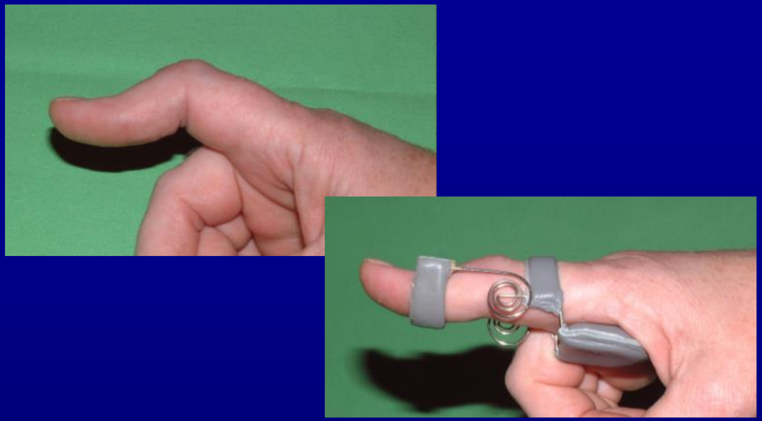
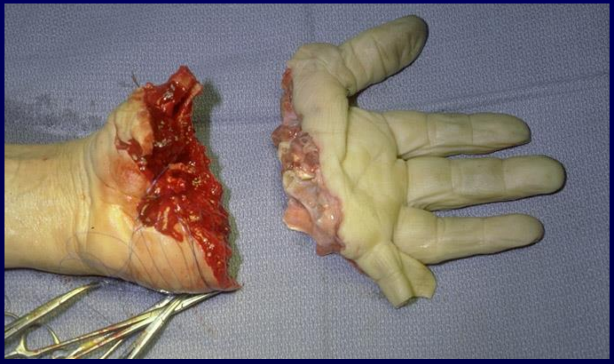
HAND INUJURIES, HAND SURGERY

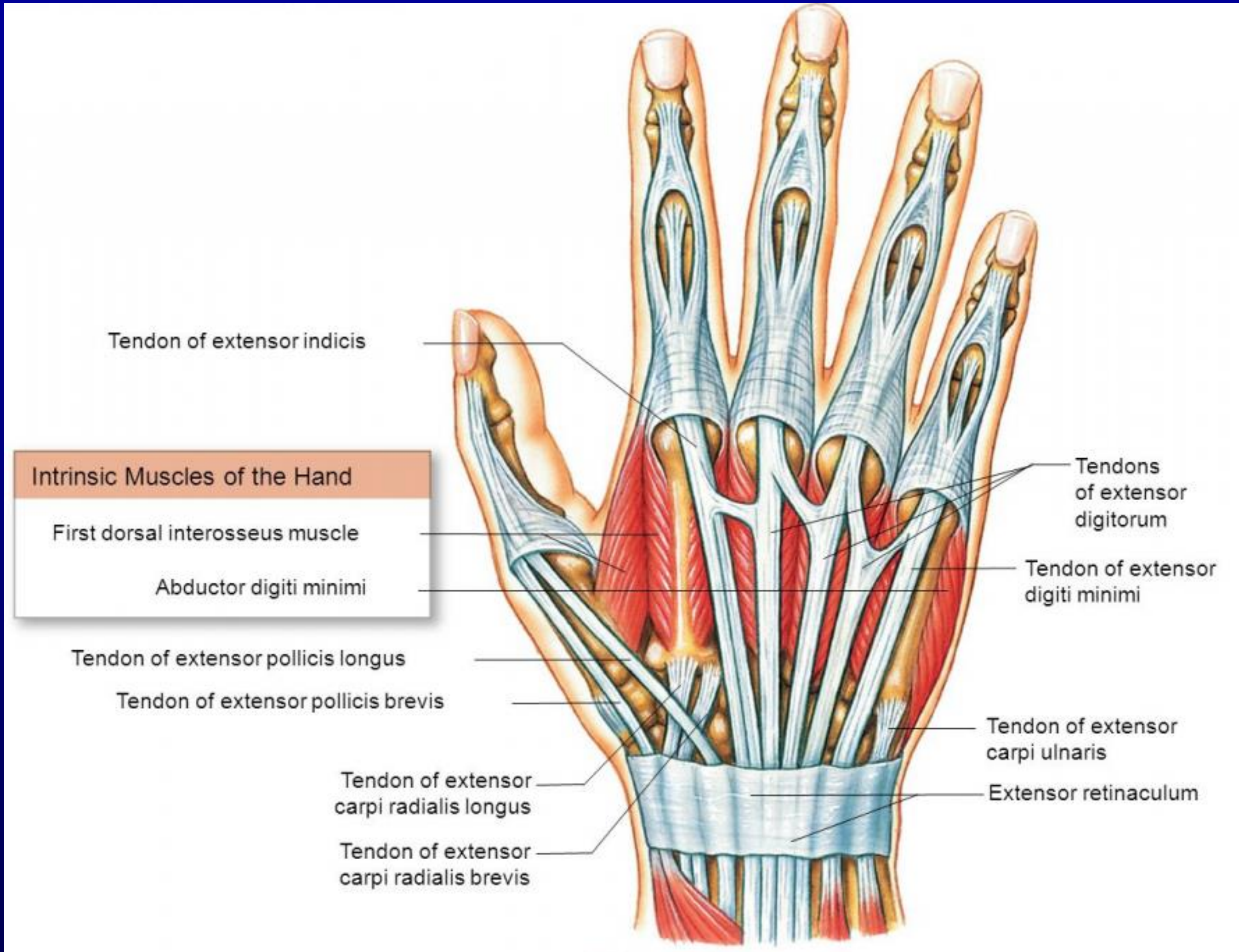


NON SCHOLAE
SED VITAE DISCIMUS
"We do not learn for school, but for life"
(Seneca)

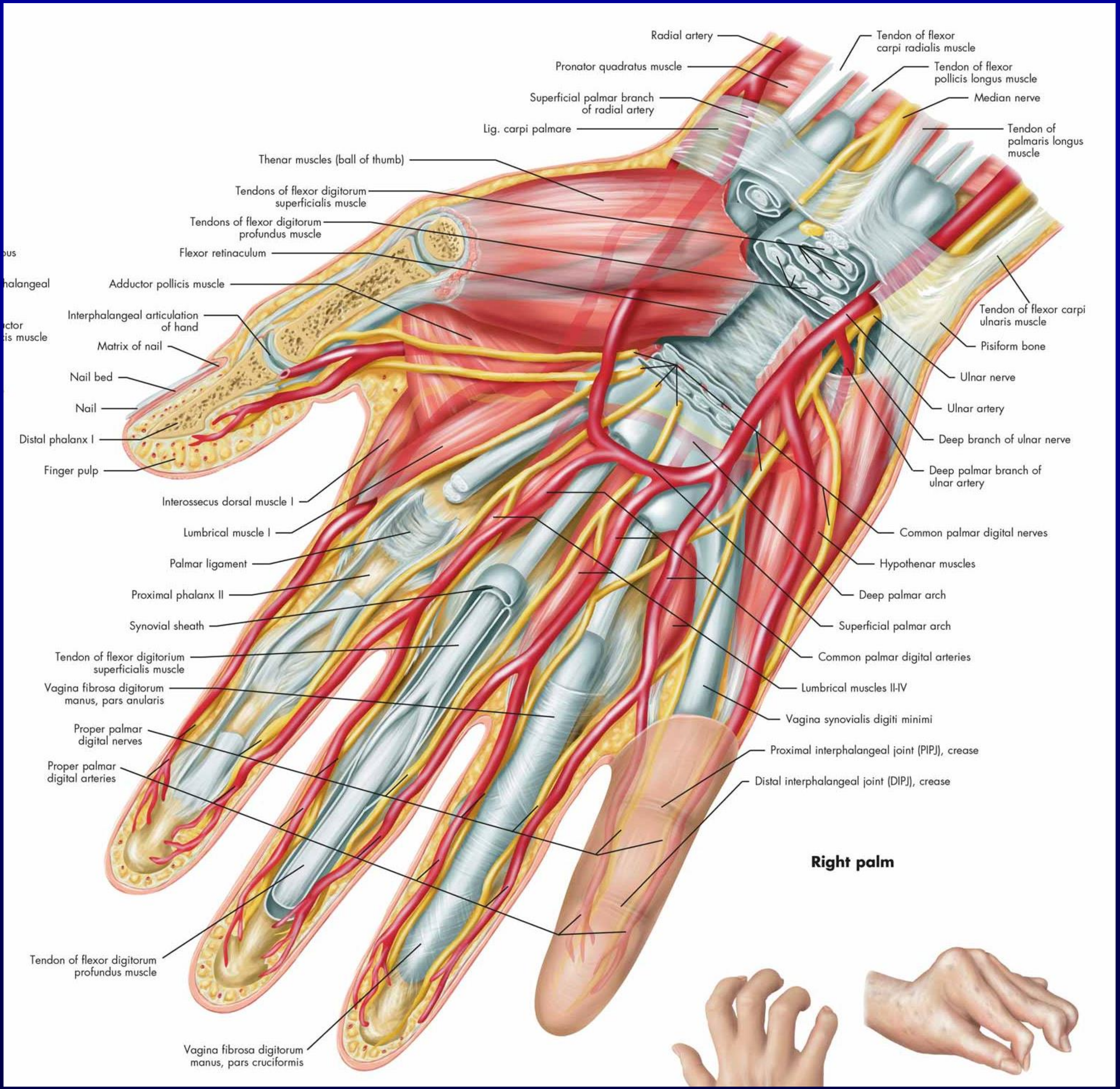


Anatomy

Having a fundamental knowledge of anatomy is essential in understanding hand surgery.

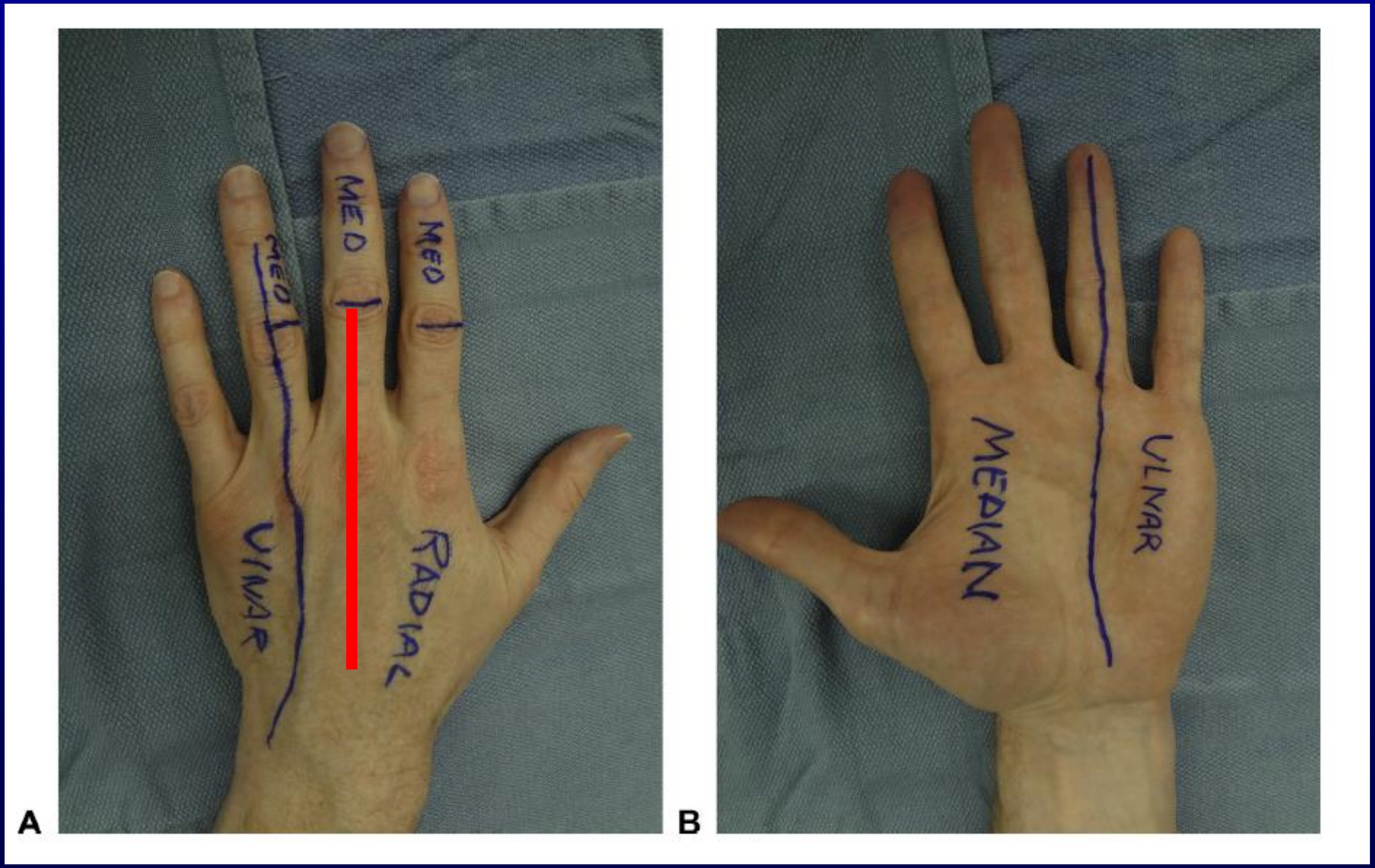


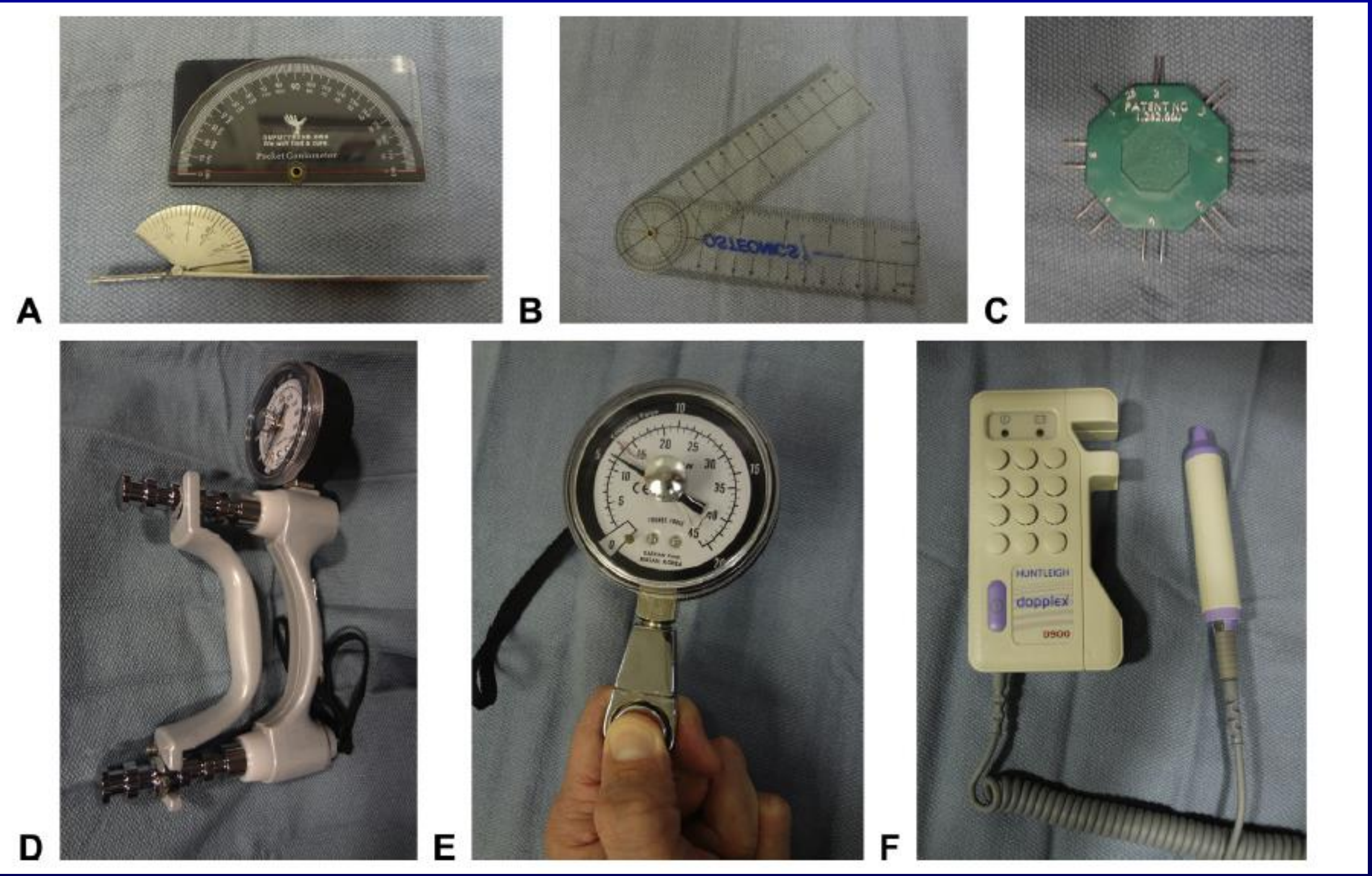
b Right hand, posterior view



Radial artery
Pronator quadratus muscle
Superficial palmar branch of radial artery
Lig. carpi palmare
Thenar muscles (ball of thumb)
Tendons of flexor digitorum superficialis muscle
Tendons of flexor digitorum profundus muscle
Flexor retinaculum
Adductor pollicis muscle
Interphalangeal articulation of hand
Matrix of nail
Nail bed
Nail
Distal phalanx I
Finger pulp
Interossecus dorsal muscle I
Lumbrical muscle I
Palmar ligament
Proximal phalanx II
Synovial sheath
Tendon of flexor digitorium superficialis muscle
Vagina fibrosa digitorum manus, pars anularis
Proper palmar digital nerves
Proper palmar digital arteries
Tendon of flexor digitorum profundus muscle
Vagina fibrosa digitorum manus, pars cruciformis
Tendon of flexor carpi radialis muscle
Tendon of flexor pollicis longus muscle
Median nerve
Tendon of palmaris longus muscle
Tendon of flexor carpi ulnaris muscle
Pisiform bone
Ulnar nerve
Ulnar artery
Deep branch of ulnar nerve
Deep palmar branch of ulnar artery
Common palmar digital nerves
Hypothenar muscles
Deep palmar arch
Superficial palmar arch
Common palmar digital arteries
Lumbrical muscles II-IV
Vagina synovialis digiti minimi
Proximal interphalangeal joint (PIPJ), crease
Distal interphalangeal joint (DIPJ), crease
Right palm

Sensory innervation of the hand, there is no strict anatomical distribution.
On the dorsal side of the hand the red line shows the proper border between the radial and ulnar nerve's innervation area.

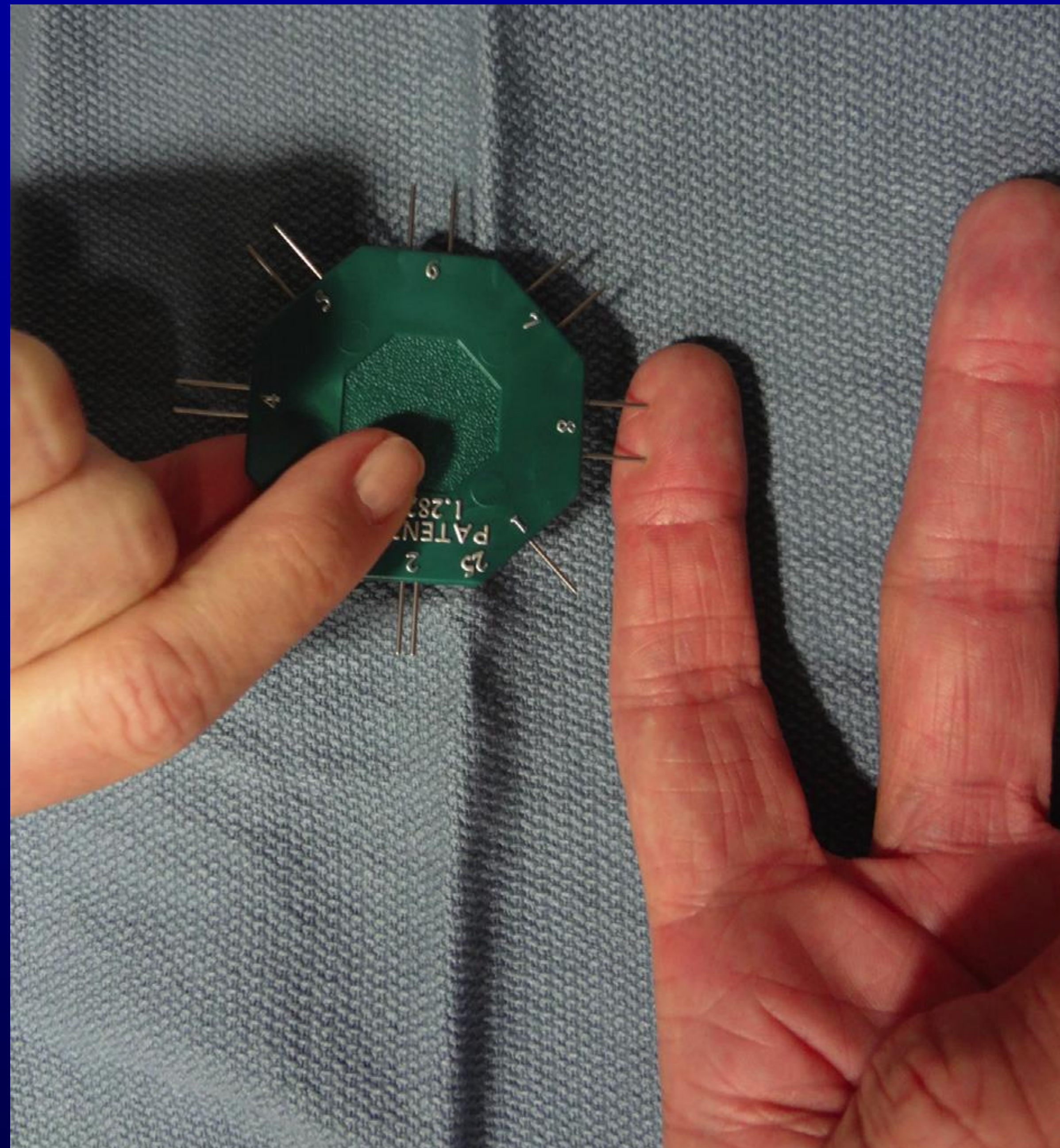




Essential instruments for a hand surgeon.

