

Mechanisms of the human hand & how to emulate them

Abstract

To date no robotic manipulator matches the sensitivity and dexterity of the human hand.

This talk provides a review of the of the materials and mechanisms of human hand anatomy, together with a report on progress in our lab in 'histomimetic' techniques reproducing those materials, and mechanisms including - dermal structures, ligamentous joints, tendon networks and embedded somatic sensors.

Nick Hockings
PhD student

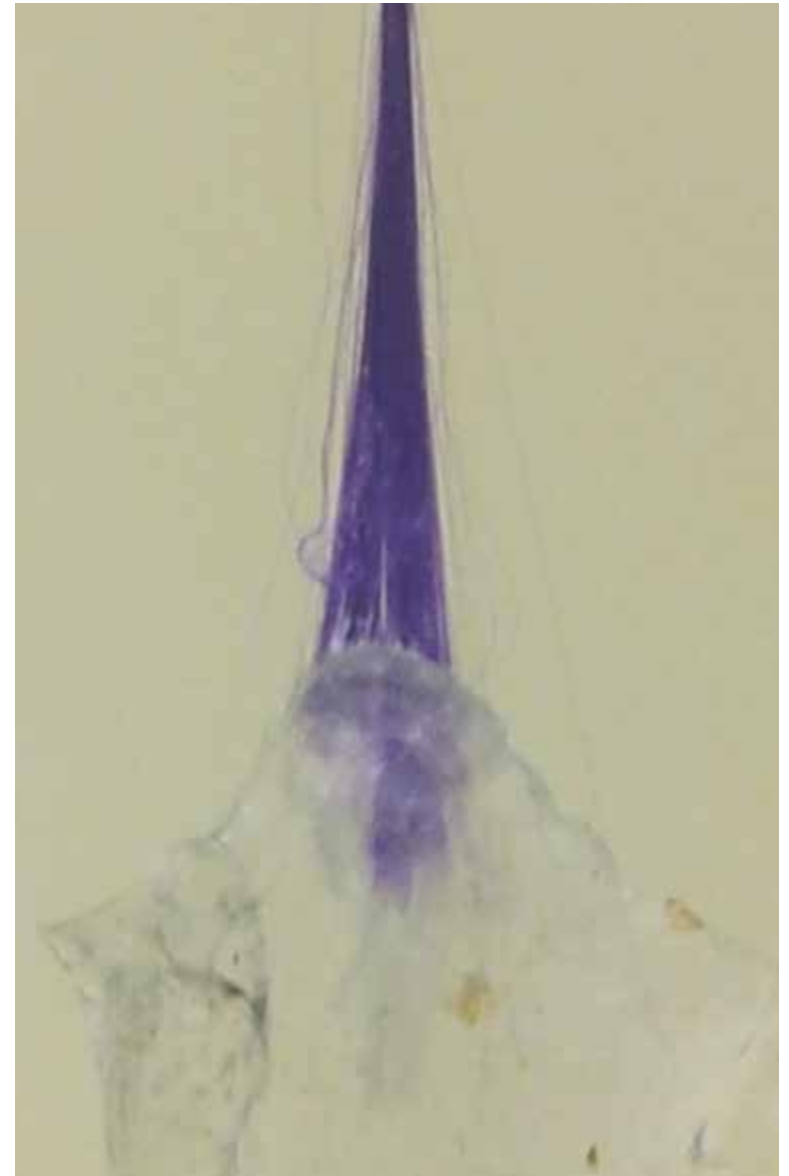
Supervisor Dr Pejman Iravani
Robotics Lab



Acknowledgement to
University of Sussex, Clinical
Imaging Research Centre
and Fitzpatrick's Referrals,
for MRI scans of hands & paws.

Sections

- Sensitivity of the hand
- Preflexes - tendon networks
- Retinacular ligaments
- Ligamentous joints



1 Sensitivity of the Hand

- Dermal structures
 - Finger pad
 - Finger nail
 - Crease ligaments
- Strain & temp sensors

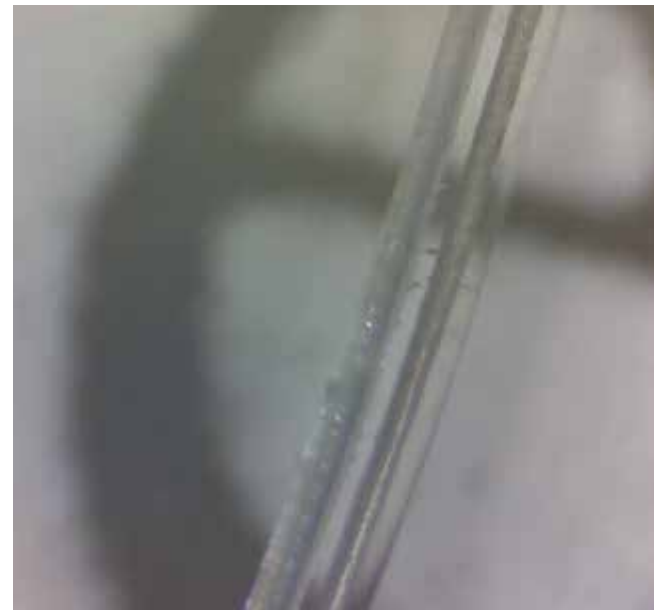
Structure of the Finger Tip

- P3 shape
- Fat pad structure, Cleland's ligaments
- Dermis-epidermis structure
- Crease, Grayson's ligaments
- Nail - epidermal
- Nail bed
- Spectrum of compliance



Tactile & Proprioceptive Sensors

- Epidermal
 - Merkel cells, Meissner's corpuscles
- Dermis, joint capsules, ligaments
 - Ruffini endings, Pacinian, Golgi-Mazzoni corpuscles
 - Hot & cold receptors, Pain receptors
- Golgi tendon organs
- Muscle spindles



