

# Distal Upper Extremity Surgical Management

Live Interactive Webinar Presented By  
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## Course Overview

This course includes a review of current literature relating to surgical procedures for nerves, tendons, ligaments, and bones of the forearm, wrist and hand.

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## Course Rationale

The purpose of this course is to provide an understanding of the current trends in surgical procedures to manage degenerative, traumatic and non-traumatic pathologies of forearm, wrist, and hand. The emphasis is comparative analysis of contemporary surgical techniques to restore distal upper extremity function through repair of nerves, tendons, ligaments, and bones.

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## Goals and Objectives

- List and identify common anatomical structures of the wrist and hand.
- Distinguish neuropathy, degenerative, traumatic, and non-traumatic distal upper extremity pathologies.
- Identify emerging surgical techniques for distal upper extremity pathologies.
- Compare nerve decompression, nerve repair, nerve graft, and nerve transfer surgical procedures.
- Identify the zones of flexor tendon repair and surgical repair techniques.
- Describe fascia surgical techniques to manage conditions of the wrist and hand.
- List surgical mechanisms of stabilization of forearm and carpal fractures.
- Identify post-surgical complications during healing of distal upper extremity fractures.
- Describe the surgical technique to manage thumb osteoarthritis.
- Recognize common hand splints indicated to manage wrist and hand disorders.

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## Disclaimer

Application of concepts presented in this webinar is at the discretion of the individual participant in accordance with federal, state, and professional regulations.

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## Course Outline and Schedule

3-hour live interactive webinar

Consider This

Topic	Time
Wrist and Hand Anatomy and Arthrokinematics	0:00-0:10
Surgical Technique and Anesthesia	0:11-0:15
Peripheral Nerve Injury	0:16-0:20
Nerve Repair, Graft, and Transfer	0:21-0:30
Compressive Neuropathy	0:31-0:35
Carpal Tunnel Release	0:36-0:50
Interactive Discussion of Clinical Applications	0:51-1:00
Ulnar Nerve Decompression	1:01-1:05
Decompressive Fasciotomy	1:06-1:10
Tendon Transfer	1:11-1:15
Flexor Tendon Repair	1:16-1:30
Trigger Finger and De Quervain's Tendon Release	1:31-1:40
Dupuytren's Fasciotomy and Fasciectomy	1:41-1:50
Interactive Discussion of Clinical Applications	1:51-2:00
Nerve, Fascia, and Tendon Rehab Considerations	2:01-2:05
Trapeziectomy	2:06-2:10
Distal Radius Fracture Stabilization	2:11-2:15
Scaphoid Fracture Stabilization	2:16-2:25
Perilunate Fracture Dislocation Management	2:26-2:30
Kienbock's Surgery	2:31-2:35
Casts and Splints	2:36-2:45
Adaptive Equipment	2:46-2:50
Interactive Discussion of Clinical Applications	2:51-3:00

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## Distal Upper Extremity Anatomy

► Proximal to Distal

Humerus, Radius, Ulna	Elbow Joint	
Radius and Ulna	Radiocarpal Joint (Wrist)	Proximal and Distal Radioulnar Joints (PRUJ, DRUJ)
Carpals	Midcarpal Joint	Intercarpal Joints
Metacarpals	Metacarpal Phalangeal Joint (MCP)	
Phalanges	Proximal and Distal Interphalangeal Joint (PIP, DIP)	Thumb Interphalangeal Joint (IP)

Image: By LadyofHats/Mariana Ruiz Villarreal - Some of my sources: [1], Gray's Anatomy "Williams & Warwick", "Atlas der Anatomie des Menschen "Sobotta", "Anatomia del cuerpo humano "Tokuchi, Rhodin, W. et al.", and a t-shirt printed by "Yodiger - anatomie GmbH". LadyofHats, Public Domain.

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## Carpal Bones

- The 8 small bones are arranged into a proximal and distal row.
- Clockwise from Thumb:
  - Straight Line To Pinky, Here Comes The Thumb
- Counter clockwise from Pinky:
  - PTs Love Sundaes, Ten Toppings Can't Hurt

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## Normal Arthrokinematics

- Bony architecture and ligamentous stability allow the hand to sustain external loads and perform fine motor tasks.
- The wrist complex controls the length tension relationship of the extrinsic hand muscles.

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## Surgical Alteration of Biomechanics

- Surgical modifications to anatomical structures alters the geometry of the wrist and hand bones.
- Minor changes in joint congruency shift muscle-tendon paths resulting in altered biomechanics, force generation and post operative function.

