Anatomy and mechanics of the wrist

G.R. Sennwald
Consultant Handsurgeon
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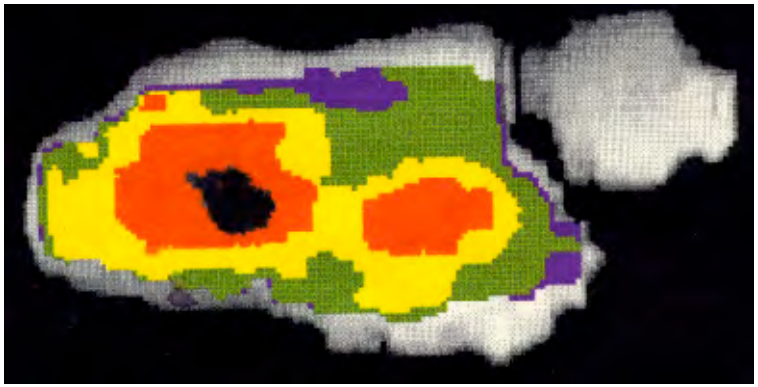
26° Congresso Brasileiro
De Cirurgia da Mão



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➡ Teaching:

Anatomy ?

Mechanics ?

Both are basic?

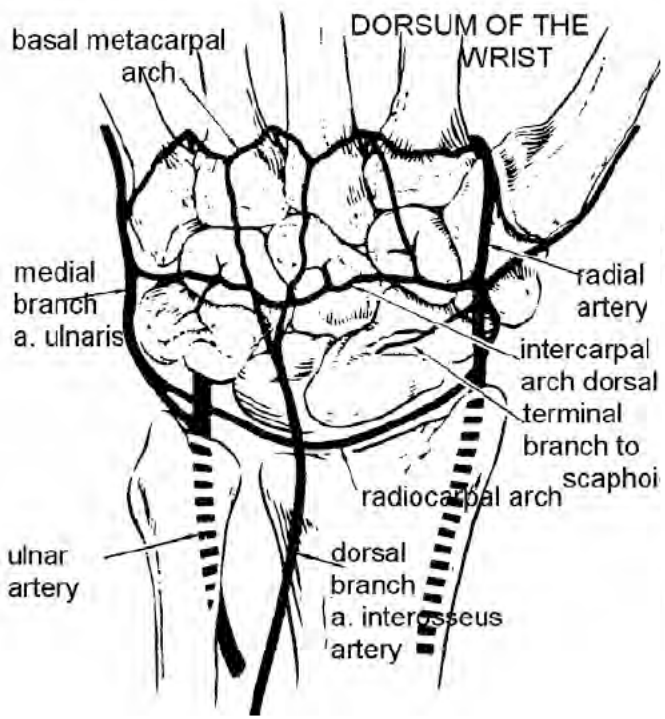
Both are evidence?

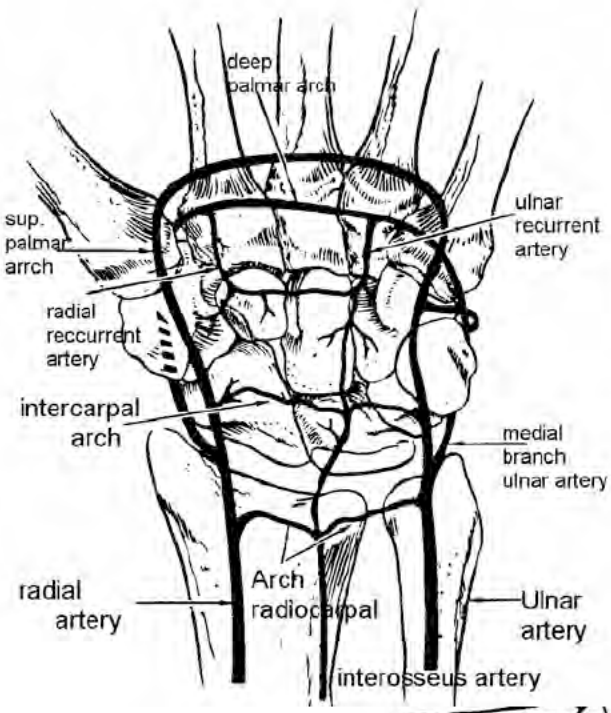
Both are related to one another!

Anatomy

Anatomy and mechanics of the wrist

vessels

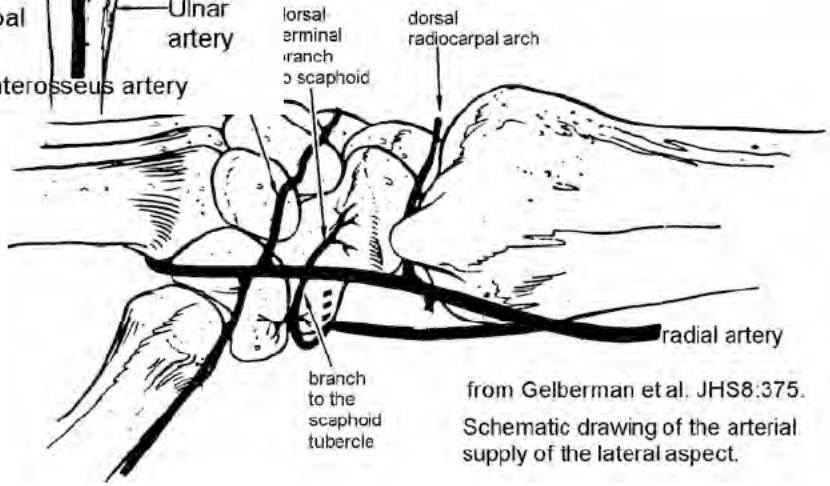




Seems accepted & important

vascularisation of scaphoid

lunate

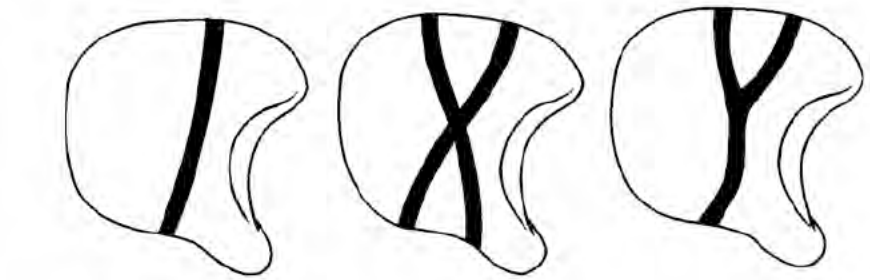


from Gelberman et al. JHS8:375.

Schematic drawing of the arterial supply of the lateral aspect.

Anatomy and mechanics of the wrist

Vascular pattern of the lunate accoring to Gelberman:
3 major vascular pattern as presented:

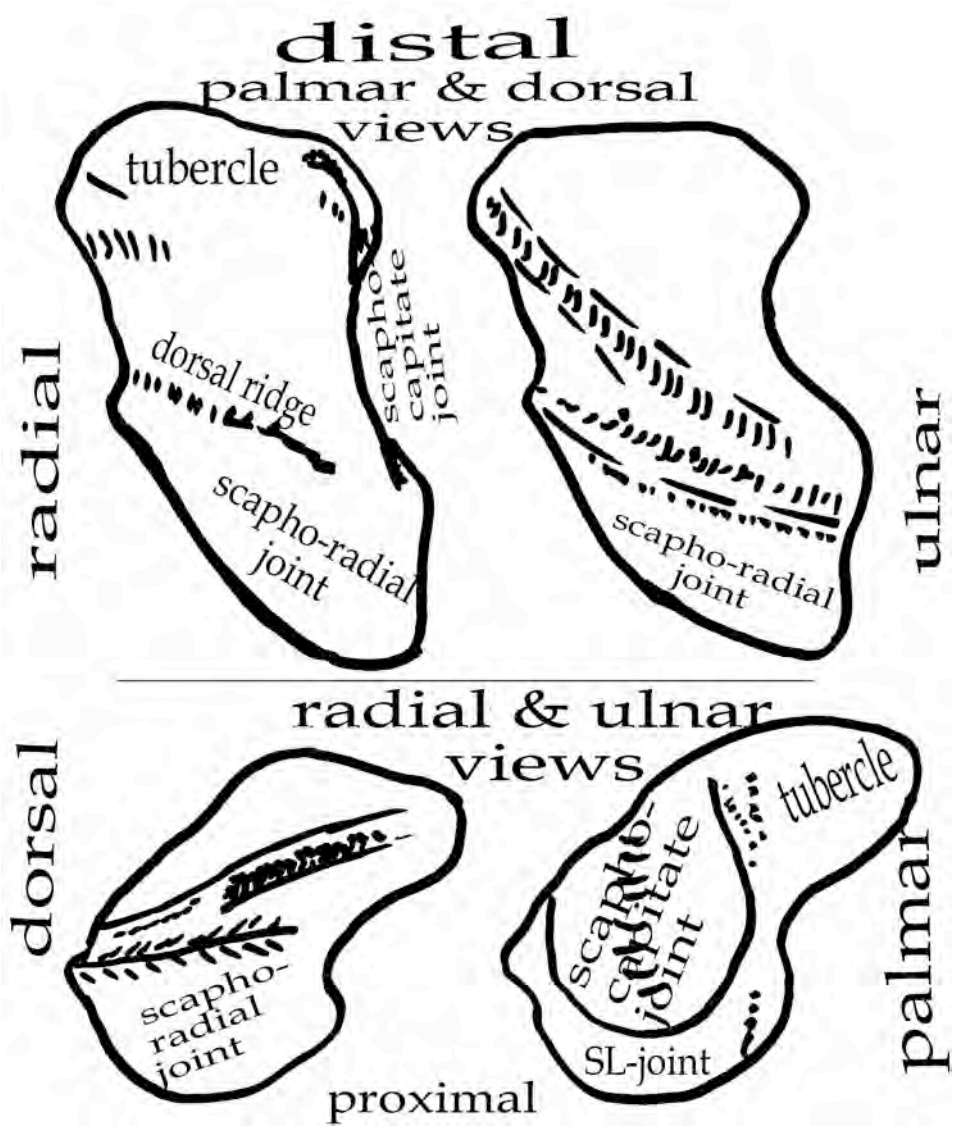


30% **10%** **60%**

But 20% have an exclusive palmar supply!

Anatomy and mechanics of the wrist

Bones

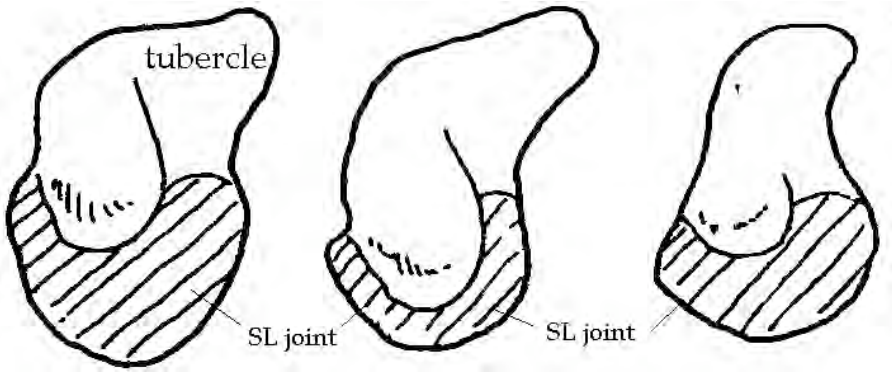


Compson: geometry of the scaphoid

The problems

- **Anatomical variations**

Consequences !