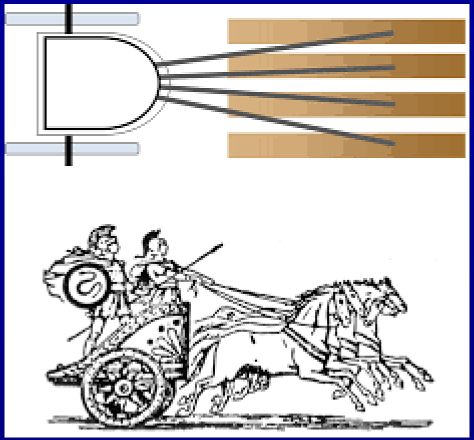
Goniometers, dynamometers, tool for 2-pont discrimination test, Doppler US scan.

Measuring of 2-point discrimination



Examining the integrity of the deep flexors and FPL tendon.

Injury of the ring finger flexors

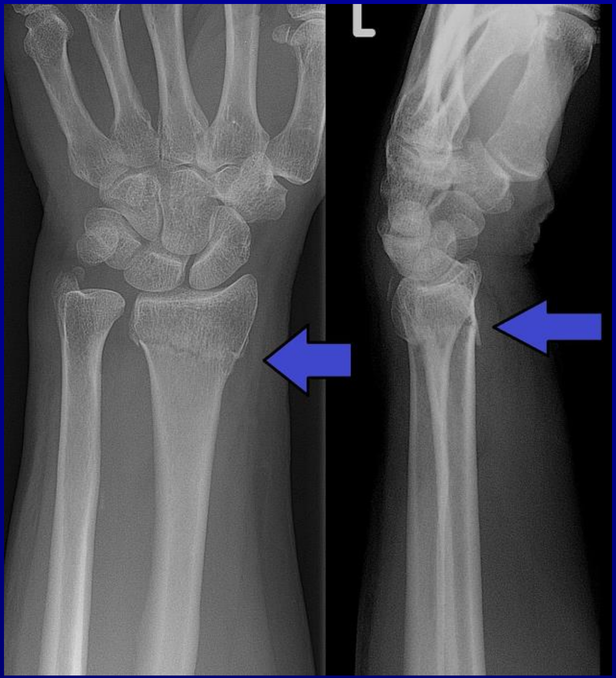


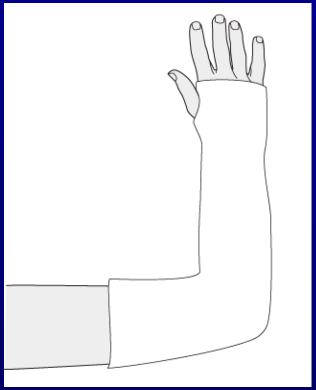
Examination of the intactness of FDS tendon on the middle finger.

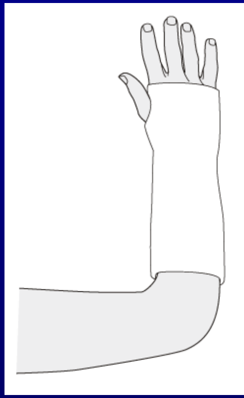
When you keep the rest of the long fingers extended, the examined finger (in the above case the middle one) can be bent by the superficial flexor tendon only (at the proximal interphalangeal joint; the distal interphalangeal joint remains straight in the absence of FDP action). This is, because in such a case the common muscle belly of the deep finger flexors kept elongated and therefore there is no motor to bend the non-stretched only finger by the FDP tendon. The four deep flexor tendons work together as the four horses in the ancient Roman quadriga.

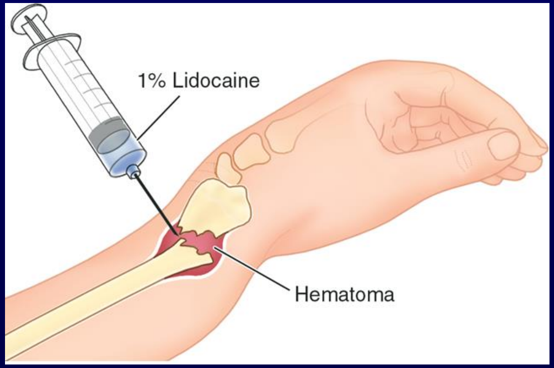
Fractures

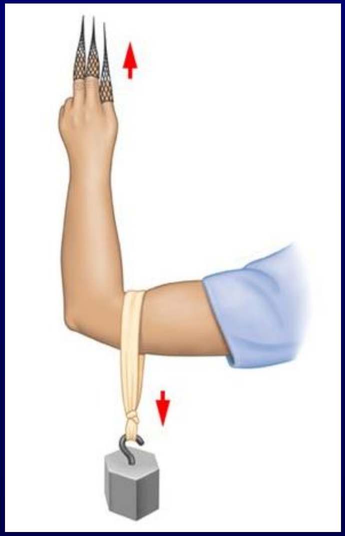
Distal radius fracture– Fractura radii in loco typico

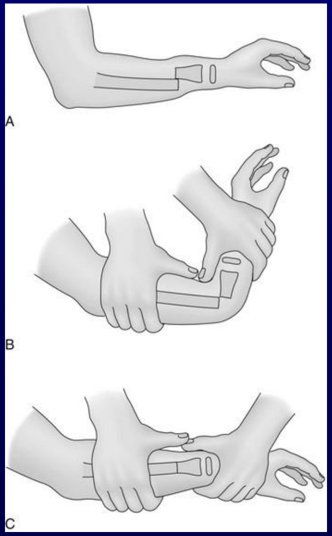




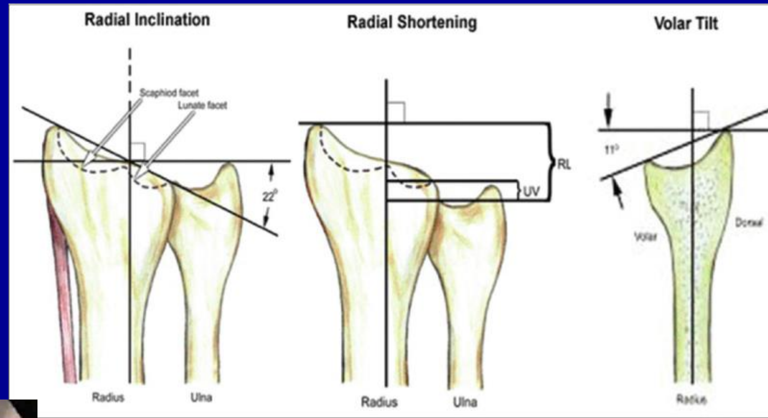




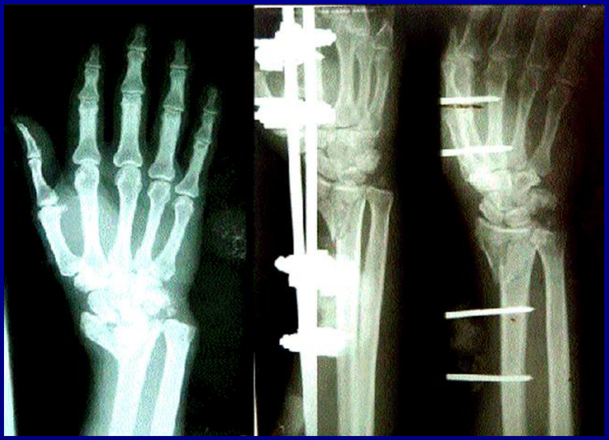


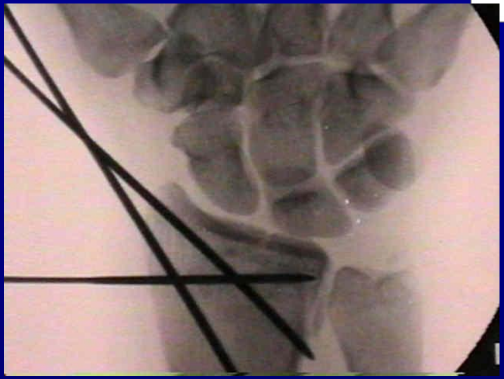


Measuring the dislocation, checking the result of the reduction.



Fixateur extern for unstable multifragmentary fractures. Plaster fixation, plate, or K-wire fixation can be performed roughly in 3 week's time



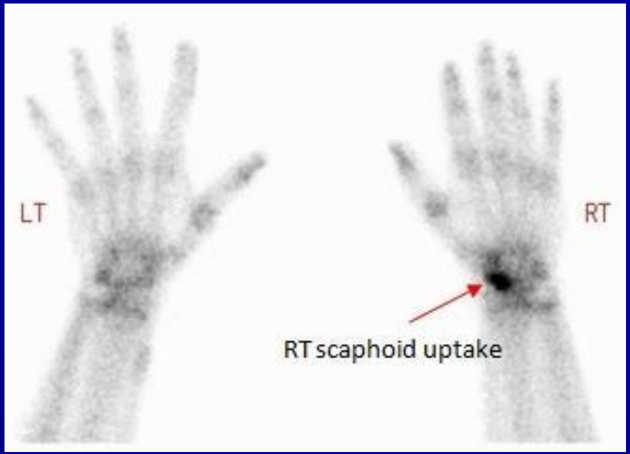


Additional plaster fixation is necessary after K-wire fixation.

Angular stable locking plates

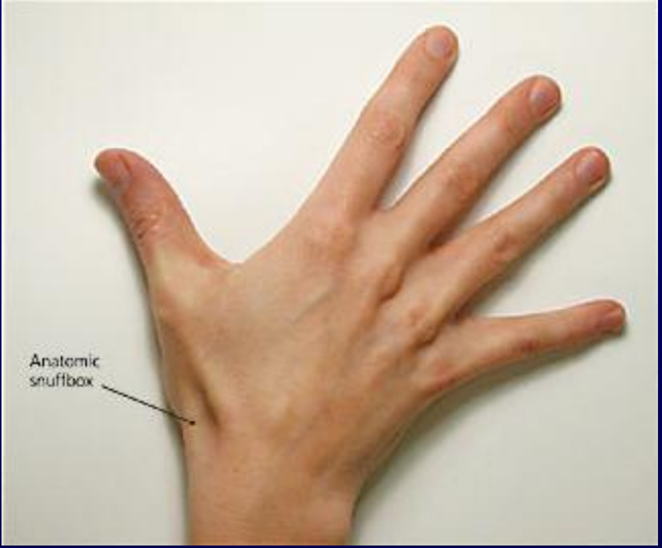
Scaphoid fractures

MR

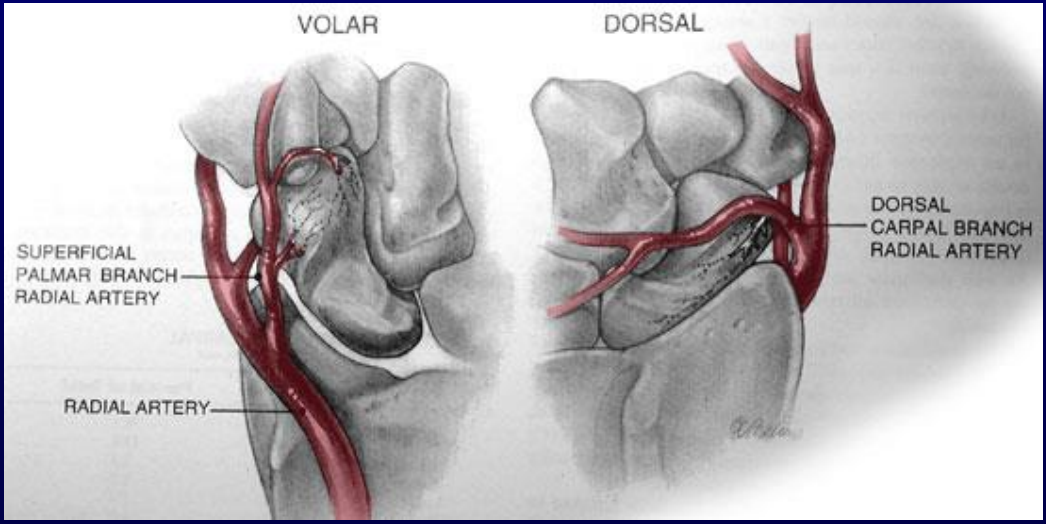


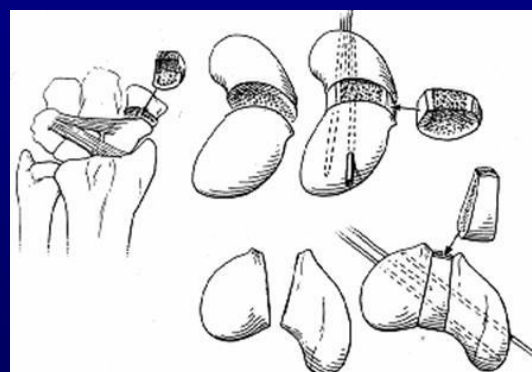
Bone scan

80% of the scaphoid is covered by cartlidge. The vessel and its branches enter distally and dorsally on the scaphoid.



Tenderness and pain at the anatomic snuffbox.

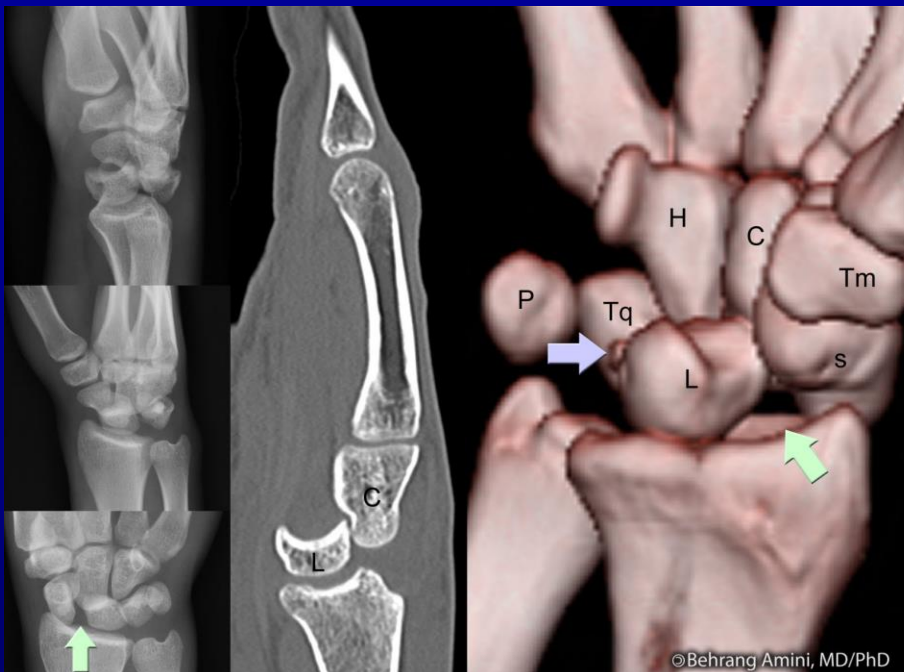




In case of PSA, bone grafting is required.

Headless compression screws

Perilunate dislocations

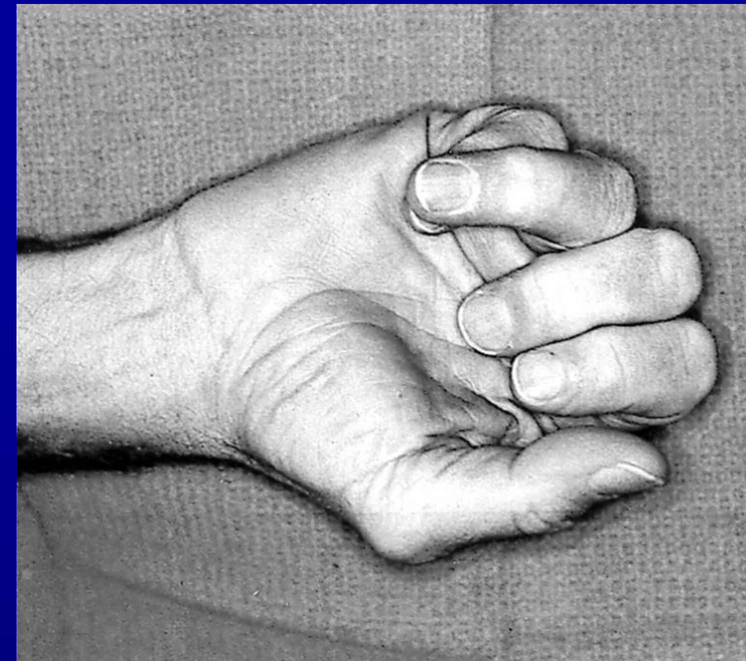


Can be accompanied by:

Radial styloid fx.
Scaphoid fx.
Scapholunate lig. injury.
Triquetrum fx.
Ulnar styloid fx.

Closed reduction alone is insufficient.
Open reduction, ligament repair and wire fixation is recommended.

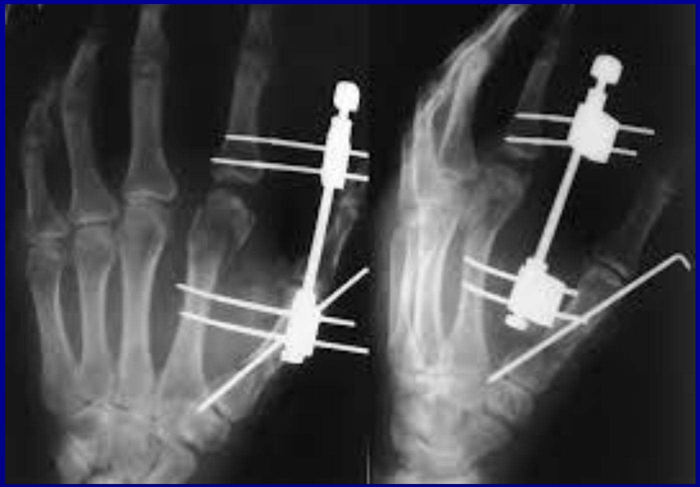
Metacarpal fractures



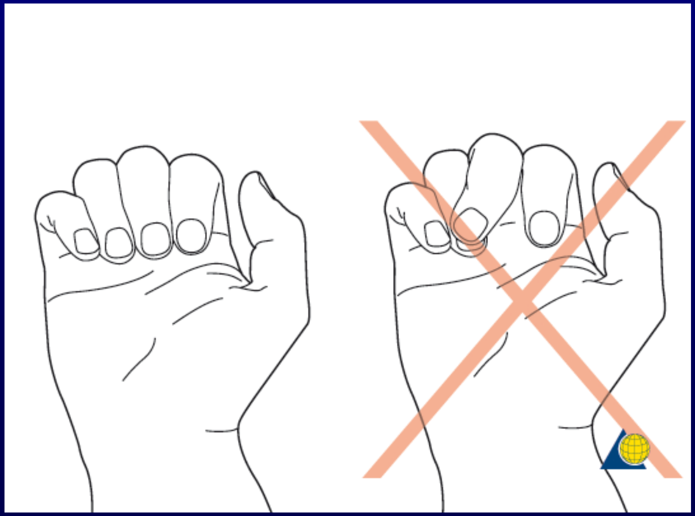
Rotational malaligment

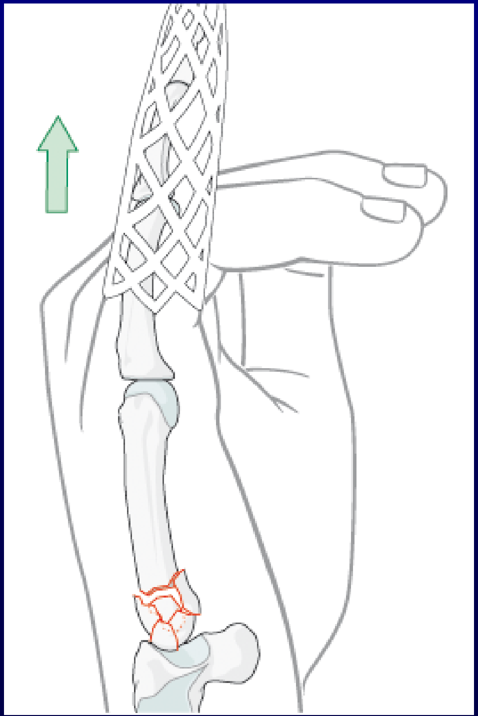
Anatomic reduction and fixation can be achieved with plates.

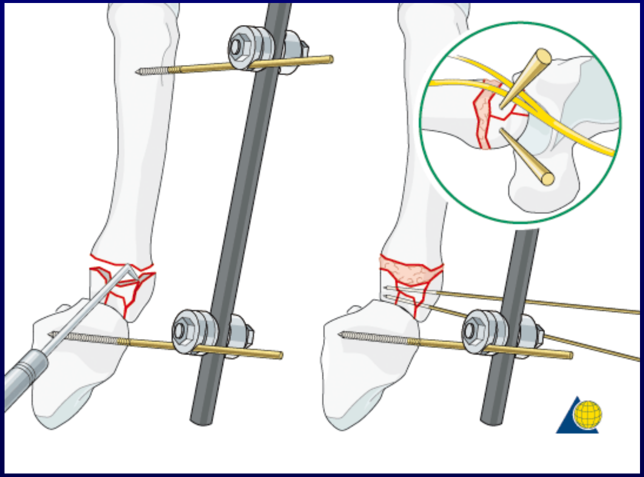
Immobilization of the adjacent finger can help to prevent rotational malaligment.



Further options for fixation of metacarpal fx. (fixateur externe, K-wire, intramedullary wire(bouquet wire).