Consider This

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## Surgical Technique

- Open Procedure
- Minimally Invasive
  - Arthroscopic
    - Direct visualization into joint
  - Endoscopic
    - Direct visualization into target area
  - Percutaneous
    - X-ray or fluoroscopy visualization
  - Combination Procedures

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### Types of Anesthesia

- General**
  - IV or inhaled delivery
  - Patient unconscious
- Regional**
  - Nerve block to body segment
  - Patient conscious
- Local**
  - Injection at site of surgery
  - Patient conscious

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### Wide Awake Local Anesthesia No Tourniquet (WALANT)

▶ Patient remains conscious during surgery able to actively perform motions.

Lidocaine pain relief + Epinephrine vasoconstriction = No tourniquet

Lalonde, D., Eaton, C., Amadio, P., & Jupiter, J. (2015). Wide-awake hand and wrist surgery: a new horizon in outpatient surgery. *Instr Course Lect*, 64, 249-259.

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### WALANT Benefits

- ▶ Improved patient comfort and convenience
  - ▶ No tourniquet
- ▶ Patient active participation
  - ▶ Immediate assessment and revision
  - ▶ Patient motivation
- ▶ Avoids general anesthesia
  - ▶ Minimize side effects and recovery time
- ▶ Cost effective
  - ▶ Clinic vs. inpatient procedure
  - ▶ Field vs. room sterility
  - ▶ Decreased surgical time
  - ▶ Less pre-operative testing

Lalonde, D., Eaton, C., Amadio, P., & Jupiter, J. (2015). Wide-awake hand and wrist surgery: a new horizon in outpatient surgery. *Instr Course Lect*, 64, 249-259.

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### Types of Surgery

- Nerve**
  - Nerve Repair
  - Nerve Graft
  - Nerve Transfer
  - Ganglion Cyst Removal
  - Carpal Tunnel Release
  - Ulnar Nerve Decompression
- Fascia**
  - Fasciotomy
  - Needle Aponeurotomy
  - Fasciectomy
- Tendon**
  - Tendon Transfer
  - Flexor Tendon Repair
  - Trigger Finger or Thumb Release
  - De Quervain's Release
- Bone/ Joint**
  - Trapeziectomy
  - Distal Radius Fracture Stabilization
  - Scaphoid Fracture Stabilization
  - Perilunate Fracture Dislocation
  - Kienbock's Surgery
- Ligament**
  - Scapholunate Instability

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### Nerve Anatomy

- Epineurium**
  - Encases entire peripheral nerve
- Perineurium**
  - Surrounds bundles of nerve fibers - fascicles
- Endoneurium**
  - Covers individual nerve fiber

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### Peripheral Nerve Injury

- Laceration**
  - Penetrating Trauma
  - Fracture
- Traction**
  - Athletic Activities
  - Motorcycle Accidents
  - Child birth
- Compression**
  - Ganglion Cyst
  - Myxoma
  - Lipoma
  - Decreased Tunnel Volume

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### Classification of Peripheral Nerve Injury

**Neurapraxia**

- Mild nerve stretch with focal conduction block

**Axonotmesis**

- Prolonged compression destroys the axon but not supporting structures
- Wallerian Degeneration

**Neurotmesis**

- Severe trauma completely disrupts axon and surrounding connective tissue

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### Nerve Repair

- ▶ Sharp lacerations can sever nerves requiring fascicular matching of the proximal and distal segments.
- ▶ Direct repair is performed with end-to-end epineural microsutures.
- ▶ Caution is taken when approximating the nerve to avoid strangulated or loose nerve ends of the coaptation.

Rinker, B. D. (2018). Nerve Repair Manual: A Practical Approach to Injuries and Repair in the Brachial Plexus and Upper Extremity. *Annals of plastic surgery*, 80(1), et.

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### Nerve Graft

- ▶ A primary repair may not be possible if too much tension would be created or if there is a loss of nerve length not allowing the ends to approximate.

**Autograft**

- Provides original internal scaffolding
- Medial antebrachial cutaneous
- Radial sensory branch
- Dorsal ulnar cutaneous

**Allograft**

- Host axons and Schwann cells repopulate scaffold
- Decellularized to minimize immunogenic reactions

Houshyar, K. S., Momeni, A., Pyles, M. N., Cha, J. Y., Maan, Z. N., Duscher, D., ... & Schoonhoven, J. V. (2016). The role of current techniques and concepts in peripheral nerve repair. *Plastic surgery International*, 2016.

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### Artificial Conduits

- ▶ Biologic or synthetic conduits are used to bridge the defect in the nerve to guide regeneration.
- ▶ Implants may be laced with support cells and nerve growth factor to enhance axon migration.

Arslanturani, D., Duran, T., Yucel, D., Hascirci, N., & Hascirci, V. (2014). Peripheral nerve conduits: technology updates. *Medical devices (Auckland, N.Z.)*, 7, 405-424.