2 Preflexes

"preflexes" mechanical responses, which have zero delay and may be programmed by the nervous system over a wide range of magnitudes - Loeb 1995

- Thumb web
- Palm & carpal tunnel
- Under-actuation
- Volar plate of DIP
- Check ligaments
- Extensor hood
- Spiral oblique retinacular ligament

Thumb Web

- Structure
- Finger closing action
- Thumb positioning

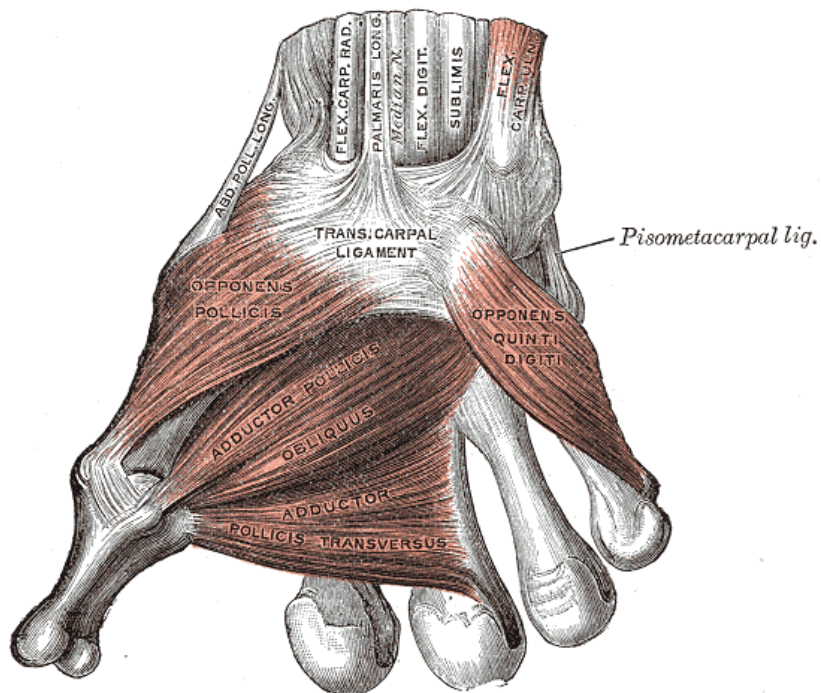


Fig 426, Gray's Anatomy 1918, Bartleby.com



Palm & Carpal Tunnel

- Fingers form a cage
- Palmar fascia / flexor tendon reflex

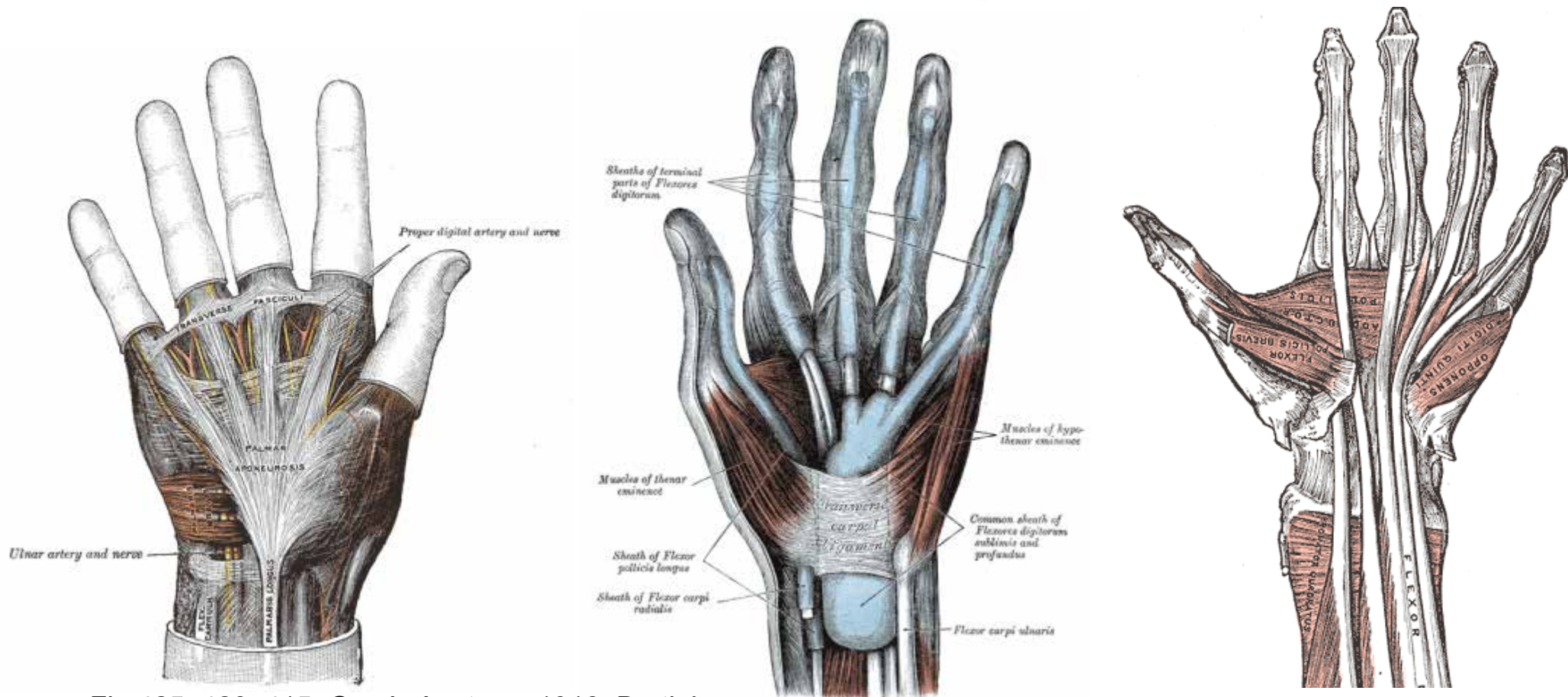
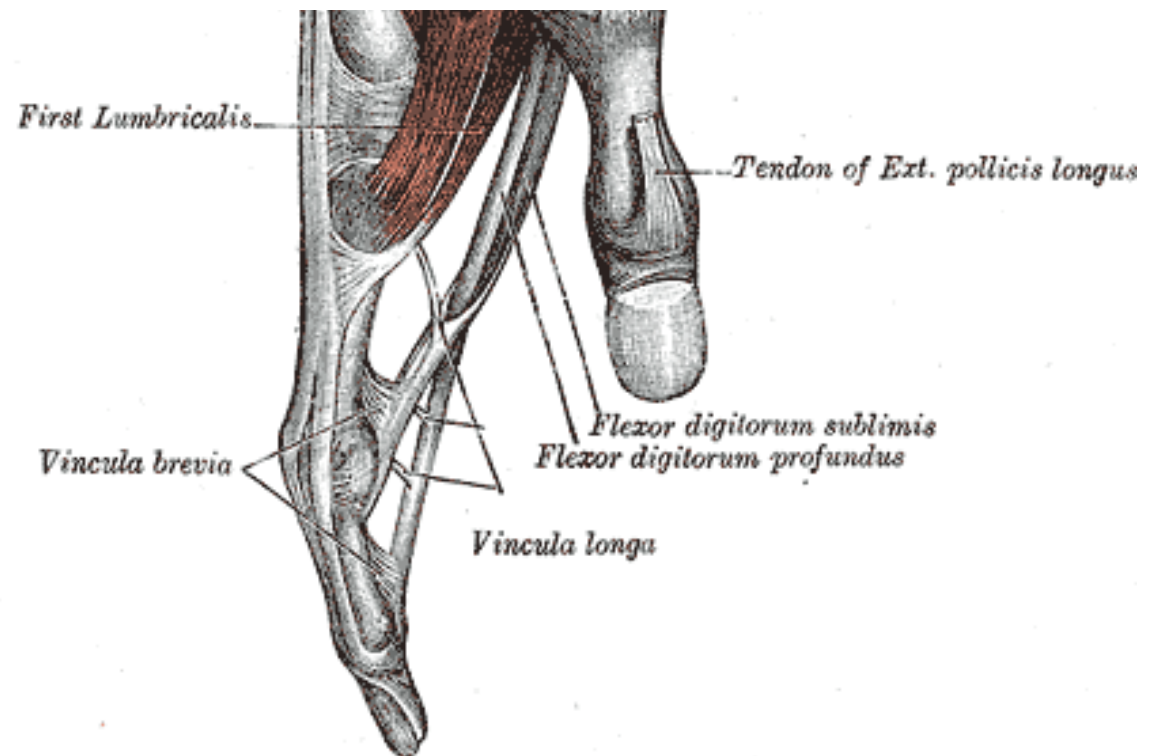
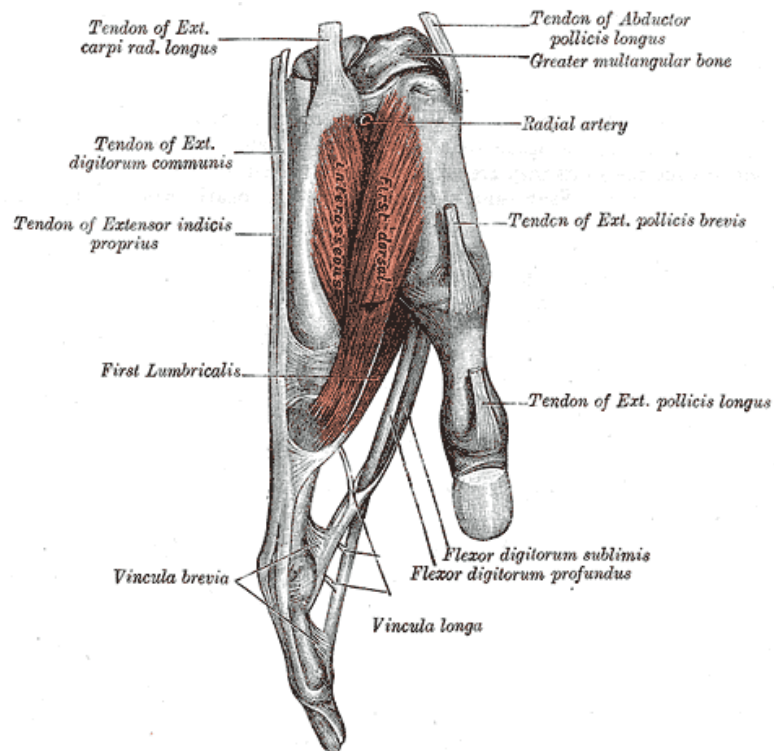


