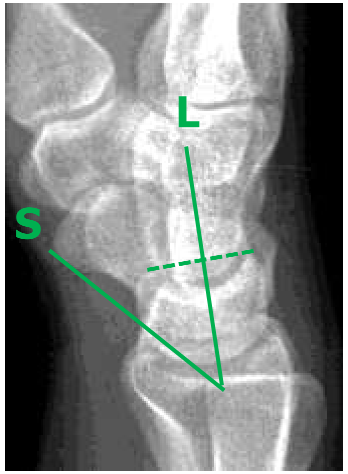
Proximal carpal row - Pathology (5)

Scapholunate angle

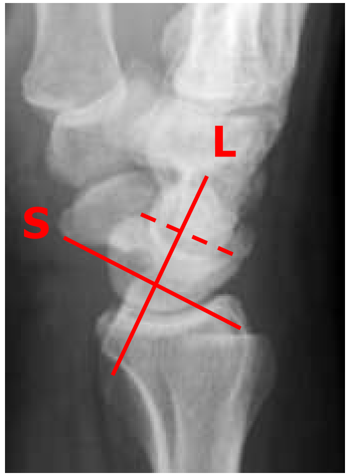
- tangential method
- normal 30 – 60 degrees
- always to be determined

normal





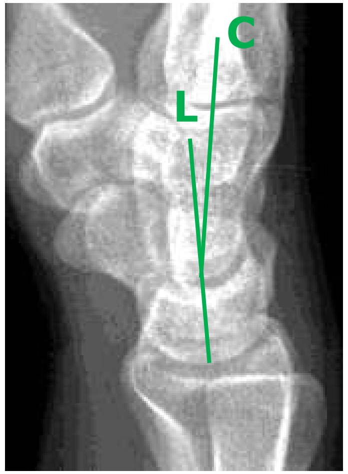
DISI at SLD



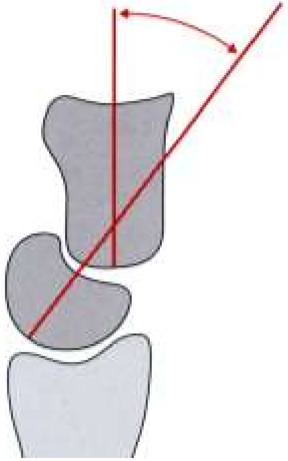
Middle column collinear

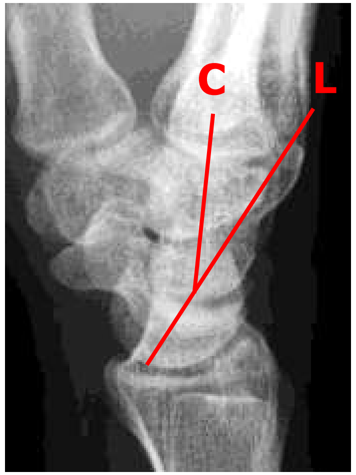
- line connecting the radius, lunate, capitate and MC III
- range 0 ± 15 degrees

normal



DISI at SLD



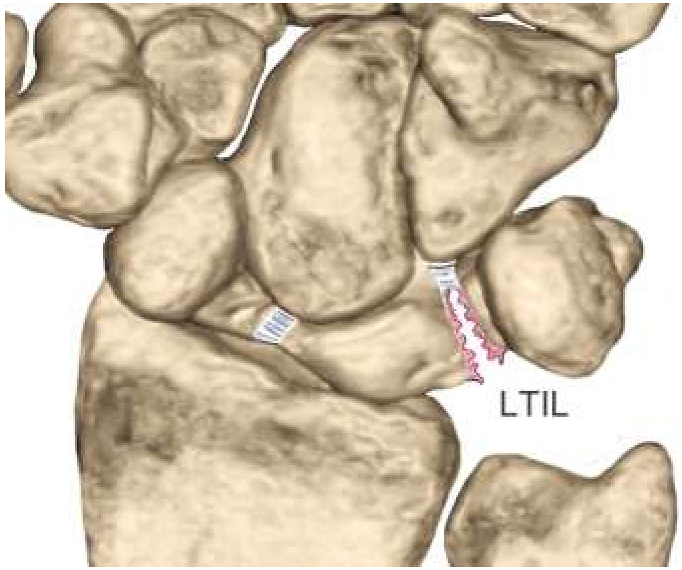


Larsen CF, et al. J Hand Surg Am 1995;20:757 – Berdia S, et al. Hand Clin 2001;17:533
Schmitt R, et al. Semin Musculoskelet Radiol 2021;25:191

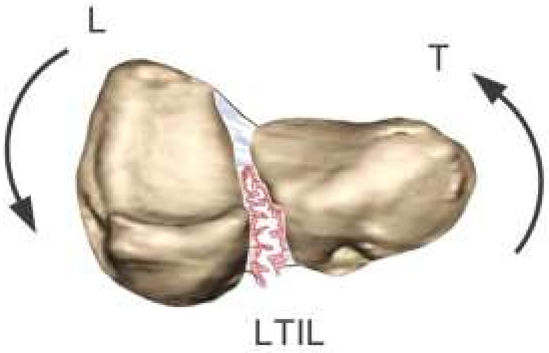
Proximal carpal row - Pathology (6)

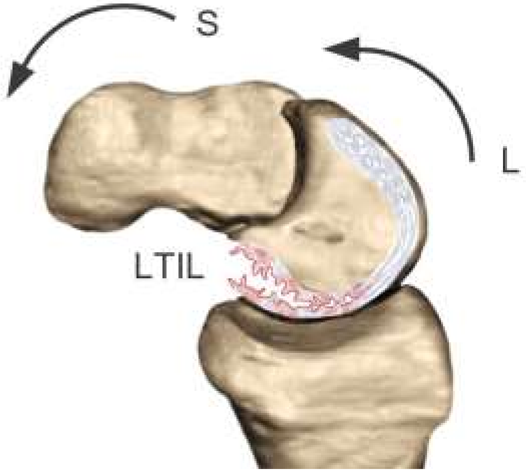
Lunotriquetral dissociation (LTD)

- less common than SLD
- 50 % by hyperpronation injuries,
  50 % by inflammatory diseases, …
- often combined with a TFCC lesion
- **Dynamic LT instability**
  - LTIL ruptured separately
  - loss of alignment under load (= <u>dyskinematics</u>)
- **Static LT instability**
  - LTIL + secondary stabilizers ruptured
  - loss of alignment already at rest (= <u>dyskinesia</u>)



- scaphoid-lunate bloc is flexed ➡ PISI



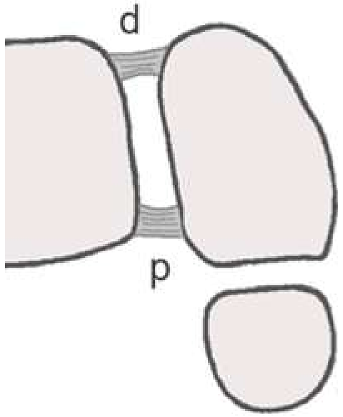


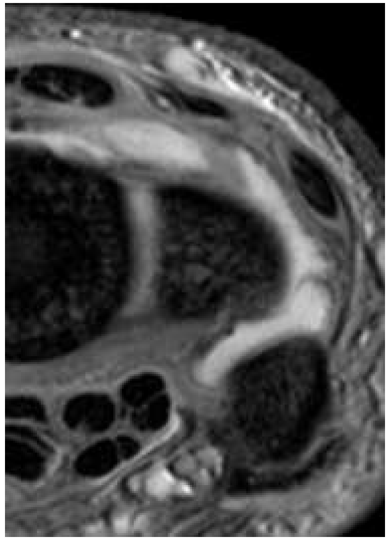
- triquetrum is extended

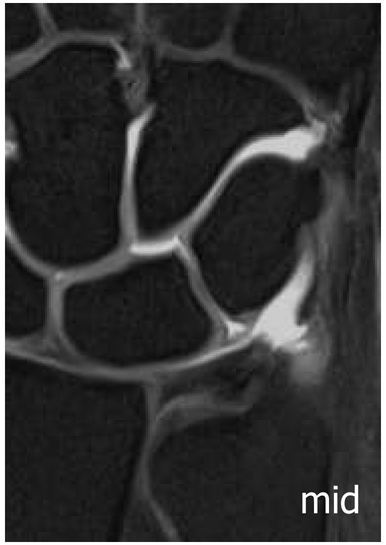
Linscheid RL, et al. J Bone Joint Surg Am 1972;54:1612 – Ambrose L, et al. Hand Clin 1992;8:653
Murray PM, et al. J Hand Surg Am 2012;37:721

Proximal carpal row - Pathology (7)

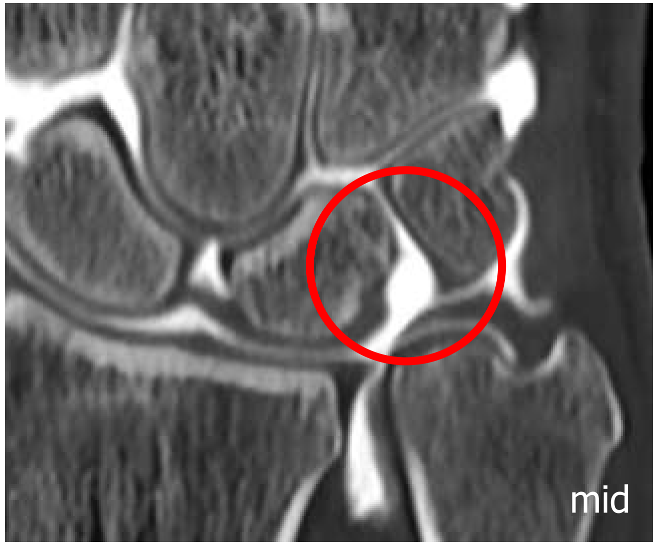
Normal LT ligament
(MR arthrography)







Torn LT ligament
(CT arthrography)



Linscheid RL, et al. J Bone Joint Surg Am 1972;54:1612 – Amadio PC. Clin Anat 1991;4:1
Murray PM, et al. J Hand Surg Am 2012;37:721

Proximal carpal row - Pathology (8)

Perilunate injuries (according to Mayfield 1980)