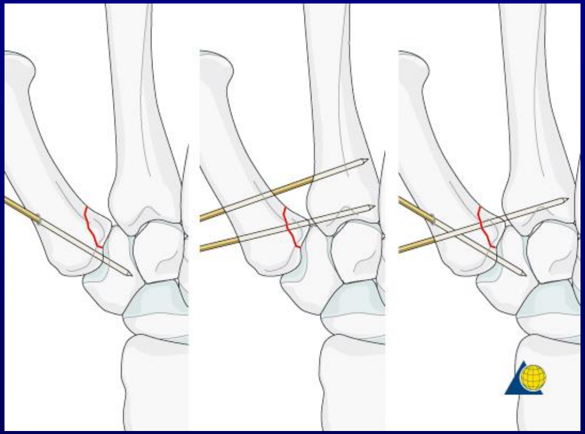


Fractures of the thumb metacarpal base

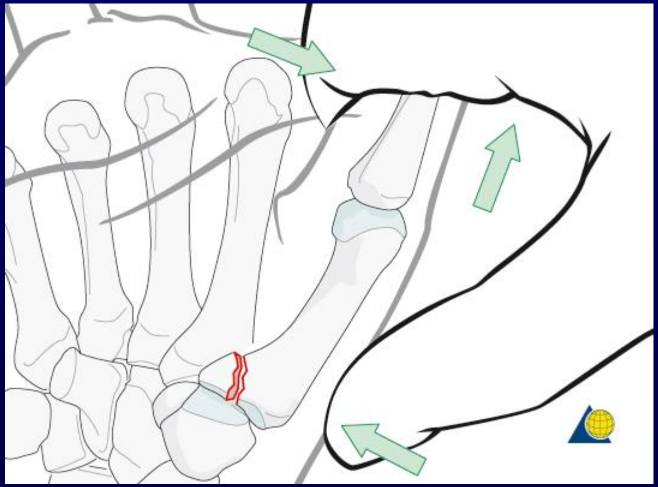
Bennett's fracture

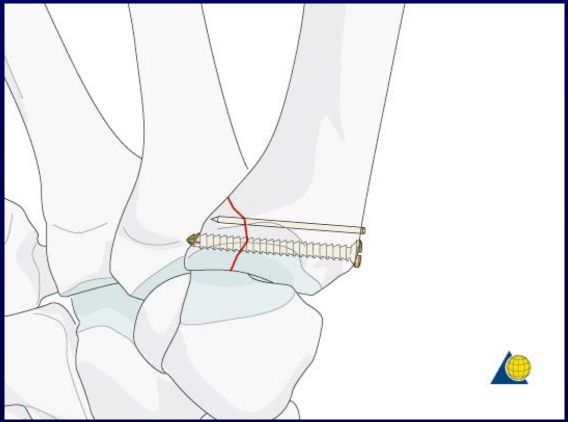
(An articular fracture of the base of the thumb metacarpal consisting of a single, variable-sized, volar-ulnar fracture fragment)

Explanation of the fracture-subluxation.



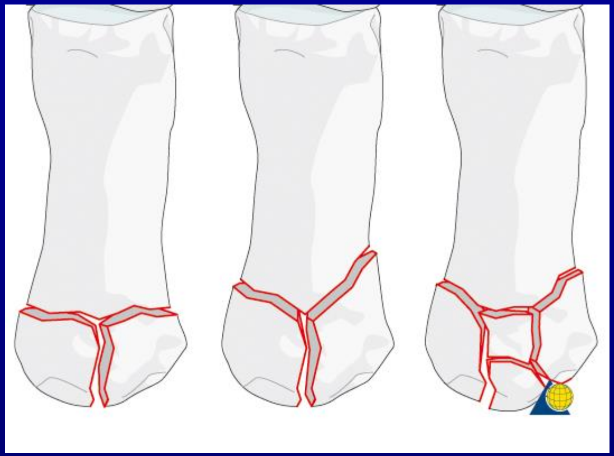
Reduction technique

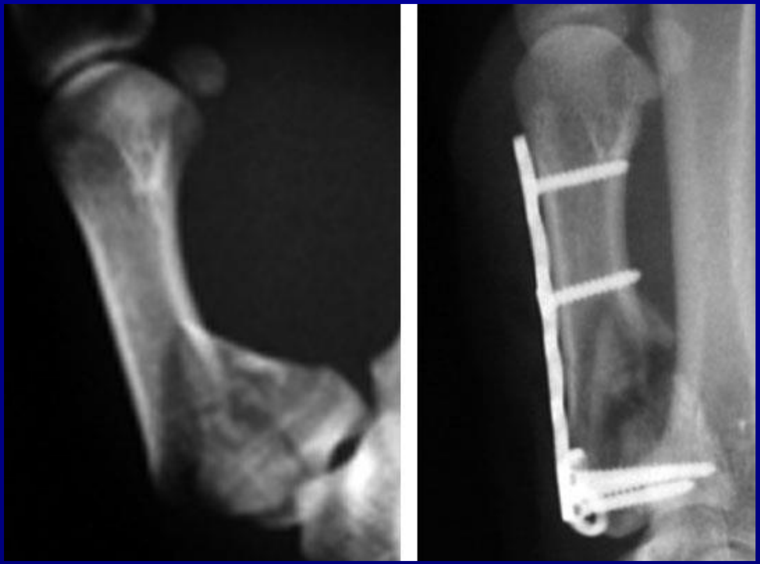


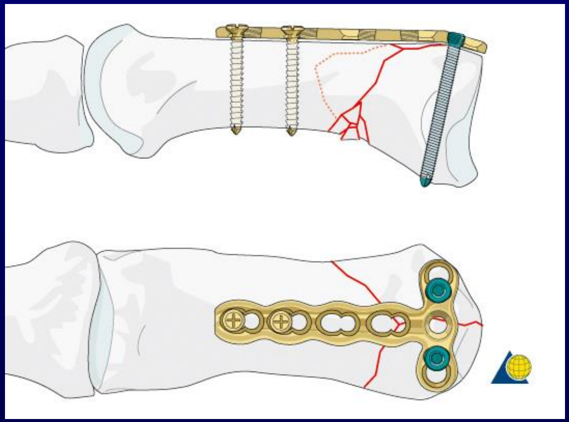


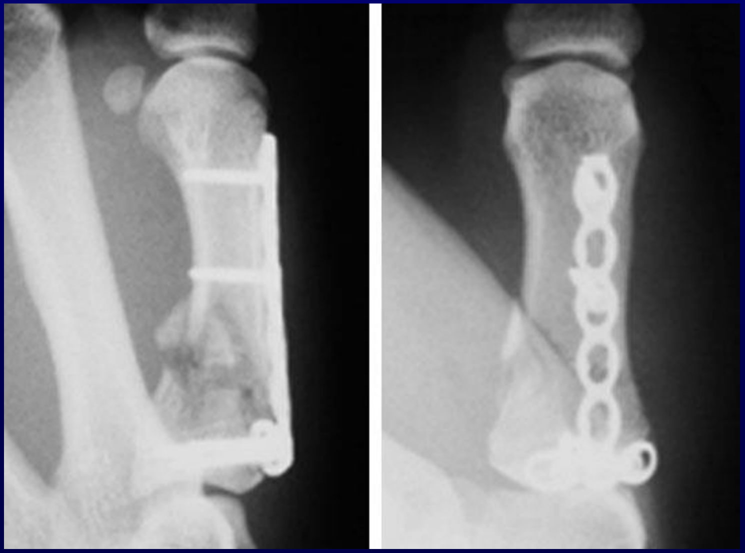
Fractures of the thumb metacarpal base

Rolando's fracture (comminuted intra-articular fracture of the base of the thumb metacarpal.

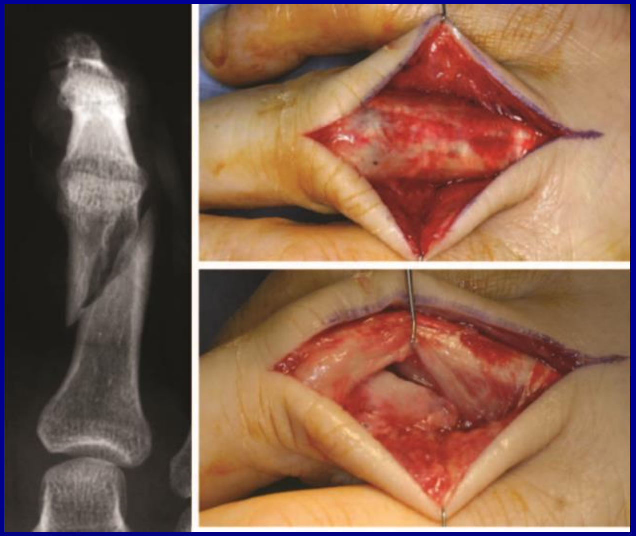


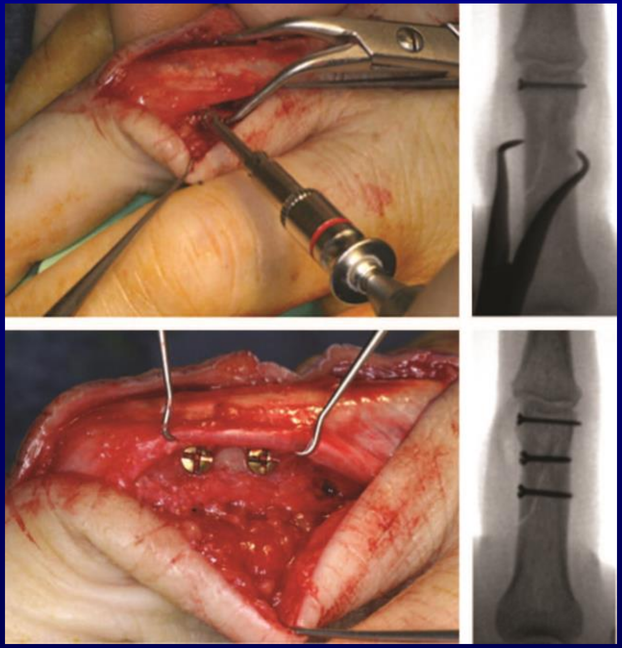


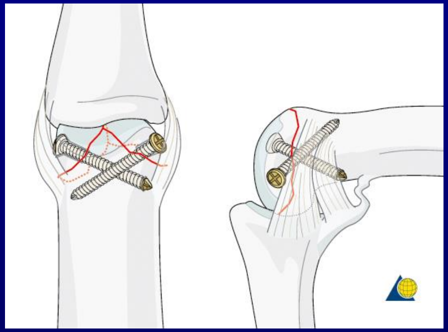




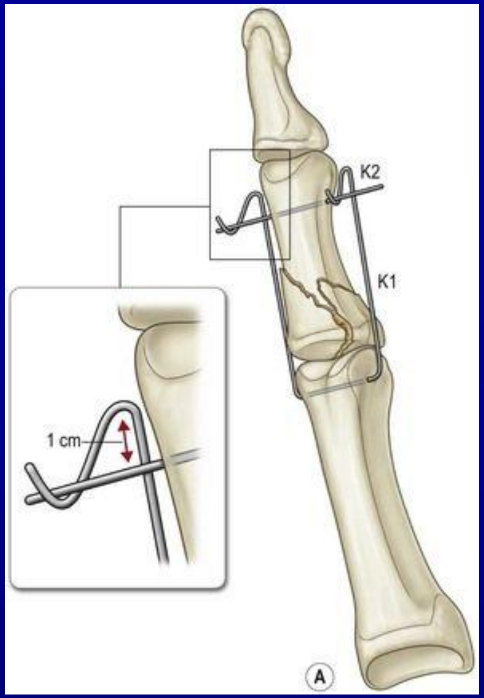
Phalangeal fractures



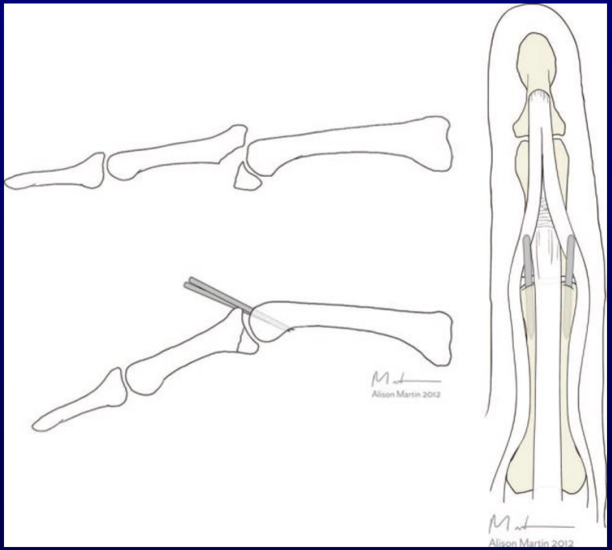




K-wire fixation is usually sufficient, but screw fixation can provide better stability.

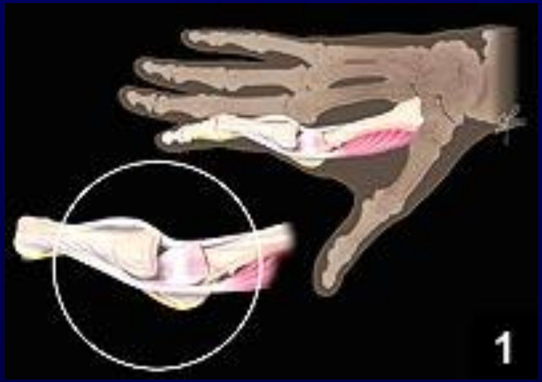


Dynamic skeletal traction for pilon fractures
(Kirschner wire external fixation, commercial fixators)

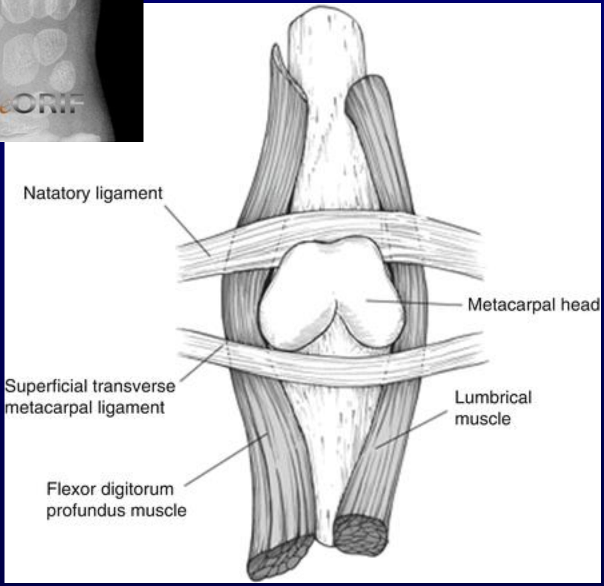


Extension block pinning

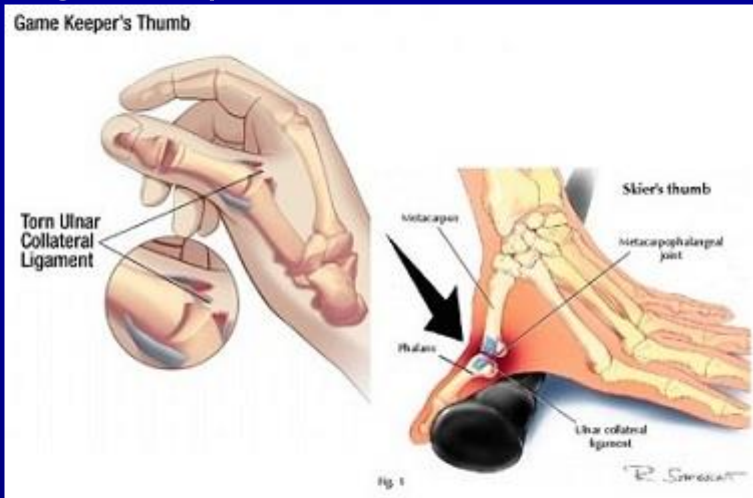
Luxation, ligament injuries, fracture dislocations



Attempt of closed reduction can be unsuccessful.

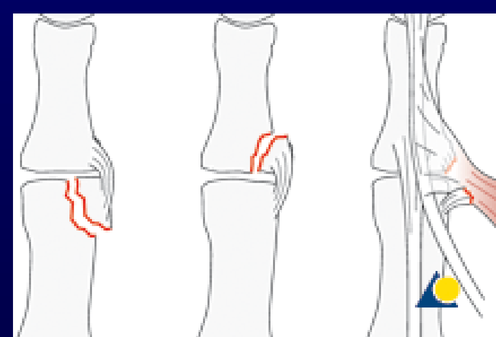


Injuries of thumb’s UCL (ulnar collateral ligament)



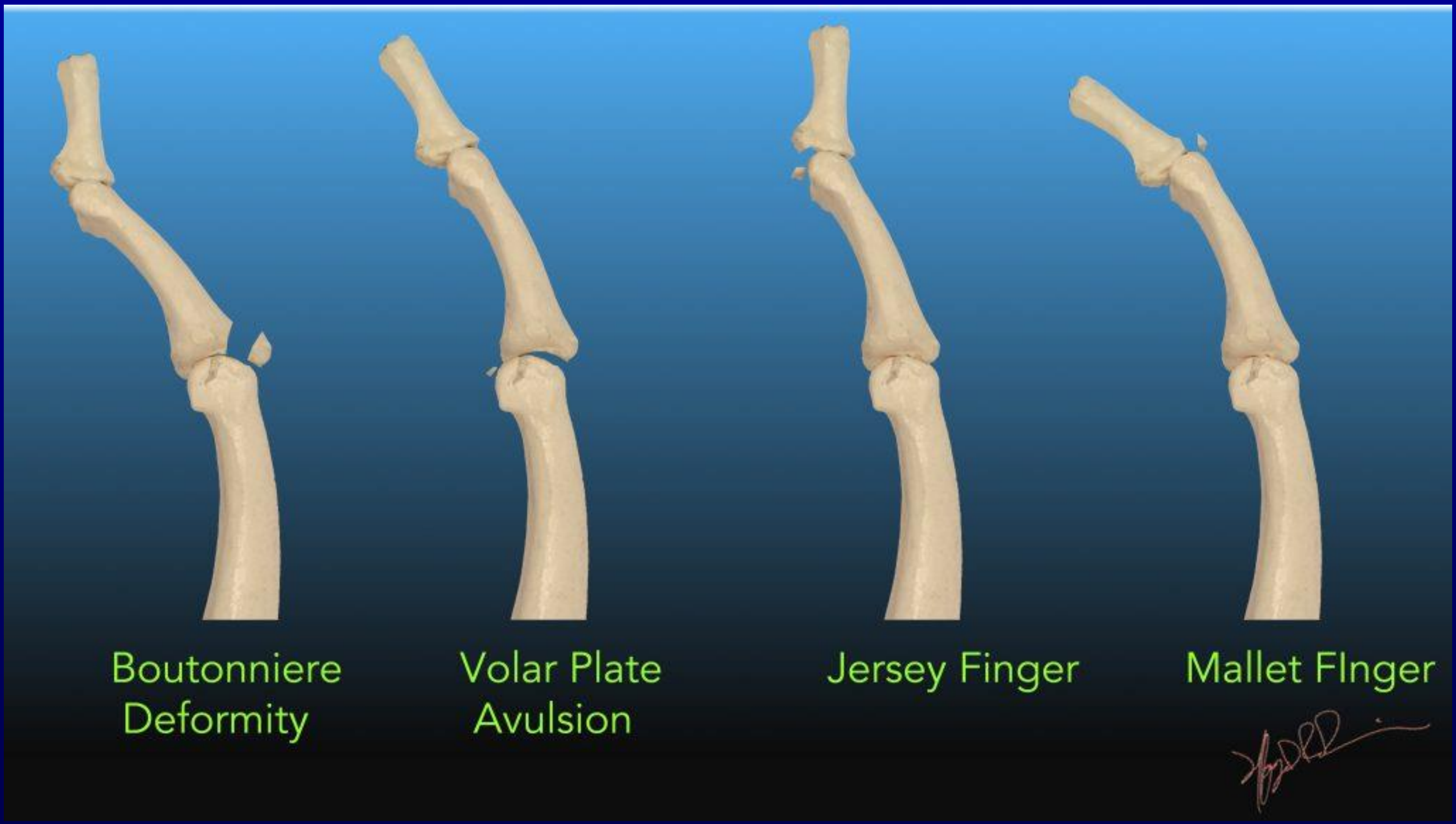
Can be bony avulsion or clear ligament rupture.

Stener lesion: adductor aponeurosis interposed between the distally avulsed ligament and its insertion into the base of the proximal phalanx

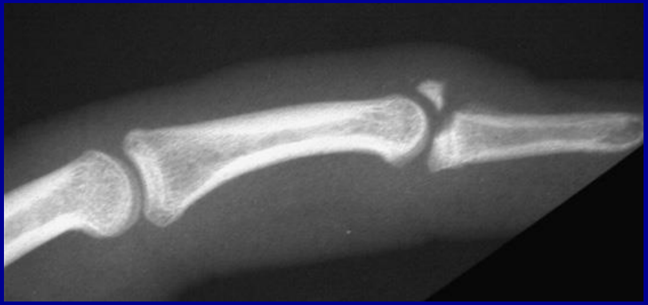


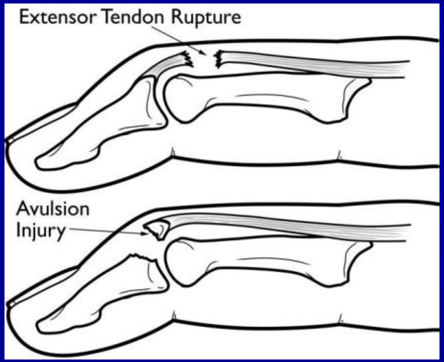
Unstable MP joint caused by bony avulsion or ruptured UCL always requires operative treatment.