Fig 425, 423, 415, Gray's Anatomy 1918, Bartleby.com

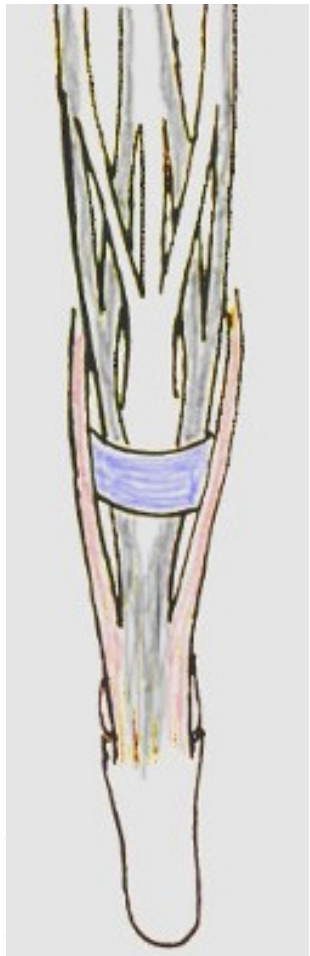
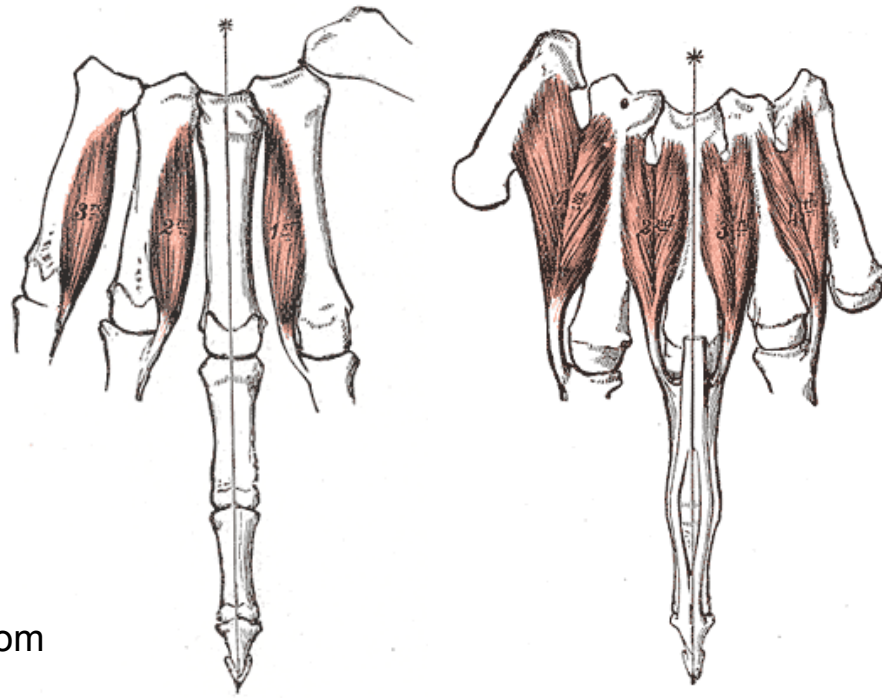
Under-actuation & Check Ligaments

- Finger hooking
- Check ligaments
- DIP volar plate & superficial flexor tendon



Extensor Hood

- Winslow's Rhombus - logic Valero-Cuevas
- Inter-osseous muscles
- Lumbricals
- Extrinsic extensors



Dorsal Oblique & Transverse Ligaments

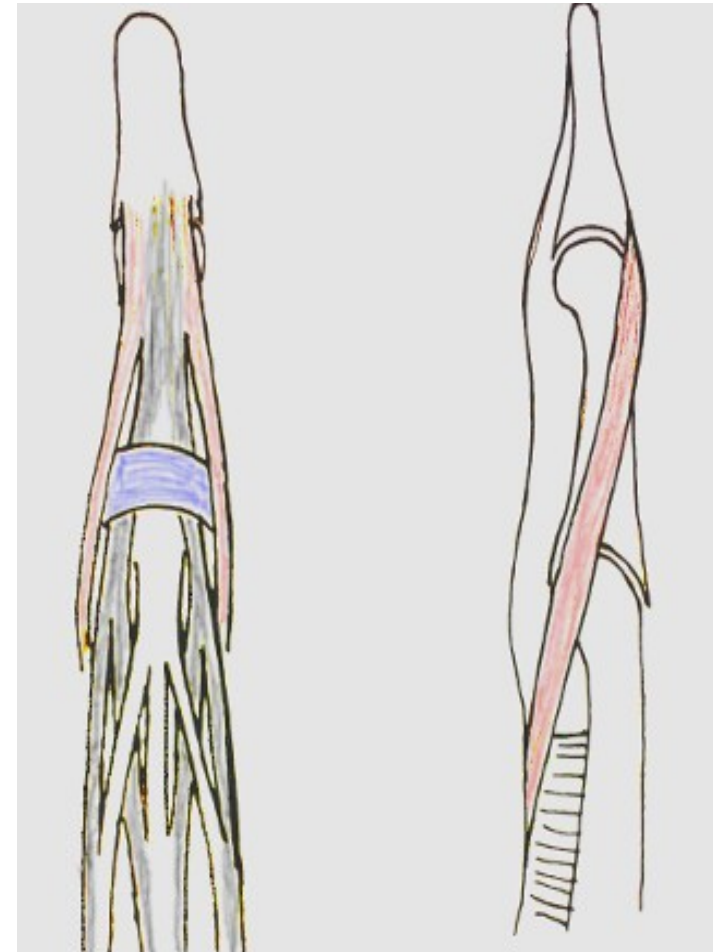
- Mechanism & effect on flexion-extension of DIP & PIP
 - Oblique (red)
 - limits relative phase of DIP-PIP
 - => extension of DIP from fully flexed
 - => flexion of PIP from fully extended
 - Transverse (blue)
 - part of extensor retinaculum
 - stabilises distal extensor slips

Ref:

Thompson J.S., Littler J.W., and Upton J.