Stage I

- SLIL partially ruptured
- subluxation of the scaphoid

Stage II

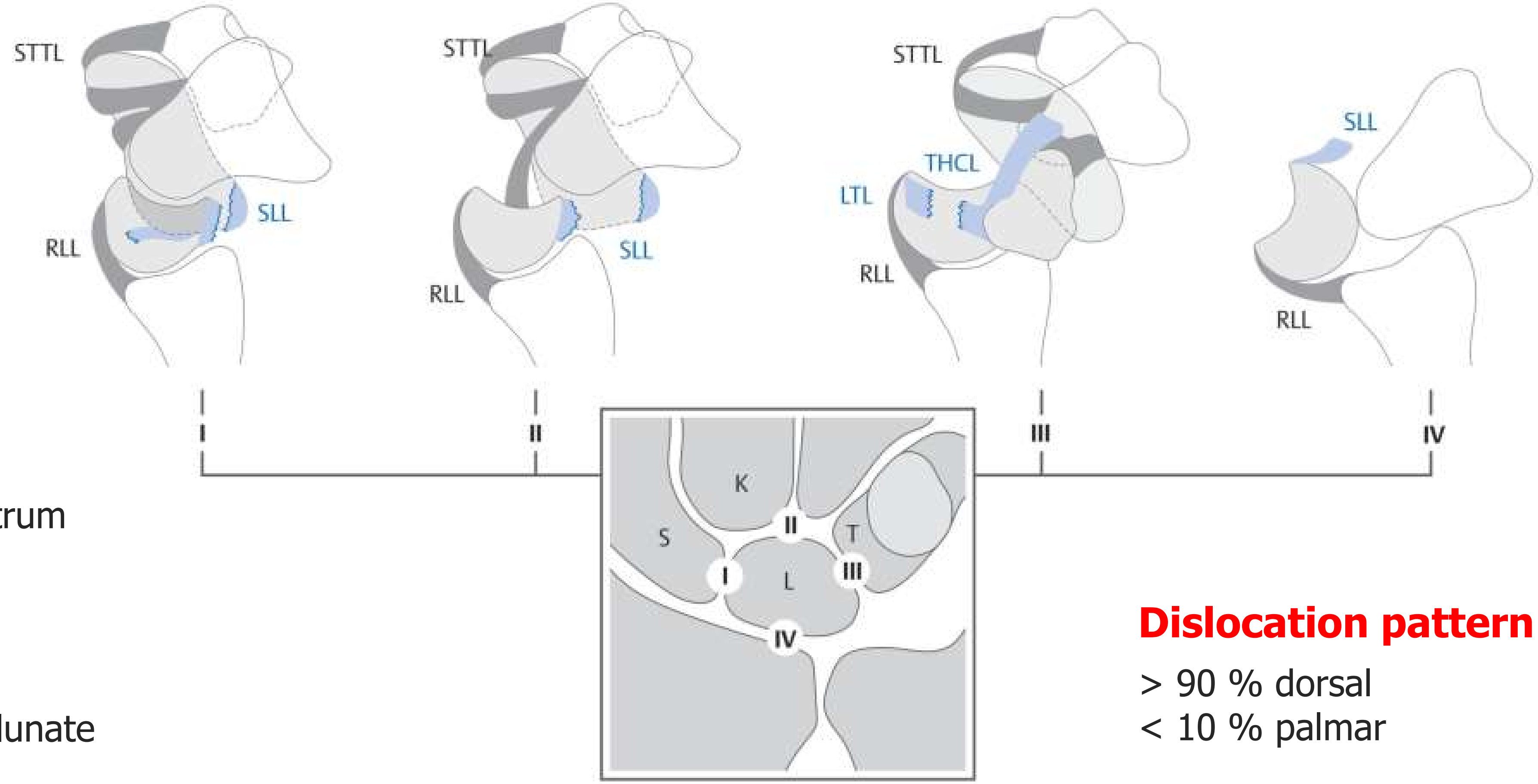
- SLIL completely ruptured
- dislocation of the scaphoid (DISI)

Stage III

- SLIL + LTIL ruptured
- dislocation of the lunate and triquetrum

Stage IV

- SLIL + LTIL + DRLTL ruptured
- complete palmar dislocation of the lunate



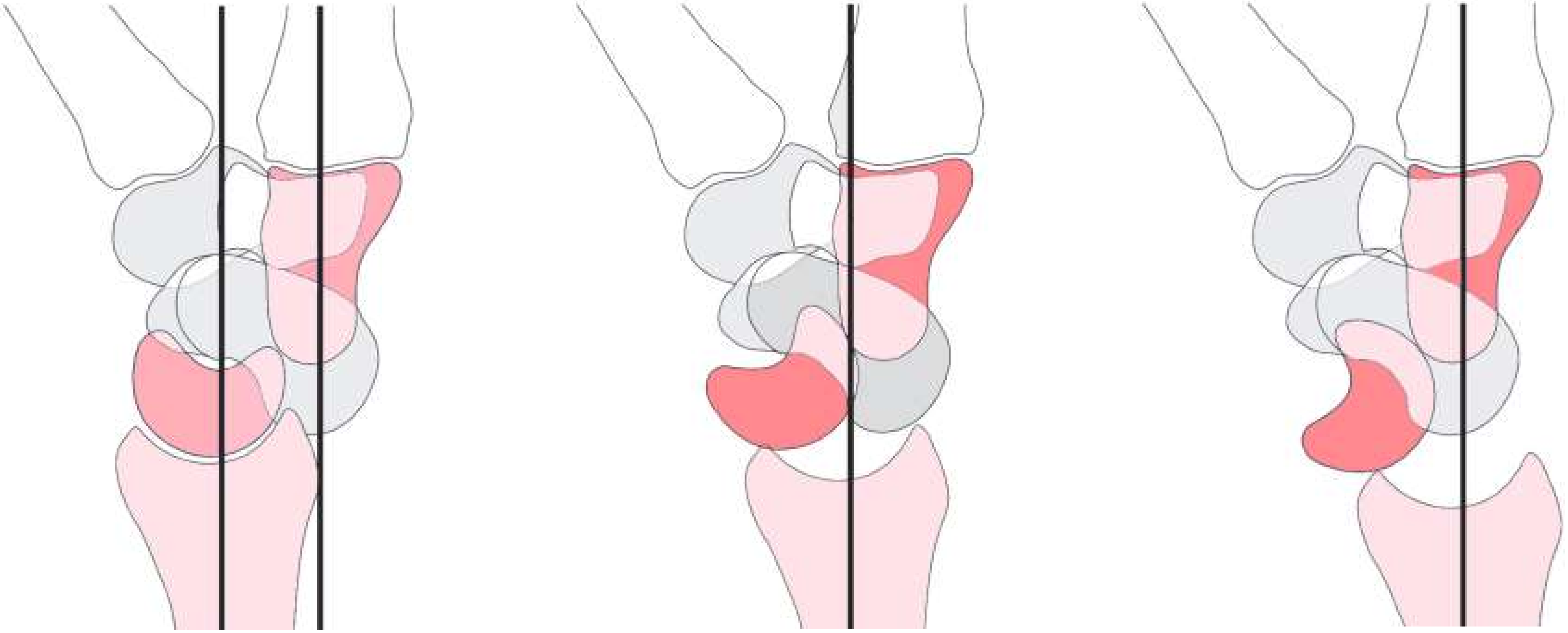
Dislocation pattern

> 90 % dorsal
< 10 % palmar

Proximal carpal row - Pathology (9)

Position of the lunate depends on

- rotational state (DISI, PISI)
- location with the radiocarpal and midcarpal joints



Perilunate dislocation
- lunate in the fovea lunata
- wrist displaced relative to the radiocarpal joint

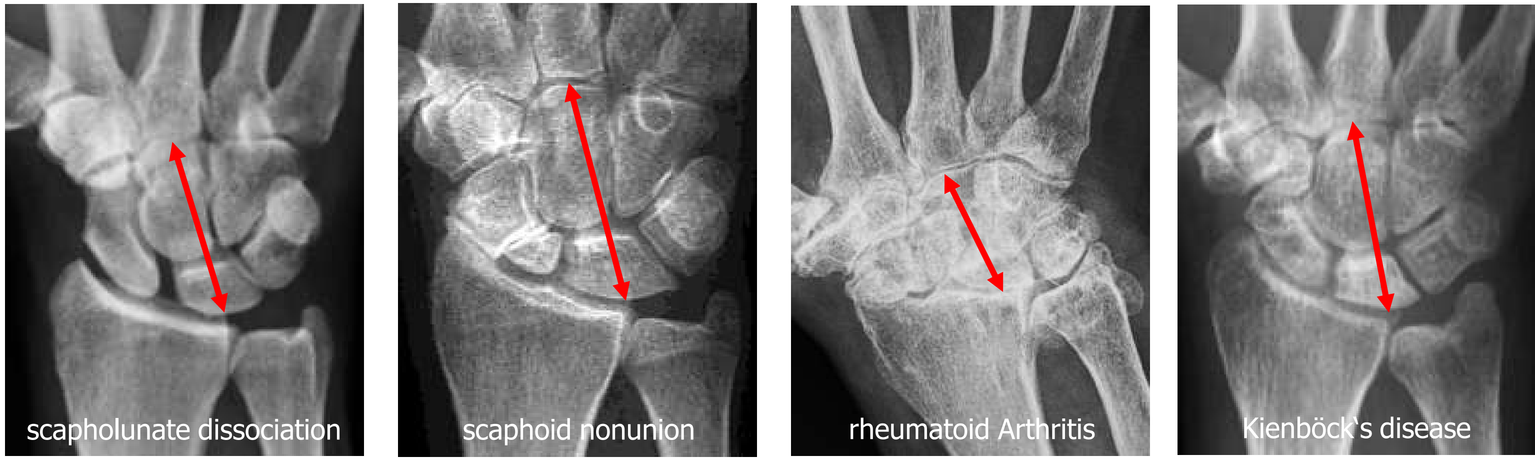
Midcarpal instability
- lunate subluxated palmarly
- wrist displaced relative to the radiocarpal joint

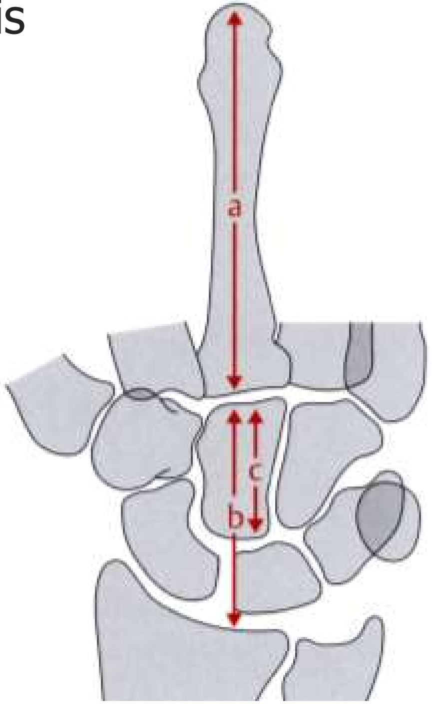
Lunate disloaction
- lunate completely protruded
- rest of the wrist collinear with the radius

Proximal carpal row - Pathology (9)

Reduced carpal height

- causes
  - scapholunate dissociation (SLD)
  - scaphoid nonunion
  - rheumatoid arthritis
  - Kienböck‘s disease