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### Nerve Transfer

- ▶ A non-critical close proximity donor nerve is relocated to the recipient muscle or skin region to restore motor and/or sensory innervation.
- ▶ Slow regeneration rates and motor end plate degradation over time may preclude muscle recovery in larger motor nerve defects.

Motor	Sensory
Expendable donor from less important limb muscle	Sacrifice donor sensory distribution
Intrinsic hand function	Critical sensation for grasp

Grinsell, D., & Keating, C. P. (2014). Peripheral nerve reconstruction after injury: a review of clinical and experimental therapies. *BioMed research International*, 2014, 698256. doi:10.1155/2014/698256

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### Nerves Used for Transfer

- ▶ Preference is to utilize a nerve that innervates a synergistic muscle and is in close proximity for tension free transfer.

Damaged	Lost	Transferred
Radial	Motor wrist, finger, thumb extension	Median from FDS, PL, FCR
Median	Sensory thumb and index	Ulnar Digital Branch
Ulnar	Hand intrinsic	Median Anterior Interosseous Branch

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### Neuroma Complication

- ▶ Neuroma formation during healing can lead to sensory loss, neuropathic pain, or the need for revision surgery.
- ▶ The inflammatory reaction during healing and increased concentration of nerve growth factor leads to connective tissue hyperplasia.

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### Nerve Repair, Grafting, Transfer Rehab

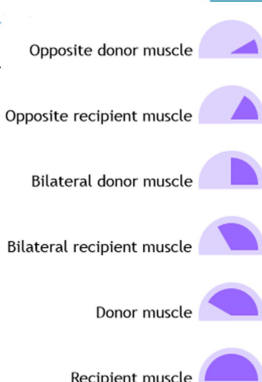
- ▶ Immobilization without tensioning the nerve site followed by gradual mobilization to prevent joint contracture.
- ▶ Hyperesthesia during healing is a positive indicator of regeneration.
  - ▶ In pediatrics manifests as biting
- ▶ Patient education on safety particularly related to hot and cold sensation.
- ▶ Alternating current electrical stimulation can be initiated once volitional twitch contraction is evident.

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### Muscle Re-education

- ▶ Biofeedback may be helpful to facilitate cortical remapping for recruitment of muscle that received nerve transfer.
- ▶ Typically rehab progression
  - ▶ Phase 1 high frequency, low load activation
  - ▶ Phase 2 progression from assisted to active then resisted exercise



Novak, C. B., & von der Heyde, R. L. (2015). Rehabilitation of the upper extremity following nerve and tendon reconstruction: when and how. *Seminars in plastic surgery*, 29(1), 73-80. doi:10.1055/s-0035-1544172

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### Compressive Neuropathy

- ▶ Nerves pass through anatomic tunnels often along with tendons and vascular structures.
- ▶ Decreased nerve conduction can result from increased volume of contents or reduced size of the tunnel.
- ▶ When conservative management fails or space occupying lesions are identified surgery may be necessary.

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### Ganglion Cyst

- ▶ A ganglion cyst is a small fluid filled sac arising from an extension of the synovial joint capsule or inflamed tendon sheath.
- ▶ Patients may be asymptomatic or present with nerve compression weakness and/or sensory impairment.

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### Ganglion Cyst Excision

- ▶ The cyst is removed along with a section of tissue near the tendon sheath or joint to minimize the risk of the cyst reforming.

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## Carpal Tunnel Syndrome

- ▶ Entrapment of the median nerve occurs beneath the flexor retinaculum of the wrist resulting in weakness.
- ▶ Motor weakness of the hand intrinsic and thenar muscles limits grasp and pinch.
- ▶ Sensory impairment involves the palmar surface and dorsal nail bed of the thumb, index, middle, and radial side of ring finger.
- ▶ Surgery is indicated when conservative management fails to relieve persistent numbness and thenar wasting is evident.

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## Carpal Tunnel Anatomy

- ▶ Tendons of the flexor digitorum profundus and superficialis along with the median nerve are encased in a synovial membrane.
- ▶ Subsynovial connective tissue is layered within the tunnel to minimize shear stress with hand motion.

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## Carpal Tunnel Release (CTR)

- ▶ Open surgical decompression to divide the transverse carpal ligament increasing the space available for the median nerve and finger flexor tendons.
- ▶ Mini-open repair may provide earlier symptom relief and return to activity, but long-term outcomes compared to standard open release are inconclusive.

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American Academy of Orthopaedic Surgeons. (2016). Management of carpal tunnel syndrome: evidence-based clinical practice guidelines. 2016.