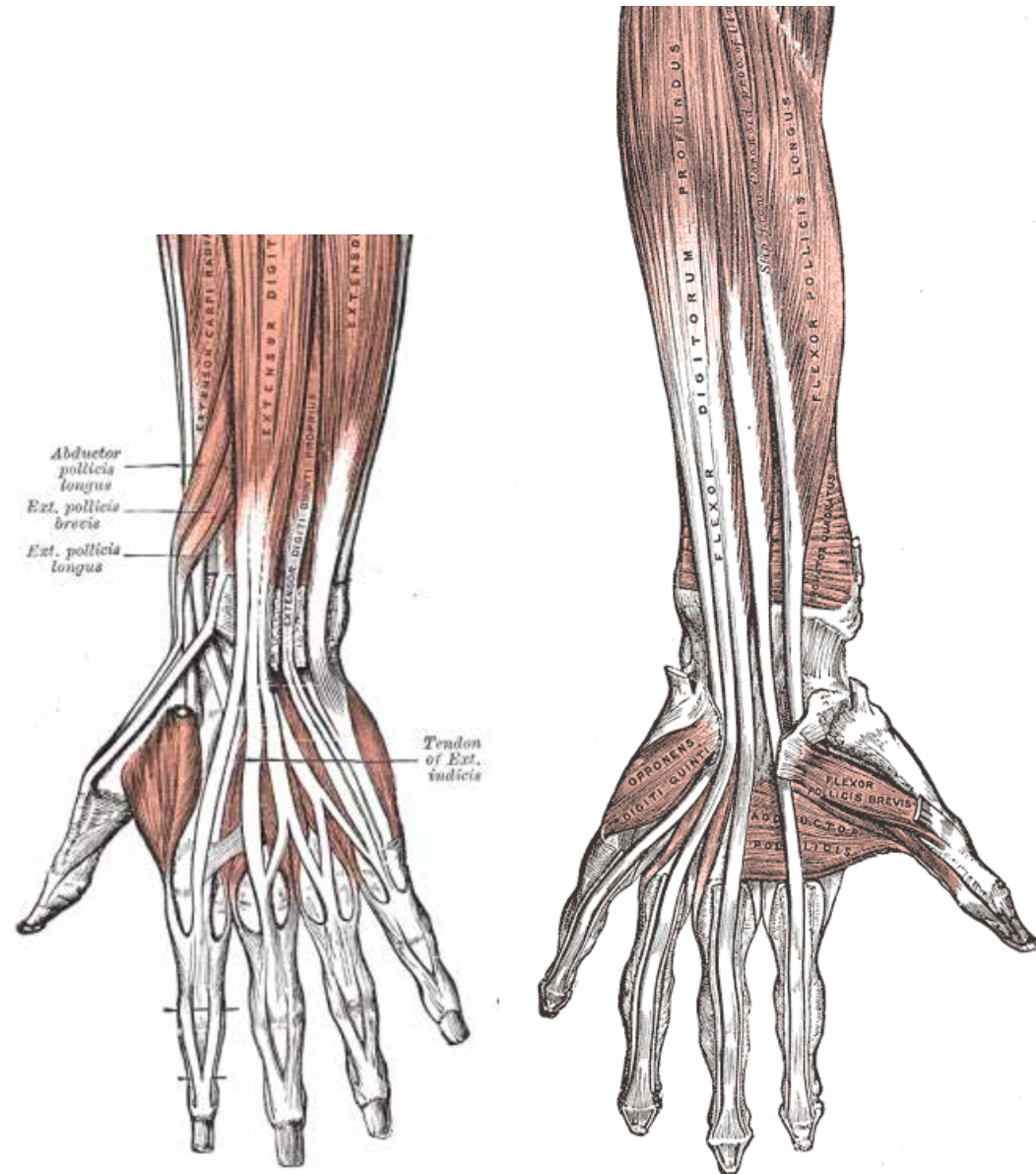
The spiral oblique retinacular ligament (SORL)

The Journal of Hand Surgery, Vol. 3, No. 5, September 1978.



Tendon Cross Connections

- Flexors - tendon shear
=> high pinch force
- Extensors - Juncturae

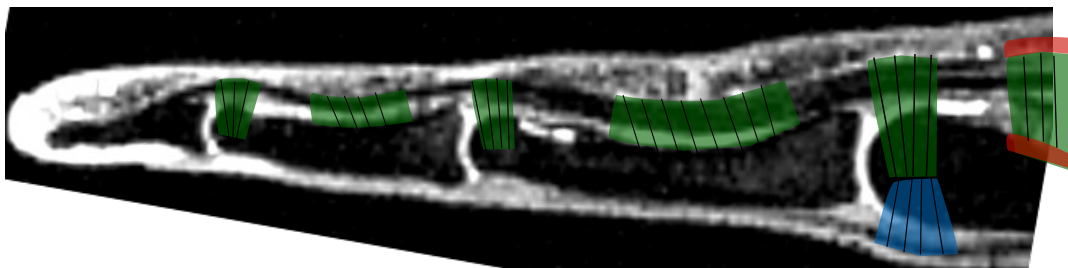
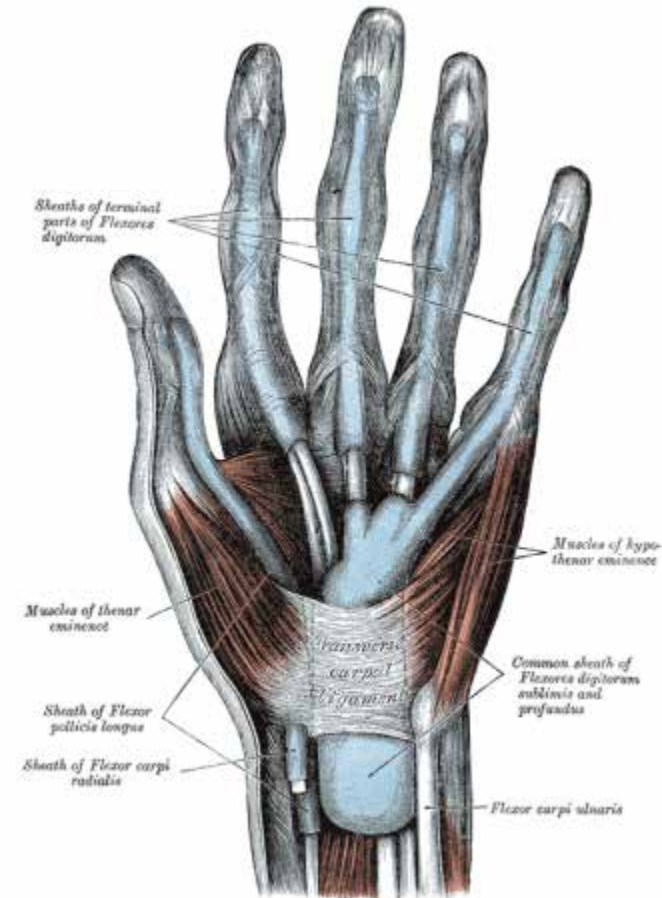