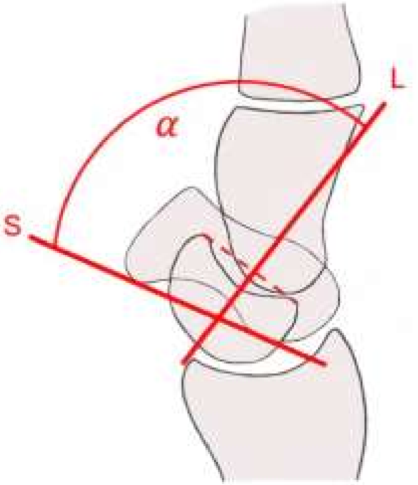
- Youm index
  - carpal height : length of metacarpal III
  - normal is 0,54 ± 0.03
- Nattrass index
  - carpal height : length of capitate
  - normal is 1,57 ± 0,05

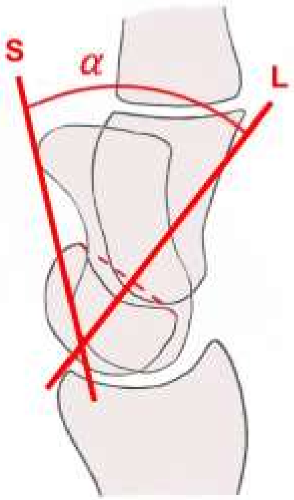
Nattrass GR, et al. J Bone Joint Surg Am 1994;76:88 –

Proximal carpal row - Pathology (10)

DISI configuration

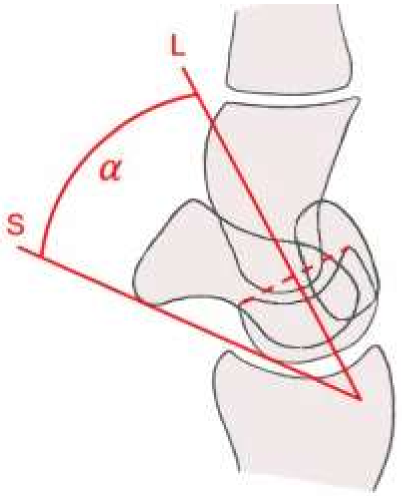
- lunate is extended
- scapholunate dissociation (SLD)
  - SL angle > 60 degrees
  - dorsal RSS
  - „ring sign“ positive
- STT osteoarthritis advanced collapse (SOAC)
  - in STT osteoarthritis
  - entire proximal row is extended
  - SL angle normal

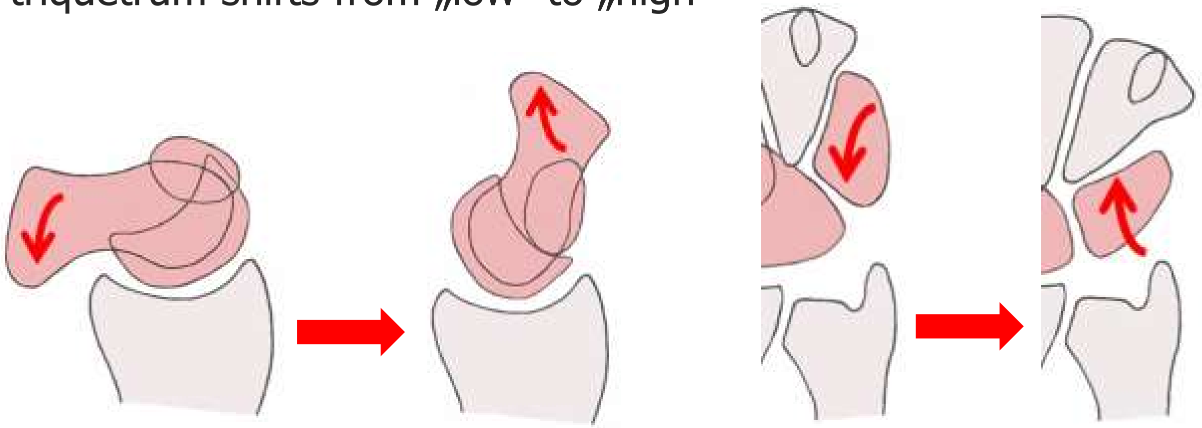




PISI configuration

- lunate is flexed
- lunotriquetral dissociation (LTD)
  - scaphoid-lunate block is flexed
  - triquetrum is extended („low“ position)
- midcarpal instability (MCI)
  - entire proximal row shifts from flexion into extension
  - triquetrum shifts from „low“ to „high“





Horii E, et al. J Hand Surg Am 1991;16:355 – Lichtman DM, et al. J Hand Surg Am 2006;31:491
Oliveira R, et al. Rev Iberoam Cirugía Mano 2020;48:93 – Cerezal A, et al. Semin Musculoskelet Radiol 2025;29:849

Radio- and ulnocarpal joints - Anatomy

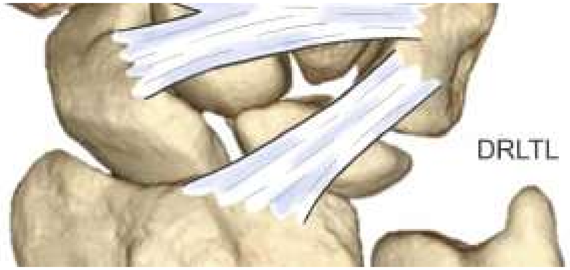
Congruent articulation

- **concave socket of the forearm**
  radius, TFCC
- **convexe condyle of the proximal carpal row**
  scaphoid, lunate, triquetrum

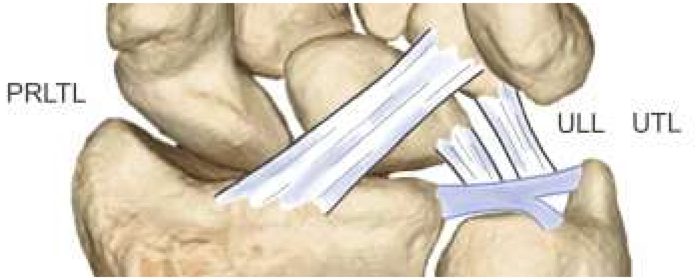
Ligament stability by

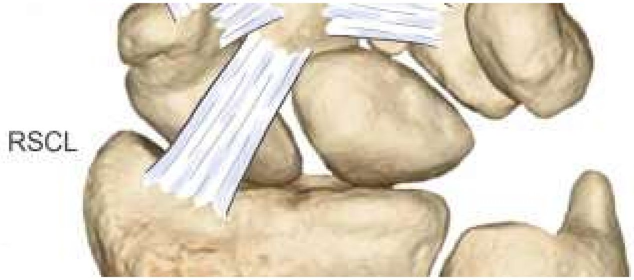
- **short radiocarpal ligaments** (palmar)
  RSL, RLL

- **long radiocarpal ligament** (dorsal)
  DRLTL



- **long radiocarpal ligaments** (palmar)
  PRLTL, RSCL
- **ulnocarpal ligaments** (palmar)
  ULL, UTL



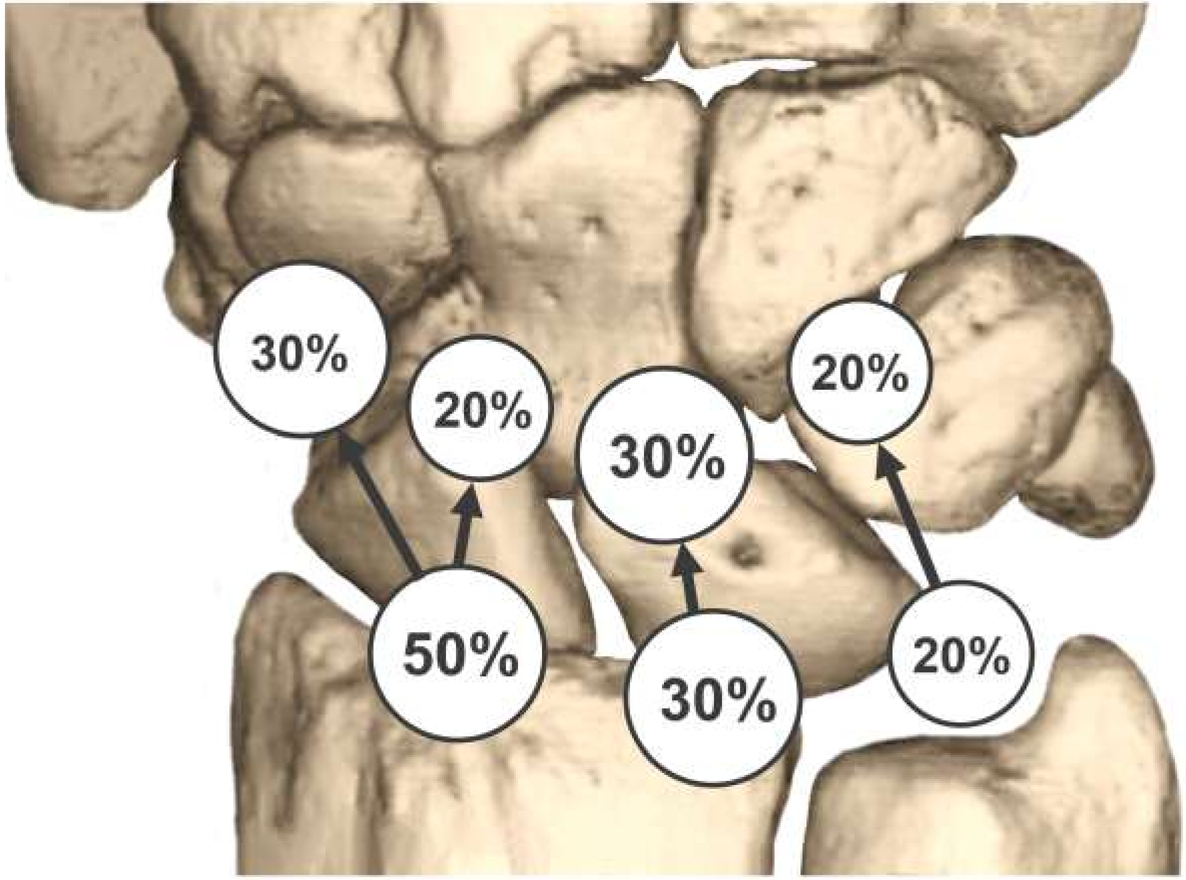


Mayfield JK, et al. J Hand Surg Am 1980;5:226 – Watson K, et al. J Hand Surg Br 1993;18:62
Viegas SF, et al. J Hand Surg Am 1999;24:456 – Moritomo H. J Wrist Surg 2013;2:186

Radio- and ulnocarpal joints - Function (1)

Axial load transfer in a neutral position

- 50 % via the radioscaphoid compartment
- 30 % via the radiolunate compartment
- 20 % via the ulnocarpal compartment



Short ulna ➡ radiocarpal load ↓
Long ulna ➡ ulnocarpal load ↑

Flexion ➡ axial load ↓
Extension ➡ axial load ↑

Radial deviation ➡ radioscaphoid load ↑
Ulnar deviation ➡ radiolunate load ↑

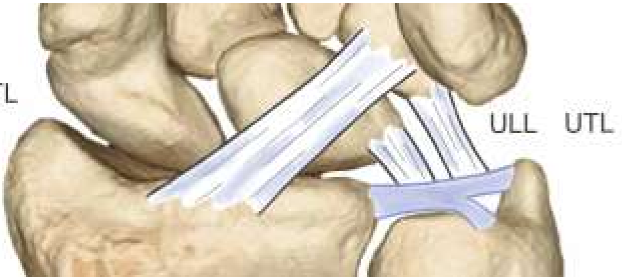
Gripping ➡ ulnocarpal load ↑
(ulnar deviation + pronation)

Hara T, et al. J Hand Surg Am 1992;17:504 – Hagert E. J Hand Ther 2010;23:2
Harley BJ, et al. J Hand Surg Am 2015;40:211

Radio- and ulnocarpal joints - Function (2)

Radial stability („sling ligaments")

- by the PRLTL and RSCL on the palmar side
- by the DRLTL on the dorsal side



Ulnar stability

- by the ULL and ULT on the palmar side

Palmar stability („suspensory ligament")

- by the RSCL

Dorsal stability

- by the RSL and RLL on the palmar side
- by the DRLTL on the dorsal side (lunate)

No collateral ligaments !