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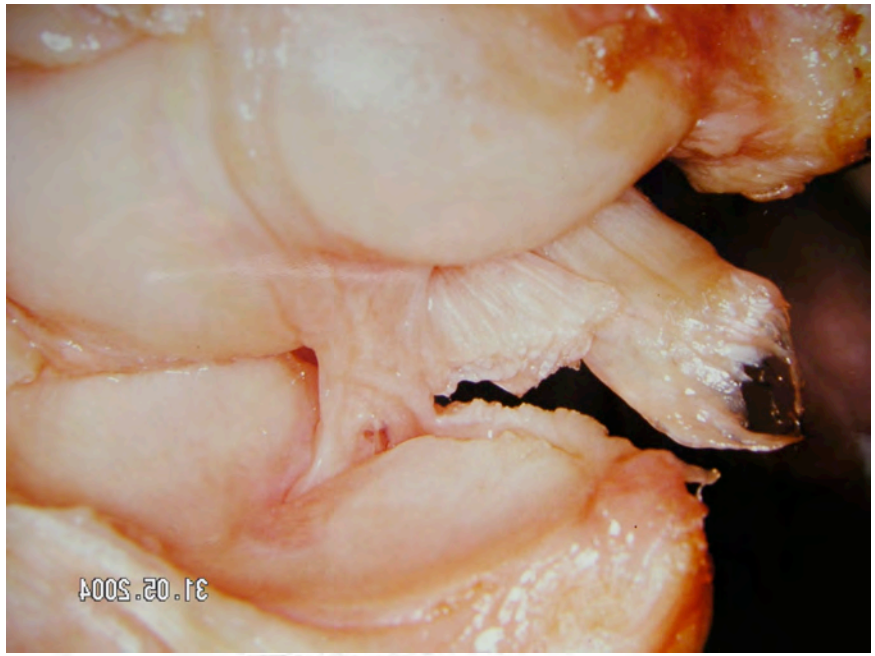
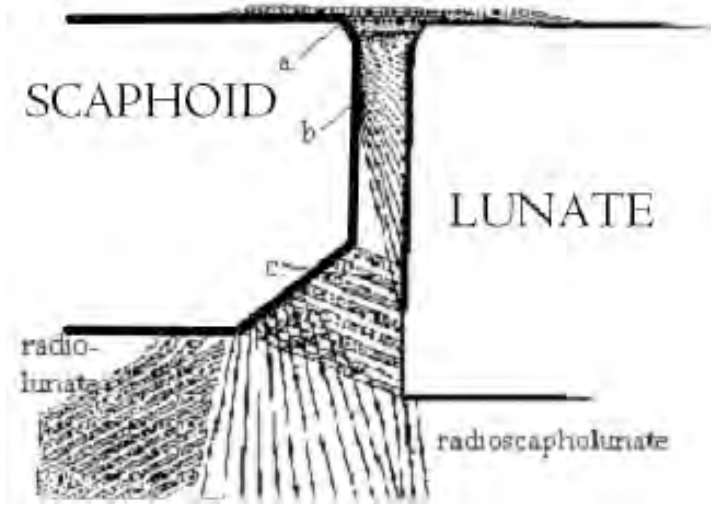
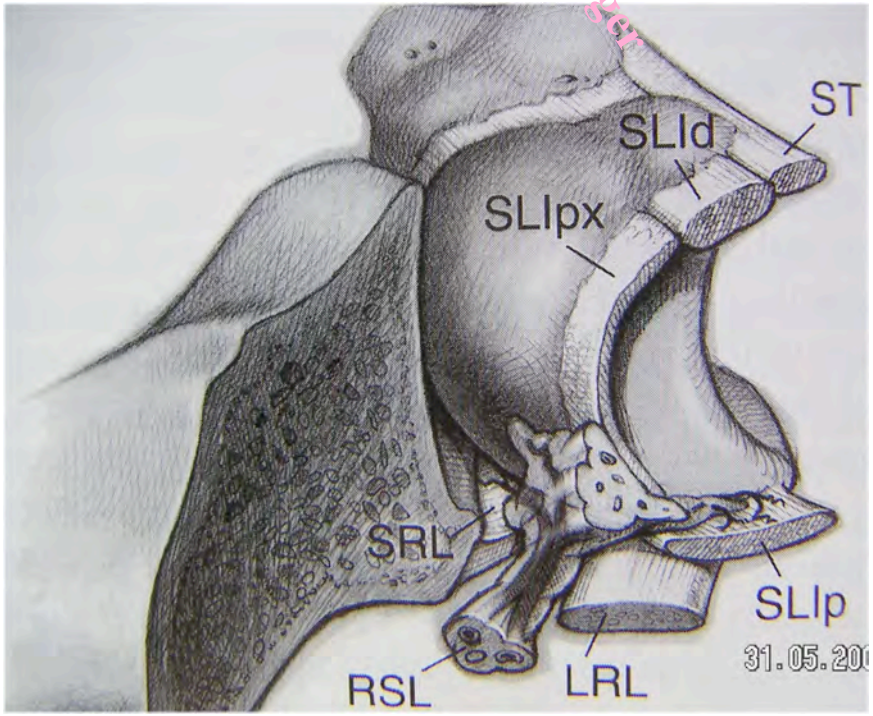




Berger
Viegas

stronger



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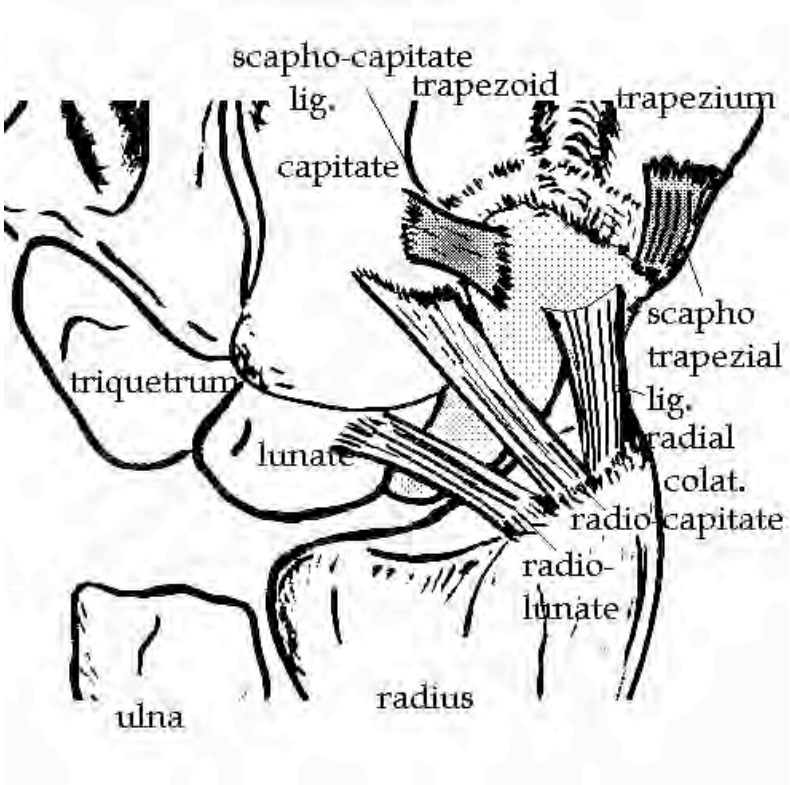
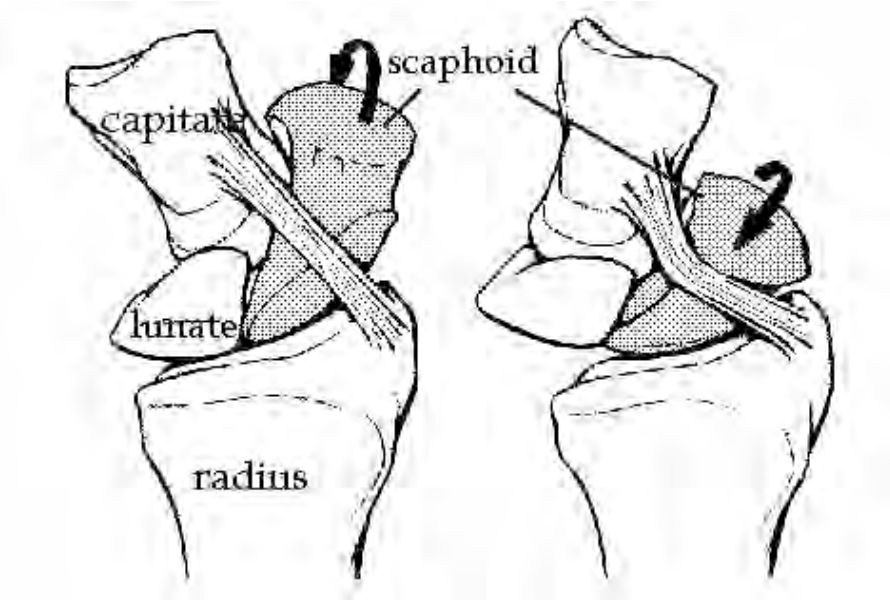
Ligaments

Kuhlmann; Masquelet



Verdan

The RC ligament



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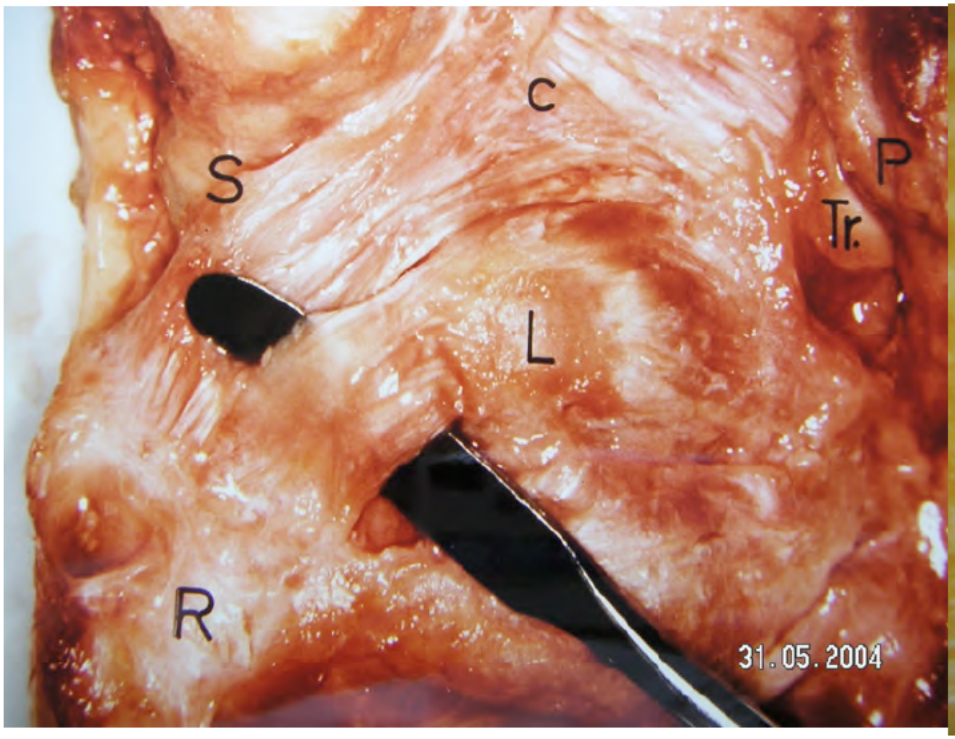
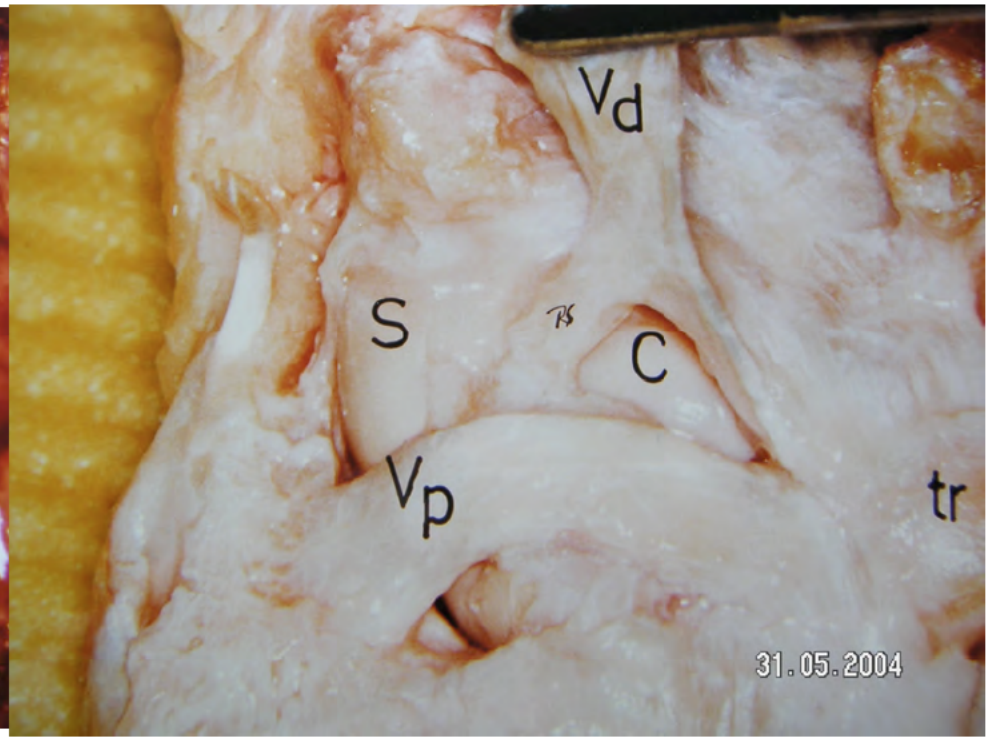
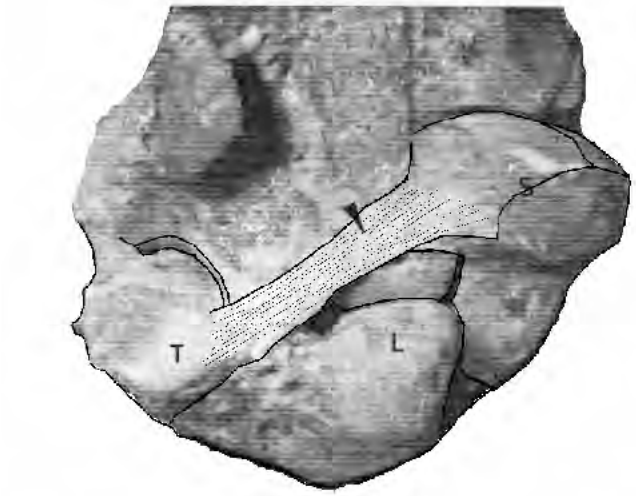
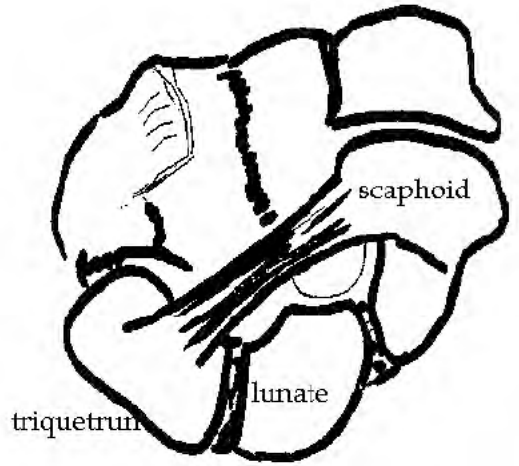
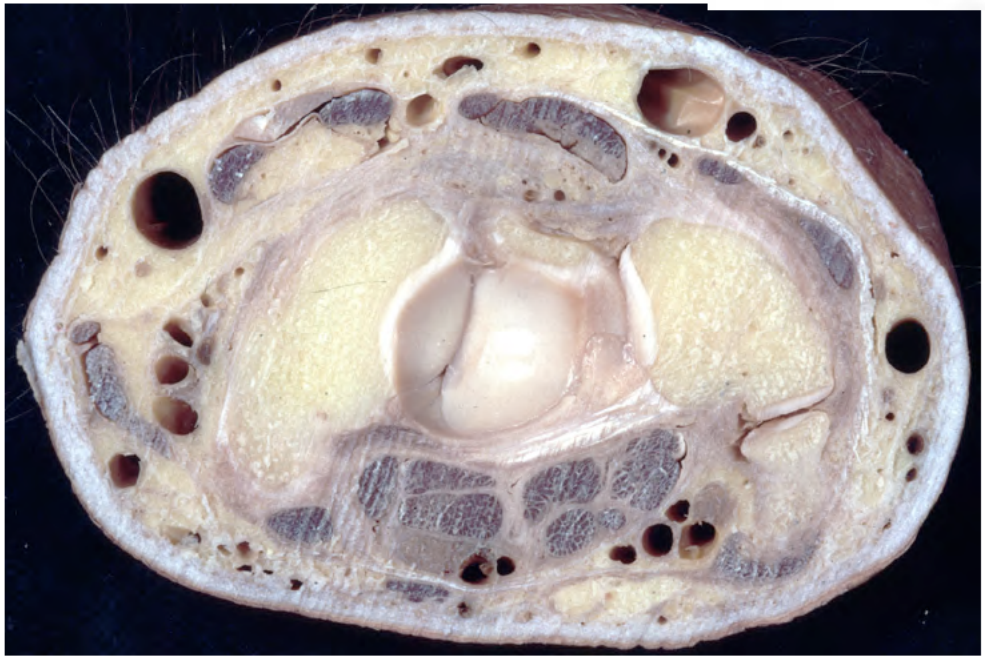