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## Endoscopic CTR

- ▶ Endoscopic release with small ports allows incision only of the tissue contributing to the compression.

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## Ultra Minimally Invasive CTR

- ▶ Emerging techniques incorporate ultrasound guiding to visualize structures with only one tiny incision for the knife.

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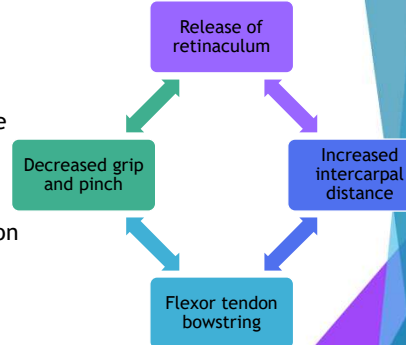
Petrover, D., Silvera, J., De Baere, T., Vigan, M., & Halmé, A. (2017). Percutaneous Ultrasound Guided Carpal Tunnel Release: Study Upon Clinical Efficacy and Safety. *Cardiovascular and interventional radiology*, 40(4), 568-575.

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## Flexor Retinaculum Reconstruction

- ▶ Research varies regarding the benefit of flexor retinaculum reconstruction or lengthening.



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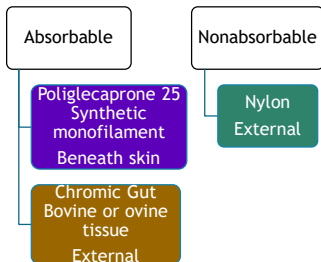
American Academy of Orthopaedic Surgeons. (2016). Management of carpal tunnel syndrome: evidence-based clinical practice guidelines. 2016.  
Lui, S., Zhang, K., Li, J., & Fu, W. (2019). Carpal tunnel release with versus without flexor retinaculum reconstruction for carpal tunnel syndrome: a short- and long-term follow-up: A meta-analysis of randomized controlled trials. *PLoS one*, 14(1), e0211369.  
Pavlidis, L., Chalidis, B. E., Demiri, E., & Dimitriou, C. G. (2010). The effect of transverse carpal ligament lengthening on carpal tunnel volumetry: comparison between four techniques. *Annals of plastic surgery*, 65(5), 490-494.

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## CTR Sutures

- ▶ The initial tensile strength of absorbable sutures diminishes as they dissolve.
- ▶ Nylon sutures require manual removal as healing of the incision occurs.



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## CTR Post Operative Splinting

- ▶ According to the AAOS, strong evidence indicates no enhancement of long-term outcomes with the use of post operative splinting.

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## CTR Complications

- ▶ Injury to palmar cutaneous or recurrent motor branch of median nerve
- ▶ Hypertrophic scarring
- ▶ Tendon adhesion
- ▶ Hematoma or infection
- ▶ Complex Regional Pain Syndrome (CRPS)
- ▶ Pillar Pain

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## Post Operative Pain

- ▶ Assess patient to determine the specific location of pain at thenar and hypothenar muscle insertions on flexor retinaculum or directly along the incision.

**P**lace  
**A**mount  
**I**ntensifiers  
**N**ullifiers  
**E**ffect  
**D**escriptors

Incision Pain

At incision site

Resolves in days to weeks

Pillar Pain

At ridge of trapezium, scaphoid tubercle, pisiform, or hook of hamate

May persist for several months

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## Complex Regional Pain Syndrome (CRPS)

- ▶ Post-operative CRPS may result in pain levels significantly exceeding pre-operative pain.
- ▶ Monitor patients for signs including:
  - ▶ Allodynia
  - ▶ Burning pain
  - ▶ Edema
  - ▶ Trophic skin changes

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## CTR Rehab

Day 2

Incision protection  
Edema control  
Tendon gliding  
Thumb and digit IP blocked AROM

Active wrist ROM

Week 3

Nerve gliding  
Scar massage and desensitization  
Therapeutic grip and pinch  
Strengthening

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## CTR Post-op Rehab Research

- ▶ Current research does not reflect a clear benefit of post-operative rehabilitation to improve outcomes.

Cohort	Interventions	Outcomes
2016 Cochrane Review	Splinting Exercise Cryotherapy Scar desensitization	Limited low quality evidence of benefit
2015 AAOS Guidelines	Supervised therapy	Moderate evidence no additional benefit

Peters S, Page MJ, Coppelieters MW, Ross M, Johnston V. (2016). Rehabilitation following carpal tunnel release. Cochrane Database of Systematic Reviews 2016, Issue 2. Art. No.: CD004158.  
American Academy of Orthopaedic Surgeons. (2016). Management of carpal tunnel syndrome: evidence-based clinical practice guidelines. 2016.