- wrist is not a hinge joint
- compensated by the - APL on the radial side and
  - ECU on the ulnar side

Elsaidi GA, et al. Clin Orthop Rel Res 2004;425:152 –Berger RA. Hand Clin 1997;13:63
Viegas SF, et al. J Hand Surg Am 1999;24:456 – Salva-Coll G, et al. J Hand Surg Eur Vol 2011;36:553

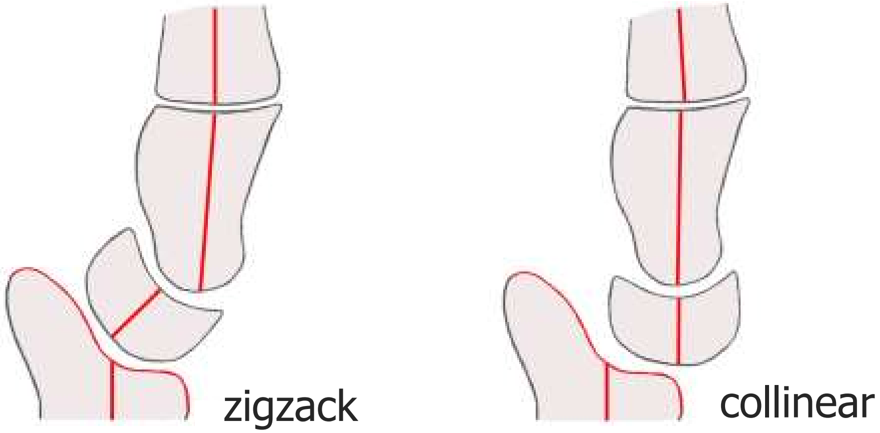
Radio- and ulnocarpal joints - Pathology (1)

Radiocarpal instability (sagittal)

is non-dissociative

- primarily, abnormal radial joint surface
  - displaced extra-articular DRF
  - Barton-type radius fracture
  - malunited distal radius fracture (dorsal inclination > 10 degrees)

- secondarily, the intact carpus compensates for stability
  - zigzack alignment = **carpal instability adaptive (CIA)**
  - collinear alignment



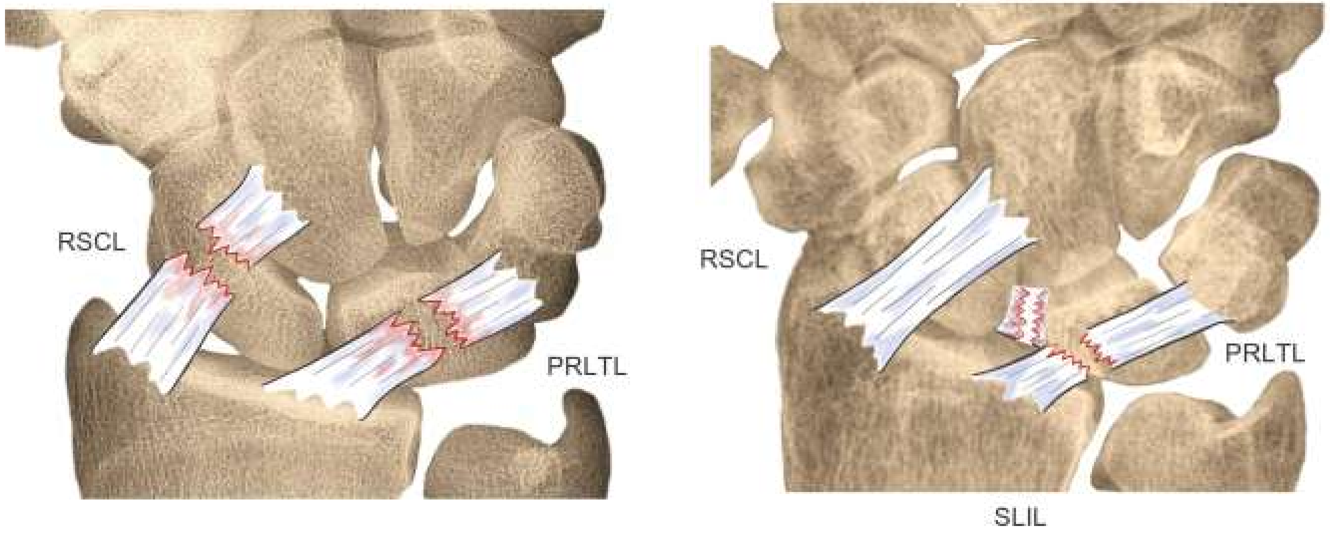
Wright TW, et al. J Hand Surg Br 1994;19:763 – Dumontier C, et al. J Bone Joint Surg Am 2001;83:212
Prommersberger KJ, et al. Handchir Mikrochir Plast Chir 2023;55:211

Radio- and ulnocarpal joints - Pathology (2)

Ulnar translocation

- insufficient slingshot ligaments (PRLTL, DRLTL, RSCL)
- in high-energy trauma, inflammatory disease (CPPD arthropathy, rheumatoid arthritis), Madelung's deformity

- **Taleisnik type I**
  the entire carpus slips in ulnar direction
  = non-dissociative
- **Taleisnik type II**
  in SLD, only the ulnar part of the carpus slips
  = combined dissociative and non-dissociative

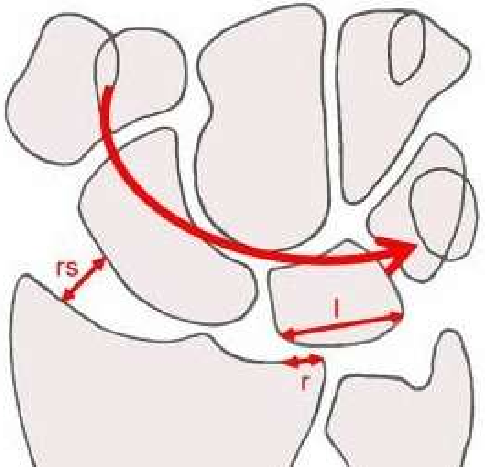


Taleisnik J. Clin Orthop Relat Res 1980;149:73 – Rayhack JM, et al. J Hand Surg Am 1987;12:180
Viegas SF, et al. J Hand Surg Am 1995;20:312 – Dumontier C, et al. J Bone Joint Surg Am 2001;83:212

Radio- and ulnocarpal joints - Pathology (3)

Ulnar translocation

- radioscaphoid joint space > 2 mm
- radiolunate contact distance < 50 %

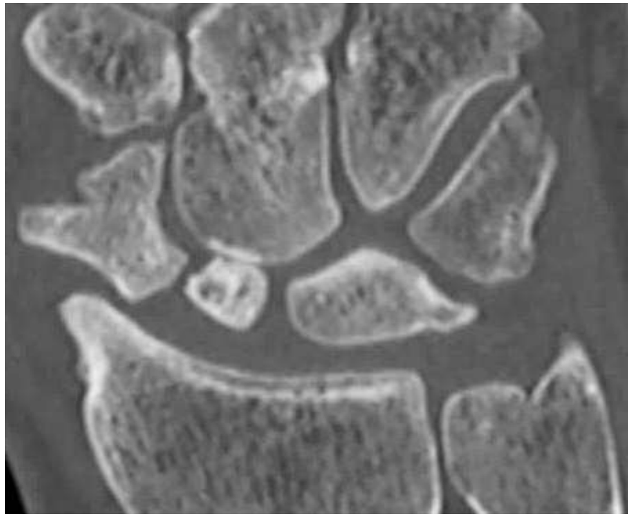


Palmar translocation

- rare, following a reversed Barton's fracture

Radial translocation

- rare, following a deplaced chauffeur fracture or deforming scaphoid nonunion

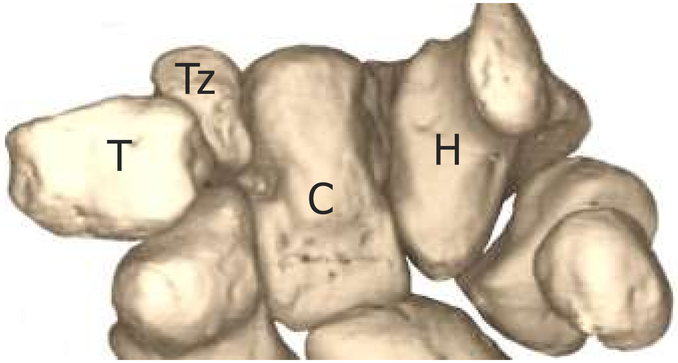


Taleisnik J. Clin Orthop Relat Res 1980;149:73 – Rayhack JM, et al. J Hand Surg Am 1987;12:180
Dumontier C, et al. J Bone Joint Surg Am 2001;83:212 – Berschback JC, et al. J Hand Surg Eur Vol 2012;37:755

The distal carpal row - Anatomy (1)