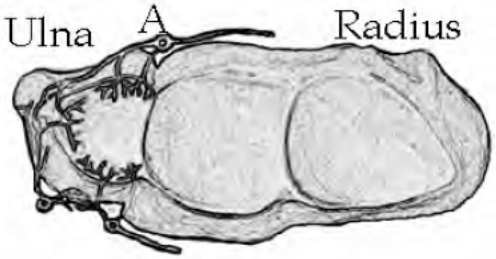
Anatomy and mechanics of the wrist



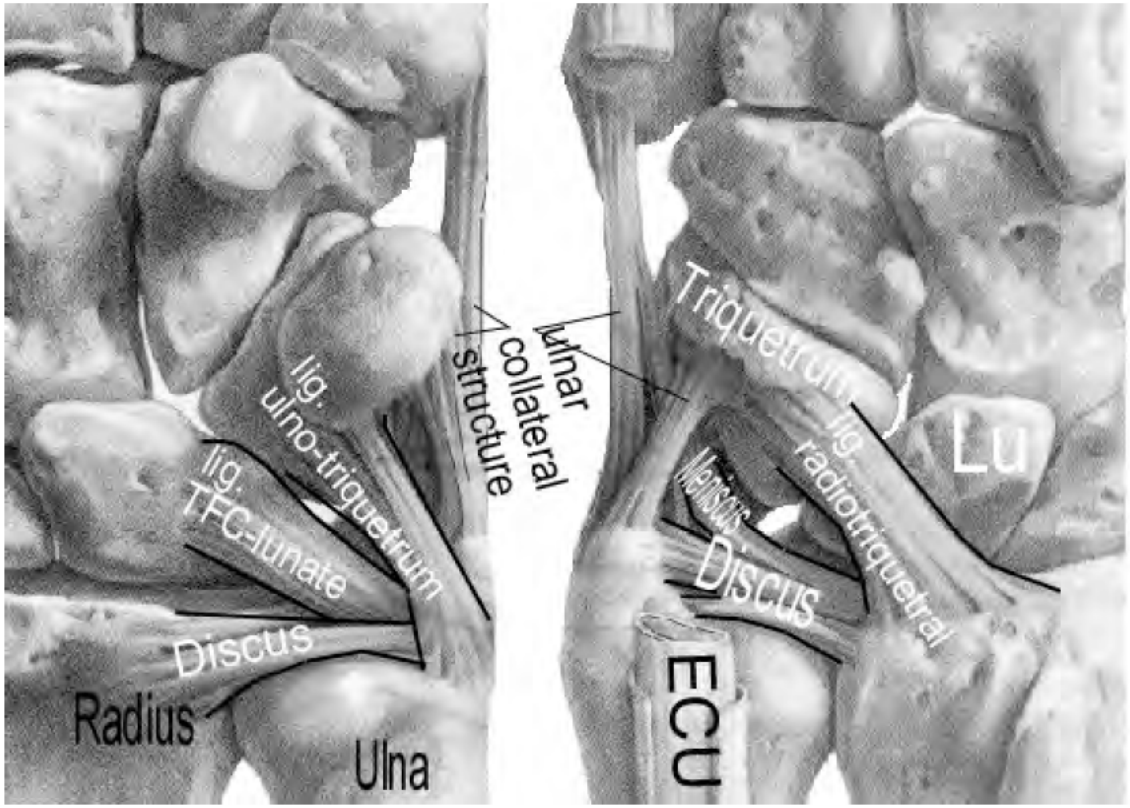


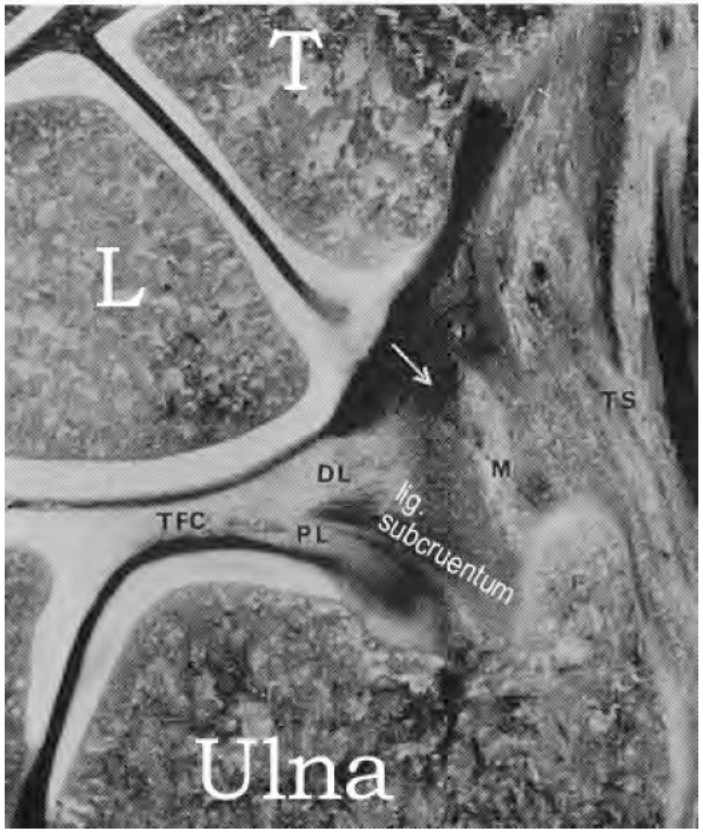


Anatomy and mechanics of the wrist

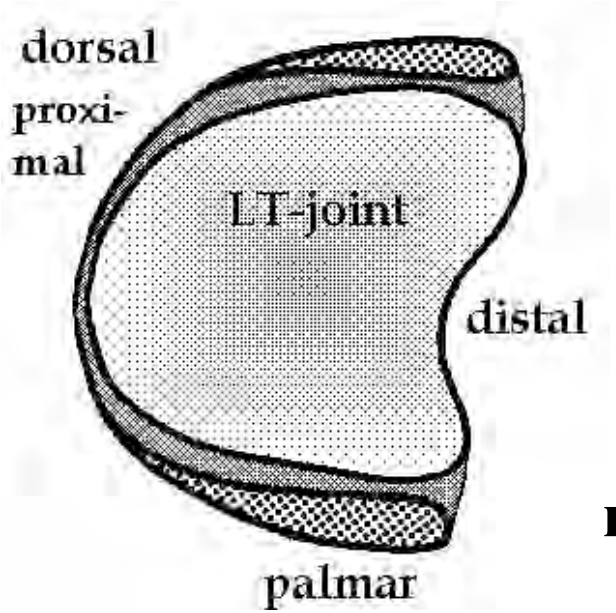


Schmid





Anatomy and mechanics of the wrist



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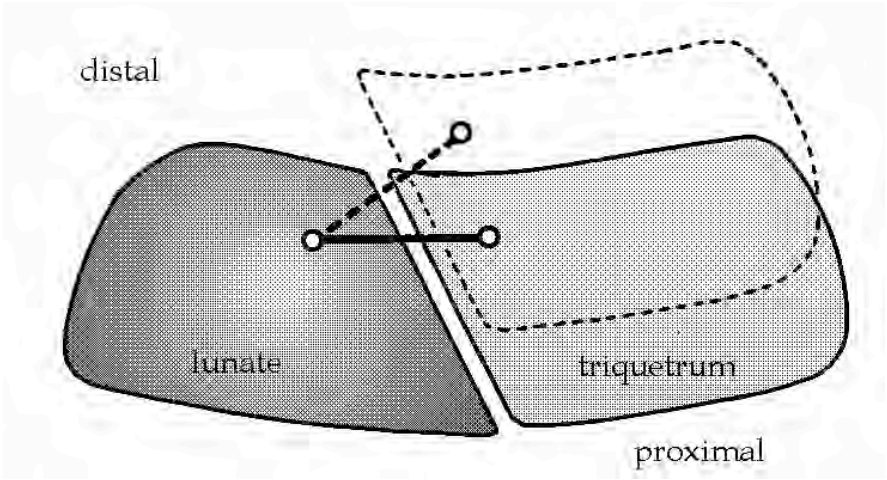
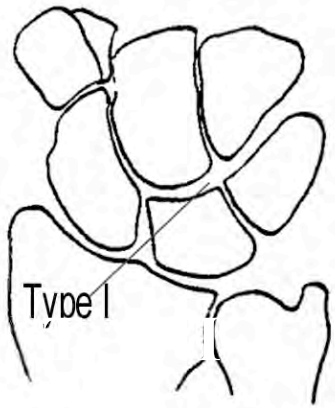
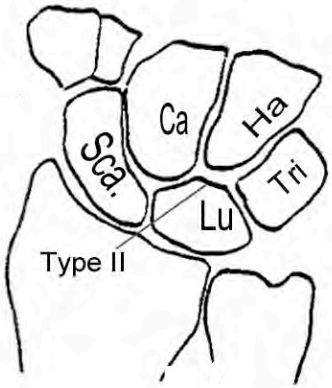
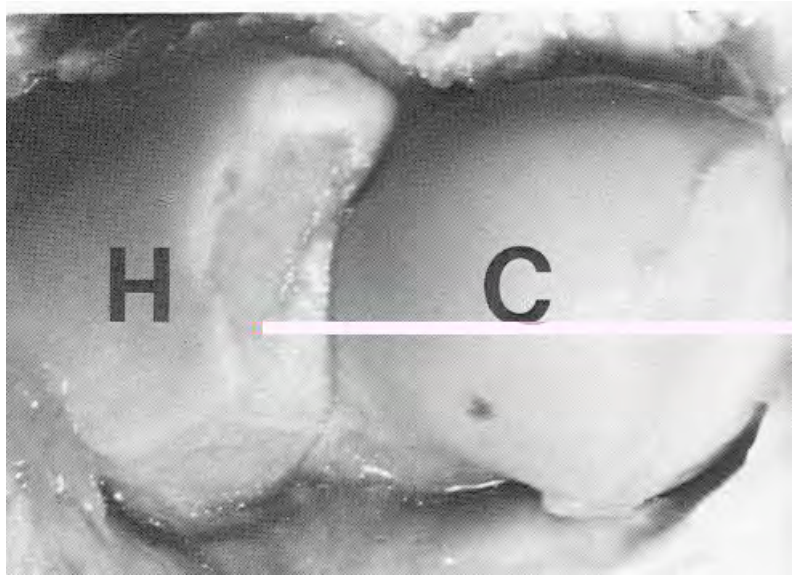