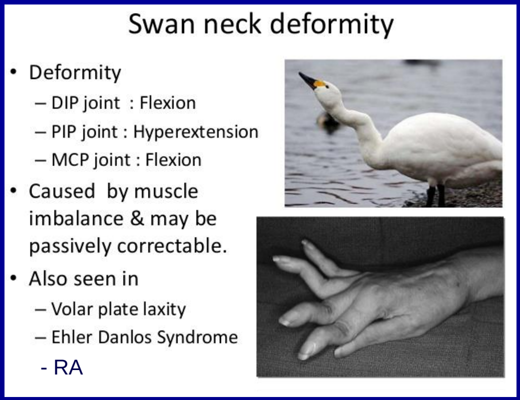
Closed tendon injuries
(with bony avulsion)

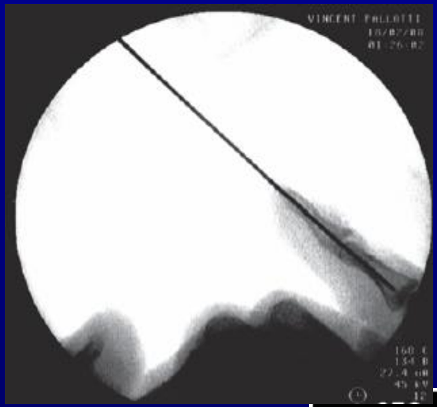


Mallet finger





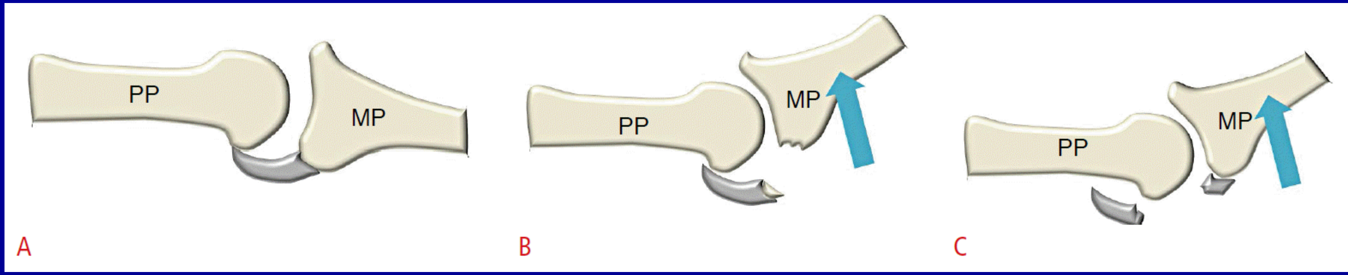




Percutaneous K-wire fixation offers good results as well.

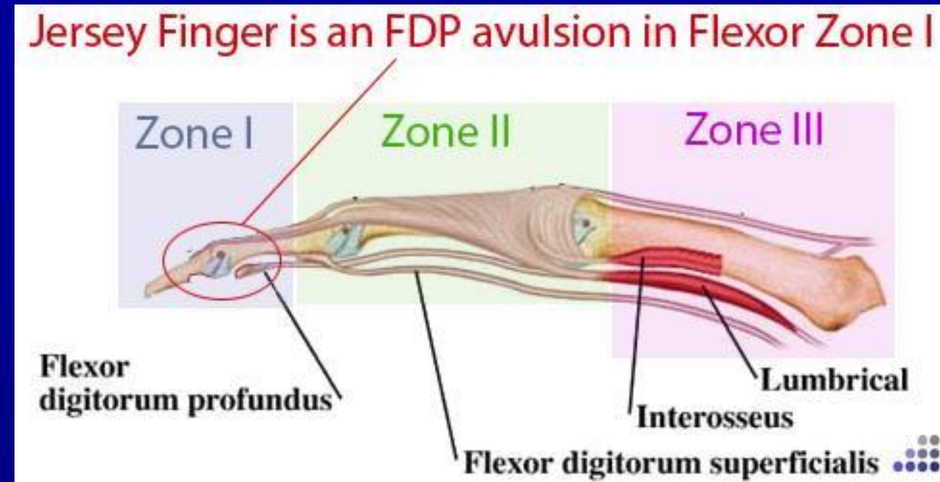
Hyperextension splinting offers good results in both tendinous and bony avulsions providing that patient keeps the splint on for 6 weeks.

Volar plate injury

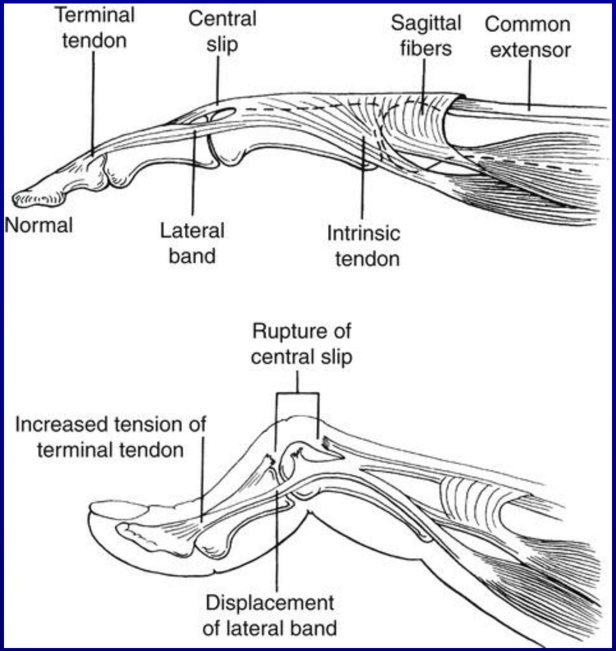


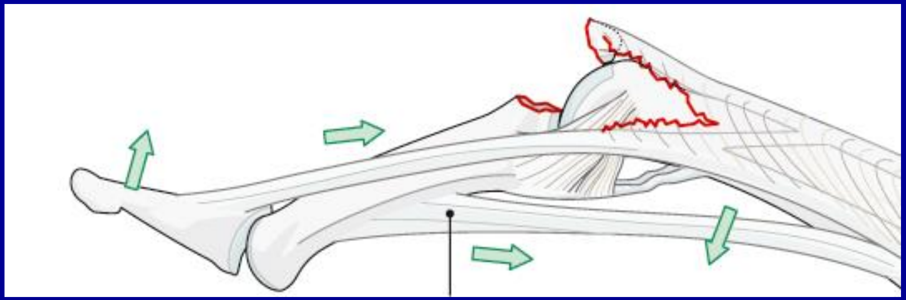
Conservative treatment with splints (static, dynamic).

FDP avulsion injury

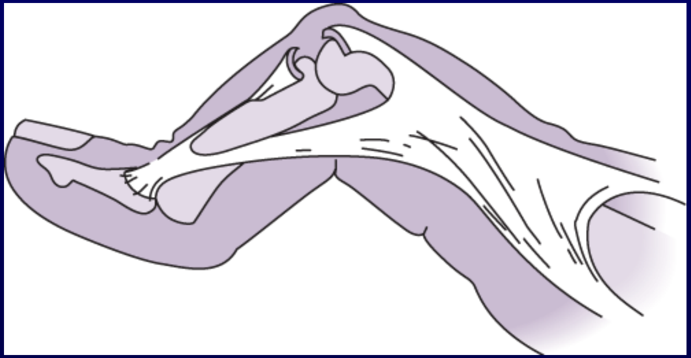


Central slip tear: Boutonnière deformity





The signs of an acute injury are not always evident, the classic presentation (PIP flexion, DIP extension contracture) is prevalent in neglected cases.



Injuries diagnosed acutely can be effectively treated with spring loaded (Capener-) splint.

Important infections of the hand

Usually bacterial, however...!!!

Herpetic whitlow

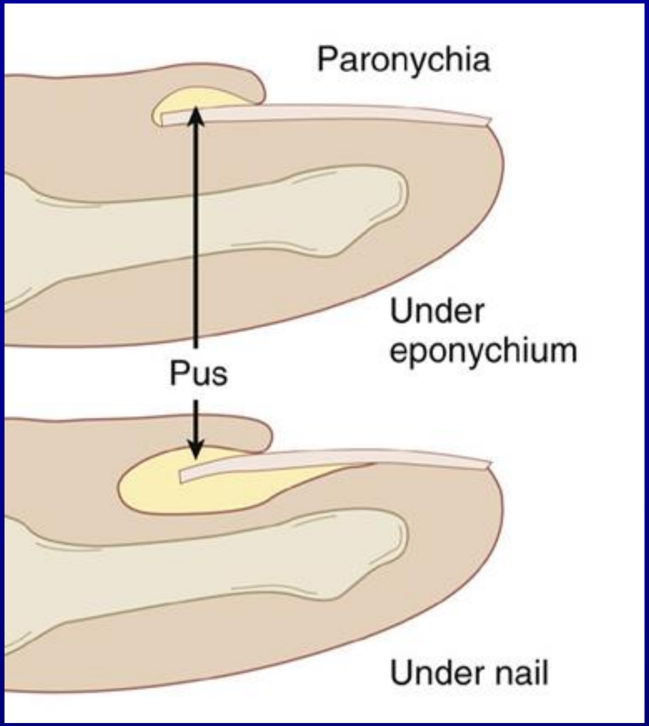
Herpes simplex virus 1 (HSV-1) 60%
herpes simplex virus 2 (HSV-2) 40%

incidence: 2.4-5.0 /100,000

Dg.: Anamnesis, inspection(culture., PCR, serol., Tzank)

Th.: Symptomatic (Acyclovir, bullectomy, ± antibiotic, ~~incision~~)

Paronychia

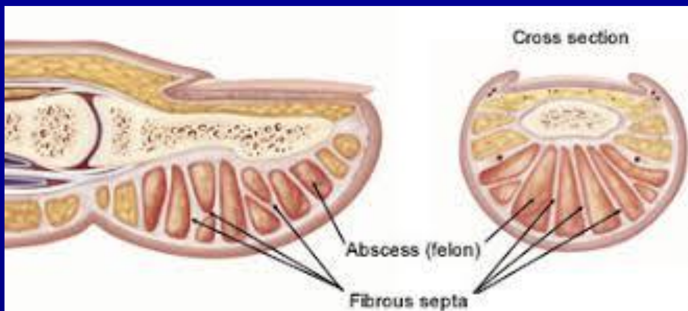


Surgical tx.: pus evacuation, (partial) nail resection.

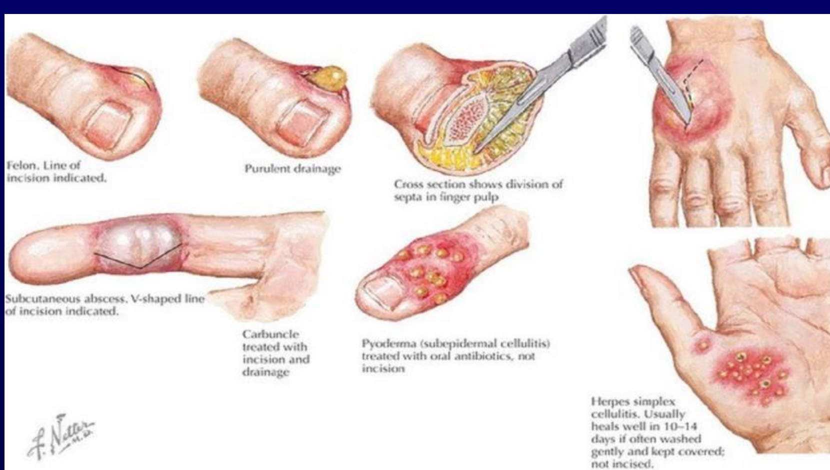
Osteomyelitis could be a complication especially in patients with other comorbidities (diabetes)

Subcutaneous abscess (felon, „panaritium subcutaneum”)

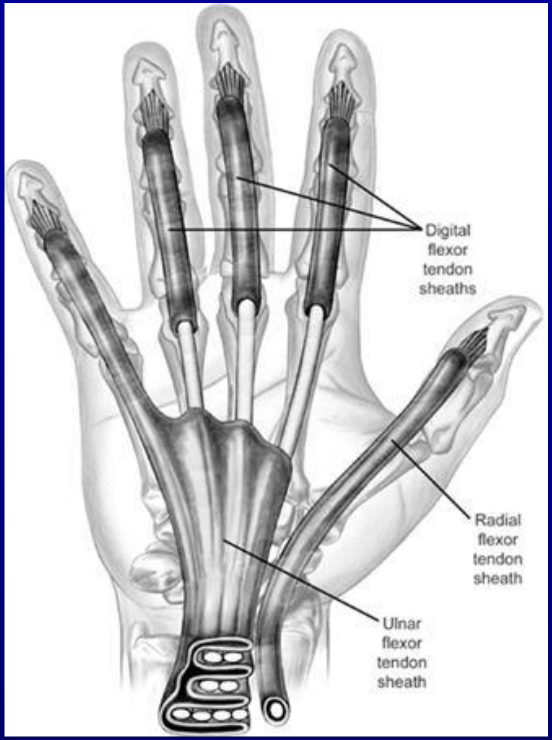
The unique anatomy of the volar skin-subcutaneous area!



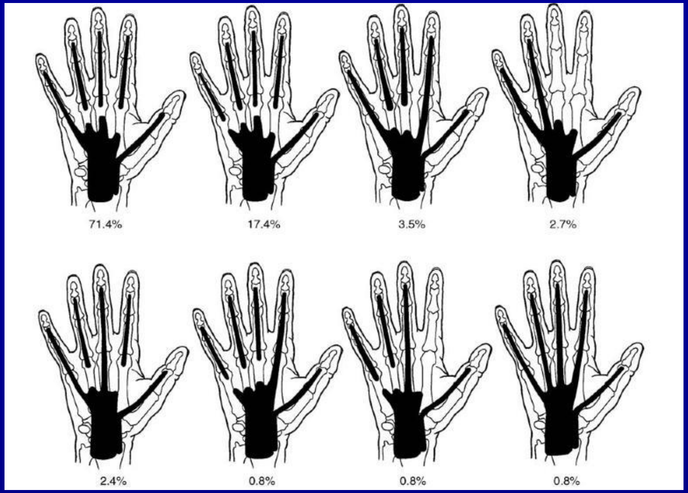
Swelling and hyperaemia can be marked dorsally, even the pus could infiltrate the dorsal regions, however the site of the most tender area is orienting.

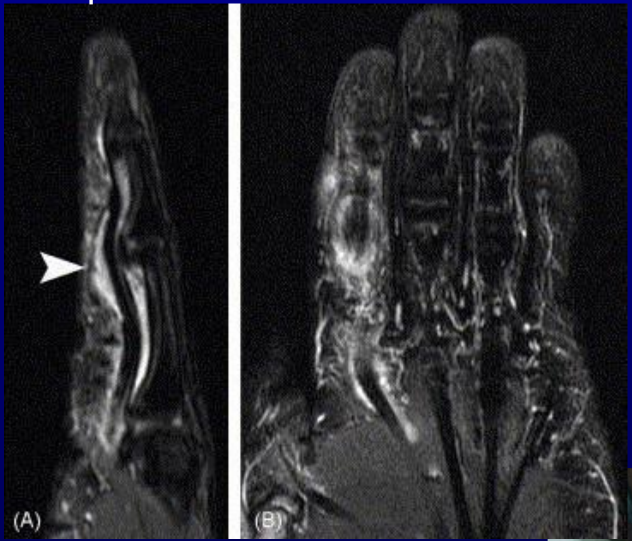


Purulent Tenosynovitis (septic flexor tenosynovitis, „panaritium tendinosum”)



The diagnosis is based on the findings during physical examination, the area of tenderness correlates to the flexor tendon sheath anatomy. Anatomic variations could be present.





The MRI presentation is only a radiologic curiosity, not a diagnostic necessity!

Classic semi-flexed finger position. Both flexion and extension movements aggravate the pain.

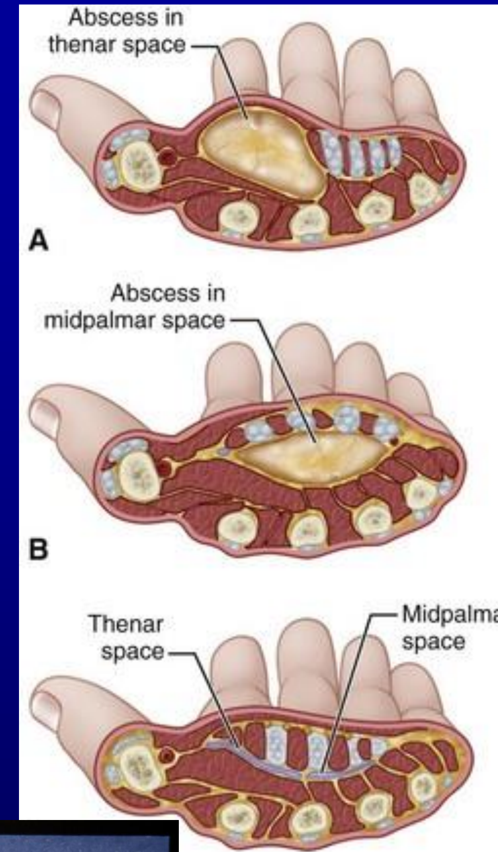
The optimal timing of the surgical incision should be after the patient’s first sleepless night.

Purulent Arthritis (septic arthritis, „panaritium articulare”)

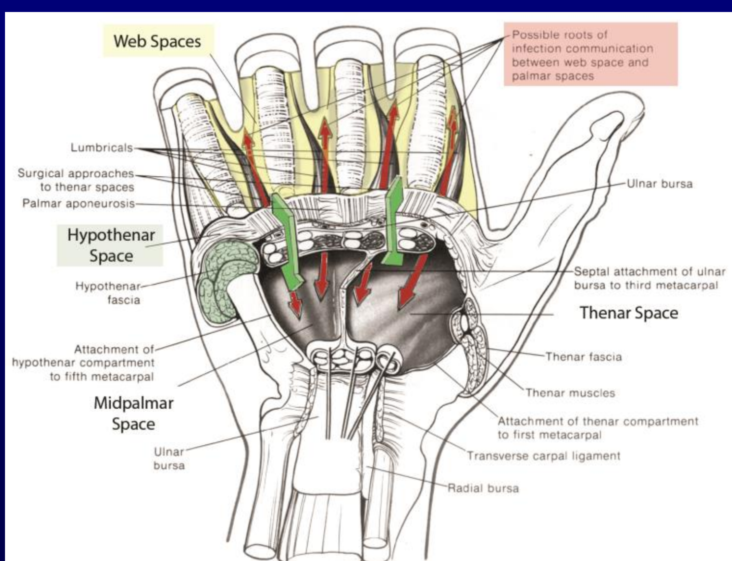
History can be orienting e.g.

- injury caused by (human) tooth
- gout

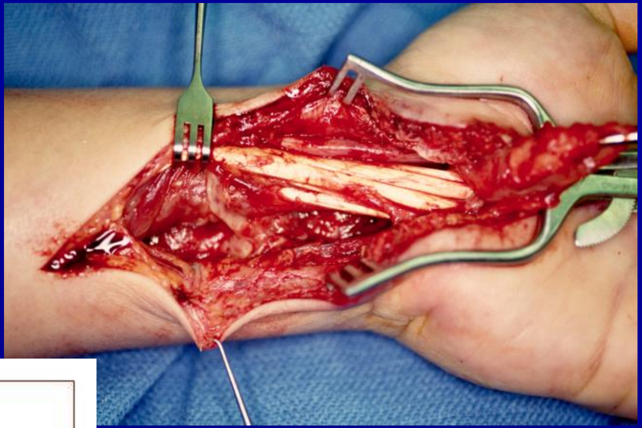
Palmar Abscess – (deep palmar phlegmone, thenar space infection, radial space infection / radial bursa infection, ulnar bursa infection)



Virtual spaces which become more evident as a result of pus collection. Infection spreading both from surrounding and toward surrounding tissues is possible.

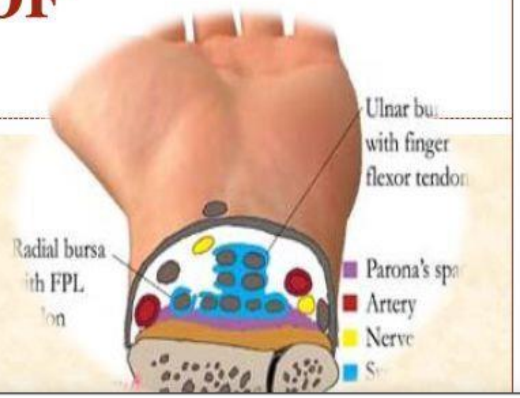


„Parona-space” abscess – Infection spreading to forearm

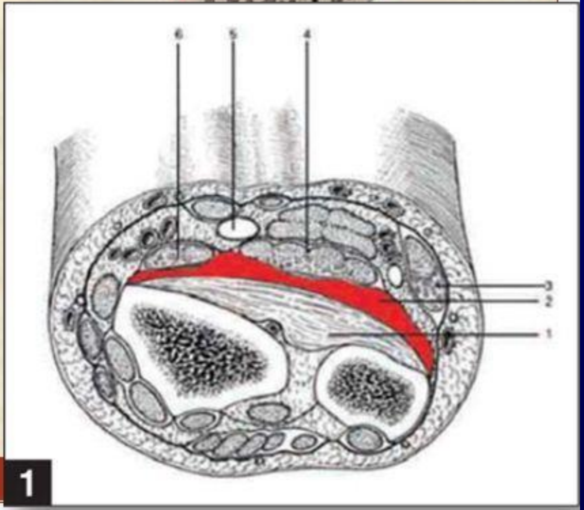


FOREARM SPACE OF PARONA

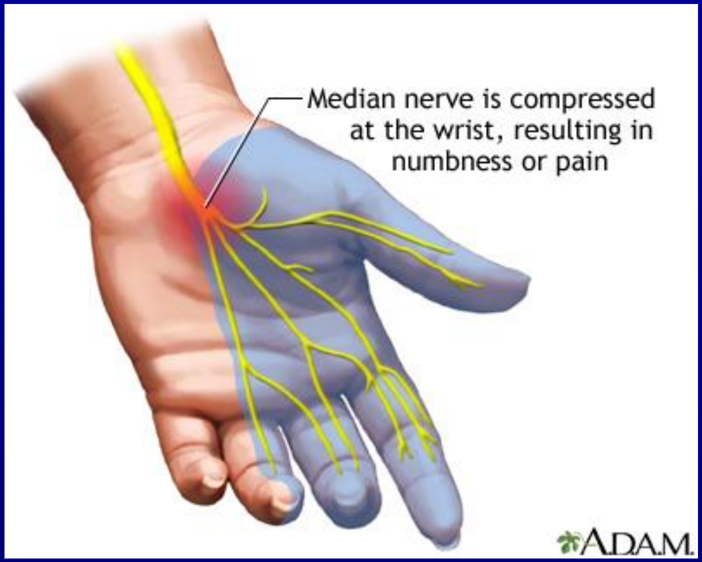
- **Location**
- **Boundaries**



The space of Parona and its boundaries.
1 Pronator quadratus;
2 Space of Parona;
3 Flexor carpi ulnaris;
4 Flexor digitorum profundus;
5 Median nerve;
6 Flexor pollicis longus.