3 Retinacular Ligaments

- Flexor retinacular system
- Extensor retinacular system

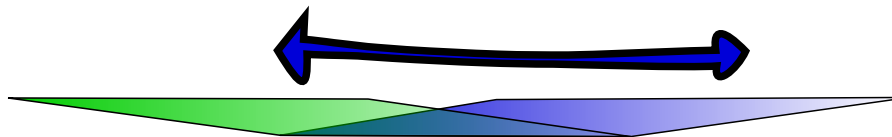
Flexor Retinacular System

- Tendon sheaths
- Annular ligaments
- Cruciate ligaments
- Transverse palmar fascia
- Transverse carpal ligament
- Distal forearm fascia



Extensor Retinacular System

- Sagittal bands
- Hyper-elastic peritendon
- Dorsal carpal retinaculum
- Distal forearm fascia



1mm layer allows 10mm shear at +/- 500% strain

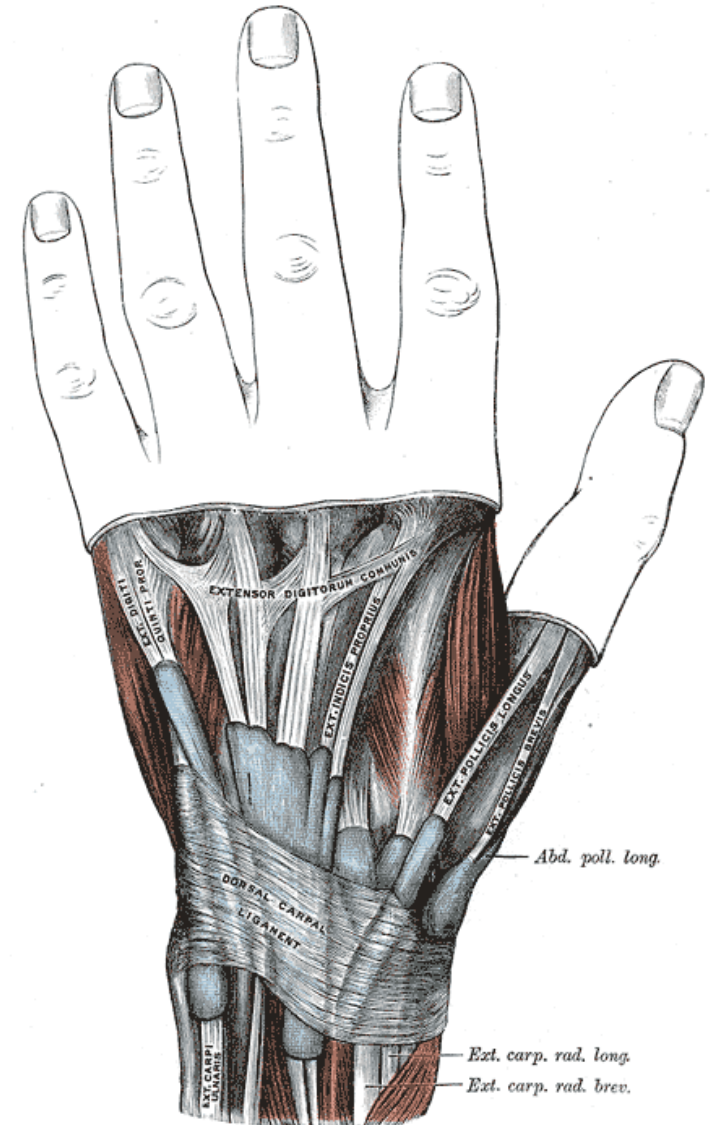


Fig 424, Gray's Anatomy 1918, Bartleby.com

4 Ligamentous Joints

- General properties
- DIP/PIP
- MCP
- Inter-Metacarpal
- Trapezio-Metacarpal (base of thumb)
- Carpus - inter carpal & Radio-carpal

General Properties of Ligamentous Joints

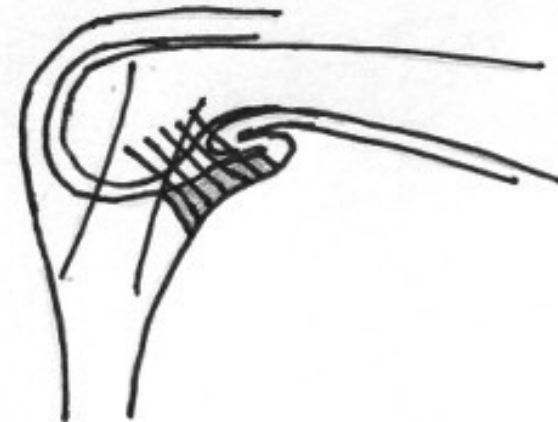
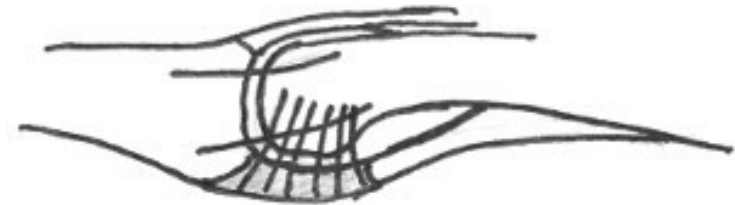
- Bone shape/structure
- Hyaline cartilage & synovial fluid
- Joint capsule - circumferential fibres
- Ligaments - fibres cross matrix boundaries
- Force path
- Spacial efficiency