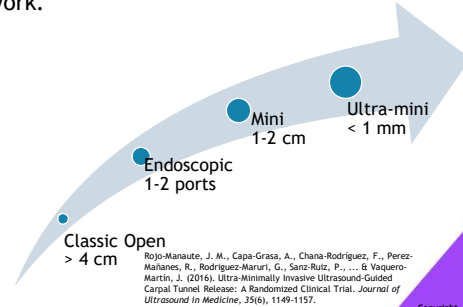
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## CTR Outcomes

- ▶ Smaller incisions result in better cosmetic results, lower pain rates, and faster return to work.



Rojo-Manaute, J. M., Capa-Grasa, A., Chana-Rodriguez, F., Perez-Marianes, R., Rodriguez-Manari, G., Sainz-Ruiz, P., ... & Vaquerio-Martin, J. (2016). Ultra-Minimally Invasive Ultrasound-Guided Carpal Tunnel Release: A Randomized Clinical Trial. *Journal of Ultrasound in Medicine*, 35(6), 1149-1157.

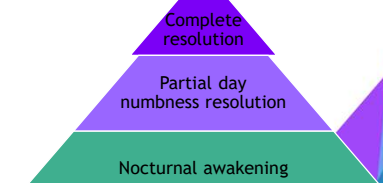
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## CTR Sensory Outcomes

- ▶ The vast majority of patients experience improvement in sensation, but the extent varies.
  - ▶ The persistence of nocturnal awakening is infrequent.
  - ▶ Percentage improvement of numbness appears to diminish with advancing age.

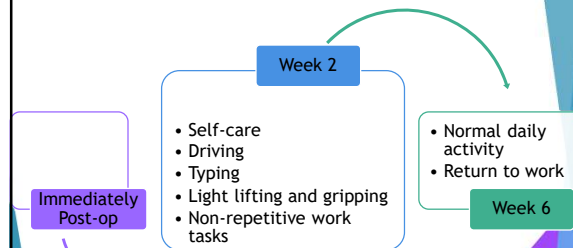


Watchmaker, J. D., & Watchmaker, G. P. (2018). Independent variables affecting outcome of carpal tunnel release surgery. *HAND*, 13(3), 285-291.

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## CTR Return to Function



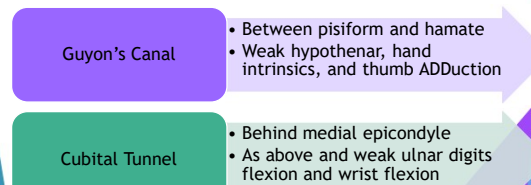
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## Ulnar Nerve Compression Syndrome

- ▶ Traumatic, overuse or space occupying lesions result altered sensation of the ring and pinky finger combined with motor impairment.



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## Cubital Tunnel Cyst

- ▶ Space occupying lesions or altered bone geometry from fracture can create compression of the ulnar nerve behind the medial epicondyle of the humerus.

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### Ulnar Nerve Decompression

- ▶ Post traumatic skeletal deformity altering geometry of the cubital tunnel may require surgical decompression.

Decompression	• Fewer complications
Anterior Transposition	• New compression point risk
Medial Epicondylectomy	• Medial elbow destabilization risk

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### Restoring Functional Fine Motor

- ▶ Tendon transfer from the thumb can restore the lateral prehension due to atrophy of index finger dorsal interossei muscle.

Bruner  
Extensor Pollicis Brevis  
Interphalangeal stability

Neviaser  
Abductor Pollicis Longus  
Requires tendon grafting

Nabuta, S., Sato, K., Kanazawa, K., Hatori, M., & Itoi, E. (2009). Effects of tendon transfer to restore index finger abduction for severe cubital tunnel syndrome. *Upsala Journal of medical sciences*, 114(2), 95-99. doi:10.1080/03009730802702602

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### Guyon's Canal Cyst

- ▶ Surgical excision is required to restore motor function to hypothenar muscles and sensation to pinky and ring fingers.

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### Guyon's Canal Decompression

- ▶ Variability in the motor and sensory branches of the ulnar nerve complicate surgery.

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### Compartment Syndrome

- ▶ Altered hemodynamics of forearm and hand fascial compartments occurs from acute trauma or chronic overuse of forearm muscles.
- ▶ Post trauma patients must be monitored for the "6Ps"
  - ▶ Pain disproportionate to injury
  - ▶ Paresthesia
  - ▶ Pallor
  - ▶ Paralysis
  - ▶ Poikilothermia
  - ▶ Pulselessness

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### Decompressive Fasciotomy

- ▶ Incisions into the fascia relieve pressure to restore perfusion to nerves, muscles, and soft tissues to avoid severe ischemia requiring amputation.
- ▶ Surgical site is often left open for irrigation and debridement in the days following initial surgery.