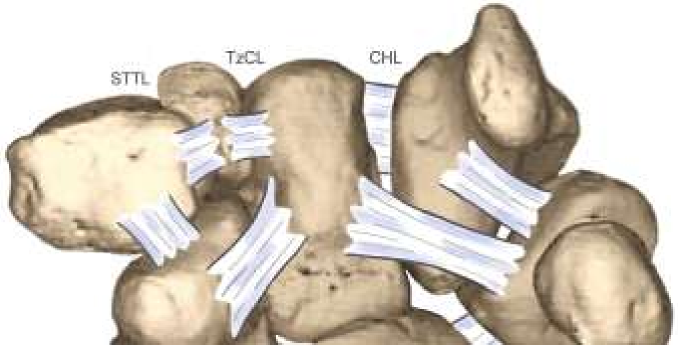
Bones

- trapezium, trapezoid, capitate, and hamate



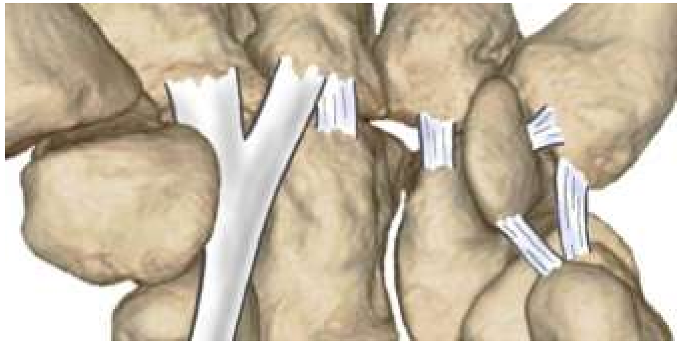
Ligaments

- <u>intercarpal</u> (IMCL)
  palmar, interosseous, and dorsal layers



- flexor retinaculum
- extensor retinaculum
- dorsal intercarpal ligament (DICL)

- <u>carpometacarpal</u> (CMCL)
  palmar, interosseous, and dorsal layers



Taleisnik J. J Hand Surg Am 1976;1:110 – Garcia-Elias M. Hand Clin 1997;13:151
Viegas SF, et al. J Hand Surg Am 1999;24:456 – Reinsmith LE, et al. Radiology. 2013;267:680

The distal carpal row - Function and Pathology

Amphiarthroses

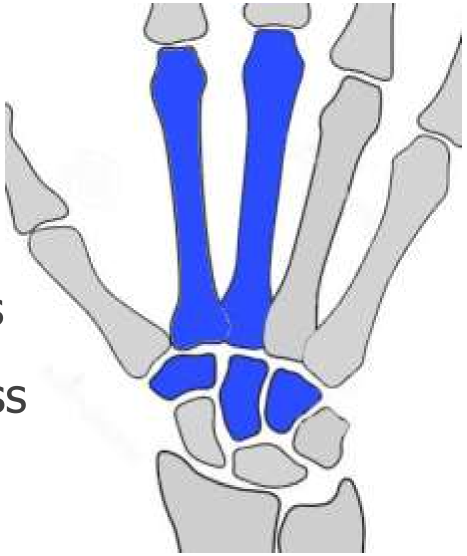
- distal carpal row is a rigid monobloc
- stability of the transverse carpal arch and carpal tunnel

Central axis of the hand

- comprises the distal carpal row and the metacarpals II and III
- fixed unit for gripping and fine motor skills

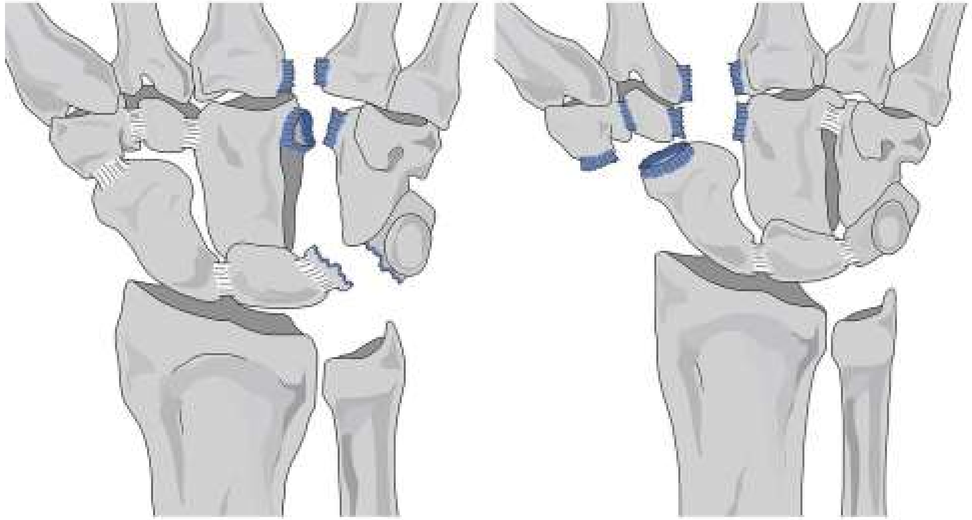
Carpometacarpal mobility

- CMC joints II, III - immobile
- CMC joint IV - ROM of 5 – 10 degrees
- CMC joint V - ROM of 15 – 20 degress



Axial instability

- transection of the intercarpal ligaments in axial high-velocity injuries
- radial and ulnar parts of the wrist

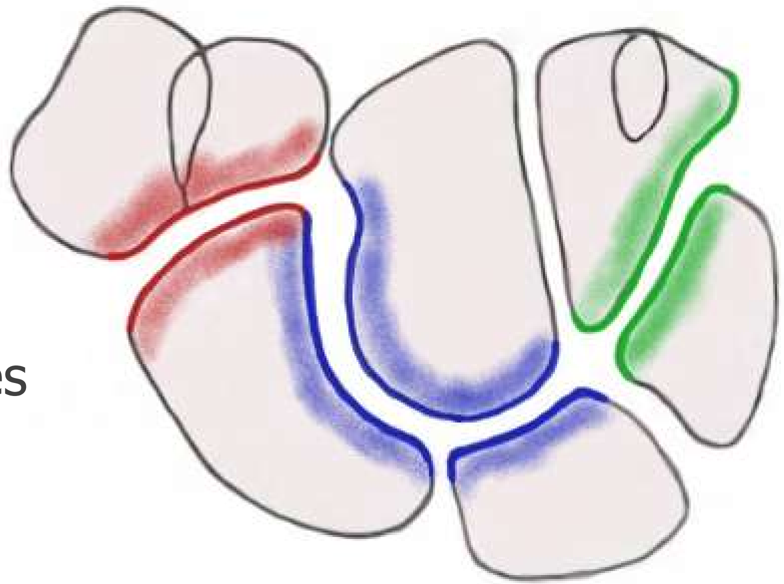


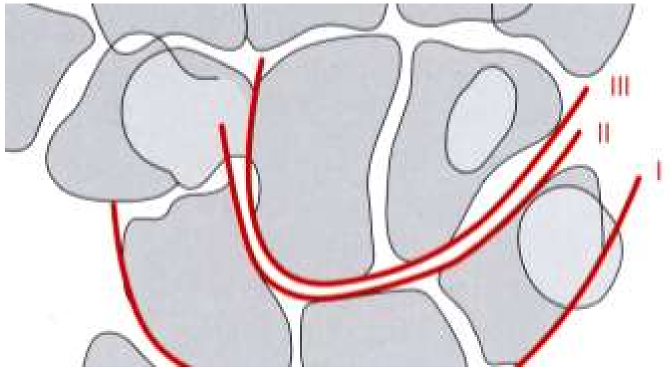
Garcia-Elias M, et al. J Hand Surg Am 1989;14:446 – Viegas SF, et al. J Hand Surg Am 1999;24:456
Reinsmith LE, et al. Radiology. 2013;267:680 – Eschweiler J, et al. Life (Basel) 2022;12:188

The midcarpal joint - Anatomy (1)

Ball-and-socket joint

- radial compartment = STT joints
  - convex distal scaphoid pole
  - concave trapezium and trapezoid bases
- middle compartment
  - deep-concave scaphoid-capitate joint
  - flat-convex lunate-capitate joint
- ulnar compartment
  - spiral-shaped triquetrum-hamate joint



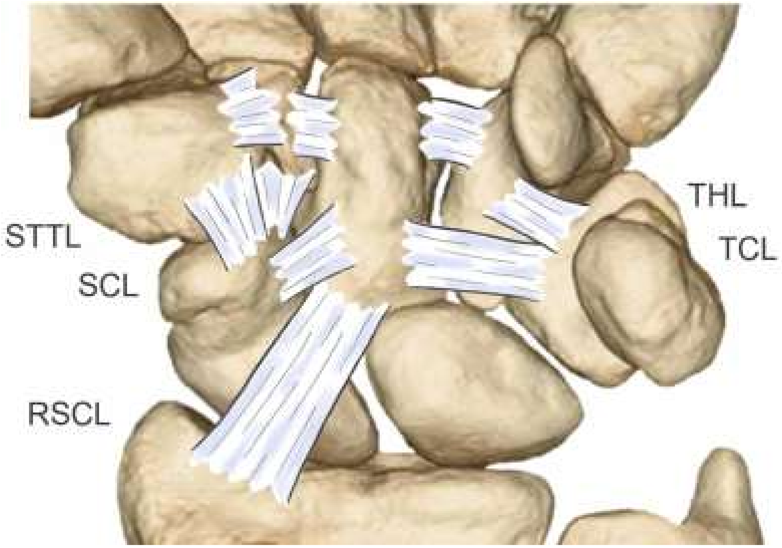


parallel Gilula arcs II + III

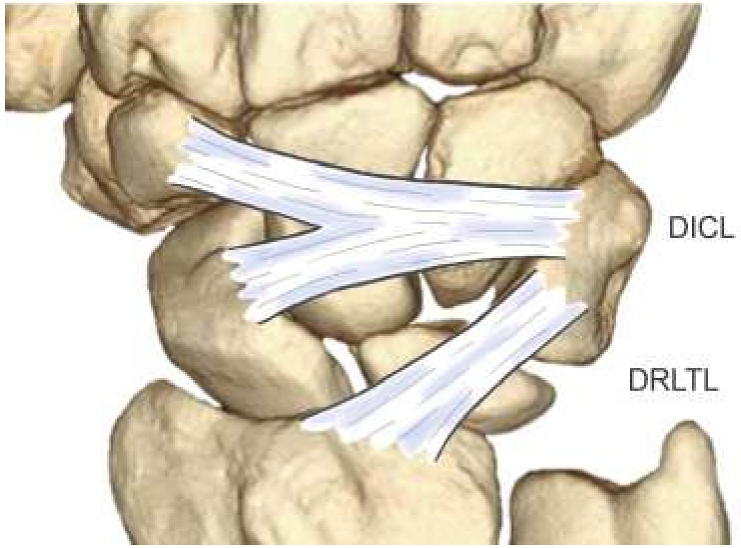
The midcarpal joint - Anatomy

Midcarpal ligaments cross the joint diagonally

- triquetrum-capitate-scaphoid ligament (TCSL) = arcuate ligament on the palmar side
  - triquetrocapitate and triquetrohamate ligaments (TCL, THL)
  - scaphocapitate ligament (SCL)
- STTL