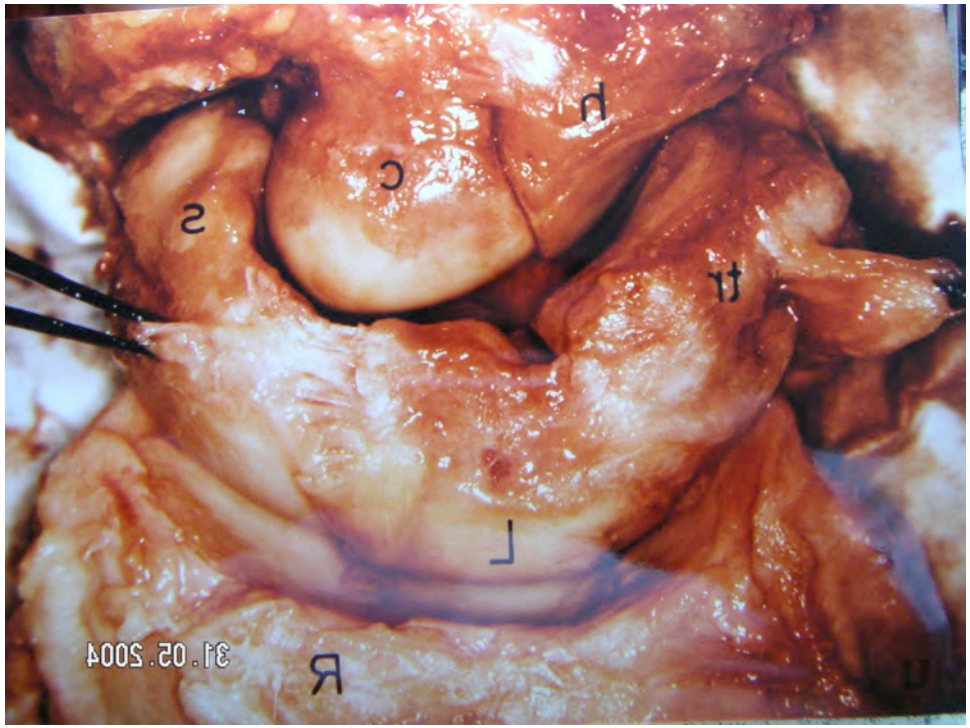


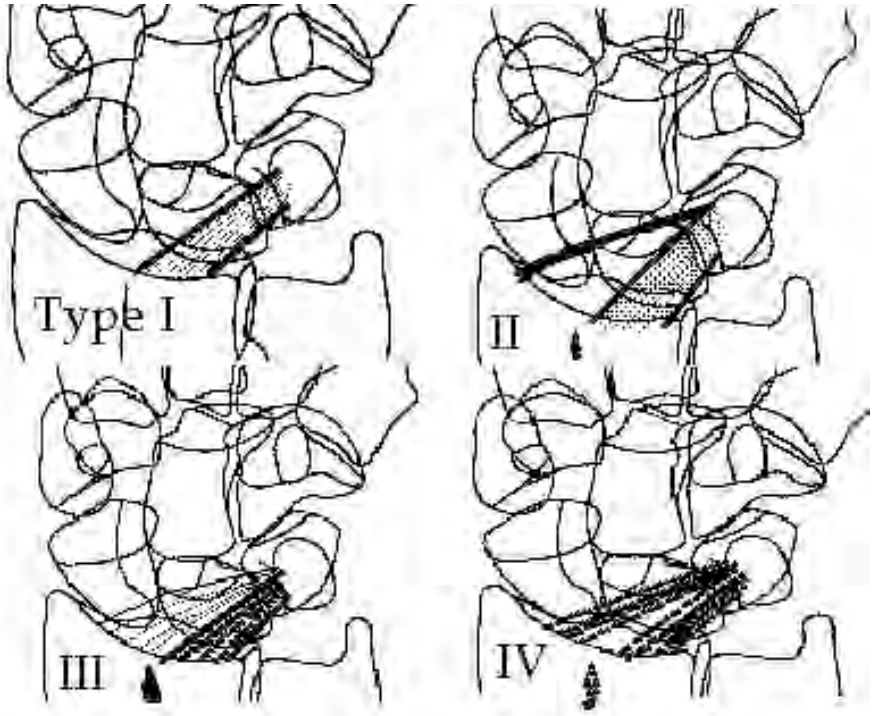




Anatomy and mechanics of the wrist

Viegas



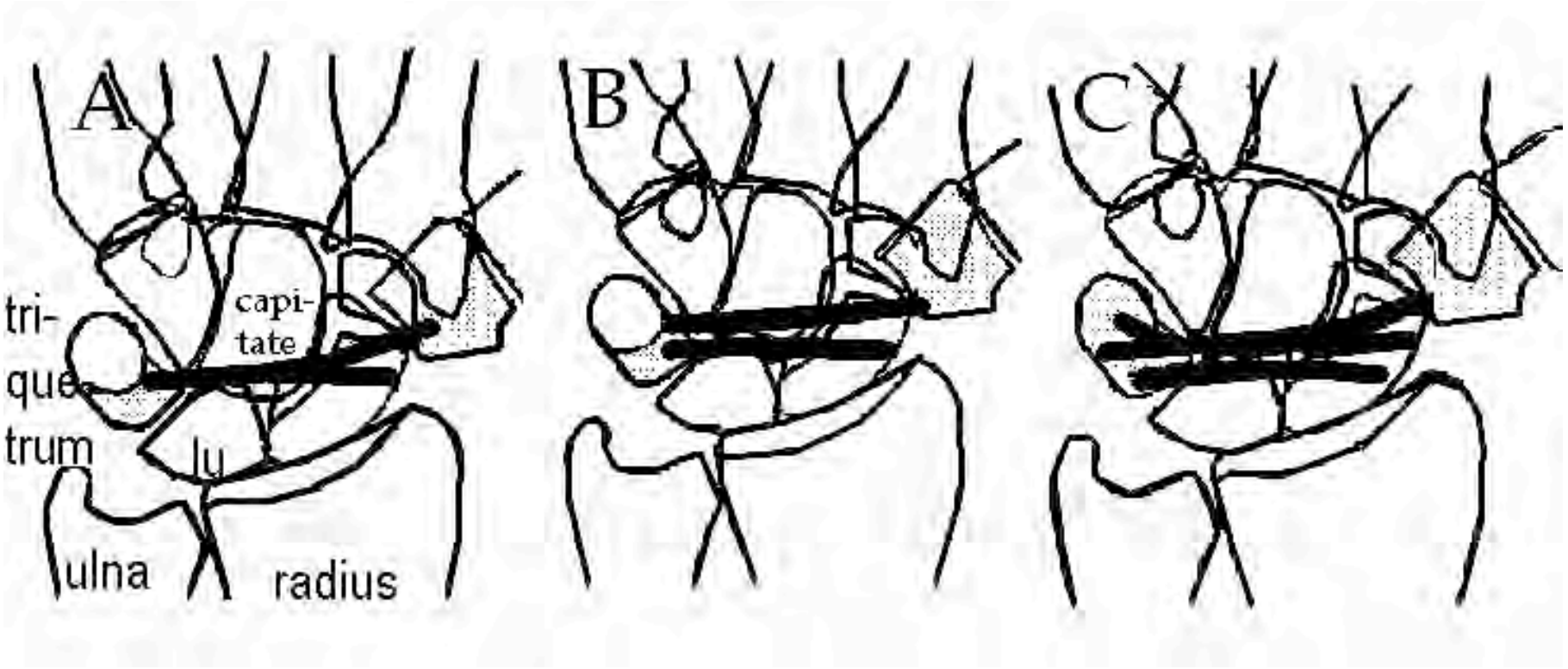


Type I = 54 % **II = 24%**

III = 12% **IV = 9%**

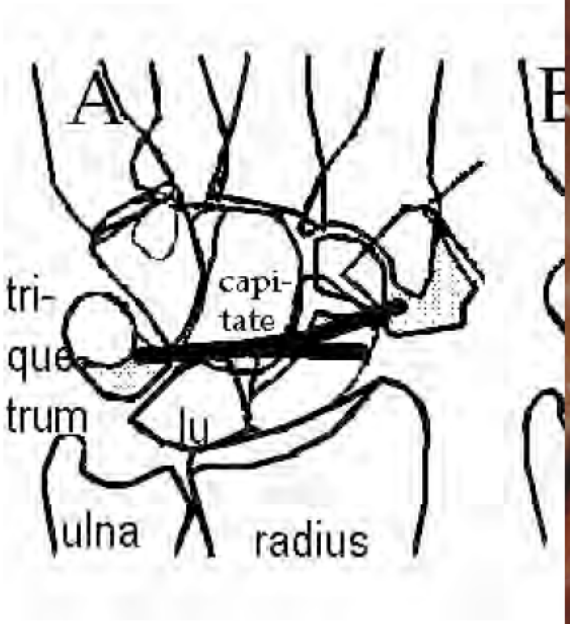
Anatomy and mechanics of the wrist

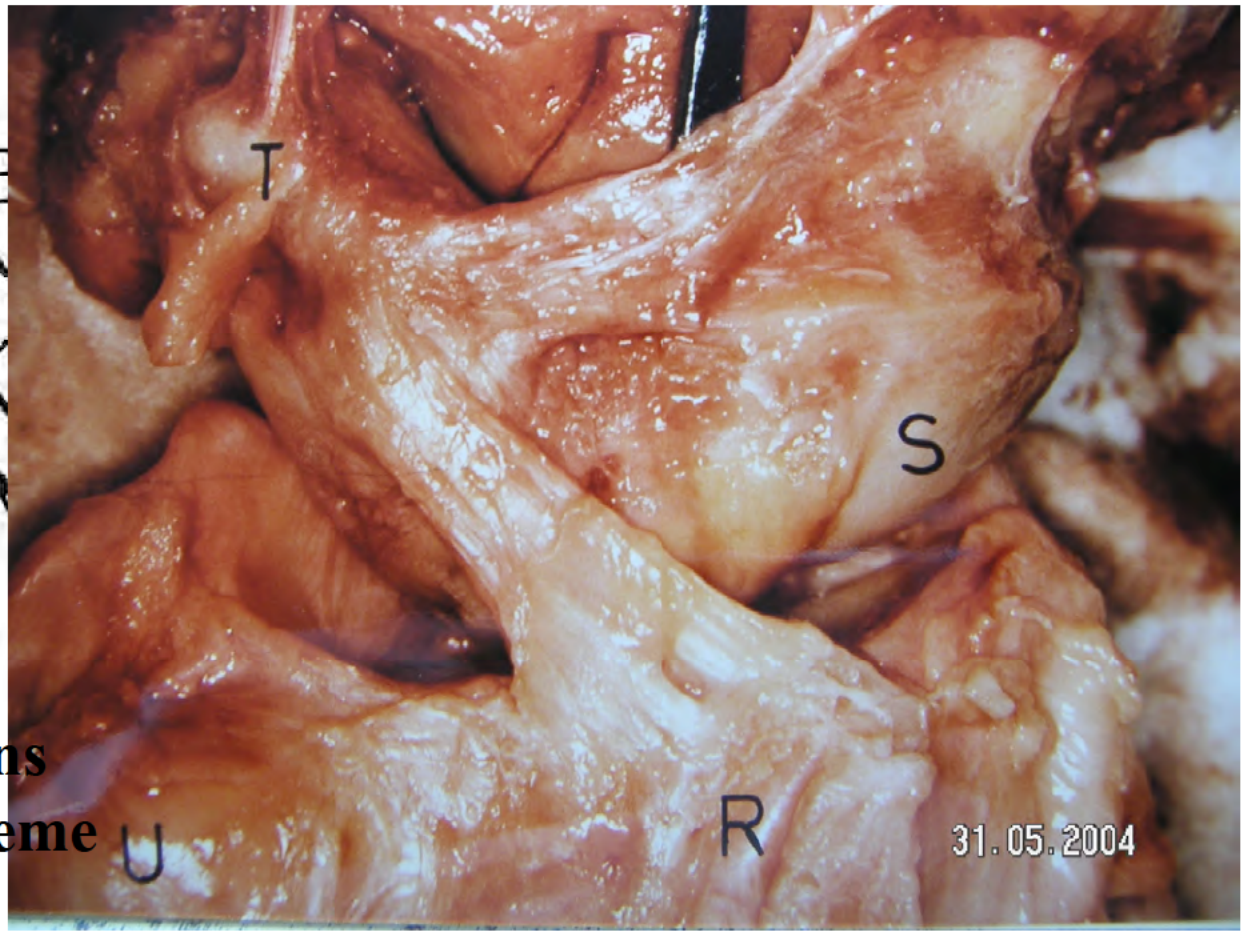
The DIC (viegas)



30% **44%** **26%**

DIC, combined to dorsal SL

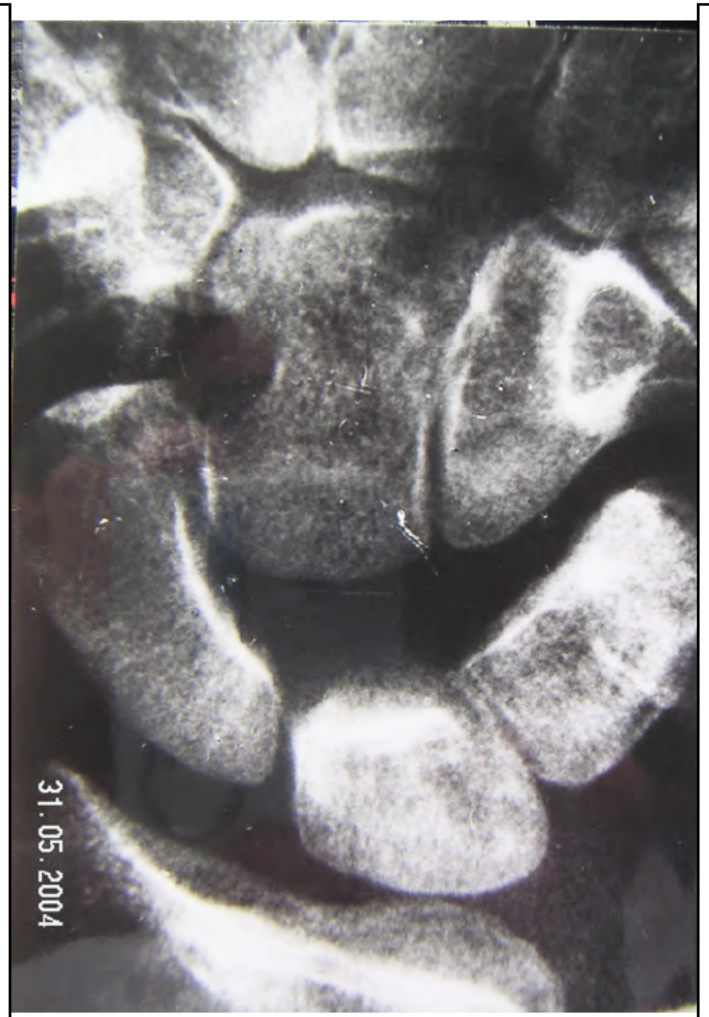




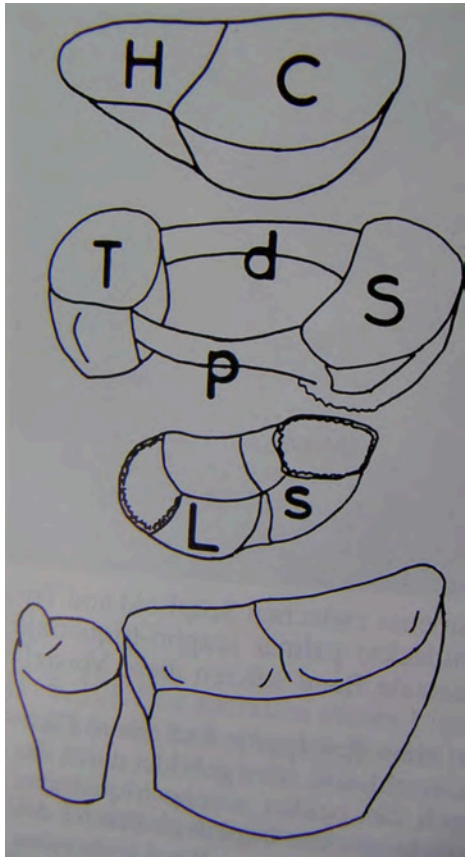
Various presentations
Taleisnik: other scheme

Anatomy and mechanics of the wrist

Orientation of ligaments render ligamentotaxis inefficient



Anatomy and mechanics of the wrist



Head of the capitate, fixed between dorsal & palmar ST ligament.