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### Volkmann's Contracture

► Muscle necrosis from tissue hypoxemia leading to contracture of the wrist and fingers is graded based on the Tsuge Classification.

Stage	Affected muscle	Treatment
Mild	Finger flexors	Splinting & tendon lengthening
Moderate	Wrist and finger flexors	Excision of necrotic tissue, neurolysis, tendon transfer
Severe	Wrist and finger flexors and extensors	

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### Tendon Transfer

► Tendon transfer may be indicated to restore functional hand to use after nerve injury, rupture due to fracture, or necrosis.

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### Common Transfer Muscles

- Finger flexion**
  - Extensor carpi radialis longus to flexor digitorum profundus
  - Flexor digitorum profundus side to side
- Thumb flexion**
  - Brachioradialis to flexor pollicis longus

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### Flexor Tendon Injury

► Traumatic closed or open injury lacerating **F D I P** tendons of the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS).

► Camper's Chiasm is where the FDS splits into 2 segments allowing the FDP tendon to pass through to insert on distal phalanx.

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### Zones of Injury

- Zone I** Distal to the FDS insertion near tip of finger
- Zone II** FDS insertion to distal palmar crease or MCP A1 pulley No Man's Land
- Zone III** A1 pulley to carpal ligament in palm region
- Zone IV** Carpal tunnel near wrist crease
- Zone V** Proximal to carpal tunnel

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### Tendon Healing

► Tendons receive vascular perfusion directly through vincula and through synovial sheath diffusion.

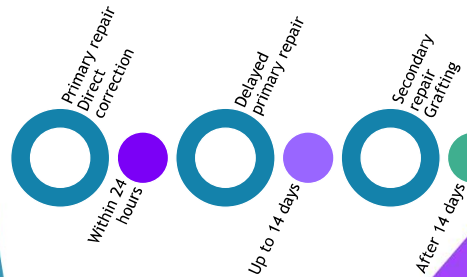
► Two pathways contribute to healing that progress is through inflammatory, fibroblastic, and remodeling phases.

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## Flexor Tendon Repair

- ▶ The zone of injury and timing of the repair influence rehabilitation outcomes.



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## Flexor Tendon Primary Repair

Retrieve proximal and distal tendon ends

Core suture to secure proximal stump

Frielich, A. M., & Chhabra, A. B. (2007). Secondary flexor tendon reconstruction, a review. *The Journal of hand surgery*, 32(9), 1436-1442.

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## Suture Techniques

- ▶ Multistrand techniques are suggested to complete the core suturing of the of the tendon ends.
- ▶ The goal is to provide strong gap resistance and fatigue strength.

Griffin, M., Hindocha, S., Jordan, D., Saleh, M., & Khan, W. (2012). An overview of the management of flexor tendon injuries. *The open orthopaedics journal*, 6, 28-35. doi:10.2174/1874325001206010028

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## Secondary Tendon Repair

- ▶ Reconstruction may be necessary when initial surgery is required to manage vascular or bony injuries, delayed presentation, or when primary repair has failed.
- ▶ Autogenous tendon graft
  - ▶ Palmaris longus
  - ▶ Plantaris
  - ▶ Extensor digitorum longus

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## Tendon Repair Splinting

- ▶ Immobilization maintains the repaired musculotendinous unit in a shortened position and prevents forceful contraction.
- ▶ Dorsal blocking splint
  - ▶ Wrist neutral to 40 degrees of flexion
  - ▶ MCP 50 to 70 degrees of flexion
  - ▶ IP extension
- ▶ Kleinert splint
  - ▶ Dorsal extension with rubber band traction
- ▶ Manchester short splint

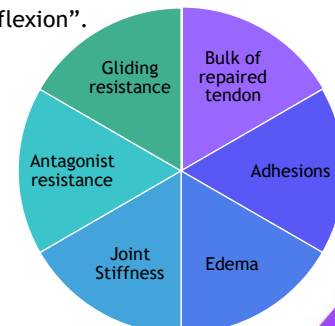
Khor, W. S., Langer, M. F., Wong, R., Zhou, R., Peck, F., & Wong, J. K. (2016). Improving outcomes in tendon repair: a critical look at the evidence for flexor tendon repair and rehabilitation. *Plastic and reconstructive surgery*, 138(6), 1055e-1058e.

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## Flexor Tendon Repair Rehab

- ▶ Timing of active rehab considers multiple intrinsic and extrinsic factors related to the “work of flexion”.



Novak, Christine B, and Rebecca L von der Heyde. "Rehabilitation of the upper extremity following nerve and tendon reconstruction: when and how." *Seminars in plastic surgery* vol. 29,1 (2015): 73-80.