- dorsal intercarpal ligament (DICL) on the dorsal side
  - intrinsic, obliquely running
  - weaker than the palmar arcuate ligament (TCSL)

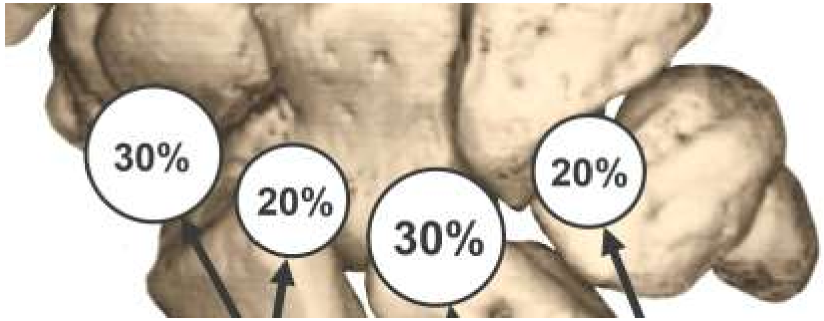


Ambrose L, et al. Hand Clin 1992;8:653 – Lichtman DM, et al. J Hand Surg Am 2006;31:491
Rhee PC, et al. J Hand Surg Am 2009;34:1633 – Wessel LE, et al. J Hand Surg Am 2023;48:1139

The midcarpal joint - Function (1)

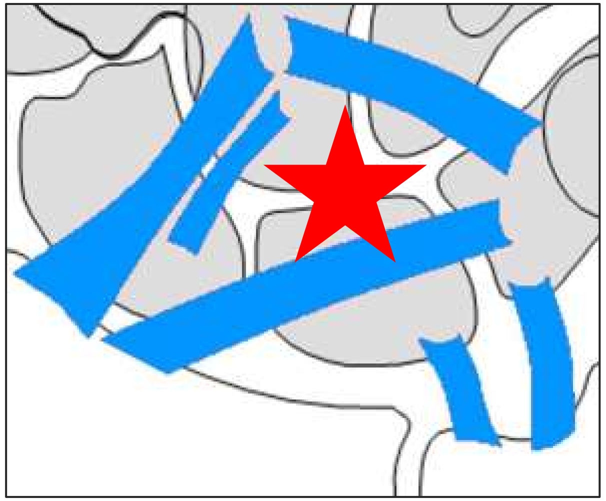
Midcarpal load transfer

- STT joints 30 %
- scaphocapitate joint 20 %
- lunocapitate joint 30 %
- triquetrohamate joint 20 %

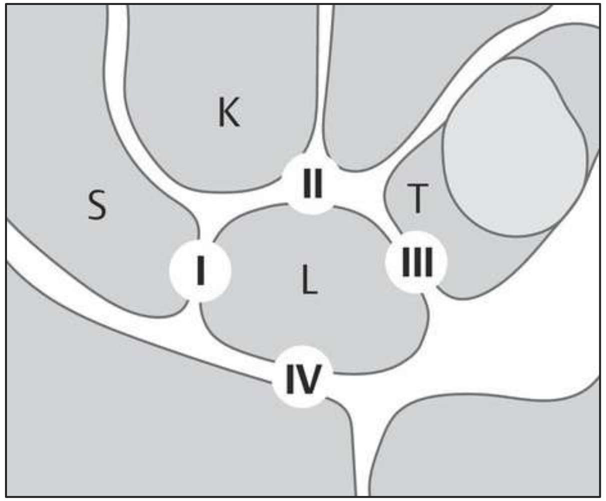


Poirier's space

- ligament-free zone at the lunocapitate level
- between the proximal and distal groups of the palmar V-ligamant complex
- predisposes to perilunate instability



Poirier's space



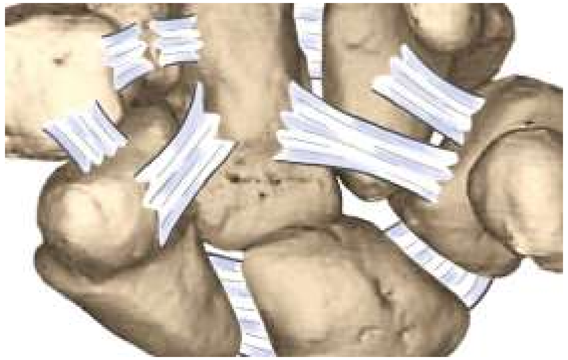
Mayfield's perilunate instability

Taleisnik J. J Hand Surg Am 1976;1:110 – Mayfield JK, et al. J Hand Surg Am 1980;5:226
Berger RA, et al. J Hand Surg Am 1990;15:847 – Viegas SF, et al. J Hand Surg Am 1999;24:456

The midcarpal joint - Function (2)

Midcarpal stabilizers and coordinators

- arcuate ligament (THCS) stabilizes at the palmar side



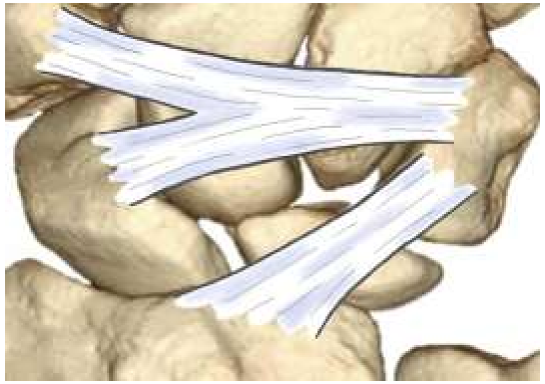
- DRLTL stabilizes at the dorsal side

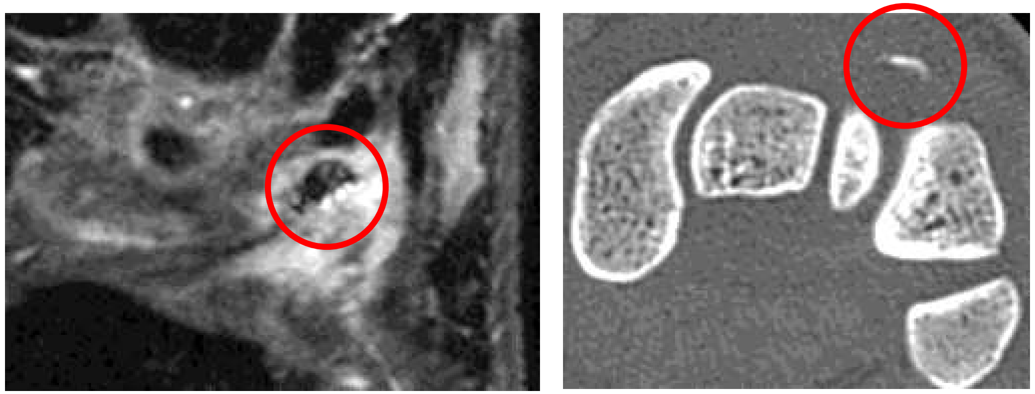
Both ligament groups coordinate <u>combined </u>midcarpal movements

- flexion + radial deviation
- extension + ulnar deviation

Avulsion fractures of the triquetrum

DRLTL and DICL converge toward the triquetrum



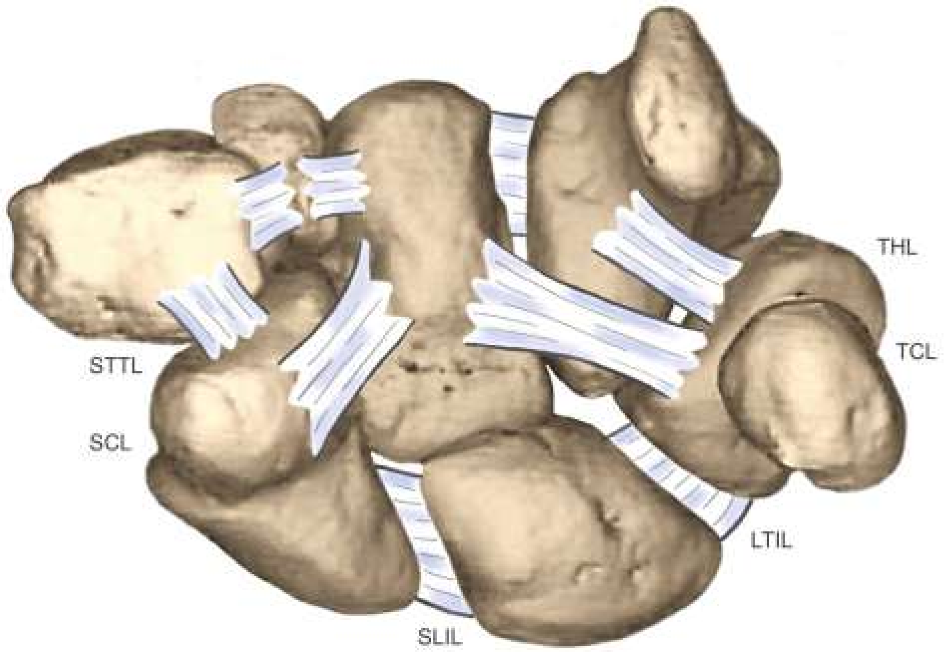


Viegas SF, et al. J Hand Surg Am 1999;24:456 – Elsaidi GA, et al. Clin Orthop Rel Res 2004;425:152
Salva-Coll G, et al. J Hand Surg Eur Vol 2011;36:553 – Becce F, et al. Am J Roentgenol 2013;200:608

The midcarpal joint - Function (3)

Ring concept of the carpus (Lichtman 1993)

- two carpal rows connected to each other by radial and ulnar links
  - radially, via the strong SCL and STTL
  - ulnarly, via the THL and TCL
- proximally, the ring is closed by the SLIL and LTIL