Simple Ligamentous Joints

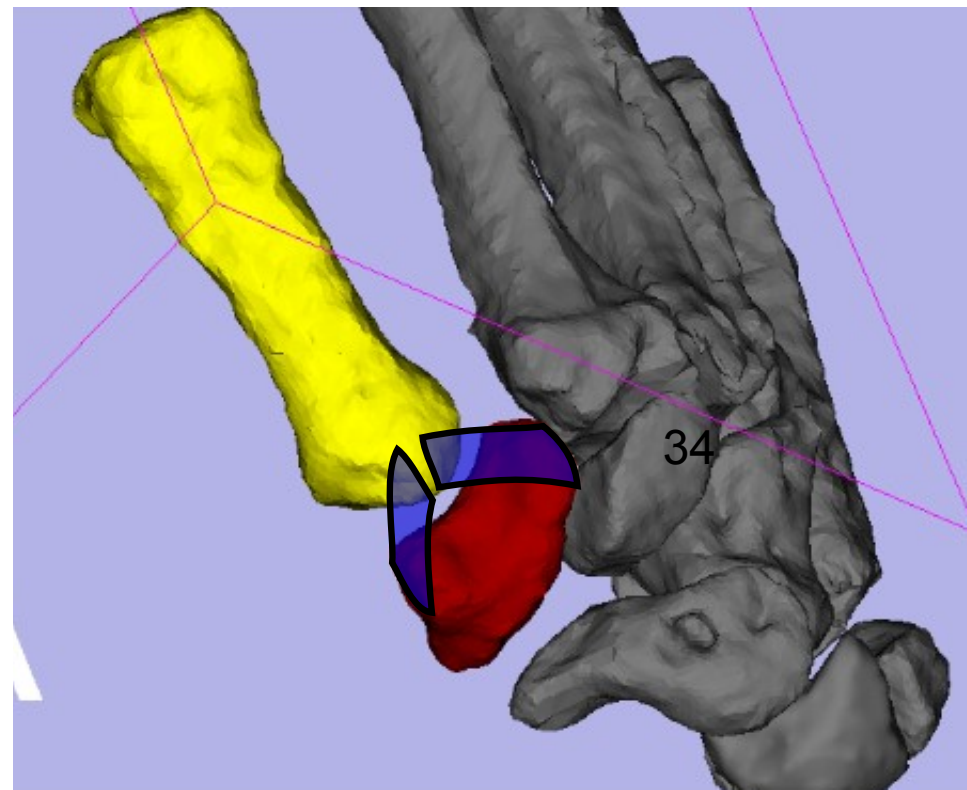
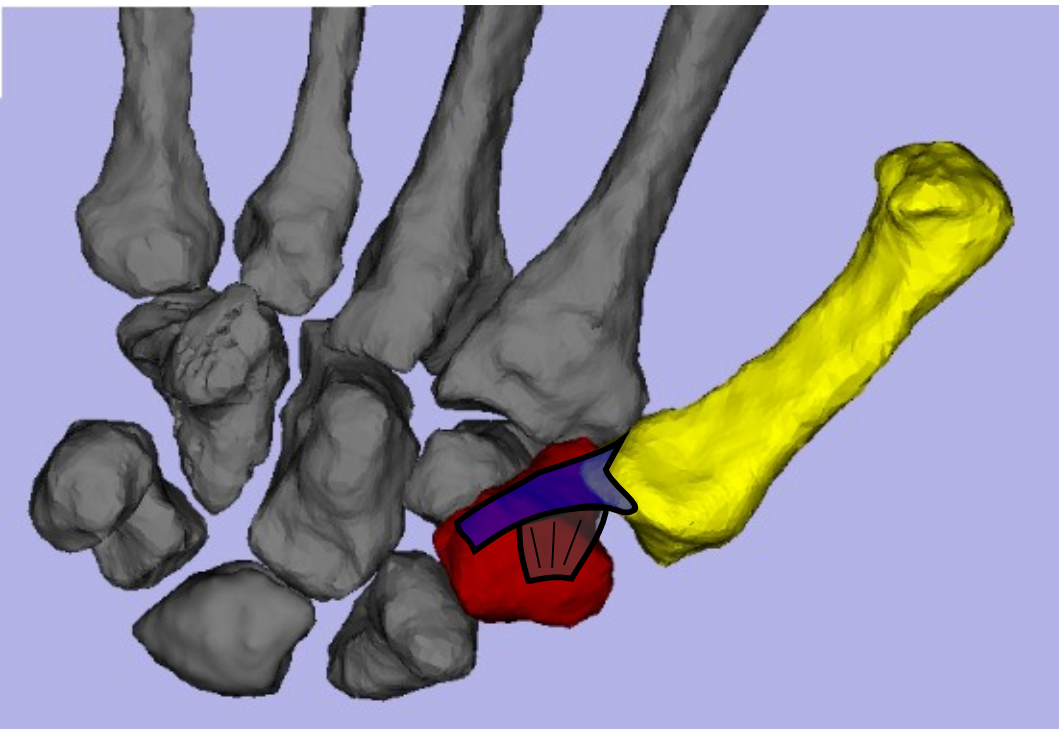
DIP & PIP

- Volar plate
- Collateral ligaments
- Accessory collateral ligaments
- Extensor slip 'patella'
- Joint capsule - circumferential fibres
- Metacarpo-phalangeal joint
 - slack collateral ligaments
 - depends on inter-osseous tendons