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### Flexor Tendon Rehab

- ▶ Follow the physician protocol.
- ▶ Initially no passive wrist extension or finger extension, active flexion of involved tendons.
- ▶ Tendon gliding of uninvolved fingers may be permitted.

Phase 1 Splint Wound management Edema Control mobilization

Phase 2 Splint Place and hold exercise

Phase 3 Short splint Active flexion extension

Phase 4 Discharge splint Blocking exercises

Phase 5 Resistance

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### Controlled Mobilization

- ▶ Following specific active mobility protocols improves tendon healing biology, limits restrictive adhesions, and leads to increased tendon excursion.
- ▶ Duran
  - ▶ Passive finger flexion
- ▶ Kleinert
  - ▶ Passive flexion and active extension
- ▶ Early Active Motion (EAM)
  - ▶ Active flexion

Jha, B., Ross, M., & Peters, S. E. (2017). Rehabilitation following surgery for flexor tendon injuries of the hand. *The Cochrane database of systematic reviews*, 2017(1).  
Yousef, J., & Anthony, S. (2018). *Flexor Tendon Injuries. Essentials of Hand Surgery*, 21.

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### Complications

- ▶ Bowstringing
- ▶ Tendon adhesions
  - ▶ Tenolysis may be necessary
- ▶ Rupture
  - ▶ Edema and ROM considerations
- ▶ Quadrigia
- ▶ Lumbrical plus finger
- ▶ Joint contracture

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### Quadrigia

- ▶ Inability to fully actively flex the finger adjacent to a finger with a previous FDP injury.

FDP tendons common muscle belly

Over advancement of FDP tendon

Limited adjacent digit excursion

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### Lumbrical Plus Finger

Lumbricals arise from FDP tendons

- Pulls lateral bands into PIP extension
- Insert on dorsal extensor expansion
- Paradoxical extension of the DIP joint when attempting to perform full finger flexion
- Lumbricals relax for MCP flexion with IP flexion
- Tendon damage
- Lumbrical drawn proximal with flexion

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### Trigger Finger or Trigger Thumb

- ▶ Patients present with mechanical impingement “catching” of the finger locking in flexion.

- Grade I • A1 pain, tenderness
- Grade II • Catching
- Grade III • Locking passively corrected
- Grade IV • Contracture

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### Finger Flexor Pulley System

- ▶ Fibrocartilagenous metaplasia of the A1 ligamentous pulley and stenosing tenosynovitis of the ring finger and thumb at the MCP joint.

A1 Pulley	<ul style="list-style-type: none"> <li>• Outer Vascular</li> <li>• Inner Collagenous</li> </ul>
Gliding Surface	<ul style="list-style-type: none"> <li>• Fibroblasts</li> <li>• Ovid Cells</li> </ul>
Tendon	<ul style="list-style-type: none"> <li>• Avascular Side</li> <li>• Vascular Side</li> </ul>

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### Trigger Finger or Thumb Release

- ▶ Through open or percutaneous technique the A1 pulley and tendon sheath at the MCP joint is freed of fibrotic restrictions allowing the swollen tendon to glide more easily.
- ▶ Active motion confirms release with modifications possible before incision closure.
- ▶ With ROM and strengthening caution with
  - ▶ Composite wrist/finger extension
  - ▶ Repetitive gripping

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### De Quervain's Release

- ▶ Stenosing tenosynovitis of the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) from repetitive thumb motions or grasping with ulnar deviation results in radial sided wrist pain.
- ▶ The presence of a septum between the tendons and multiple slips of the APL may contribute to fibrosis.
- ▶ Endoscopic or open procedure to release the first dorsal compartment retinaculum.

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### De Quervain's Release Rehab

- ▶ The radial nerve superficial sensory branch can become inflamed or damaged during decompression surgery.
- ▶ Thumb spica splinting protects the surgical site.

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### Dupuytren's Contracture

- ▶ Patients with a genetic predisposition develop progressive palmar fibromatosis leading to contracture of the ring and pinky finger MCP joints.

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### Dupuytren's Surgical Procedures

Enzymatic Fasciotomy

Needle Aponeurotomy

Fasciectomy

- ▶ Recurrence defined as "more than 20 degrees of contracture recurrence in any treated joint at one year post-treatment compared to six weeks post-treatment."

Kan, H. J., Verrijp, F. W., Horius, S., van Nieuwenhoven, C. A., Dupuytren Delphi Group, B Selles, R. W. (2017). Recurrence of Dupuytren's contracture: A consensus-based definition. *PLoS one*. 12(5), e0164849.