Potential shear forces = scaphoid fracture

Mechanics

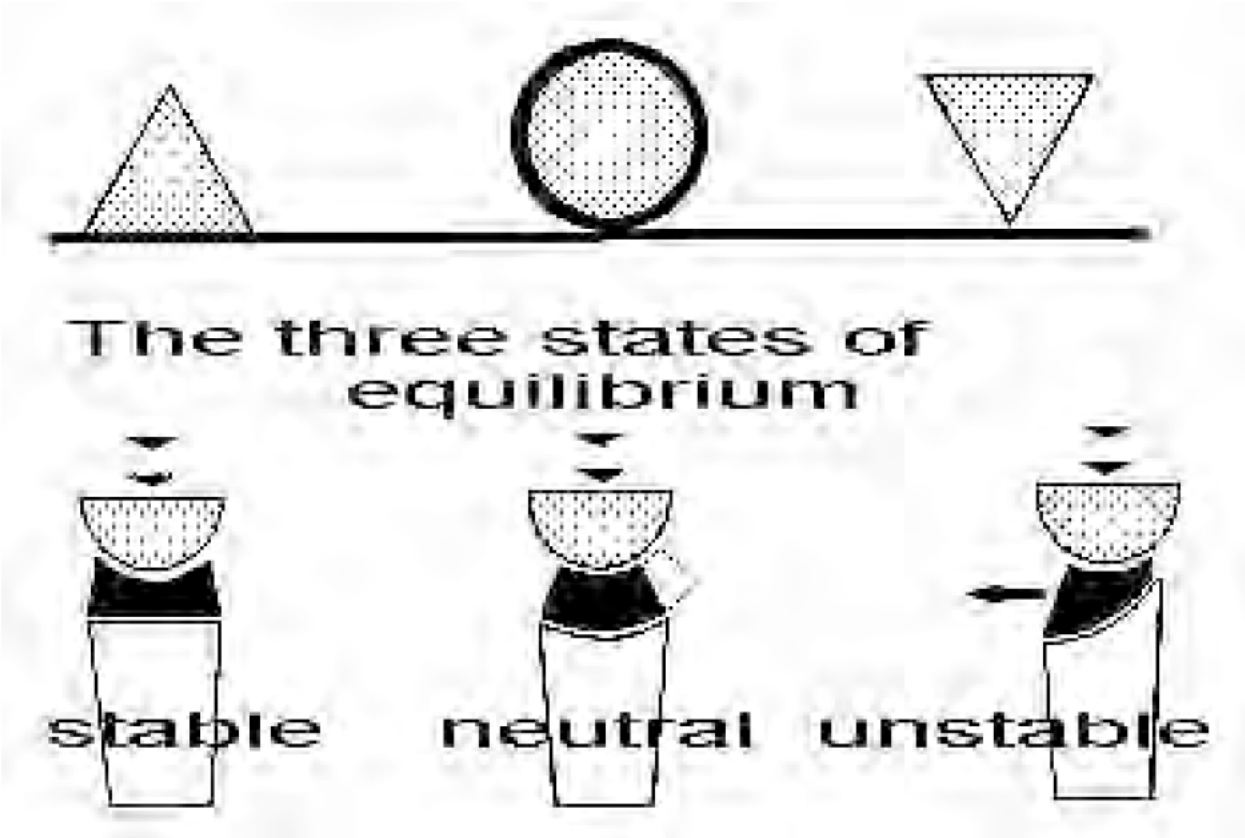
Understanding of mechanical laws i.e.

load transfer

stability.

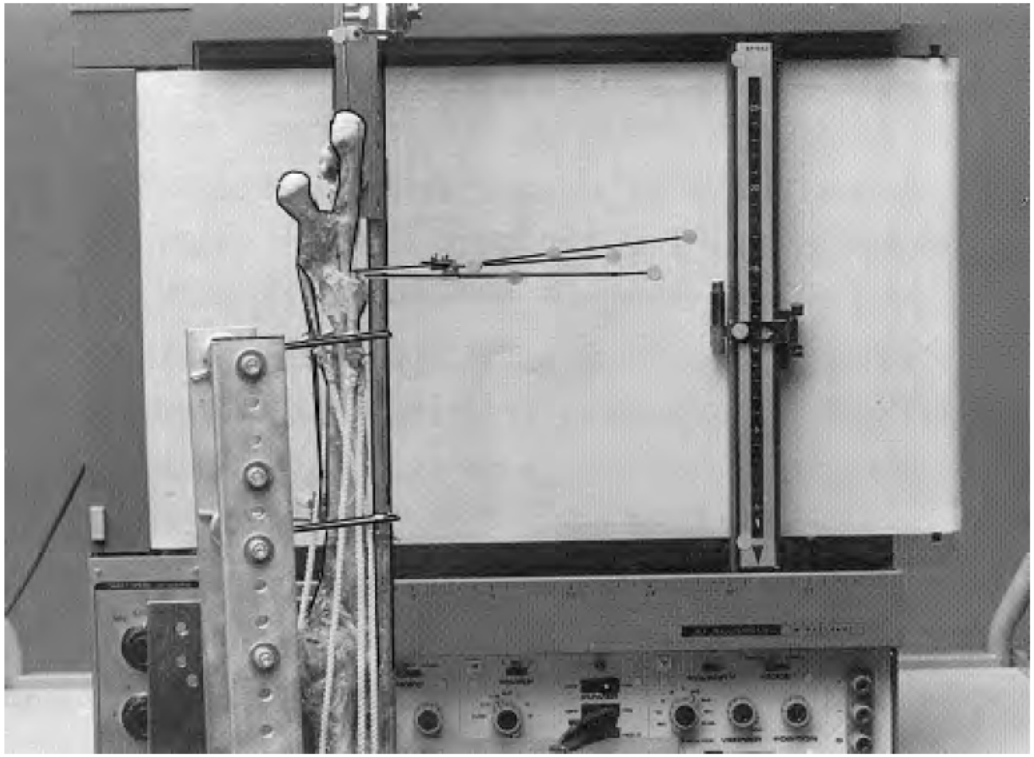
Anatomy and mechanics of the wrist

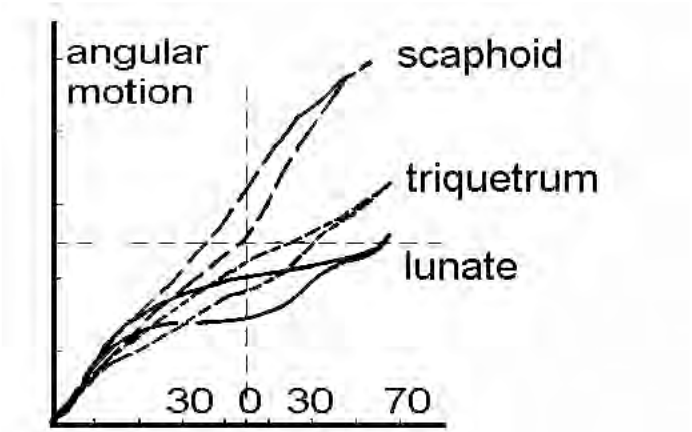
Definition of stability
Mechanical approach



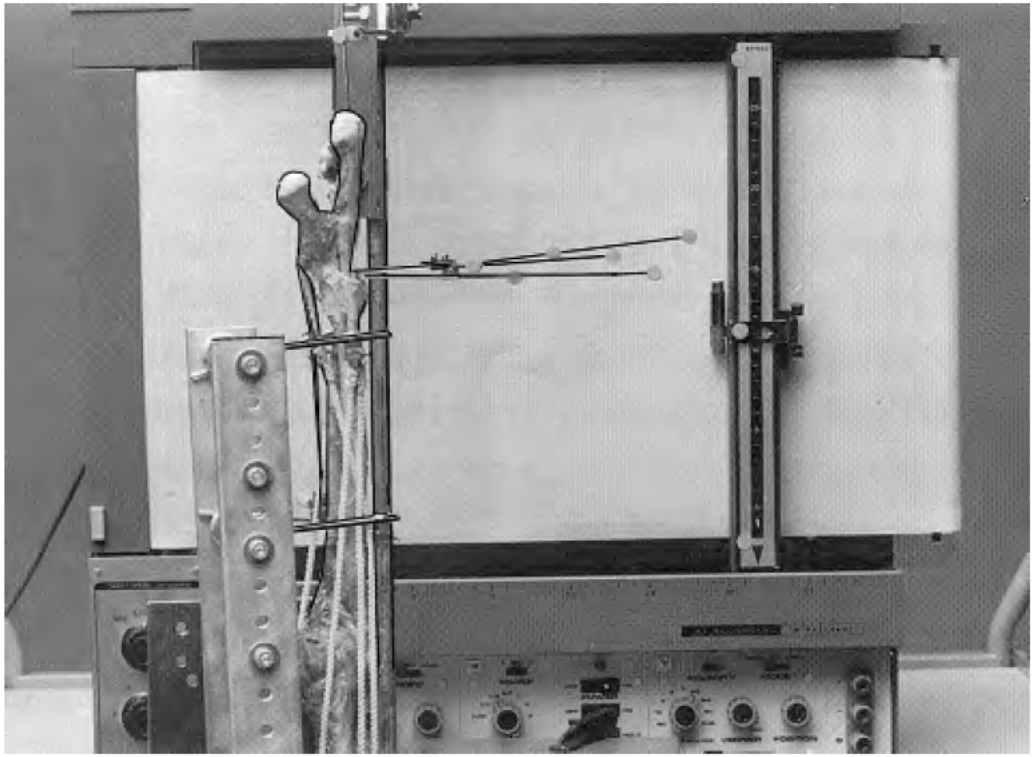
Anatomy and mechanics of the wrist

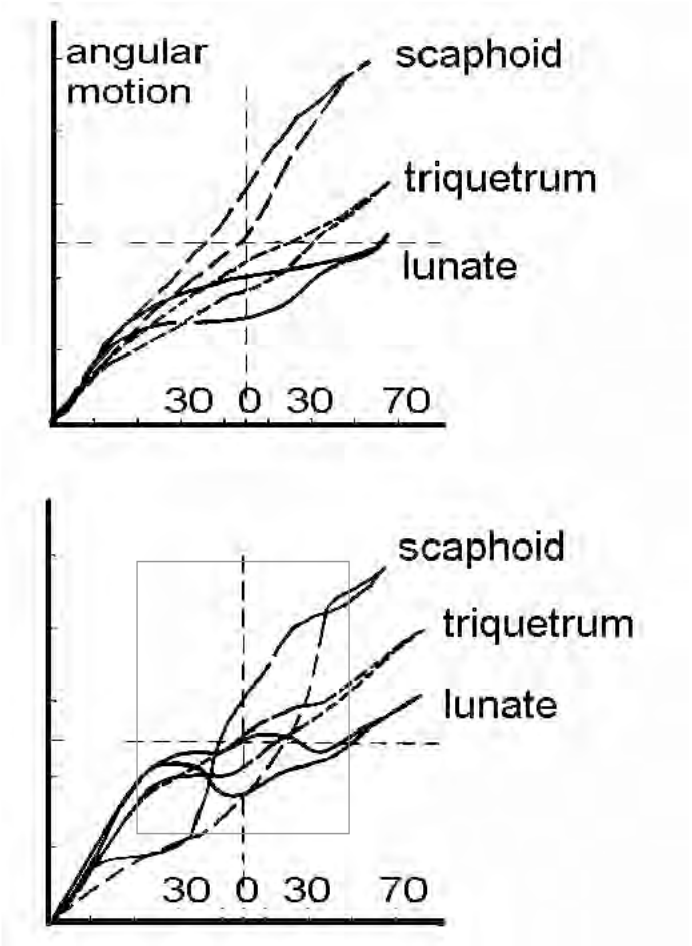
All ligaments intact





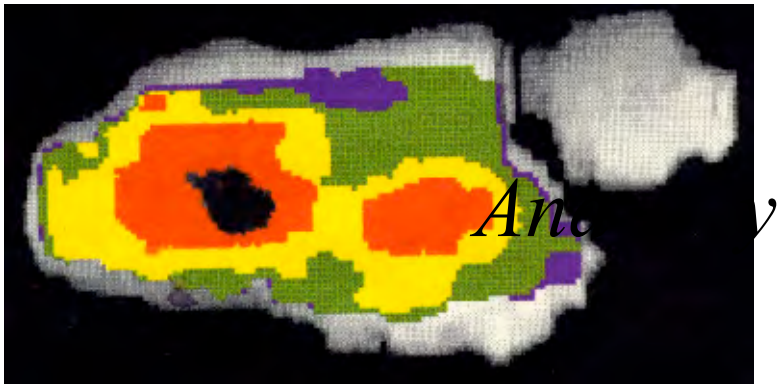
Anatomy and mechanics of the wrist





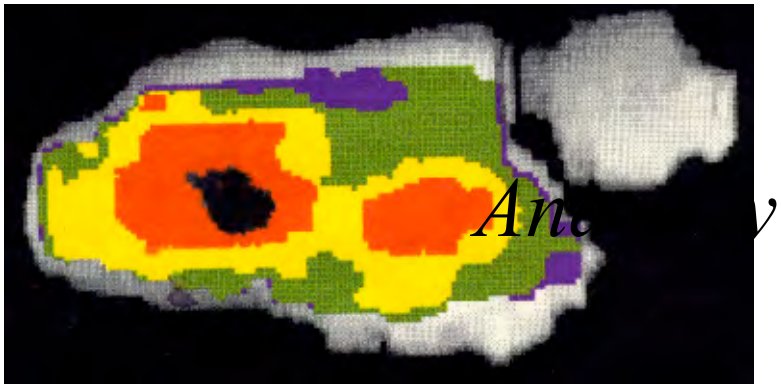
ut

⇨ ***A stable wrist has the ability to return to a definite position after removal of any destabilizing force at any point within the whole physiological range of motion.***



Anatomy and mechanics of the wrist

- ***⇨ Stability enables optimal joint contact, minimizes stress in any physiological position of the joint.***
- ***⇨It ensures a smooth and reproducible motion pattern.***
- ***⇨ It warrants optimal load transfer.***



Anatomy and mechanics of the wrist

⇨ ***Intact ligaments essential for***

stability

smooth

reproducible

correct motion

i.e. perfect load transfer in any position of the wrist.