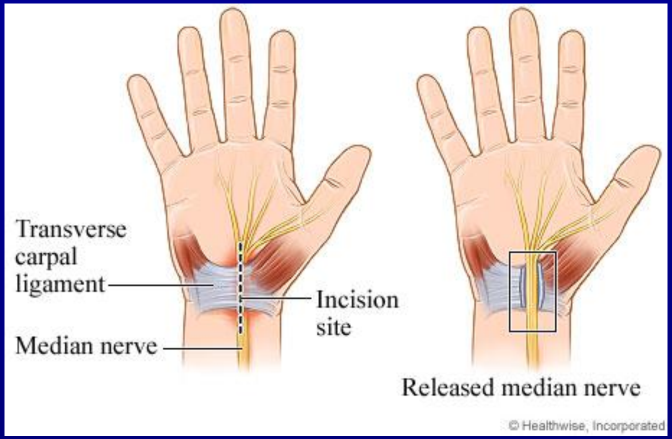


Carpal tunnel syndrome

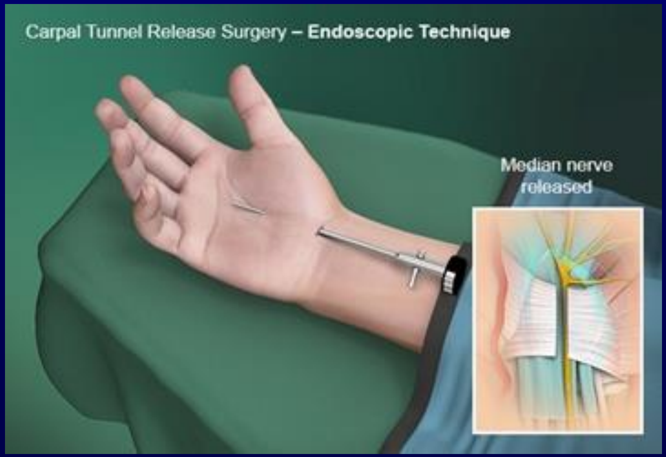


Typical thenar atrophy

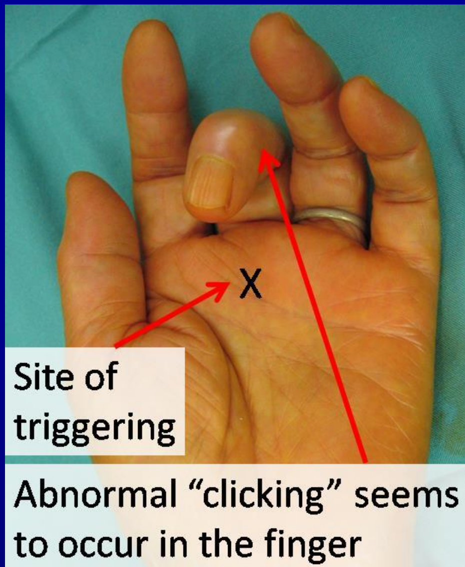
Conservative treatment : splinting (wrist brace), local steroid injection.

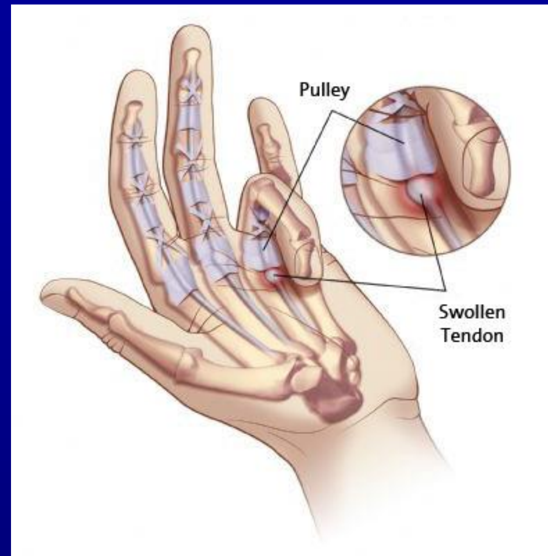


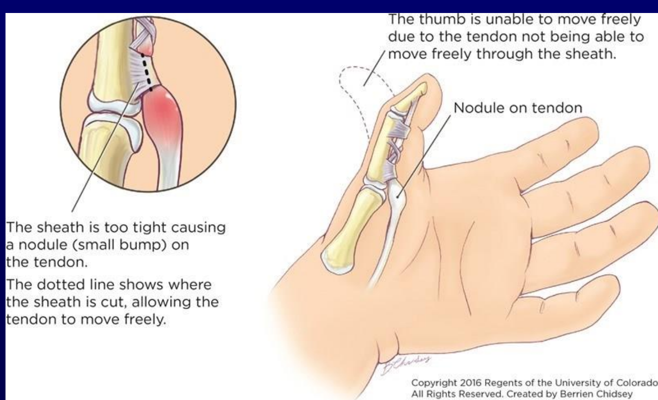
Transverse carpal ligament transsection might be done by either open or endoscopic surgery.

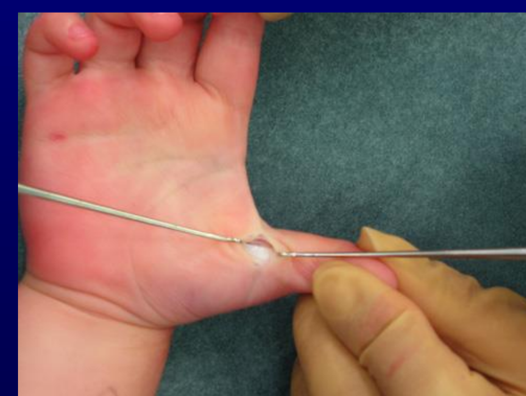


Digitus saltans – Trigger finger



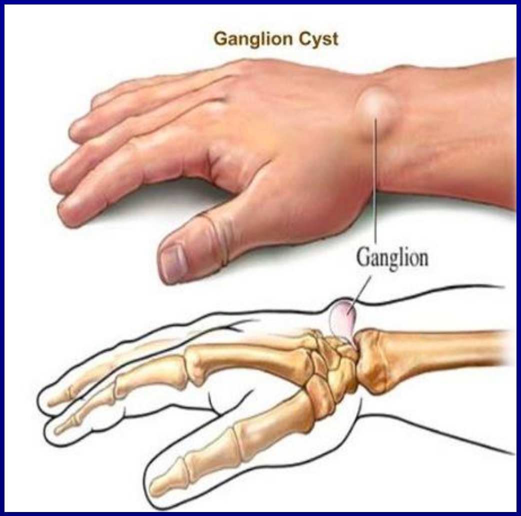


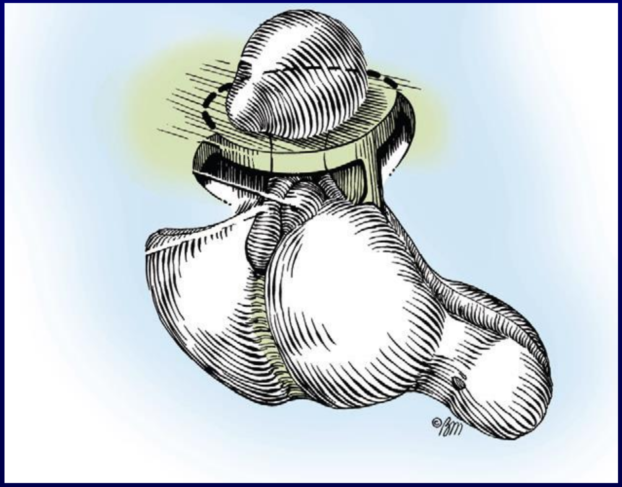


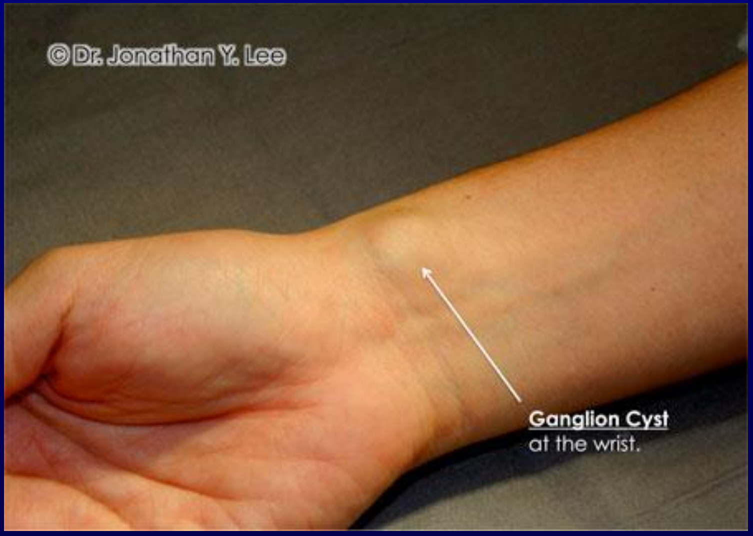


Congenital trigger finger also exists.

Ganglion – Could arise from a joint or tendon sheath, needle aspiration of its highly viscous content rarely gives lasting result.

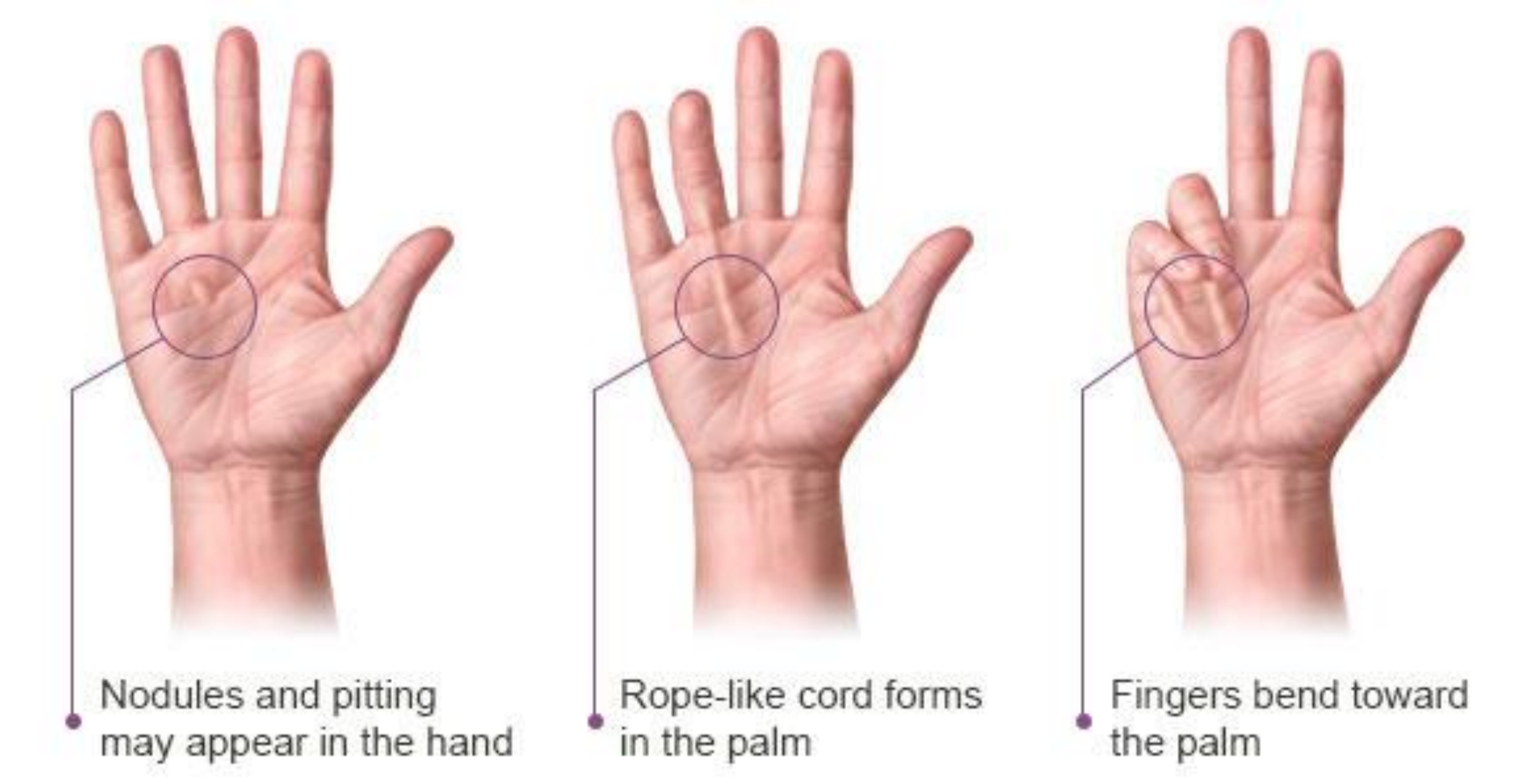




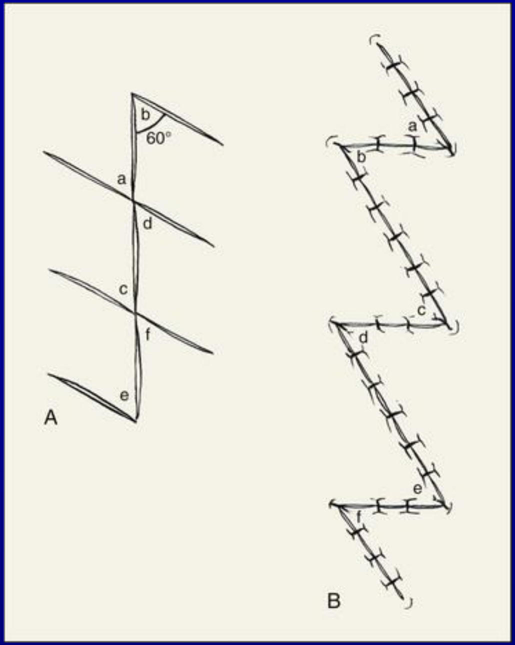


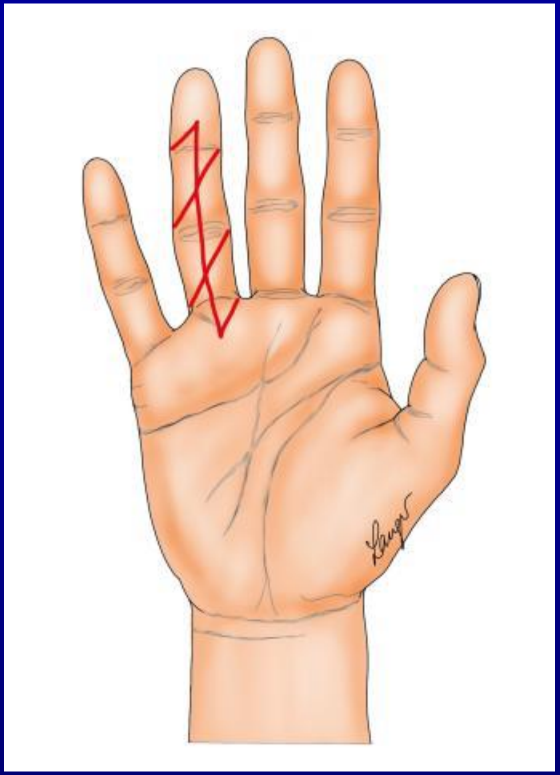
Dupuytren contracture

Iselin stages



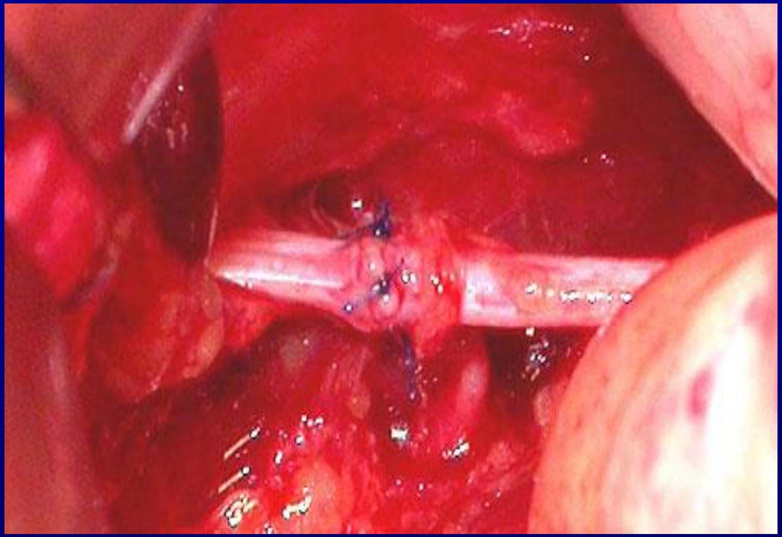
Indication for surgery:
- painful scar formation
- MP extension deficit.





Skin scarring and shrinking caused by the contractures can be managed surgically by multiple Z-plasty, skin defects can be covered using skin grafts, respectively.

NERVE INJURES



Typical appearance of the hand after *radial nerve injury at upper arm level*: wrist, MP joints as well as thumb IP joint active extension lost. Note that ability to actively extend PIP and DIP joints will be preserved.

Appearance of the hand in *old, wrist level ulnar nerve palsy*. Due to the loss of interosseus-lumbrical action the IV-V MP joints move into hyperextension at attempted finger extension, while the PIP-DIP joints remain bent. The 1st and 2nd lumbricals are capable to keep the index and middle fingers straight as their median nerve supply is intact.

Typical picture of *old median nerve palsy* at the wrist level: atrophy of thenar eminence.

Important notice!

Based on these typical pictures one might be tempted to establish a diagnosis “at a glance”. However injuries to the median and ulnar nerves at the elbow level or above, the (not uncommon) combined injuries of the nerves, the atypical hand/finger posture due to concomitant tendon injuries, as well as the time elapsed post-injury (e.g. muscle atrophy) might substantially change the look of the hand.
For this reason, the diagnosis should be rather based on the results of the systemic physical examination and the thorough evaluation of the findings on the preserved and missing, motor and sensory functions of the hand.

Majority of peripheral nerve injuries affects the upper limb and is traumatic in origin.

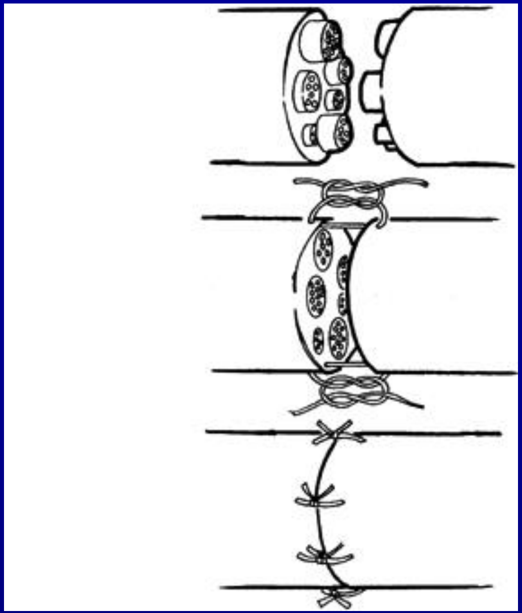
Unequal distribution: young, healthy and economically active individuals overrepresented

Quality of life: ↓↓↓

Median and ulnar nerve repairs:

satisfactory (M4-5) motor regeneration:	51,6 %
satisfactory (S3+ – S4) sensory regeneration:	42,6 %