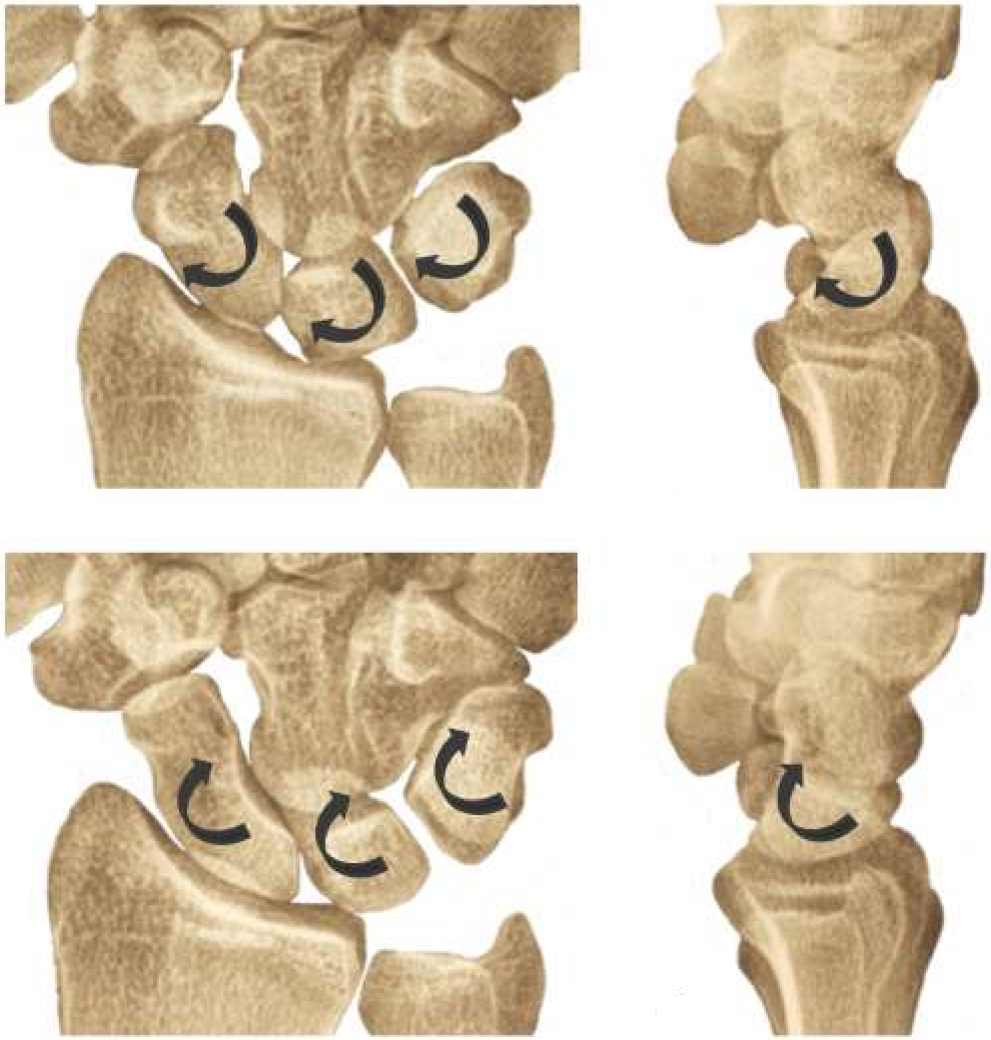


The midcarpal joint - Pathology (1)

Midcarpal instability (MCI)

Carpal Instability NonDissociative (CIND)

- abnormal mobility of the entire proximal carpal row
  - jumps suddenly into extension
  - relative to the distal carpal row
- pathomechanism unclear
  - congenital vs. acquired ?
  - arcuate ligament vs. DICL ?



Louis DS, et al. J Bone Joint Surg Am 1987;69:950 – Wright TW, et al. J Hand Surg Br 1994;19:763
Lichtman DM, et al. J Hand Surg Am 2006;31:491 – Garcia-Elias M. J Hand Surg Eur Vol 2008;33:698

The midcarpal joint - Pathology (2)

Midcarpal instability (MCI)

- **dynamic MCI**
  en bloc rotation during radial/ulnar deviation
- **static MCI**
  proximal row flexed at rest (= PISI)
- **palmar MCI**
  most common, general ligament laxity
- **dorsal MCI**
  rare, forced extension + ulnar deviation
- **Capitolunate Instability Pattern (CLIP)**
  capitate head dislocates relative to the lunate

Movement patterns

- **2D cinematography**
  high temporal resolution, DDx: MCI vs. LTD
- **Time-resolved CT („4D“)**
  multi-planar and multi-axial MPR

Linscheid RL, et al. J Bone Joint Surg Am 1972;54:1612 – Louis DS, et al. J Bone Joint Surg Am 1987;69:950
Wright TW, et al. J Hand Surg Br 1994;19:763 – Lichtman DM, et al. J Hand Surg Am 2006;31:491

The midcarpal joint - Pathology (3)

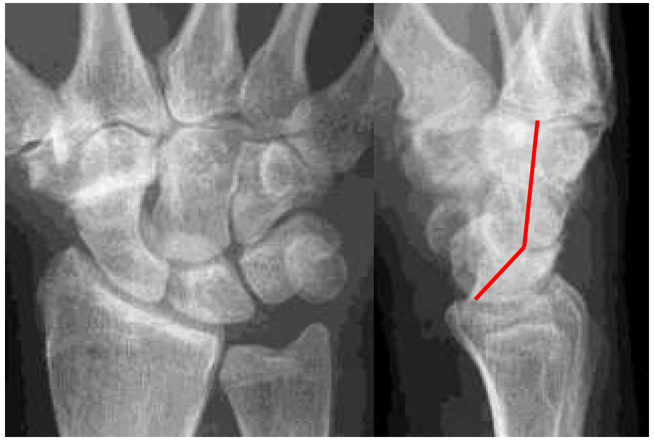
Hamate tip syndrome
= lunohamatal impaction syndrome

- accessory facet of the lunate
- pathological articulation with the hamate tip
- midcarpal mobility is restricted

Scaphotrapeziotrapezoid (STT) osteoarthritis

- abnormal STT joint surfaces or hypoplastic STTL, forms:
- local
- diffus = STT Osteoarthritis Advanced Collapse (SOAC)
  - SOAC I = isolated STT osteoarthritis
  - SOAC II = fixed scaphoid and lunate extension
  - SOAC III = lunocapitate osteoarthritis

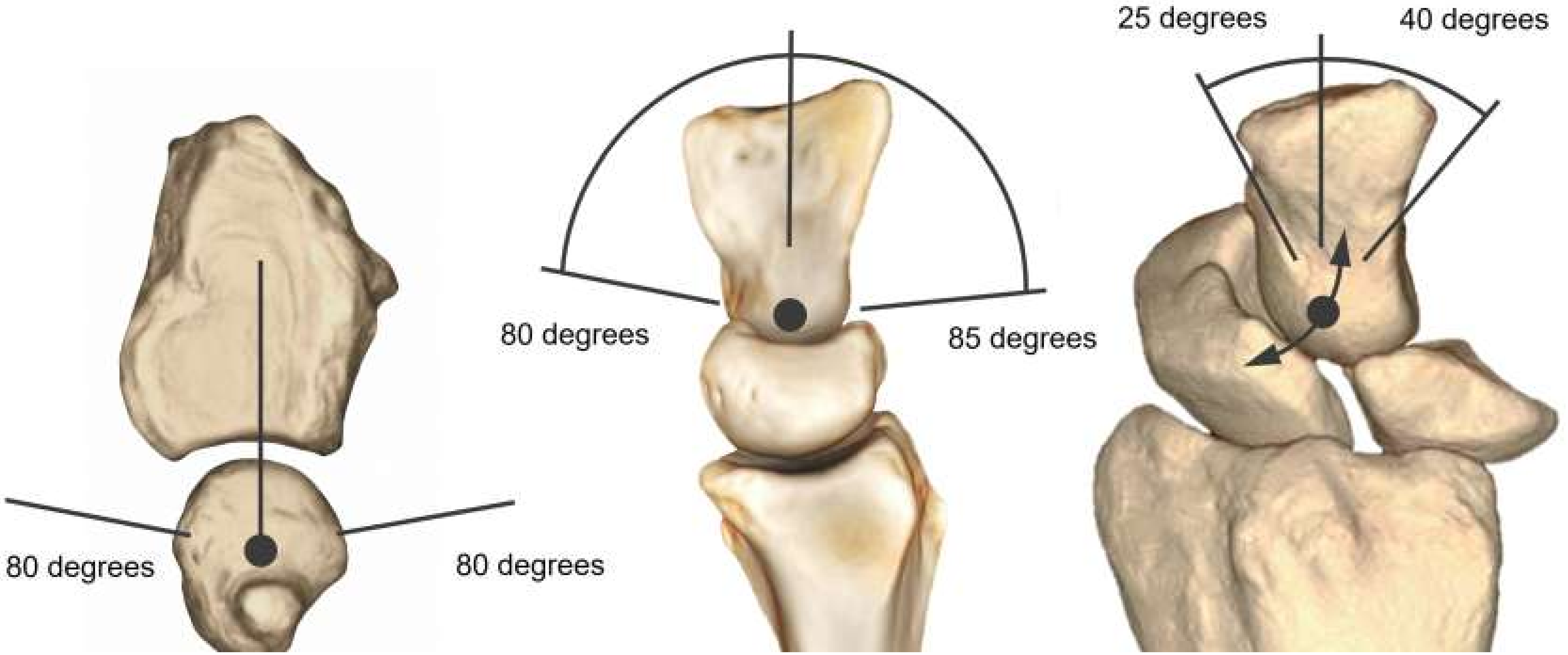
SOAC I



SOAC II

Viegas SF, et al. J Hand Surg Am 1993;18:14 – Moritomo H, et al. J Hand Surg Am 2000;25:899
Rhee PC, et al. J Hand Surg Am 2009;34:1633 – Oliveira R, et al. Rev Iberoam Cirurgía Mano 2020;48:93

The wrist as a whole - Kinematics (1)



For most activities of daily life

- 40 degrees of flexion, 40 degrees of extension
- 10 degrees of radial deviation, 30 degrees of ulnar deviation

Pronation-supination

- 90 % in the PRUJ and DRUJ (rotation center in the ulnar head)
- 10 % at the midcarpal joint

Flexion-extension

- beginning at the midcarpal joint (rotation center in the capitate head)
- followed by the radiocarpal joint

Radial-ulnar deviation

- instantaneous center of rotation (= ICR) near the capitate head

Ruby LK, et al. J Hand Surg Am 1988;13:1 – Ryu JY, et al. J Hand Surg Am 1991;16:409
Wolfe SW, et al. J Hand Surg Am 2000; 25:860 – Salva-Coll G, et al. J Hand Surg Eur Vol 2011;36:553

The wrist as a whole - Kinematics (2)