Anatomy and mechanics of the wrist

- Ligaments of the proximal carpal row further function.

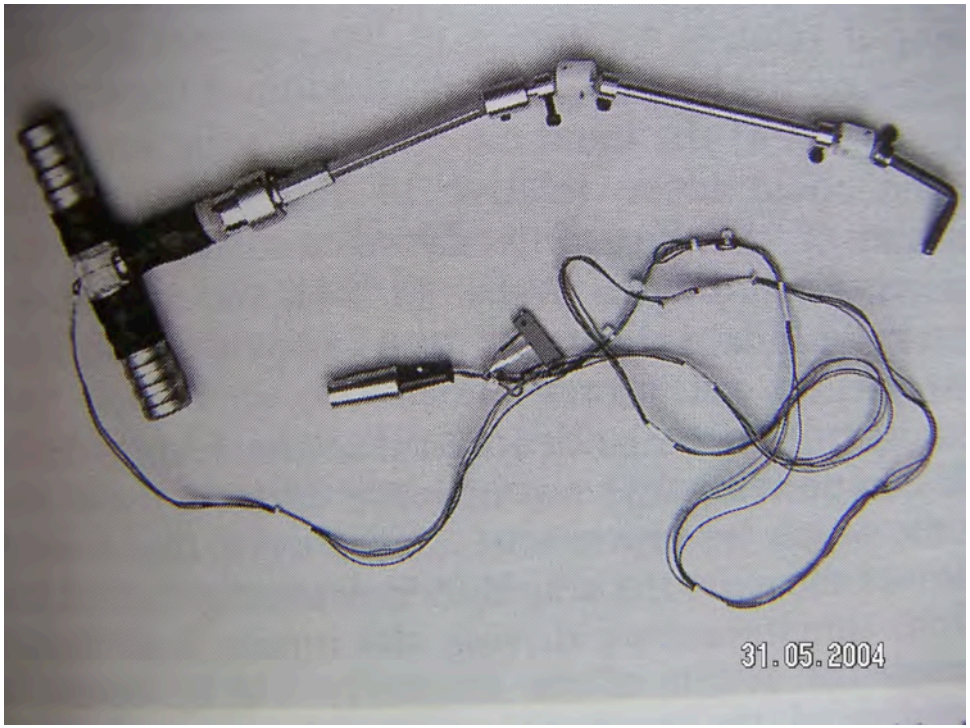
Mechanics, proximal row

The Wrist

➢ **Characteristics of pure torque is important:**

pure torque can be introduced with the same effect at any point of the object.

Torque wrench with Hooke's universal joints



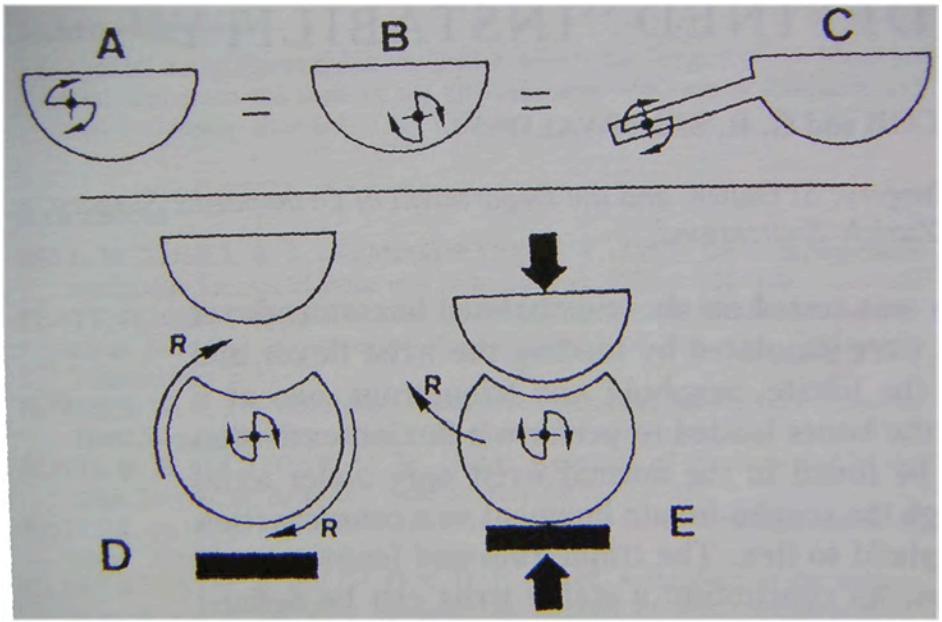
Mechanics, proximal row

The Wrist

- **Characteristics of pure torque is important:**

  pure torque can be introduced with the same effect at any point of the object.

- **The Reaction R of the pure torque depends on the constraints applied to the object.**



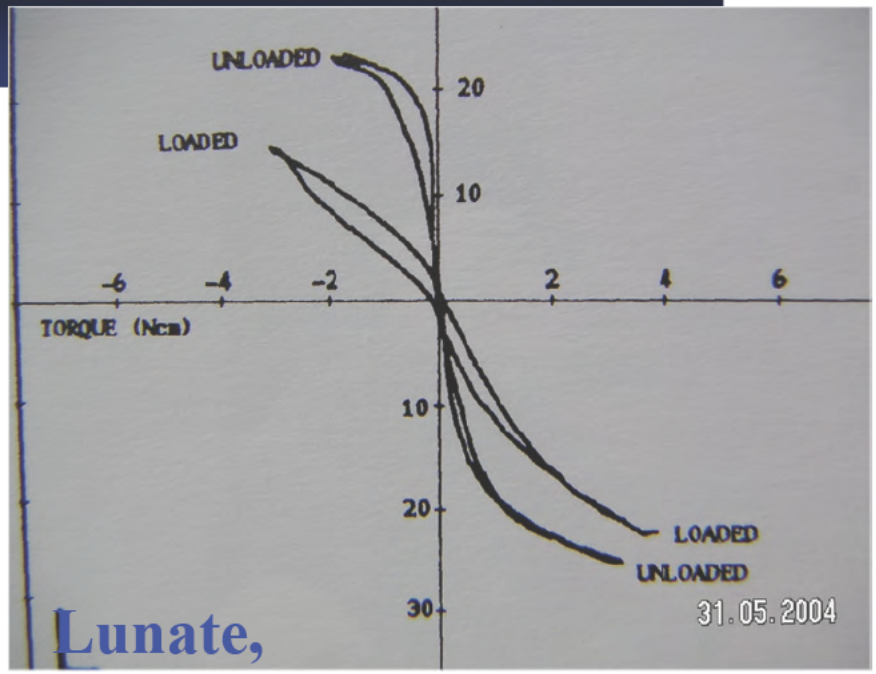
Mechanics, SL function

The Wrist

- Primary angular motion of the lunate in relation to the applied torque (Ncm).

After ***loading***, the shape of the curve became oblique showing that much more torque is required to displace the bones.

On release of torque, the starting position is immediately regained.



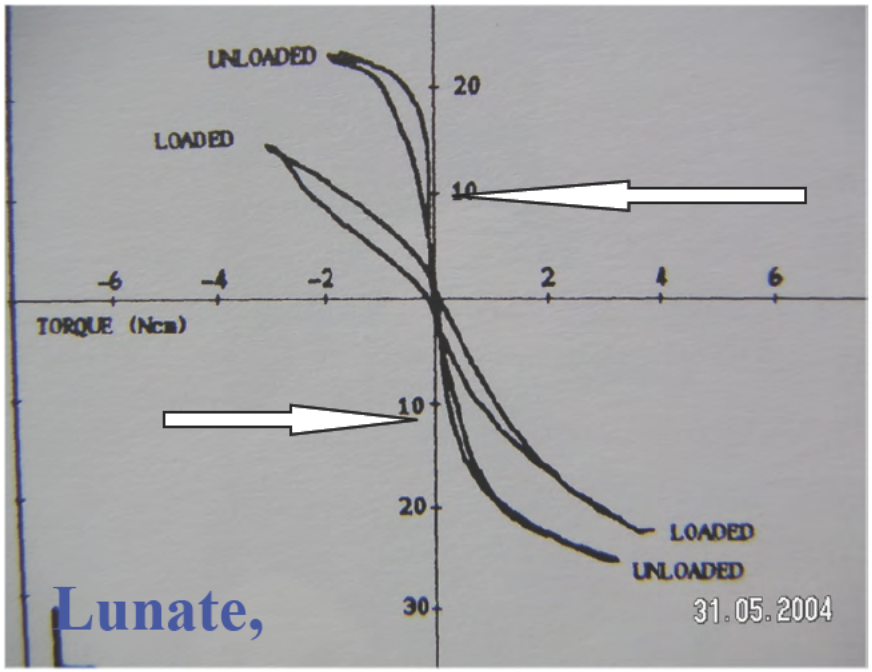
Lunate, flexion

Mechanics, proximal row

The Wrist

- Unloaded curve:

Its middle part shows a range of positions within which the bones can be moved on application of a minimum amount of torque***, remaining stationary in the newly acquired position: this represents***



Lunate,

NEUTRAL EQUILIBRIUM

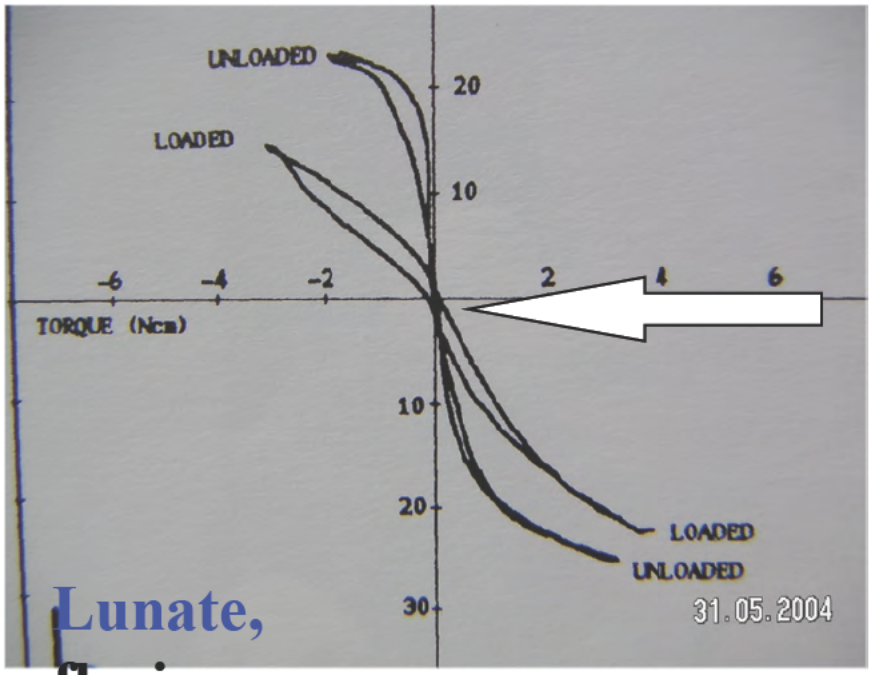
Mechanics, proximal row

The Wrist

- Loaded curve:

The curves became oblique at the zero-torque crossing. They show that much more torque is required & that the starting position is immediately regained on release of the torque:

STABLE EQUILIBRIUM



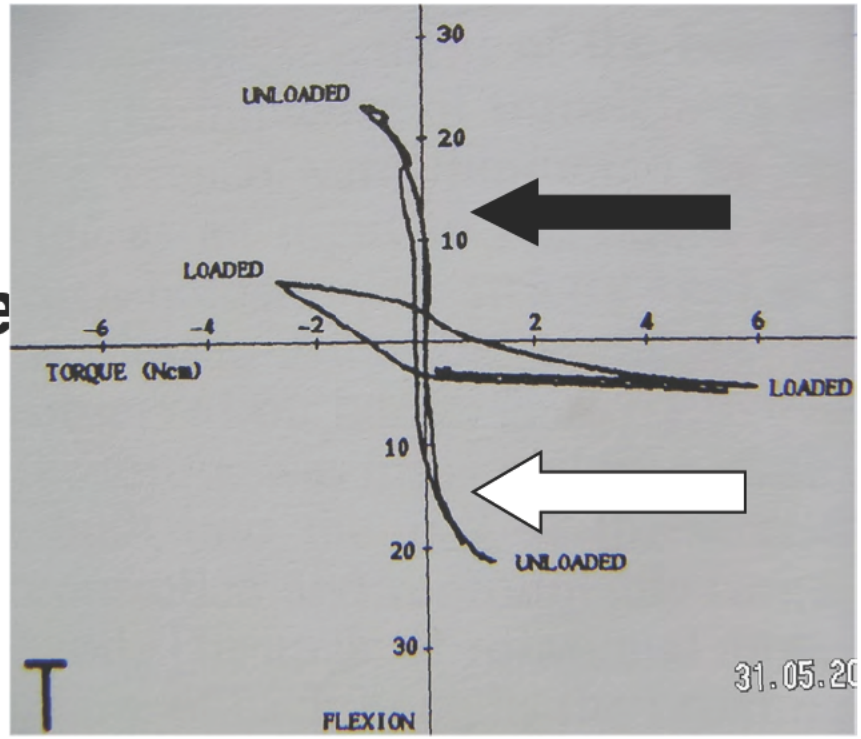
Lunate, flexion

Mechanics, proximal row

The Wrist

- Primary angular motion of the triquetrum in relation to the applied torque (Ncm).