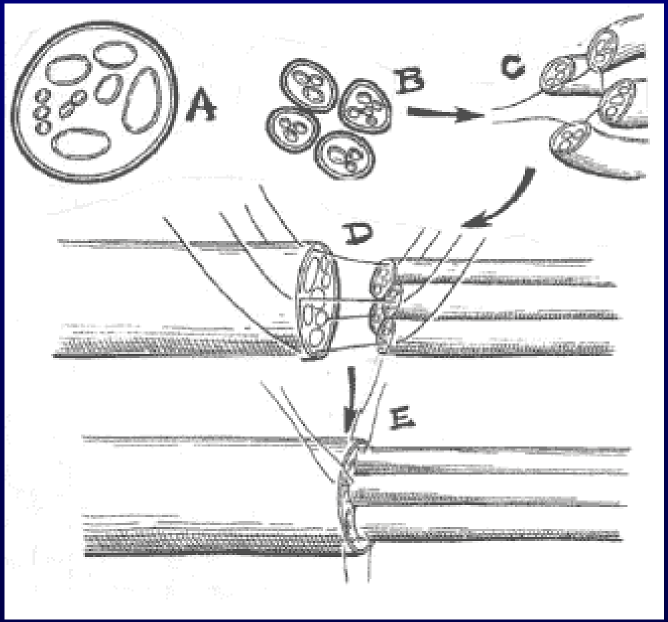
Results concerning the repair of the damaged peripheral nerve during the last 50 years:



epineural suture

end-to-end neurorraphy

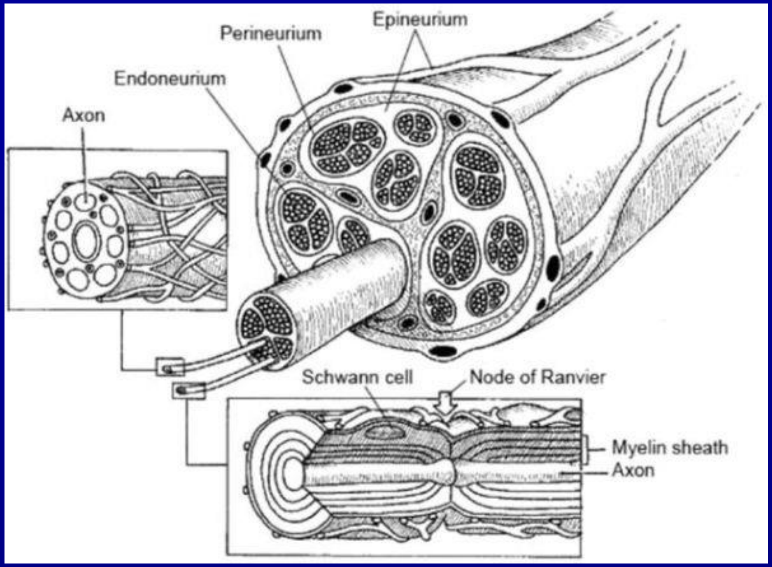
autolog interposition graft

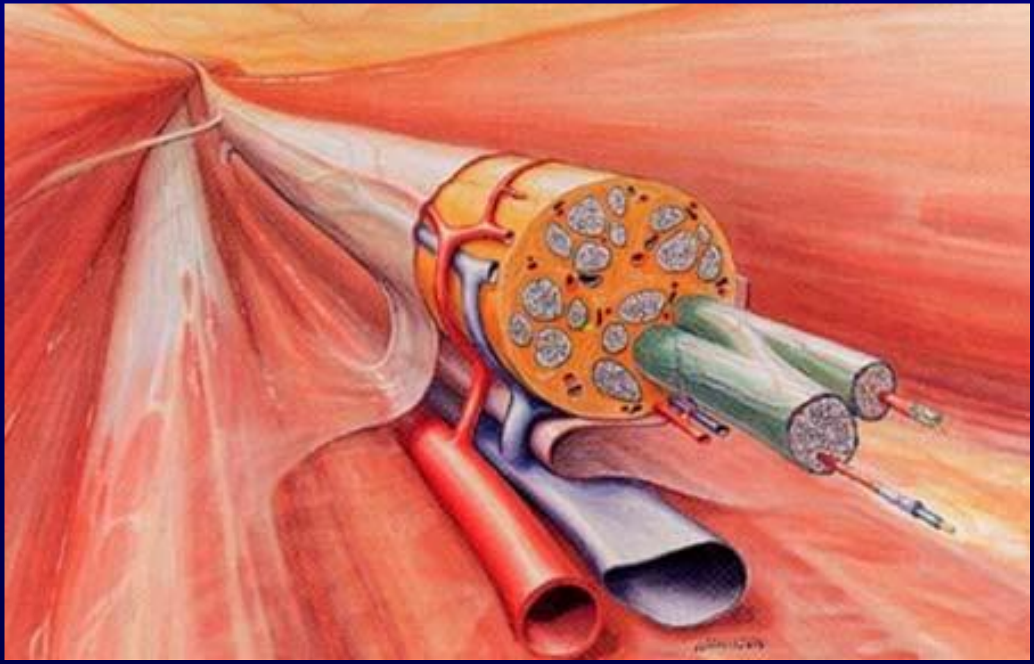


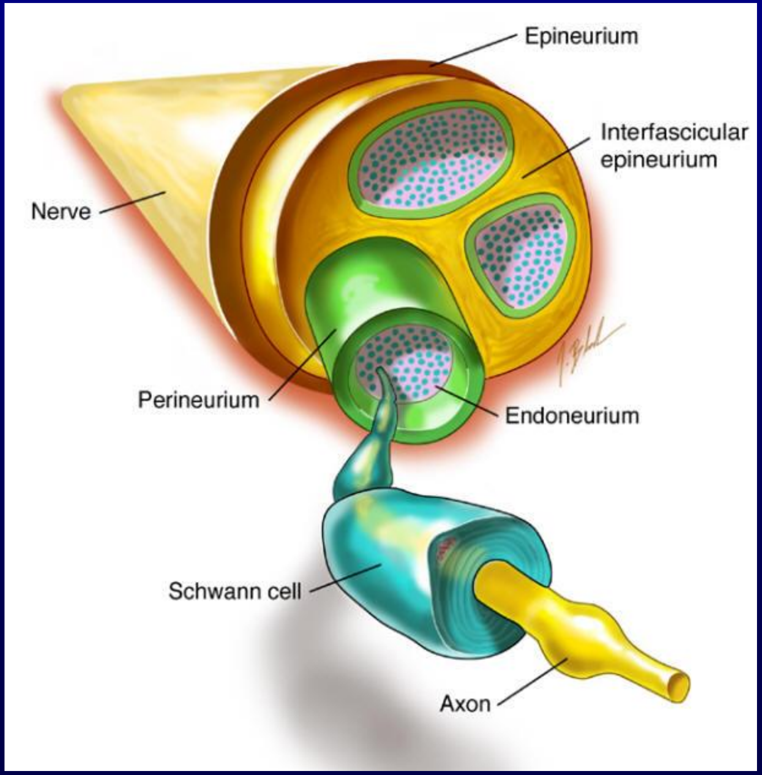
Peripheral nerve anatomy

Endoneurium
Perineurium – surrounding the fascicles
Epineurium
Mesoneurium – providing blood supply

Nerve sutured under tension: blood supply ↓↓↓



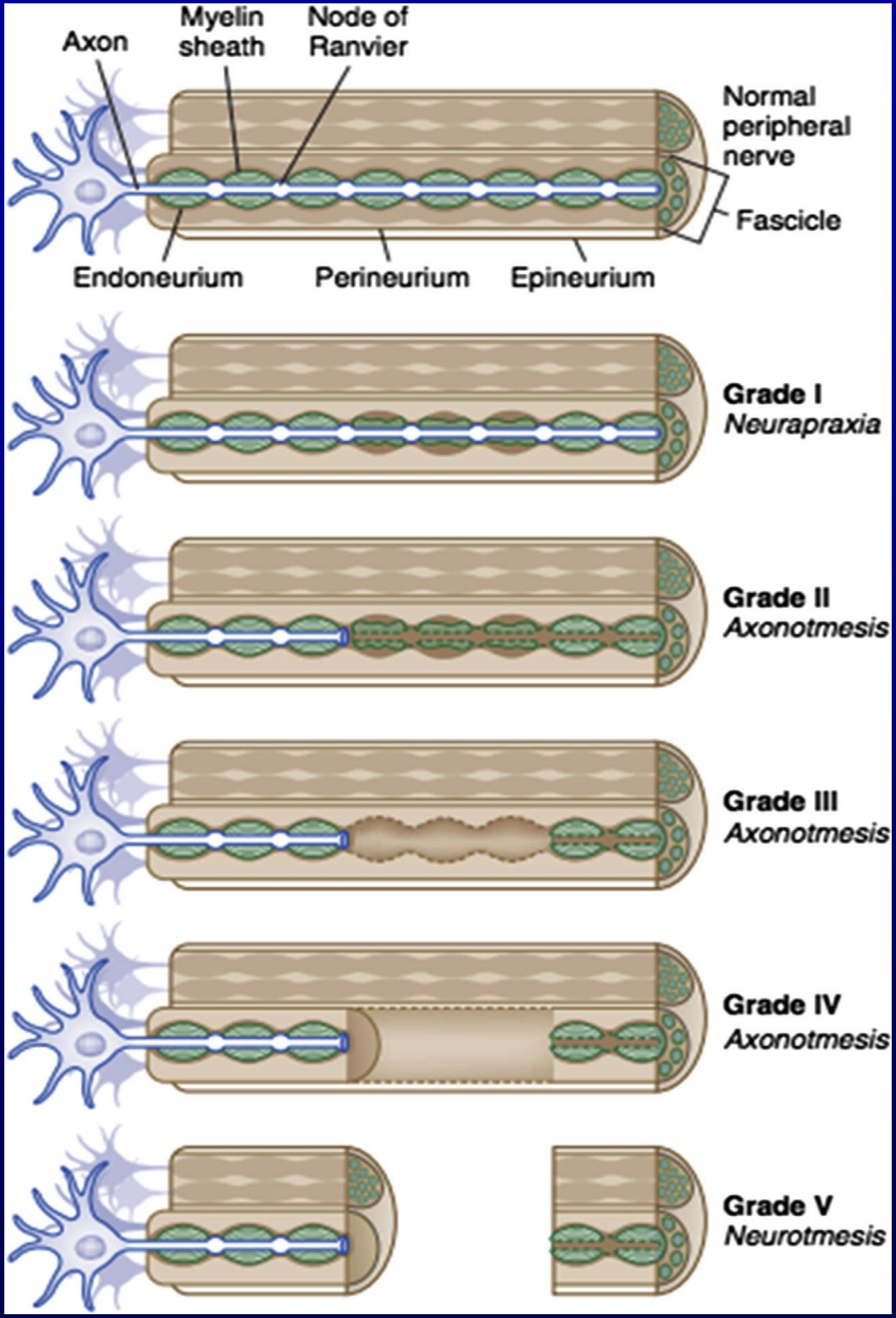




Classification of nerve injury

Seddon (1943):	neuropraxia, axonotmesis, neurotmesis
Sunderland (1951):	+ 3 types of axonotmesis
Mackinnon and Dellon (1988):	+ mixed levels of injury along the nerve („neuroma in continuity”)

Seddon	Sunderland	Pathophysiologic Basis
Neuropraxia	I	Local myelin damage. Axons preserved. No degeneration.
Axonotmesis	II	Endoneural tube preserved. Axon degeneration.
	III	Loss of endoneural tube continuity. Perineurium intact. Axon degeneration.
	IV	Endoneural tube and perineurium disrupted. Epineurium intact. Axon degeneration.
Neurotmesis	V	Complete loss of neural continuity.



Schwann-cell damage

Axonal degeneration only
+ Schwann cells ↓

Perineurium intact

Epineurium intact

Clinical classification

Kompressziós sérülés

Acute (e.g.: radial n. mononeuropathy) – regeneration: weeks → months, year

Chronic (e.g.: CTS) – progressive sensory, motor signs

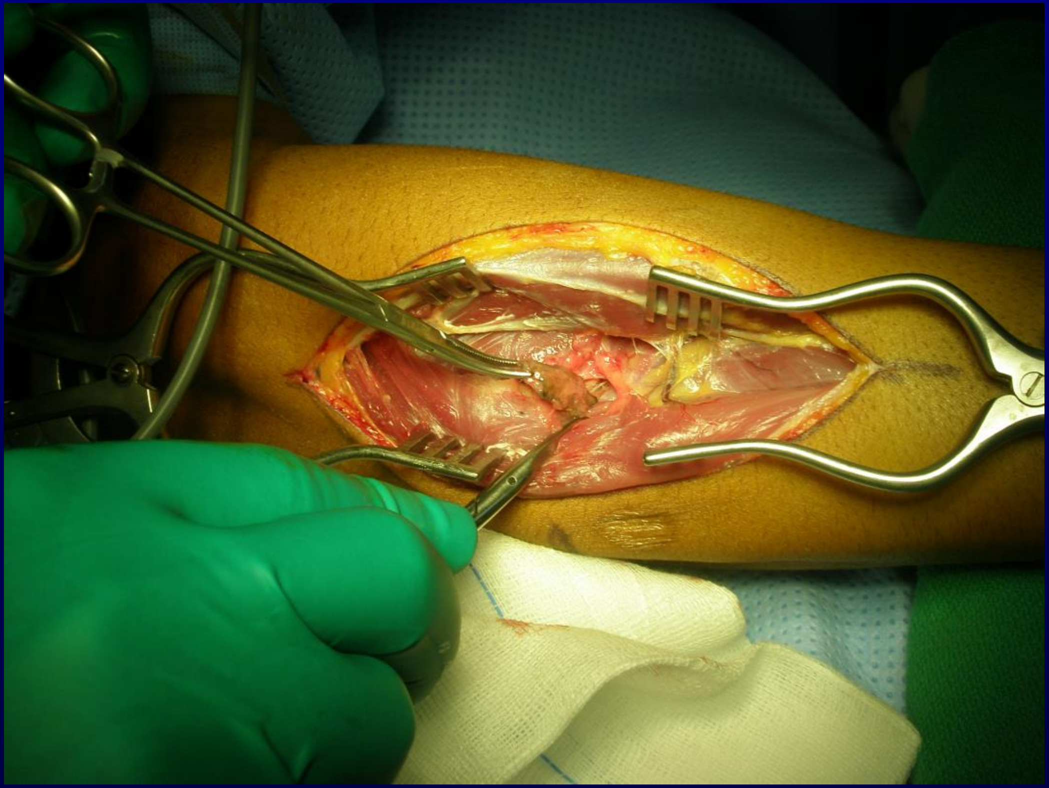
Local demyelination
pathophysiol. background: thinner myelin sheath,
decreased internodal length,
increasing Schwann cell metabolism
Proposed mechanism
- ischemia due to pressure elevation
- venous stasis → extraneural edema → fibrosis, → intraneur. oedema
Lack of axonal damage

Crush (a) and *transection (b)* injury

a./ Often represent mixed injuries (different axonotmesis forms)

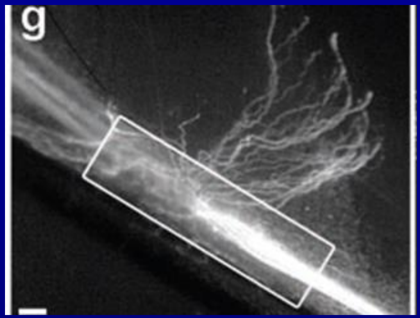
b./ Complete transection

(Ballistic injuries are a special case that tends to combine both transection and crush of the nerve from the shockwave that moves through the tissue after the passage of the bullet, which has both a tearing and compressing effect on the nerve, even without the actual passage of the projectil through the nerve itself.)



Reinnervation: 2 different ways

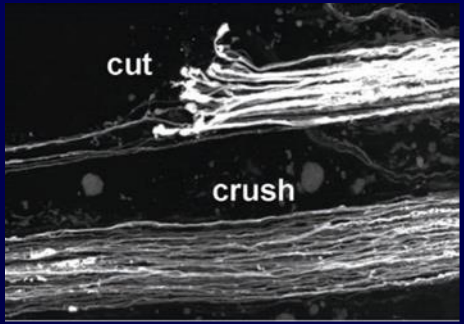
1./ Collateral sprouting of intact axons



- primary mechanism, when 20-30 % of axons damaged
- begins in the first 4 days after injury and continues for approximately 3 to 6 months, until recovery occurs
- increase in motor unit size of remaining innervated muscle
- over time muscle eventually atrophies
- superfluous sprouting axonal branches degenerate

2./ Regeneration of the injured axon

- when greater than 90% of the axons damaged, primary means for recovery



Key elements in nerve regeneration:

- gap distance
- wallerian degeneration
- axon guidance specificity (bands of Büngner)
- end-organ viability

Diagnosis in acute setting still relies on clinical examination and/or surgical exploration.

There is no noninvasive diagnostic test that can diagnose the presence or severity of a nerve injury in the first six weeks after injury.

ENG, EMG: ~ 3-6 weeks (ENG: screening for conduction block; EMG: fibrillation potential)
obtained serially over time

Surgical exploration – to wait or not to wait??? (3-6 months...) (N. radialis, n. peroneus)

Timeframe for functional recovery:

Hope of motor reinnervation:	~ 1 year
Hope of sensory reinnervation:	~ 2-3 years

Regeneration fails due to chronic axotomy of the neurons and chronic Schwann cell degeneration and is not due solely to irreversible atrophy of muscle.

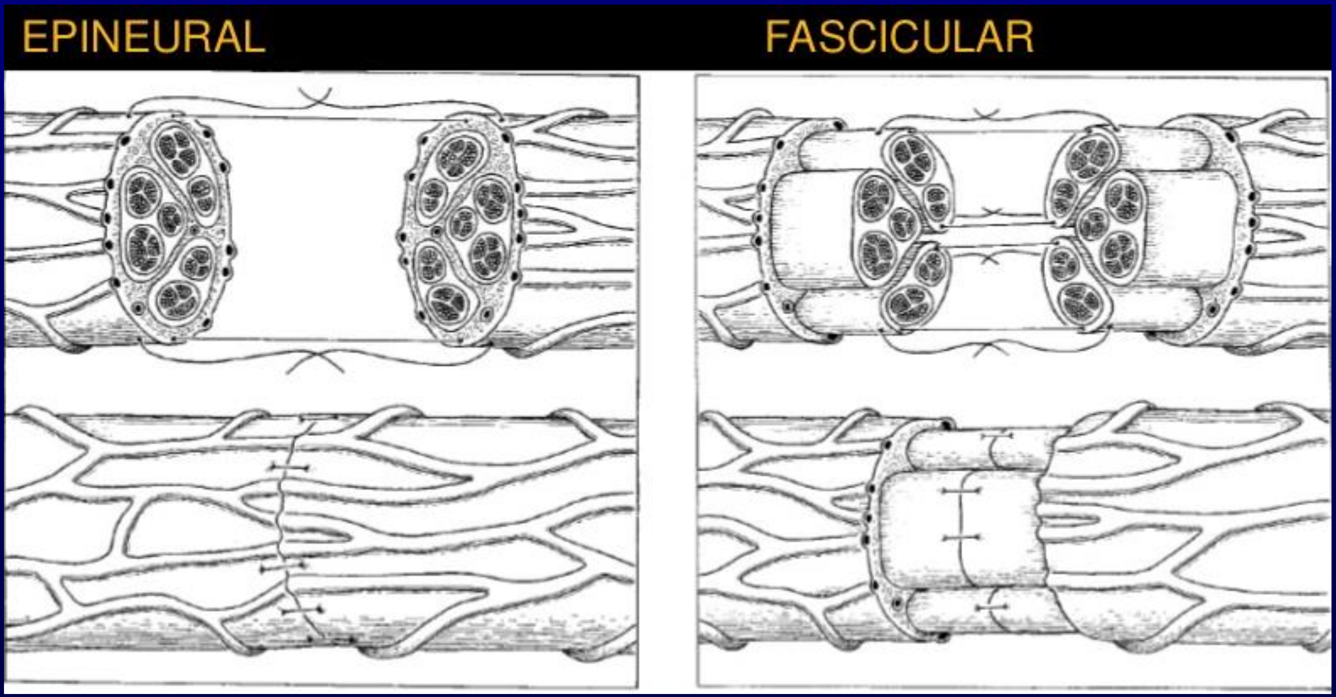
Nerve reconstruction

Epineural suture – gold standard

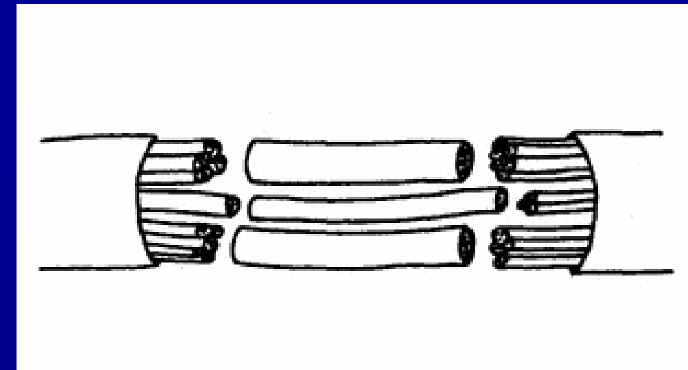
tension free, well-vascularised bed, fascicular matching

Fascicular suture – only theoretically better

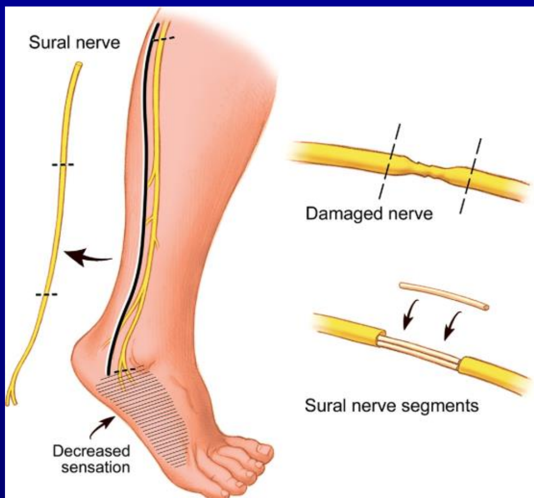
Main problem: axonal misdirection



Nerve defect: no tension free direct suture possible



Autograft:



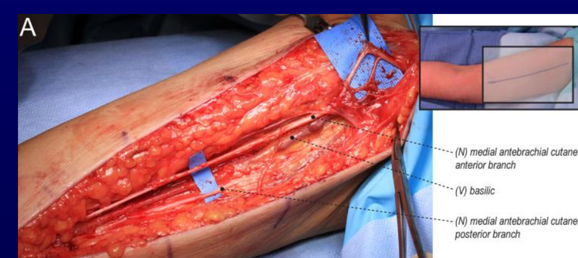
single,
cable,
nerve trunk,
interfascicular,
vascularized

Donor: sural n.; medial antebrachial n.;

Main issues: functional loss, neuroma formation
~ 50 % axonal loss at each coaptation!!!
distance of target organ

Allograft:

need of immunosuppression
decellularized allograft (< 3 cm)

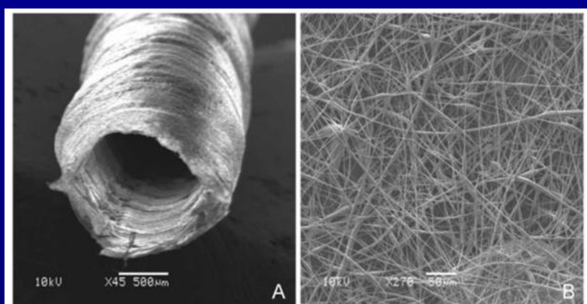


Conduits: only < 3 cm !!!!

autogenous biological: vein, artery, muscle, tendon

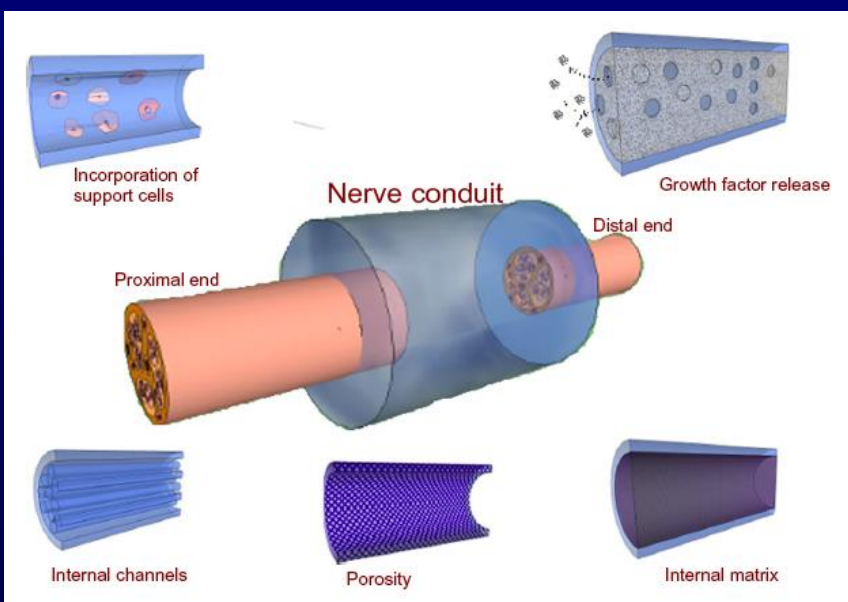
nonautogenous biologic: I, III, IV type collagen