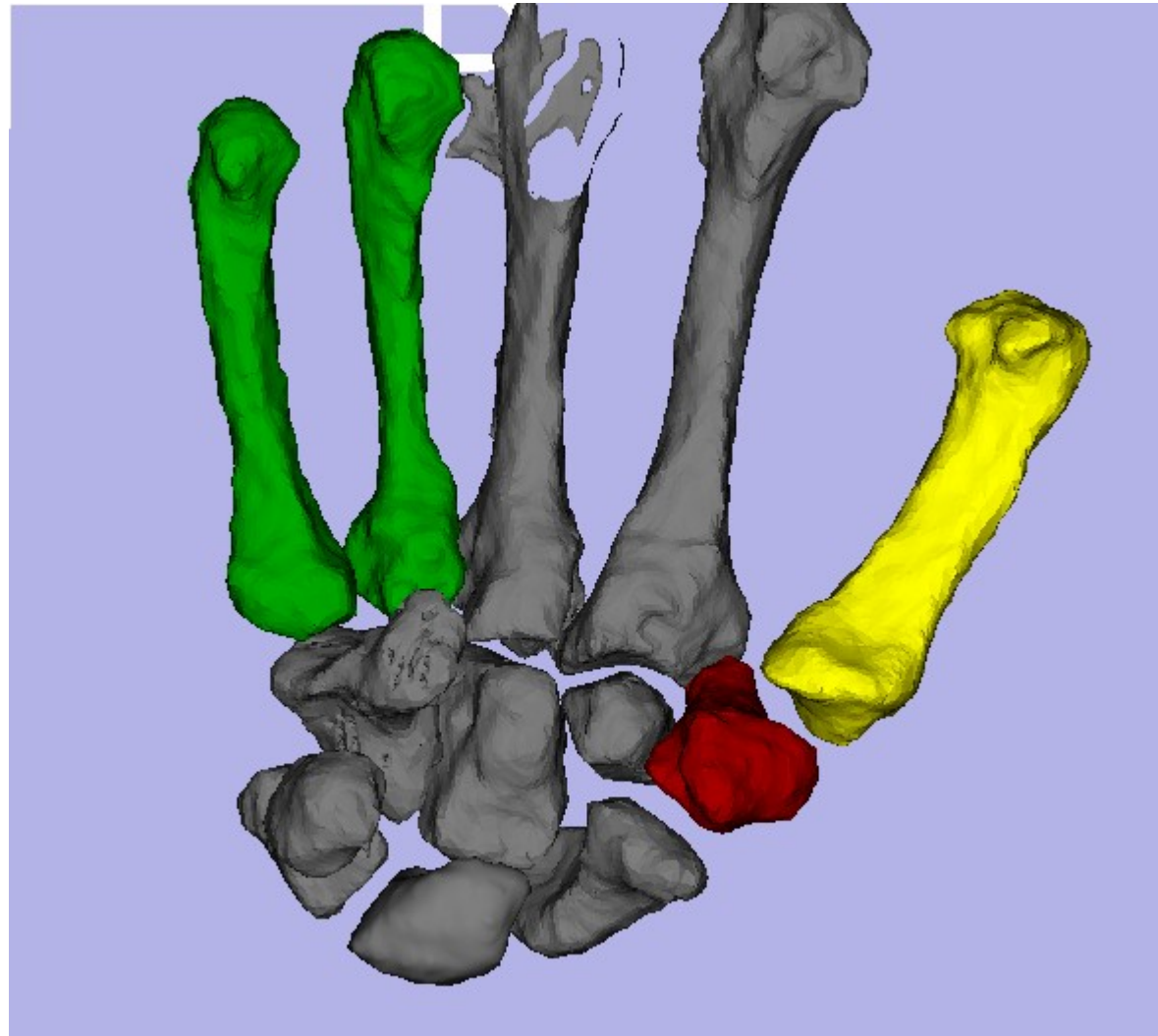
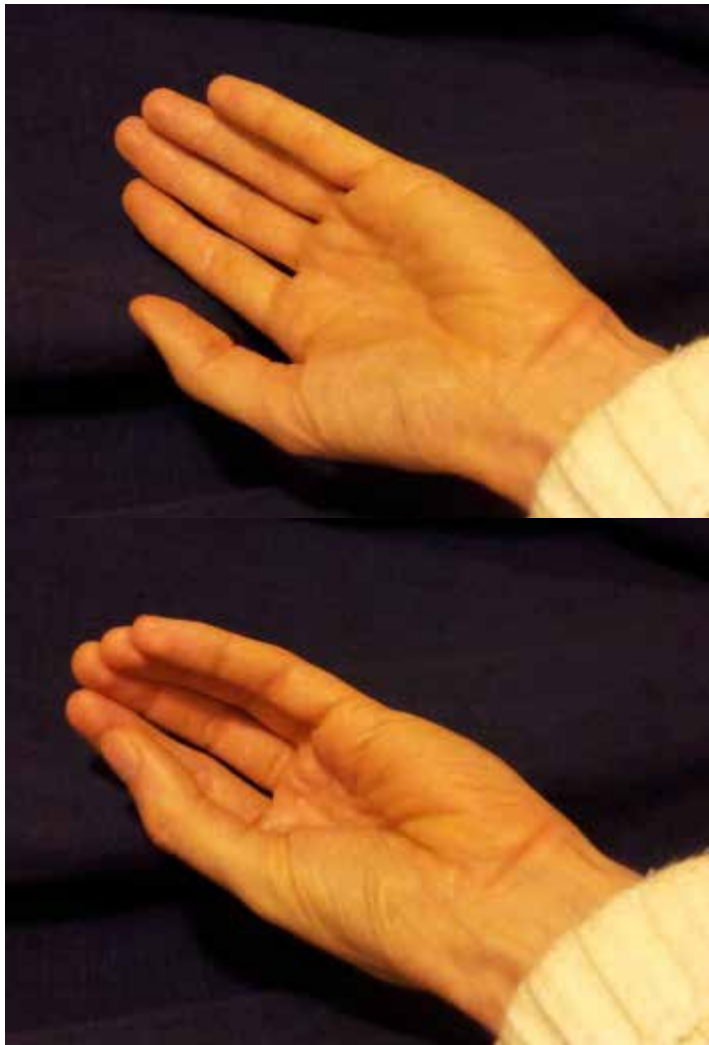
Trapezo-metacarpal Joint

- Saddle - limitations
- Beak ligament
- Collateral ligaments
- Tendons & muscles



Inter-metacarpal & Carpo-metacarpal Joints

- Flexion of the palm - MRI + highlight joints



Inter-carpal & Radio-carpal Joints

- Toroidal shape of radio-carpal joint
- Inter-carpal mechanism
- Radio-carpal ligaments
- Tendons actuating & stabilizing the wrist