How much the bone suffers displacement by application of a given small amount of torque *depends on whethe the wrist is loaded or not.* The return to the starting position = stable equilibrium



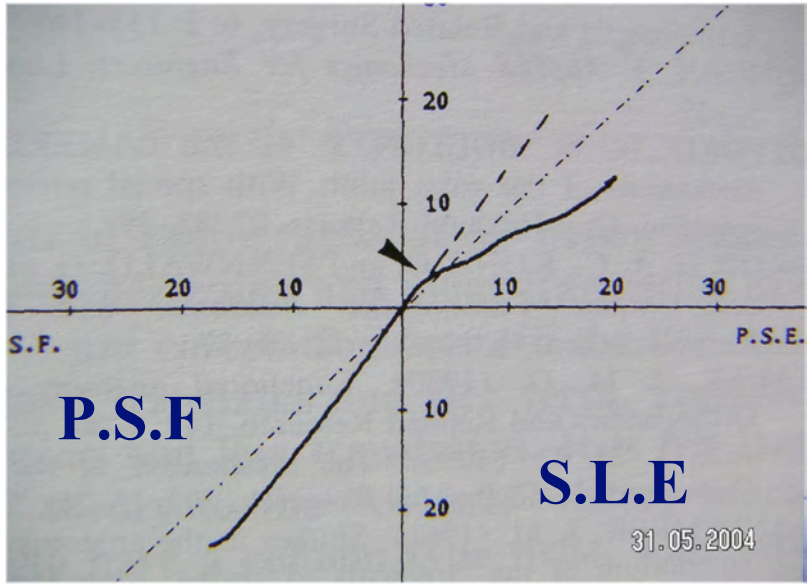
Mechanics, proximal row

The Wrist

- P.S.F: Primary Scaphoid Flexion.
- S.L.E: Secondary Lunate Extension

Primary induced motion of the scaphoid causes a secondary motion of the lunate.

During extension, the lunate suddenly follows at a slower rate!



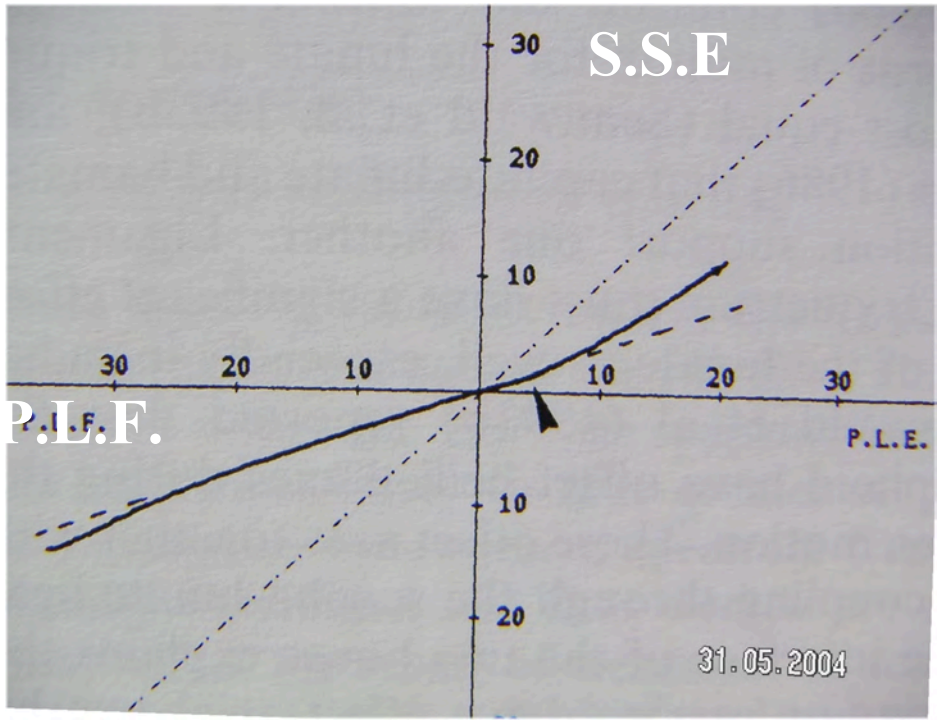
Mechanics, proximal row

The Wrist

- P.L.F: Primary Lunate Flexion.
- S.S.E: Secondary Scaphoid Extension

Primary induced motion of the lunate causes a secondary motion of the scaphoid at a lower rate.

During Lunate extension the scaphoid suddenly follows the lunate more closely !



Mechanics, proximal row

The mechanics shows:

- **that motion of the lunate and triquetrum are closely coupled bi-directionally with a lag of about 5°.**
- **a consistent return to the initial position of the bones of the proximal carpal row.**
- **that the axial load has a stabilizing effect**

Mechanics, proximal row

- primary motion of each bone in the proximal row induces a secondary motion of the other two.
- coupling between the scaphoid & lunate depends on the direction of primary motion.
- the SL ligament is under tension =

  tight coupling in flexion,

  uncoupling in extension

Mechanics, proximal row

- This might have an adverse effect in the presence of a malunion of the distal radius with dorsal tilting.
- **Permanent tension increases.**
- **the SL ligament is under tension =**

tight coupling in flexion,

uncoupling in extension

Mechanics, proximal row

- the pattern of motion between triquetrum and lunate are similar.
- capitate-lunate and hamate-triquetrum motion support one another.

Mechanics, proximal row

Stable joint

A stable should be defined as one, which, while being loaded within a physiological range of stress, does not loose its stable state of equilibrium at any point within the physiological range of motion.

The Wrist

These findings allow a simplified classification of carpal instability

stage 1 ***without dissociation***

stage 2a, ***with dissociation reducible***

Stage 2 b ***with dissociation not reducible.***

stage 3, ***with carpal collaps.***

stage 4, ***with pan - arthrosis.***

But a problem remains:

We now know what is stability,

But we still ignore some further important aspect of Ligament function, and forces that might induce pathology.

Loads

Mechanics and Diagnostic ***The Wrist***

- **Ligament function**

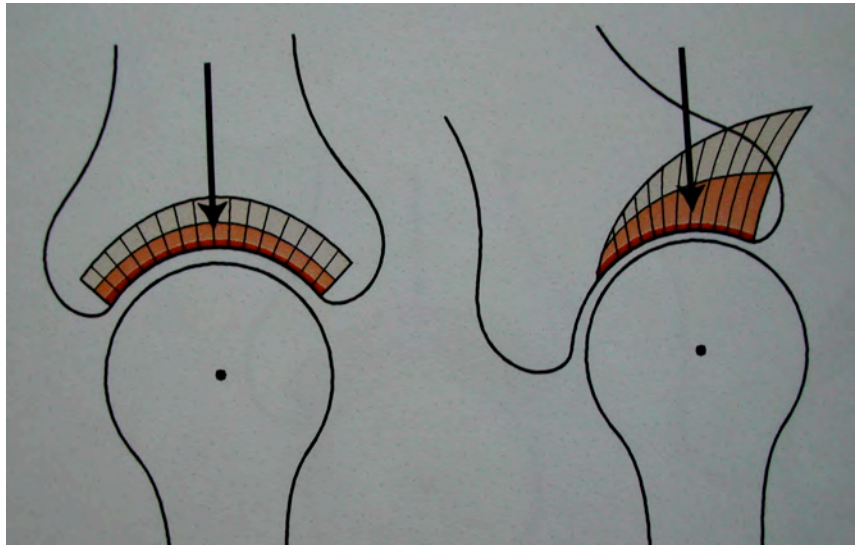
Not supposed to catch up loads but:

Restrain (limit)

Adjust (coordinate)

Guide (placement)

Neutralize (the torque within the first row)



The load is transferred through the joint.

Mechanics and Diagnostic ***The Wrist***

- **Ligament function**

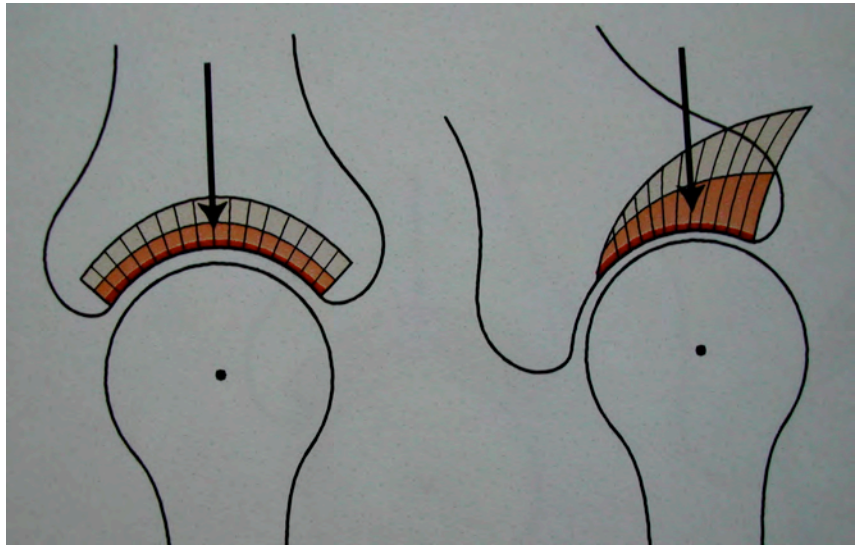
Not supposed to catch up loads but:

Restrain (limit)

Adjust (coordinate)

Guide (placement)

Neutralize (the torque within the first row)



If the ligament do not guide correctly the joint, overload can occur locally

Mechanics and Diagnostic ***The Wrist***

- **Ligament function**

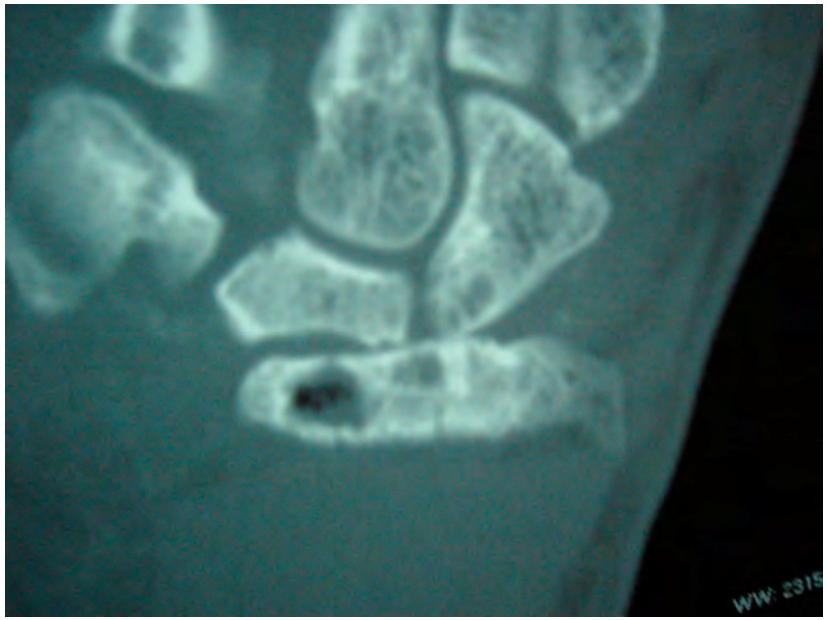
Not supposed to catch up loads but:

Restrain (limit)

Adjust (coordinate)

Guide (placement)

Neutralize (the torque within the first row)



If the ligament do not guide correctly the joint, overload can occur locally

Mechanics and Diagnostic ***The Wrist***

- Force transmission

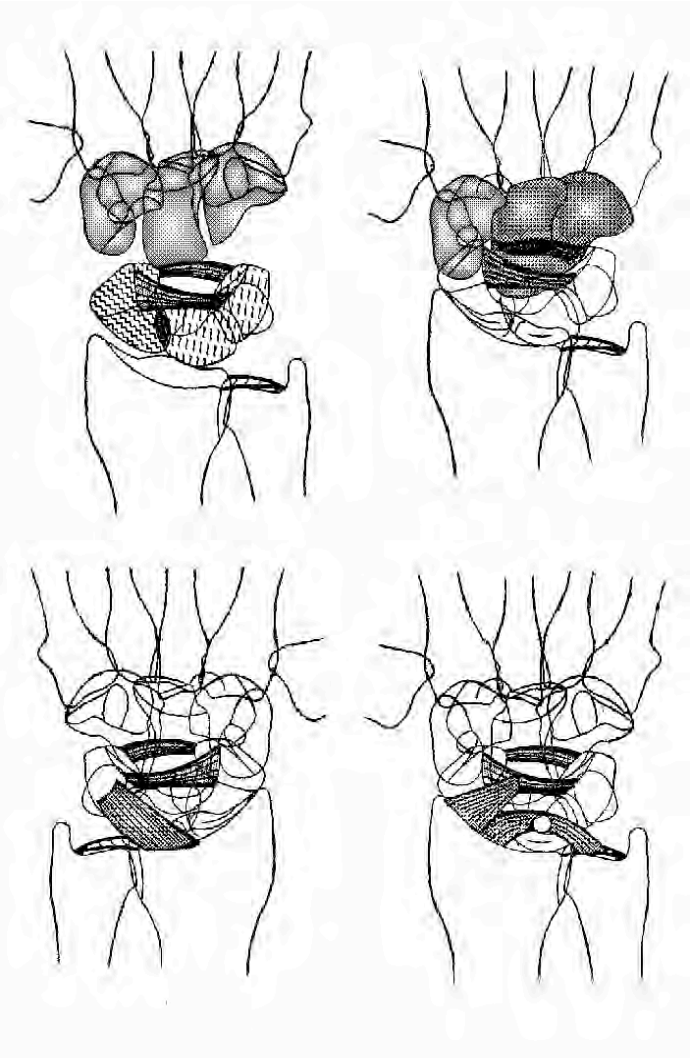
S: scaphoid /L:lunate

First row:

a. interactive
b. suspended
c. Intercalated
d. independent

Distal row:

- stable
- Fixed on a moving base
- Loosed fixation



Mechanics and Diagnostic ***The Wrist***

- Problems

Intrinsic

or

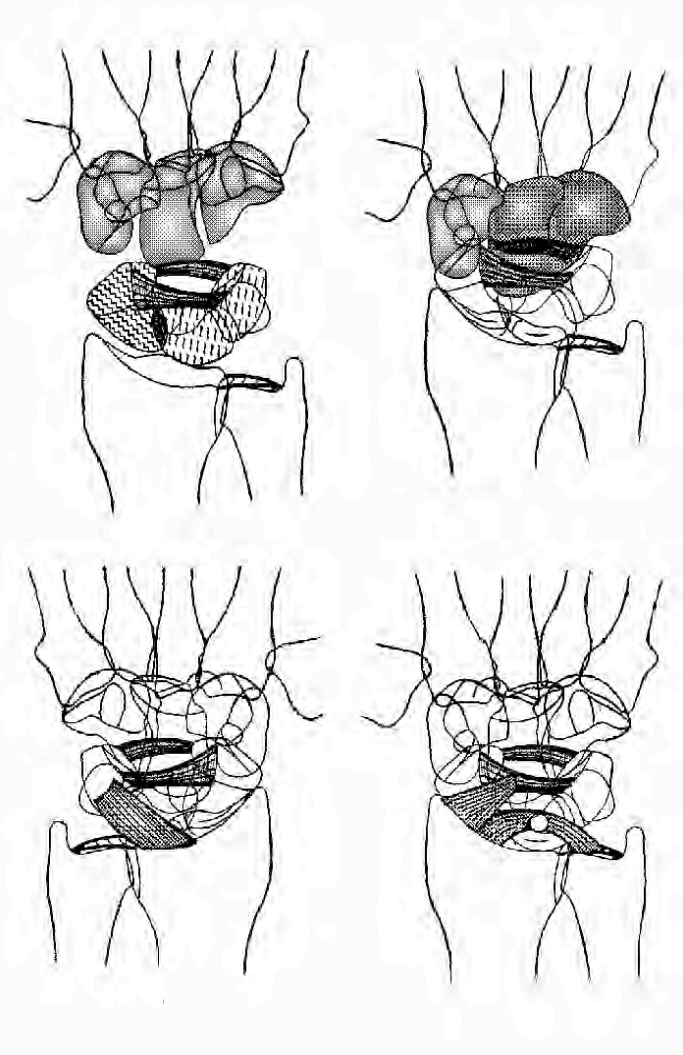
extrinsic

First row:

a. interactive
b. suspended
c. Intercalated
d. independent

Distal row:

- stable
- Fixed on a moving base



Mechanics and Diagnostic ***The Wrist***

- Problems

Intrinsic

or

Extrinsic

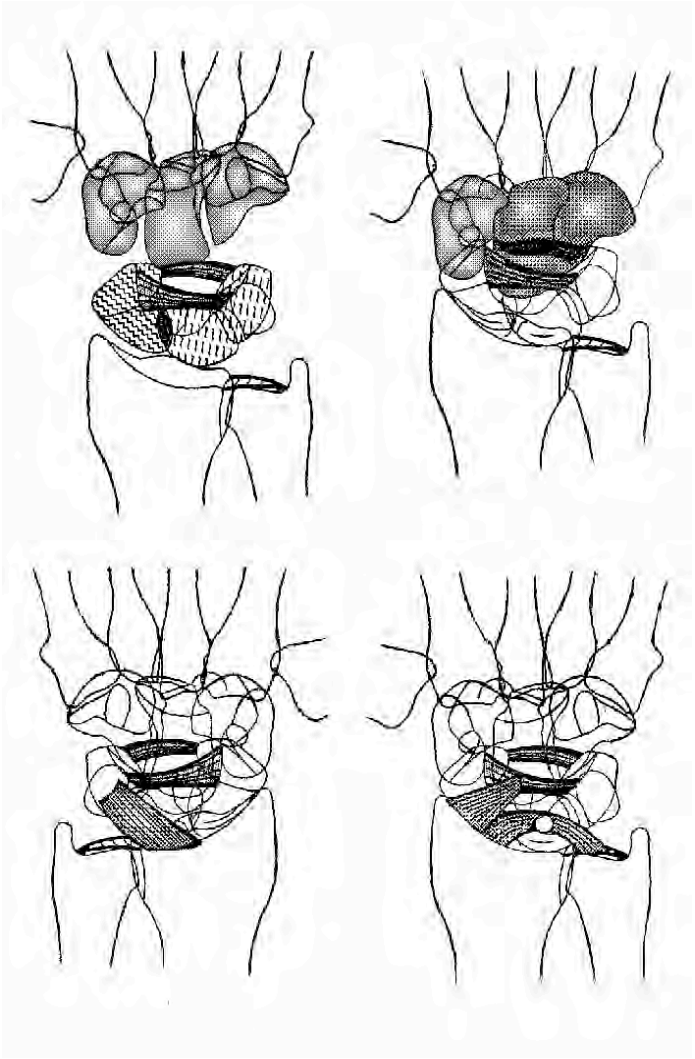
or

combined

DISI,
PISI
Dissociation

Translocation
(i.e., Rheuma)

Complex injuries



Mechanics and Diagnostic ***The Wrist***

- Problems

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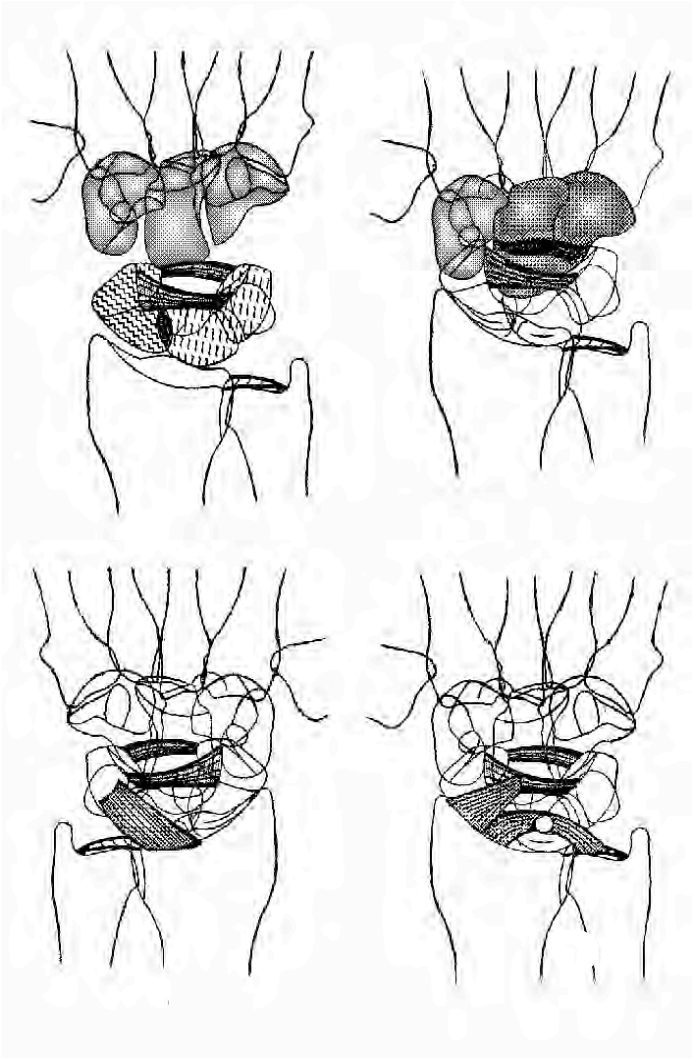


And which forces are

- **Basic physical data**

Force = mass * acceleration (F=m*a)

where

Units of force = units of mass (kg) multiplied by the units of acceleration (m/sec^2), or

Weight = Mass * acceleration = Force

Weight = kg * m / sec^2 = Force (newton)

The weight of a men with a mass of 70 kg, represents a force of 686 newtons ($70*9.81/sec^2$)

The displacement of this force through a distance induces energy, termed "work" where

Work = force * distance = Joule

If a person falls from 1 meter,

We have Work = force * distance = Joule

i.e.

686 * 1 = 686 Joule.

If a person falls from 1 meter,

We have Work = force * distance = Joule

i.e.

686 * 1 = 686 Joule.

If we consider a simple fall, the produced energy will vary between 200 à 700 Joules!

200 à 700 Joules!

This kinetic energy, transmitted through the hands and wrist, has to be neutralized when the impact occurs!

Mechanics and Diagnostic ***The Wrist***

200 à 700 Joules to be neutralized.

For a cortical long bone submitted to bending, plastic deformation appears with 1.18 joules!

Ligament failure (axial loads, best condition) vary from 60 to 300 newtons

Mechanics and Diagnostic ***The Wrist***

Neutralisation of energy needs

- **muscles (absorption)** **age**
- **reflex** **time to react**
- **correct force transfer**

  (avoid shear stress)

Facit:

- Never minimize the potential consequences of an apparent simple fall.
- Shear stress is extremely important (ligament or bone cannot neutralize them)
- Combined lesions should be the rule!

Mechanics and Diagnostic ***The Wrist***

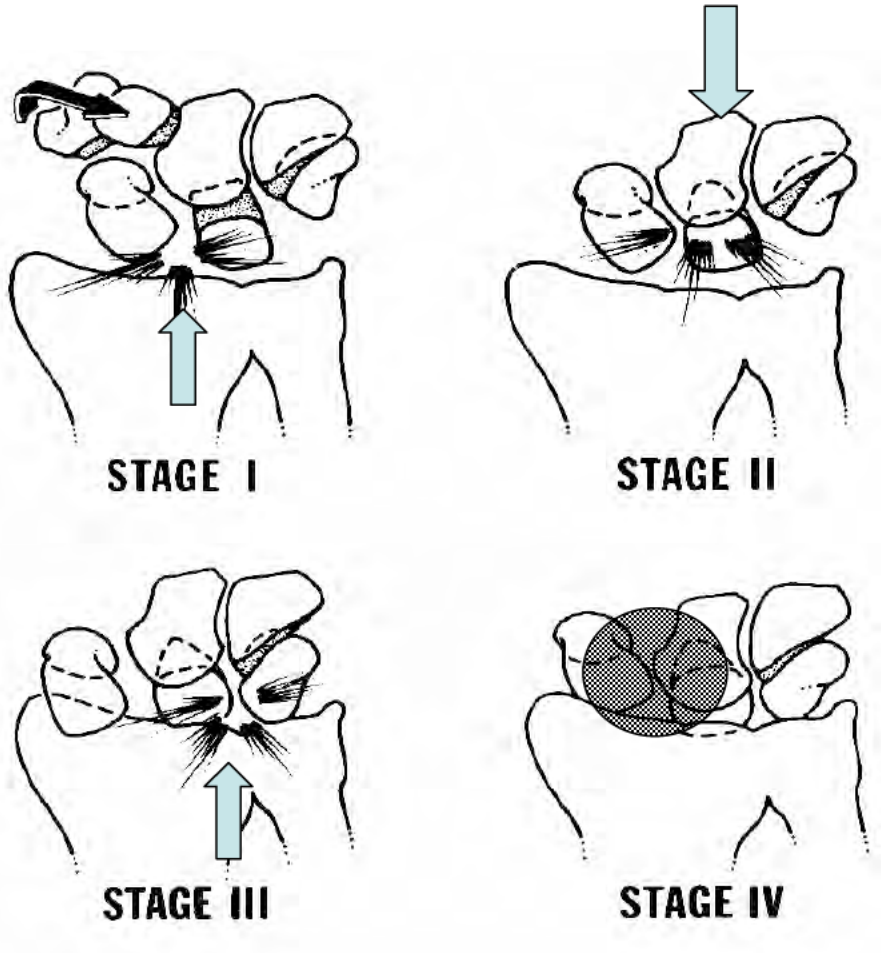
Mayfield

True?

Nicolas Barton:

I have come to believe that standard teaching on other aspects is, at best, unproved and often actually untrue.

Mechanism of injury?



Mechanics and Diagnostic ***The Wrist***

- To obtain this lesion, you do not need a Kawasaki

Mechanics and Diagnostic ***The Wrist***

- Remember

Pain may be present soon (local overload).

Bone insure shape, joint congruency &
force transmission.

Ligament restrain (limitation of motion).
adjust (coordinate position).
guide (insure placement).
neutralize opposite motion (1rst row).

Simple fall 200 to 700 Joules!

Mechanics and Diagnostic ***The Wrist***

- remember

Pain	does not require obvious lesions.
Bone	you need comparative x-rays for evaluation (variable anatomy).
Ligament	you may need stress or contrast means to appreciate any rupture partial or total.
Simple fall	may cause fracture and/or ligament ruptures (enough energy).


Thank you
for your
attention

The Wrist

Conclusion: mechanics suggest to be simple, for example, for classification of carpal instability

stage I with dissociation

stage 2a, with dissociation reducible

Stage 2 b with dissociation irreducible.

stage 3, with carpal collaps.

stage 4, with pan - arthrosis.

Thank you for your attention