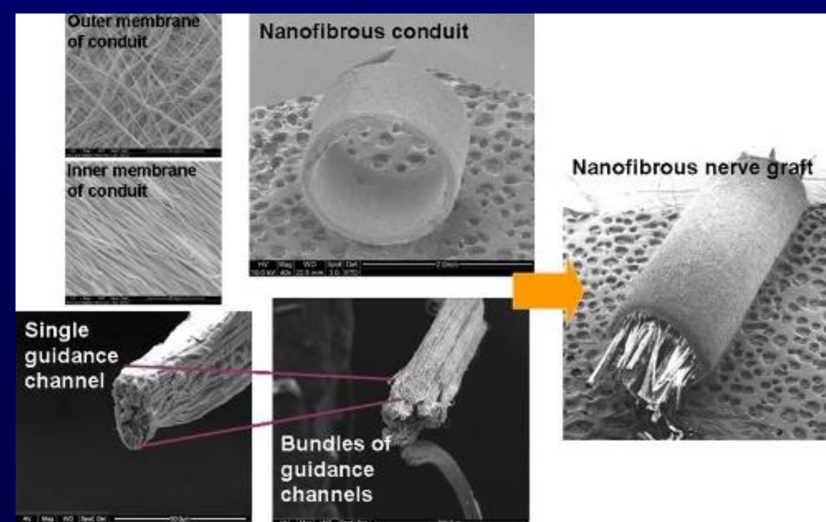
non-biologic:



absorbable: PGA (polyglycolic acid)
PLA (polylactic acid)
PLGA (poly lactide-co-glicolide acid)

non absorbable: silicone
Gore-Tex





Results:

very good (M4S3+) regeneration: 20-40 %

early repair	>	late repair
direct repair	>	graft
young patient	>	old patient
distal repair	>	proximal repair
short graft	>	long graft

Factors influencing the outcome:

Age:	children do better below 10-12 y; (similarity to learning a new language)
Cognitive brain capacity:	visuo-spatial, verbal learning
Timing of repair:	fibrosis of the distal nerve segment, atrophy of Schwann-cells, progressive loss of neurons
Type of nerve:	motor/sensory ↔ mixed (mismatch possibility)
Level of injury:	outgrowth: 1-2 mm/day
Type of injury:	crush > total severance

Sensory re-education and sensory relearning:

1./ Maintaining the cortical hand map; *visuo-tactile and audio-tactile interaction*:

premotor cortex activation

mirror training

combined mirror illusion and the true touch of the healthy hand

Sensor Glove

“the patients can listen to what the hand feels”

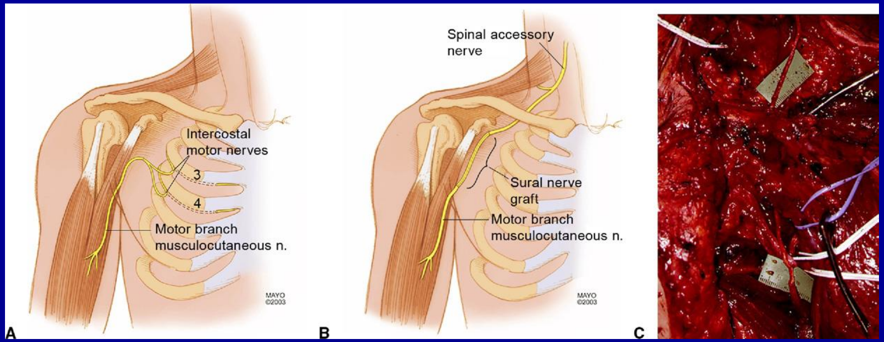
2./ Enhancing the effects of sensory re-education

Cutaneous de-afferentation of the forearm

allowing expansion of the cortical hand representation

(EMLA creme [local anaesthetic] treatment 2x weakly)

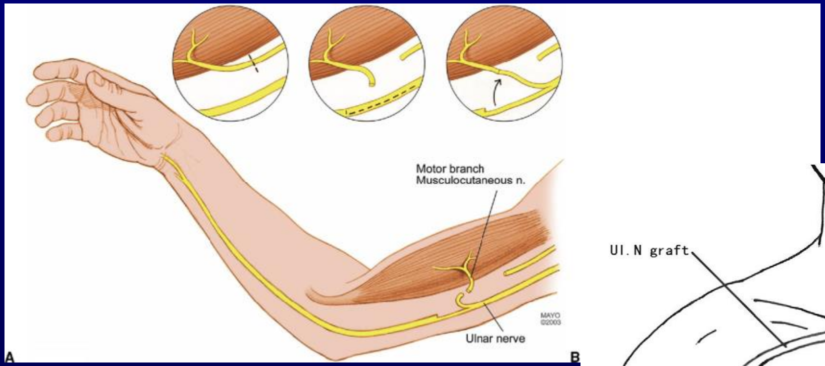
Surgical Alternatives to Nerve Repair

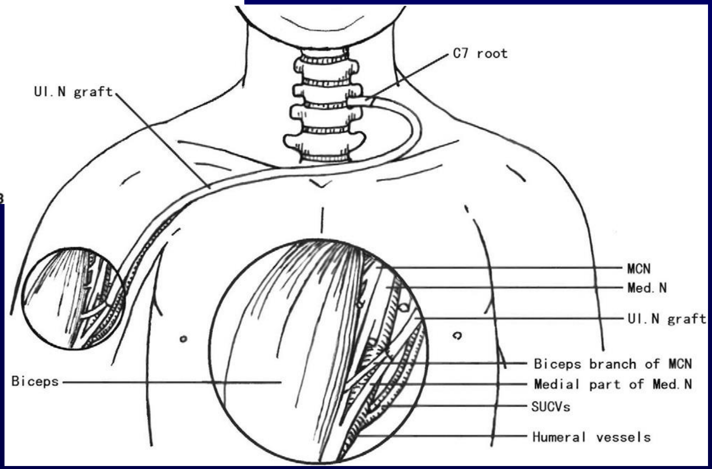


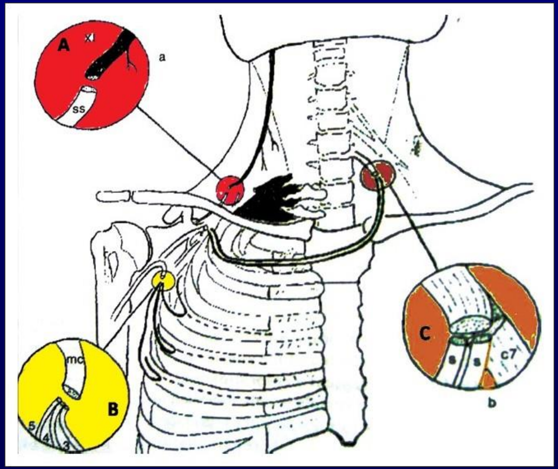
Nerve transfer / neurotization

only one neurorrhaphy site
minimizes distance over which a nerve has to regenerate
motor function unchanged ←→ tendon transfer
quicker motor reeducation

E.g.: elbow flexion, shoulder abduction, ulnar intrinsic function, radial n. function, facial nerve (smile repair)



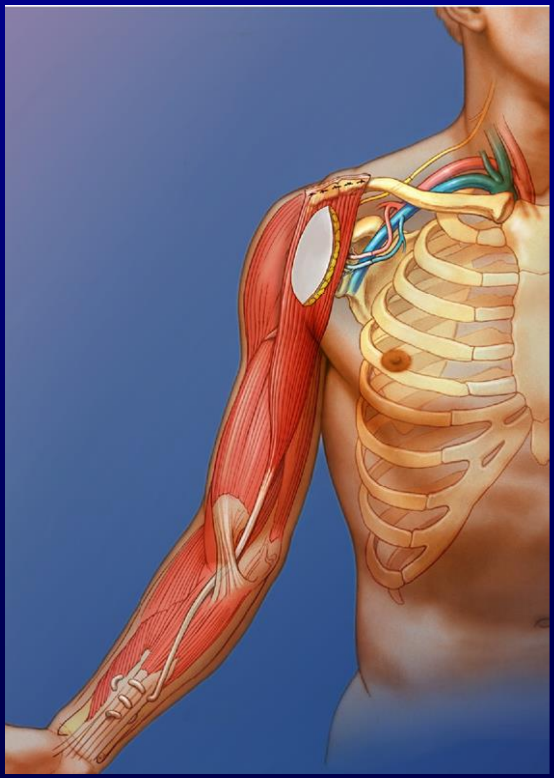


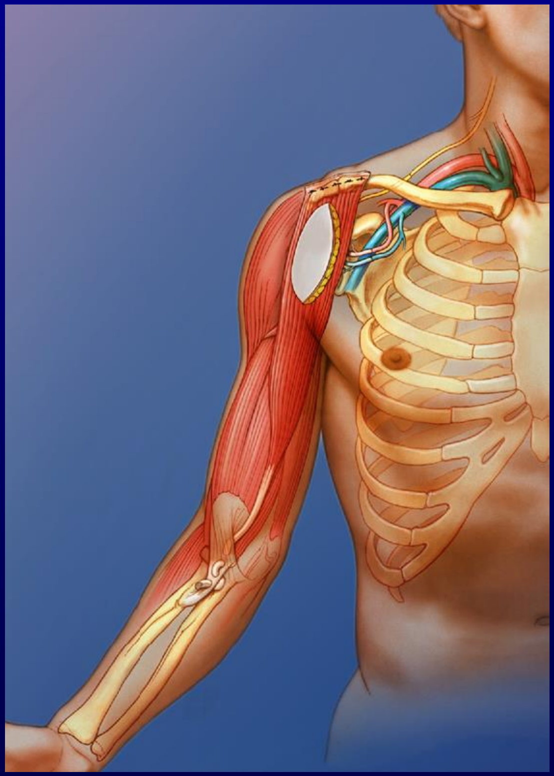


Free functioning muscle transfer

failed primary reconstruction,
both the nerve and muscle are damaged (acute/chronic)

usually in brachial plexus injuries if no other alternative exists





FLEXOR TENDON INJURIES

Table 1
Large case series of flexor tendon repair and controlled early active motion in the last 8 years

Authors, Year	Number of Digits	Zones	Core Suture Methods	Results[a]	Rupture Rate
Caulfield et al,[6] 2008	416	1–4	4-strand Strickland	74%	2%
Hoffmann et al,[7] 2008	51	2	6-strand Lim/Tsai	78%	2%
	26	2	2-strand Kessler	43%	11%
Navali & Rouhani,[8] 2008	16 (children)	2	6-strand Strickland	94%	0%
	16 (children)	2	2-strand Kessler	88%	6%
Giesen et al,[14] 2009	50	1, 2	6-strand Tang	78% (White) 82% (Buck-Gramcko)	0%
Moehrlen et al,[10] 2009	40	1–3	2-strand M Kessler	92.5%	0%
Trumble et al, 2009	119	2	4-strand Strickland	—	3%
Sandow & McMahon,[12] 2011	73	1, 2	4-strand cruciate	71%	4.6%

Ultimate goal: RUPTURE FREE, LOCKING FREE, TENDON SUTURE!

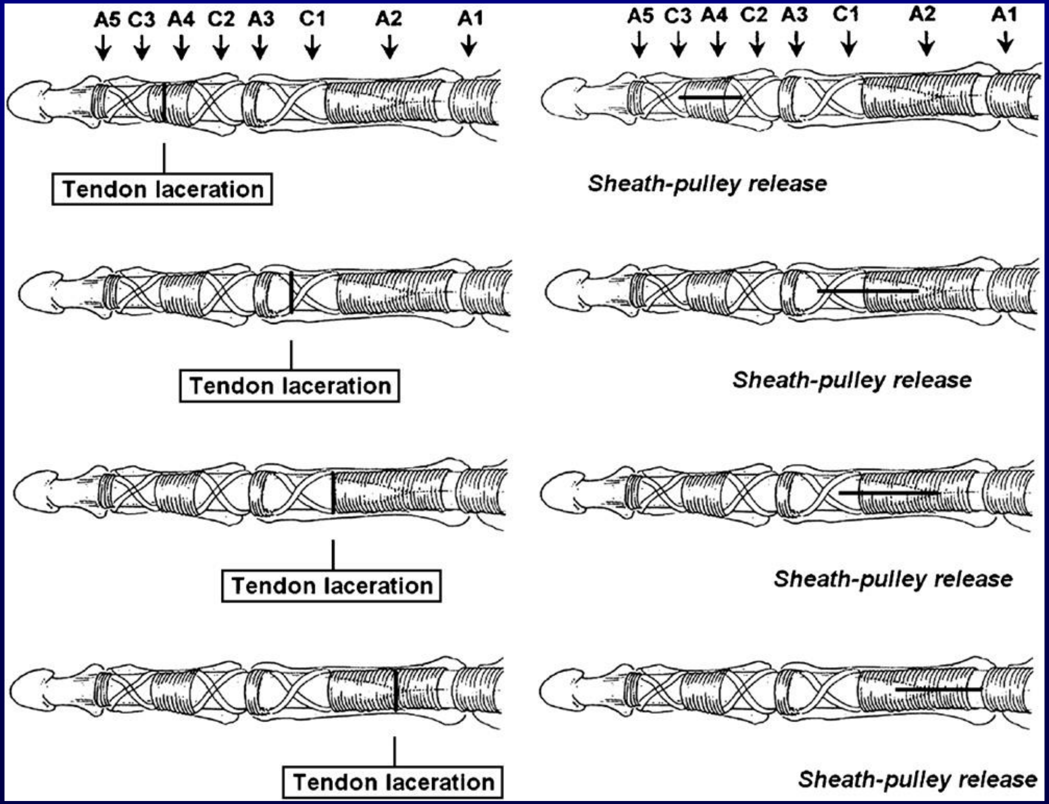
Factors affecting quality of flexor tendon repair →

Flexor tendon sheath pulleys

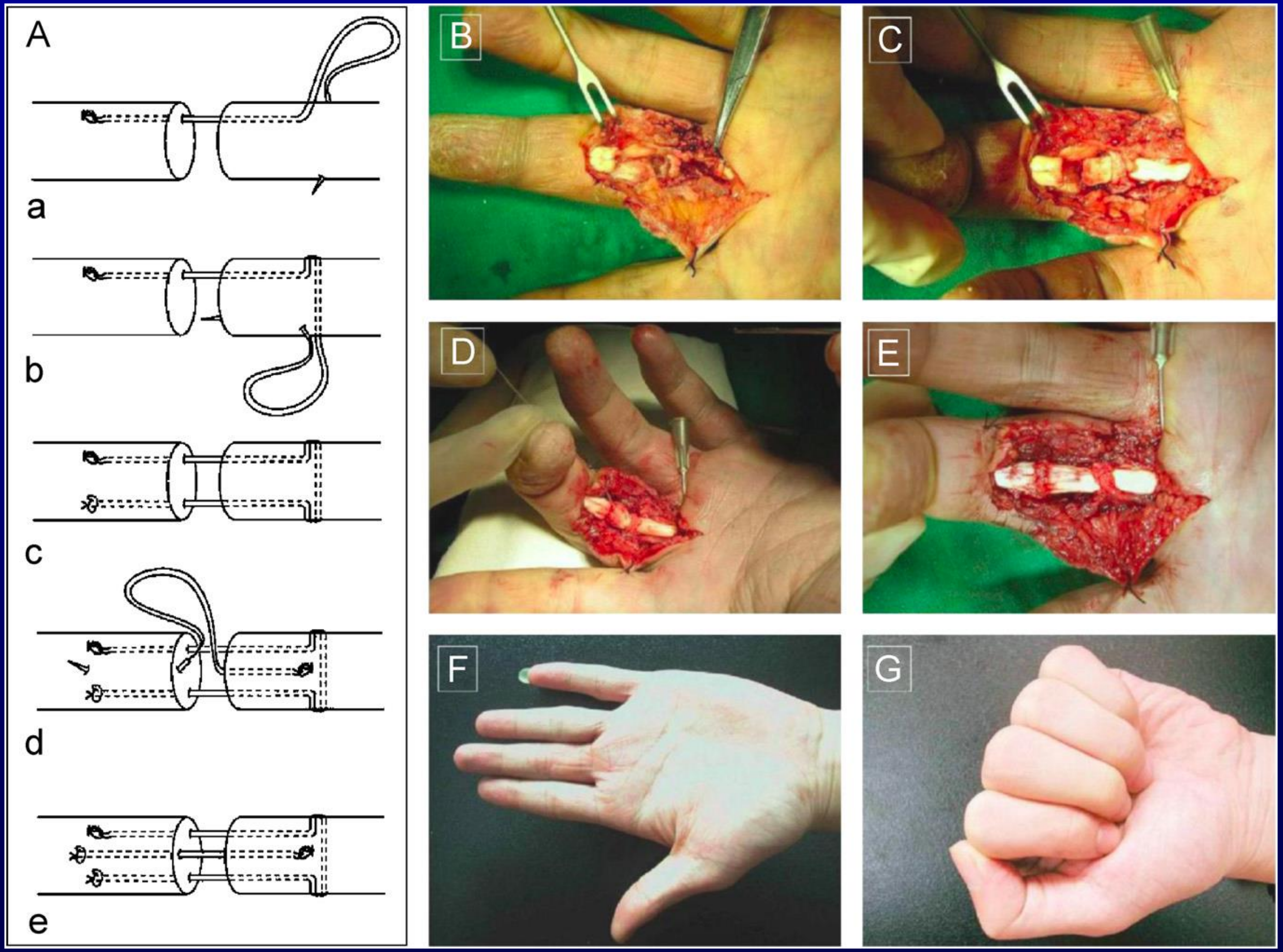
Moderate venting of pulleys encouraged

Tang 2007: pulley venting: A2, A4 + FDS slip resection

Total release < 2 cm



Preserved sections of A2 pulley during tendon repair



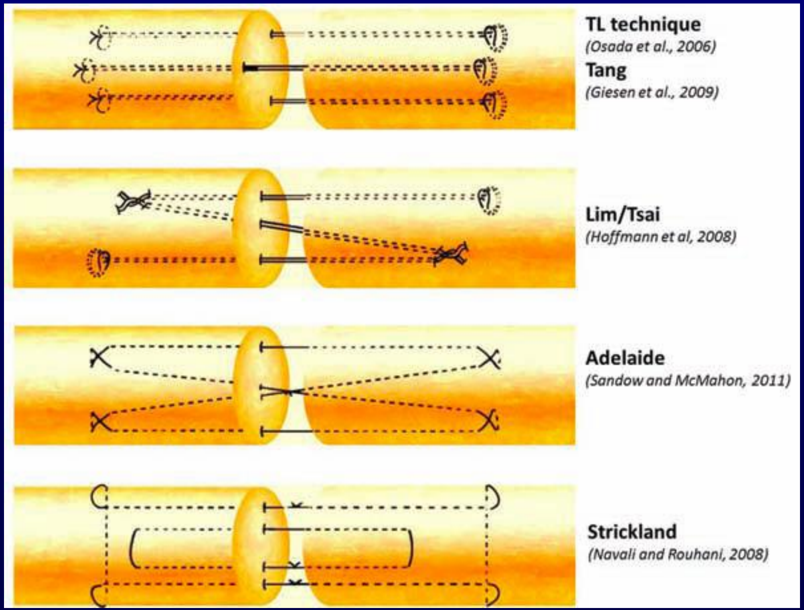
Number of strands of the core suture

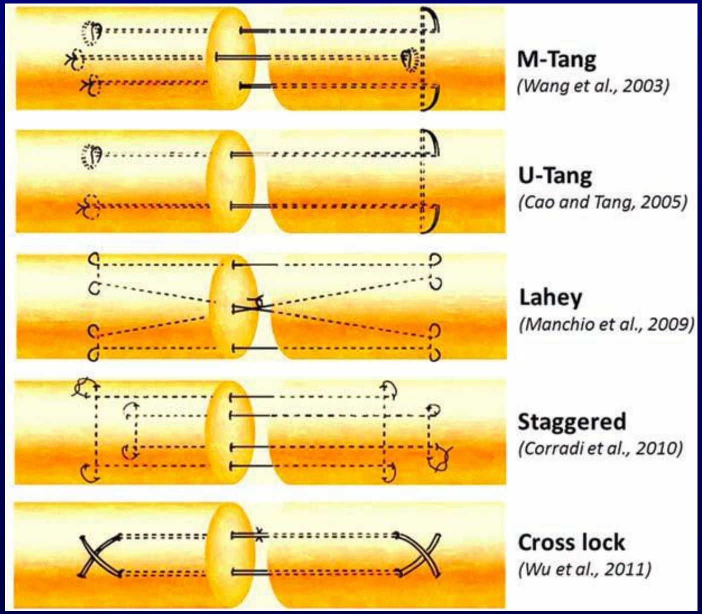
Increasing suture number → ~↑ failure strength, ↓ gap formation

2-strand suture : considered insufficient currently

4-strand suture: most common

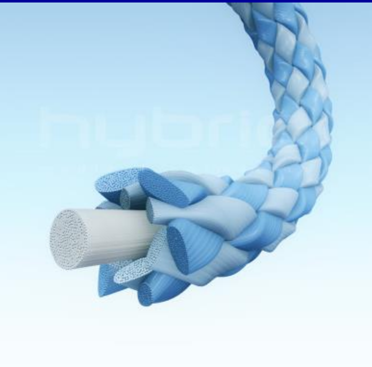
6- or 8-strand repair: no studies to compare the outcomes
more elaborate
scarring ↑??
better tensile strength