Simplified model

= combined movements multi-dimensional and <u>orthogonal</u>

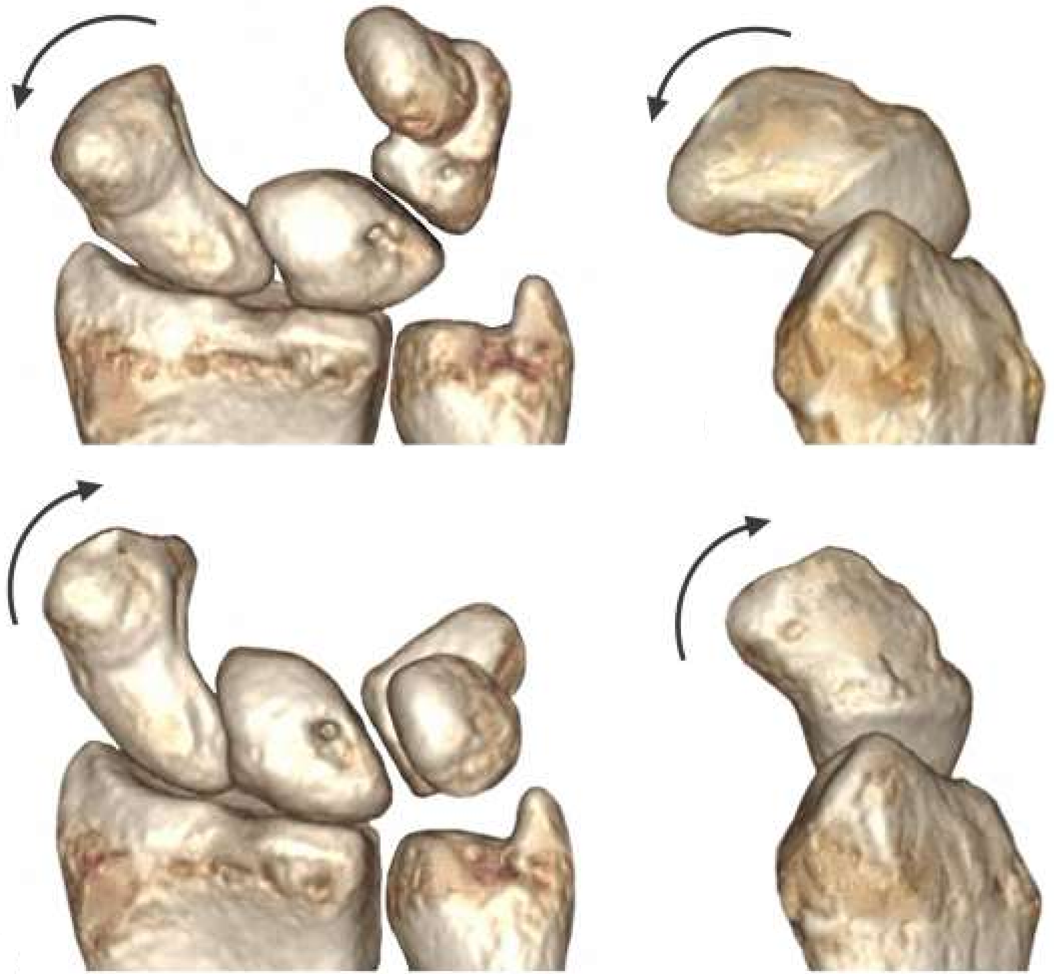
- **radial deviation + flexion**

  scaphoid at an angle of ~ 90 degrees to the radius
- **ulnar deviation + extension**

  scaphoid ~ parallel to the coronal plane

Controlled by

- the midcarpal joint surfaces
- the arcuate ligament and the DICL



The wrist as a whole - Kinematics (3)

Complex model

= combined movements multi-dimensional and <u>multi-axial</u>

Dart throwing

- start: wrist in radial deviation + extension
- during the throw: scaphoid and lunate remain in a neutral position
- end: wrist in ulnar deviation + flexion

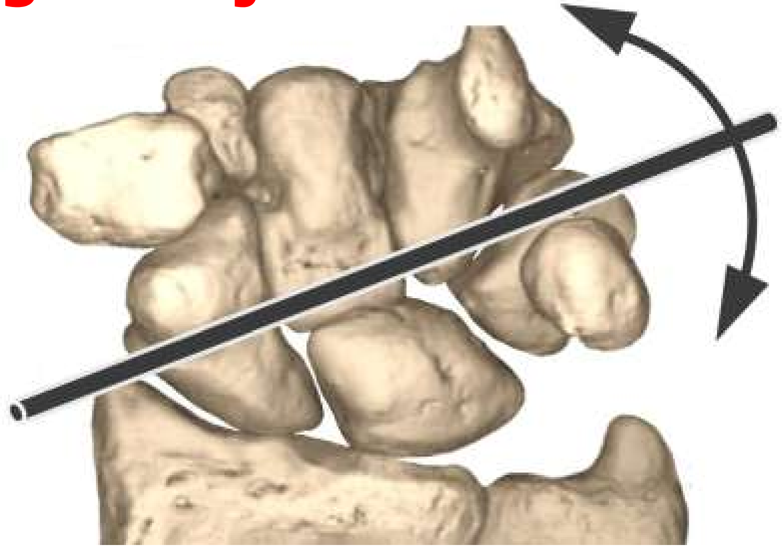
Controlled by

- the FCU muscle palmarly, and the ECRL, ECRB muscles dorsally
- the arcuate ligament palmarly, and the DRLTL and DICL dorsally

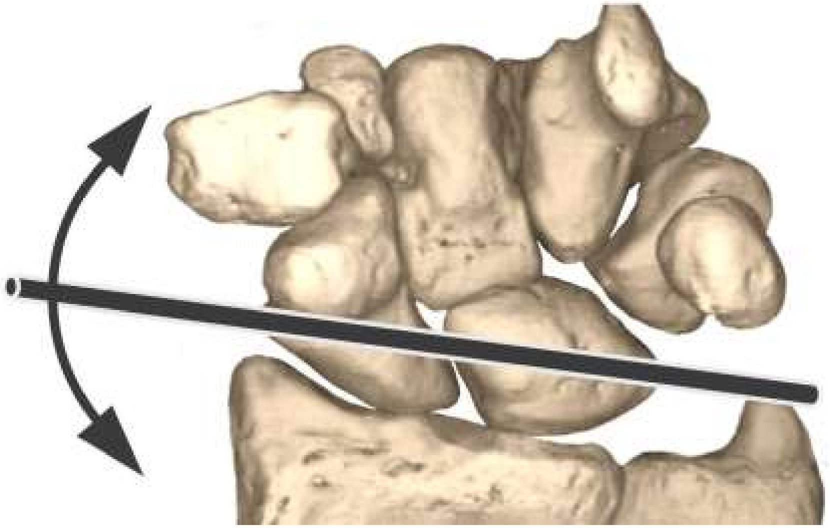
Viegas SF, et al. J Hand Surg Am 1999;24:456 – Horii E, et al. J Hand Surg Am 1991;16:355
Moojen TM, et al. J Hand Surg Am 2003;28:81 – Crisco JJ, et al. J Bone Joint Surg Am 2005;87:2729

The wrist as a whole - Kinematics (4)

Two oblique axes of rotation = wrist as a gimbal joint



- **midcarpal axis of rotation**
  diagonal across the midcarpal joint
  (centered at the capitate head)



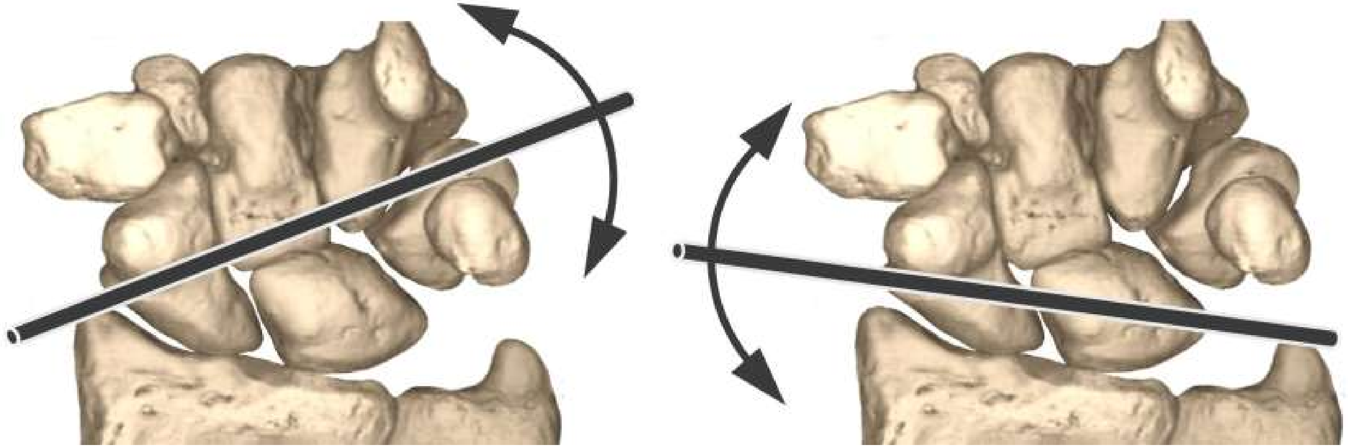
- **radiocarpal axis of rotation**
  diagonal across the proximal row
  (centered at the lunate)

Viegas SF, et al. J Hand Surg Am 1999;24:456 – Horii E, et al. J Hand Surg Am 1991;16:355
Moojen TM, et al. J Hand Surg Am 2003;28:81 – Crisco JJ, et al. J Bone Joint Surg Am 2005;87:2729

The wrist as a whole - Conclusion

In all wrist positions

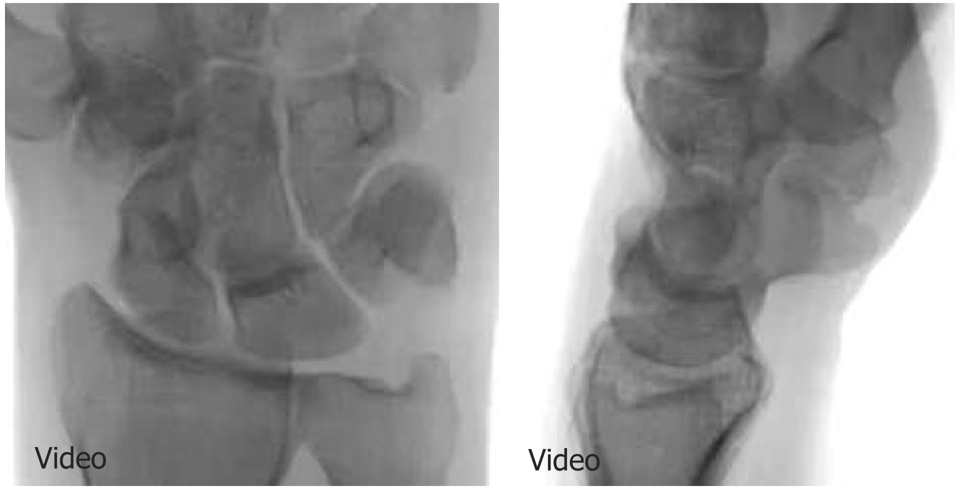
- joint congruence is maintained
- heigth of the proximal carpal row (wrist) remains constant



Proximal carpal row

- is an intercalated segment
- adapts flexibly its geometry

➡ Together with the DRUJ, the wrist is an **universal joint**



Moojen TM, et al. J Hand Surg Am 2003;28:81 – Crisco JJ, et al. J Bone Joint Surg Am 2005;87:2729

Eigene Empfehlungen