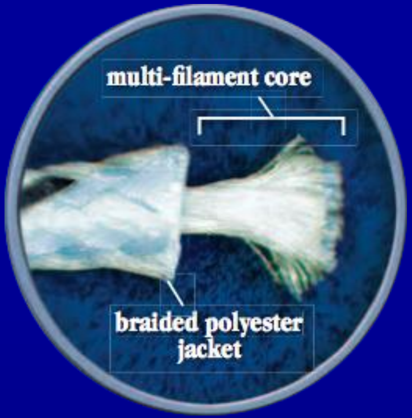




Suture materials

Ideál:
high tensile strength
easy to handle
little tissue reaction
good knot-holding



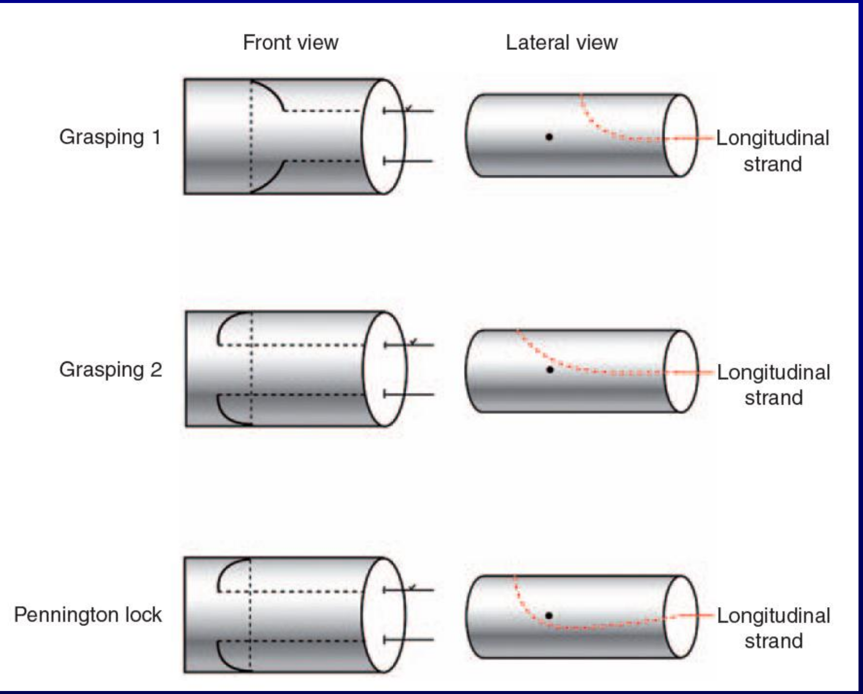


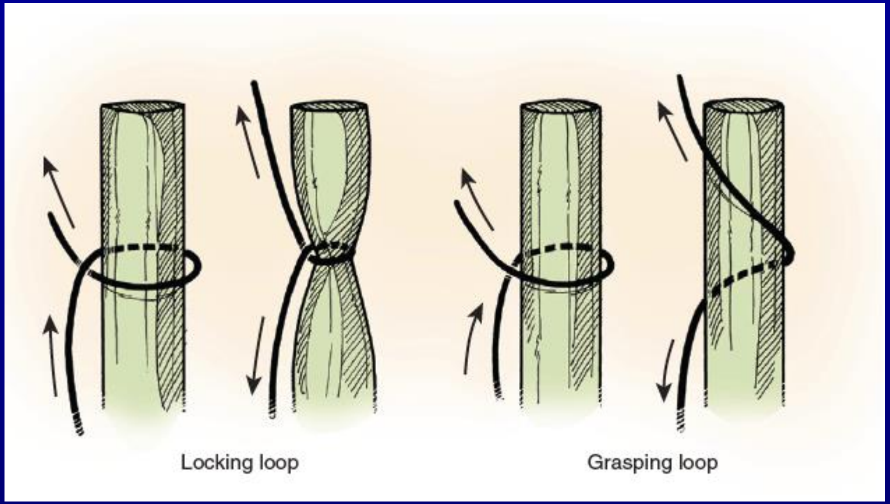
Materials	Description	Main manufacturers	Usage	Advantages	Disadvantages
Stainless steel	Stainless steel	Ethicon, Somerville, NJ, USA	Used 30–40 years ago	Highest stiffness and tensile strength	Kinking and difficult handling
Ethibond	Coated braided polyester suture	Ethicon, Somerville, NJ, USA	Currently used	High tensile strength and easy handling	Poor knot-holding
Ethilon	Monofilament nylon suture	Ethicon, Somerville, NJ, USA	Currently used	Easy handling	Comparatively inferior strength
Supramid	Braided nylon encased in smooth shell	S. Jackson, Alexandria, VA, USA	Currently used	Looped suture and easy handling	Comparatively inferior strength
Prolene	Monofilament polypropylene suture	Ethicon, Somerville, NJ, USA	Currently used, mostly in peripheral suture	Good knot-holding and less bulk to knot	Comparatively inferior strength
FiberWire	Braided polyblend polyethylene suture	Arthrex, Naples, FL, USA	Increasingly used	Higher stiffness and tensile strength	Poor knot-holding
NiTi	Nickel–titanium shape-memory alloy	Orfix, Raahe, Finland	New metal material	Superior biocompatibility, tensile strength and stiffness	
Barbed suture	Glycolic-carbonate	Covidien Deutschland GmbH, Neustadt, Germany	Rarely used	Increased suture–tendon interaction, knotless,	Suture burden, tissue handling
PDS	Polyglycolide-trimethylene carbonate	Johnson & Johnson, New Brunswick, NJ, USA	Less used	Absorbable	Loss in tensile strength of suture over time
Maxon	Bioabsorbable, polyglyconate suture	Davis & Geck, Danbury, CT, USA	Less used	Absorbable	Loss in tensile strength of suture over time

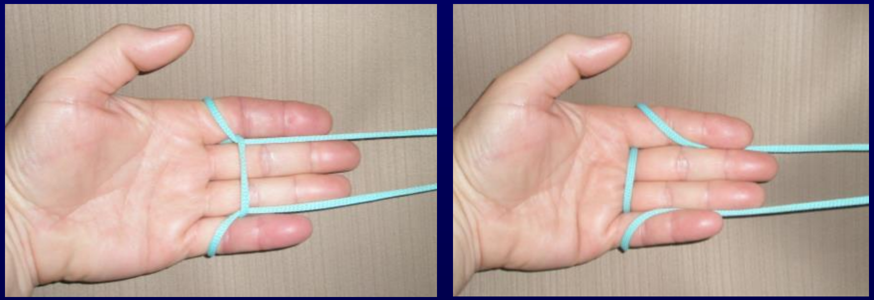
Suture diameter:
2-0 → 5-0; 3-0, 4-0 most common

Locking or grasping loops?

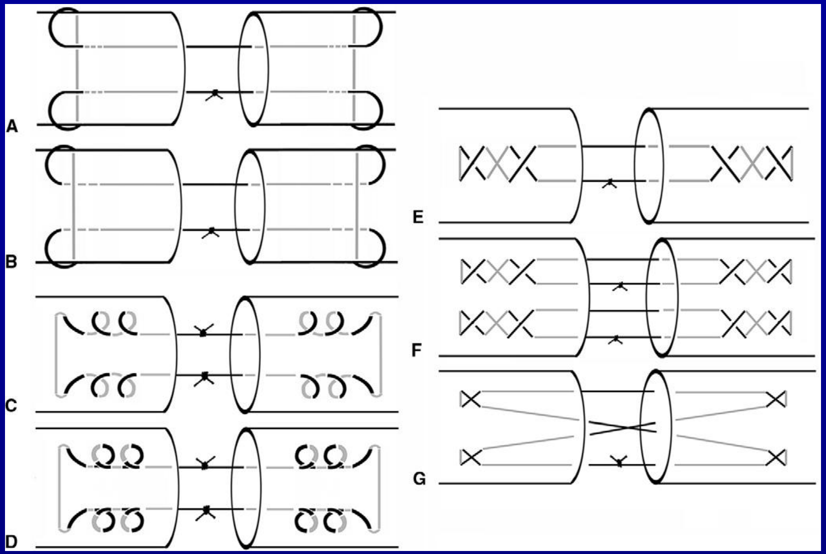
Loop diameter: at least 2 mm

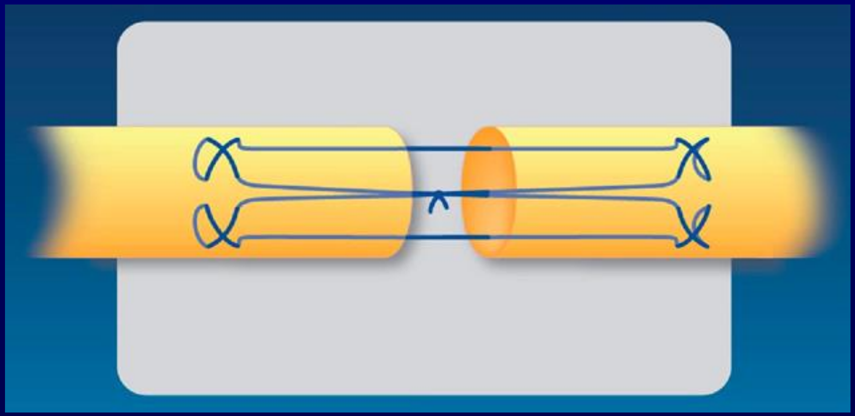




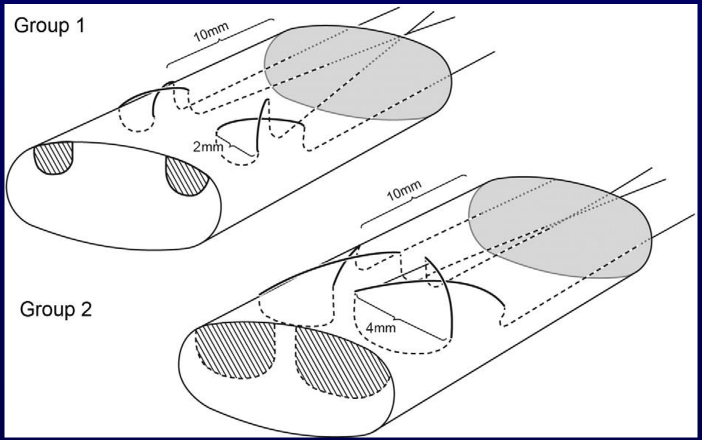


Cruciate type repair or loop type repair.

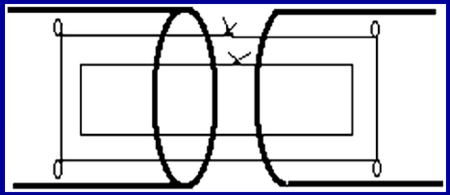


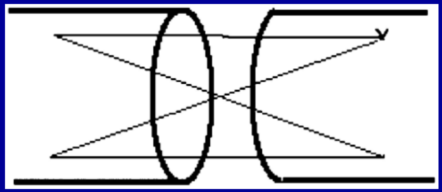


Adelaide suture



Knots





Flexor tendon repairs usually rupture at the knots.

Location of suture knots

Inside or outside?

Number of knots?

All strands in the repair with one knot are carrying equal load, while with two knots the unequal loading of the strands lead to a high risk of early failure.

At least three throws – FibreWire: 6x!!

Peripheral repairs

Most common: simple running

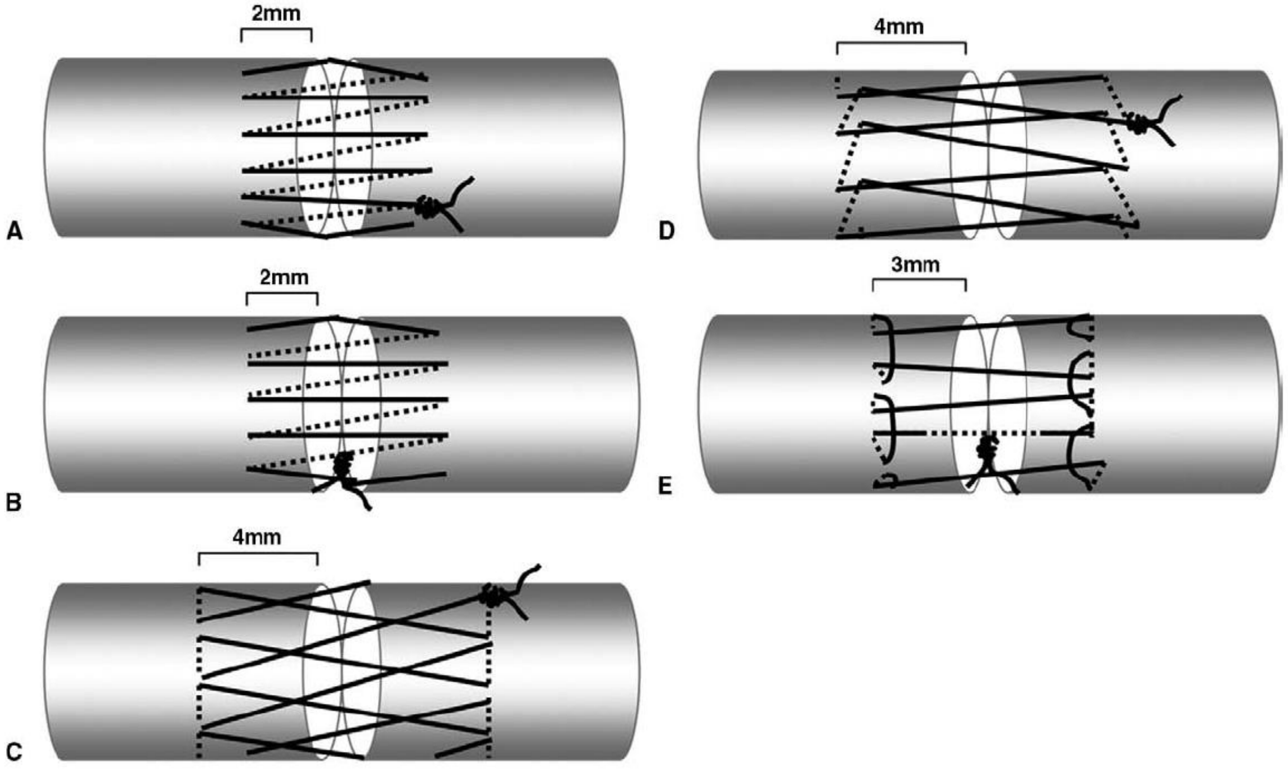


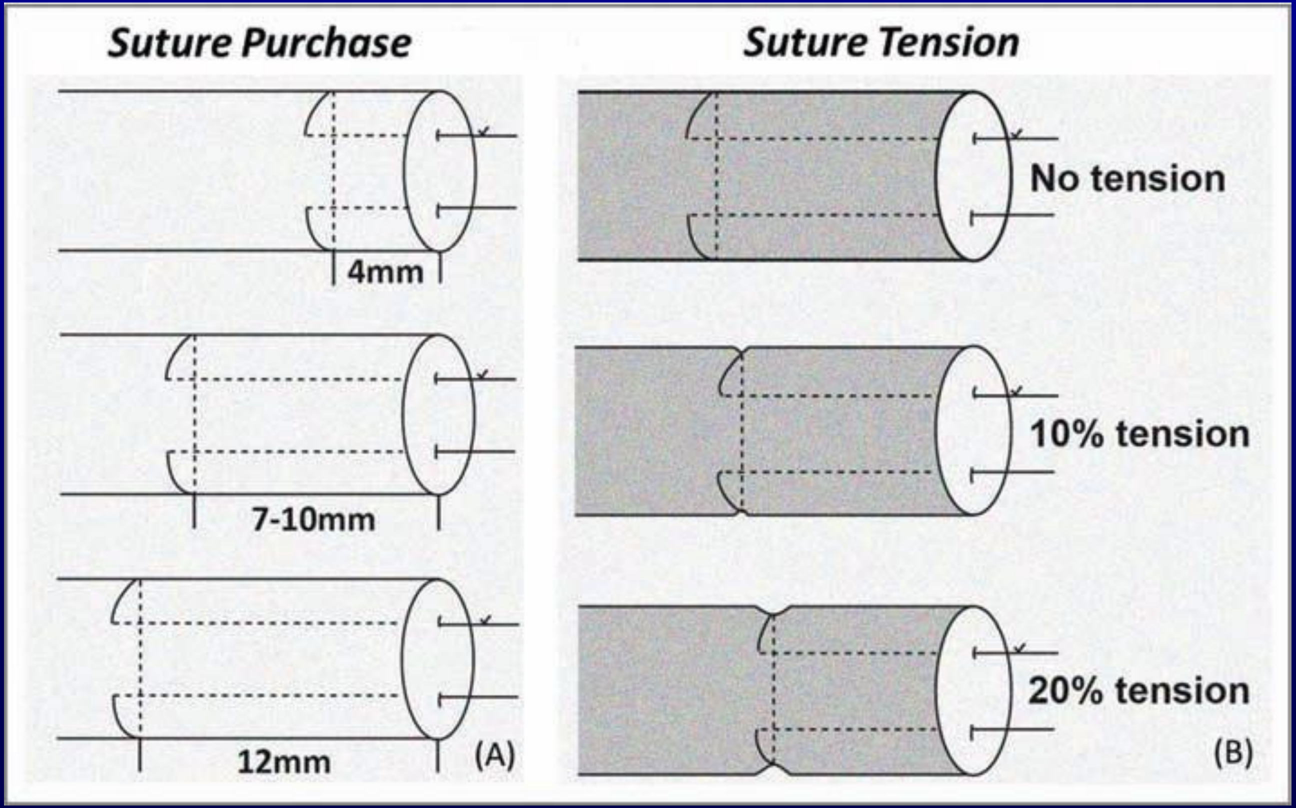
FIGURE 1: Schematic drawings of the 5 epitendinous suture methods. **A** The simple running KO suture. **B** The simple running KI suture. **C** The cross-stitch suture. **D** The IHM suture. **E** The running–locking suture.

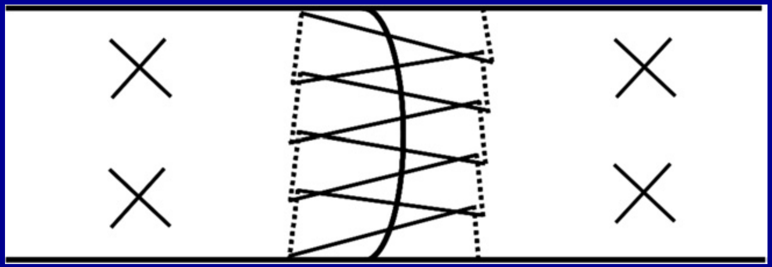
Purchase of the core suture

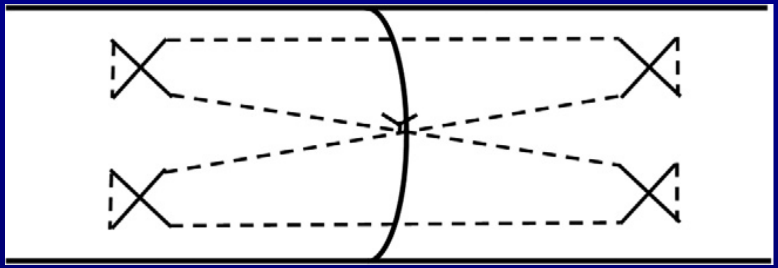
7-10 mm optimal

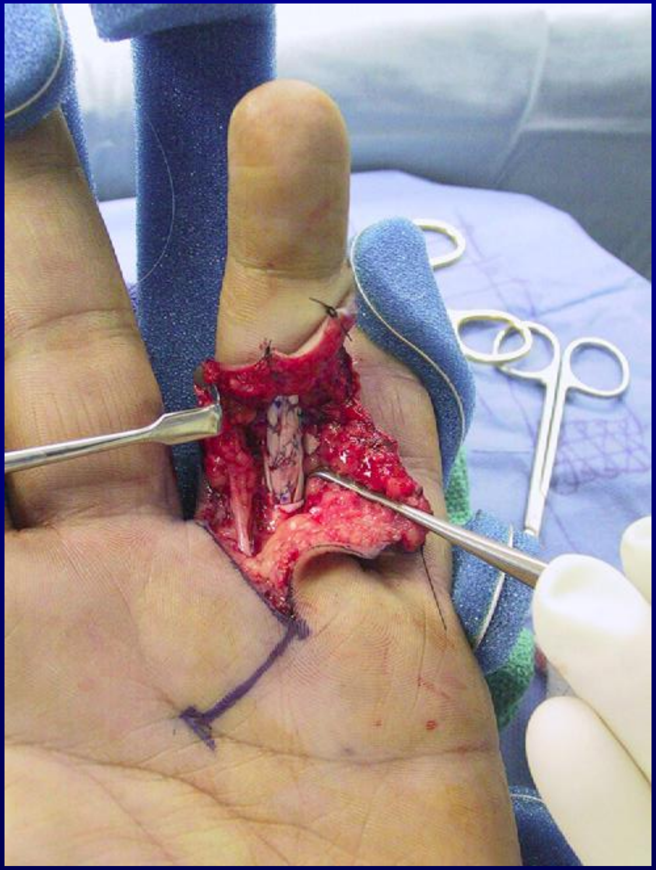
Tension of core suture

10 % optimal









Adelaide +
interlocking horizontal mattress

EXAMPLES OF SKIN DEFECT COVERAGE IN HAND SURGERY

<u>Flap</u> in plastic surgery: tissue with its own blood supply (skin, muscle, composit, …)

↔

Graft: skin without circulation: split skin graft, full-thickness, mesh, etc.

Trend:

microvascular free flap → axial-pattern flaps without anastomosis

<u>Jump flaps</u>

Reverse flow flaps

Freestyle perforator flaps

27 y/o. female, RTA, multiple trauma, radius fx, open wrist wound, lacerated long extensor tendons

Vacuum-seal for 6/7, then extensor tendon suture and flap coverage. Stem detachment after 3/52.

3/12 postop.

52 y/o male RTA OS revascularisation

1/52 postop.: skin necrosis.
Hypogastric flap.

31 y/o female

press machine

Arteficial syndactyly
+
abdominal flap coverage

Step-by-step division of fingers later.









Electric shock > open wrist wound w/ EPL rupture. Extensor digiti minimi transfer and posterior interosseous flap coverage.

6/52 F/U