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### Enzymatic Fasciotomy

- ▶ Xiaflex® is a purified microbial Collagenase Clostridium Histolyticum (CCH) that disrupts the Type I and III collagen bonds in the cords.
- ▶ Indications
  - ▶ 20\*-100\* MCP contracture
  - ▶ 20\*-80\* PIP contracture
  - ▶ 2 affected joints in the same hand

Xiaflex® <https://dupuytren-contracture.xiaflex.com/hcp/about-xiaflex/#stepThree> Copyright Jodi Gootkin 2021

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### CCH Post-Injection Protocol

Injection	Manipulation	Exercise	Recurrence
Collagenase Clostridium Histolyticum (CCH)	<ul style="list-style-type: none"> <li>• 24-72 hours later</li> <li>• MCP and IP manipulation under local anesthesia</li> </ul>	Home exercise program Splinting Short course of supervised therapy	Repeat at 30 days maximum 3 times per cord

Xiaflex® Training Guide: <https://dupuytren-contracture.xiaflex.com/public/pdf/xiaflex-dc-managed-distribution-training-guide.pdf> Copyright Jodi Gootkin 2021

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### CCH Injection Side Effects

- ▶ Monitor patient for signs of infection, nerve injury or allergic reaction.
- ▶ Some patients may experience skin tears that require bandaging.

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### Needle Aponeurotomy (NA)

- ▶ Through multiple small puncture sites, a needle divides the contracted cords and septal paths between palmar aponeurosis and dermis.
- ▶ Active range of motion can begin the day of surgery.
- ▶ Custom nighttime splint worn at night for several months may improve outcomes.
- ▶ Avoid strenuous gripping for 1 week

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### Fasciectomy

- ▶ Fasciectomy is an invasive procedure with removal of some or all of the pathologic tissue and may be accompanied by skin grafting.

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### Post Operative Fasciectomy

- ▶ Post operatively a soft dressing and splint is applied to maintain the finger in extension.
- ▶ When ROM begins avoid composite extension.
- ▶ Monitor patient for infection, neurapraxia, CRPS.

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## Dupuytren's Outcomes

Procedure	Variables	Outcome
Collagenase Injection	Primary MCP and IP ROM reached 49% at <1yr and 58% at >1yr	Short and medium term satisfactory response. Long term uncertain.
Needle Fasciotomy	50-58% recurrence 9-25% complication	Similar complication to injection
Fasciectomy	12-39% recurrence 14-67% complication	More complications than needle but less recurrence

Sanjuan-Cerveró, R., Vazquez-Ferreiro, P., Gomez-Herrero, D., & Carrera-Hueso, F. J. (2017). Efficacy of collagenase clostridium histolyticum for dupuytren disease: a systematic review. *Revista Iberoamericana de Cirugía de la Mano*, 45(8), 470-488.  
Chen, N. C., Srinivasan, R. C., Shauver, M. J., & Chung, K. C. (2011). A systematic review of outcomes of fasciotomy, aponeurotomy, and collagenase treatments for Dupuytren's contracture. *Hand*, 6(3), 250-255.

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## Rehabilitation Considerations Nerve, Fascia and Tendon Surgery

- ▶ Initial Post-op
  - ▶ Splinting
  - ▶ Wound healing
  - ▶ Edema management
  - ▶ Joint protection
  - ▶ Pain management
  - ▶ Home exercise
- ▶ Later Rehab
  - ▶ Wean splinting
  - ▶ Scar mobility
  - ▶ Protected ROM
  - ▶ Progressive strengthening
  - ▶ Functional retraining

PROTOCOL

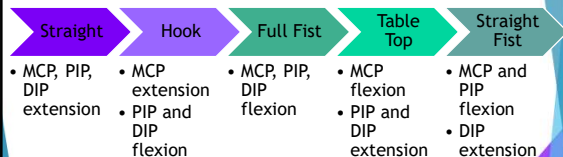
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## Tendon Gliding Exercise

- ▶ Designed to maintain free gliding between the tendons of the flexor digitorum profundus (FDP) and flexor digitorum superficialis (FDS).



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Wehbe, M. A. (1987). Tendon gliding exercises. *American Journal of Occupational Therapy*, 41(3), 164-167. Copyright Jodi Gootkin 2021

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## Post Operative Complications

- ▶ Following wrist and hand surgery, patients must be monitored for digital thrombosis that can lead to ischemia.
  - ▶ Rule out Thoracic Outlet Syndrome, Raynaud's Disease, or excessive external compression
  - ▶ Skin inspection - color and epidermolysis
  - ▶ Assess capillary refill

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## Wrist and Hand Joint Reconstruction

- ▶ Conservative treatment failure for osteoarthritis is defined as
  - ▶ 'not sufficiently effective in relieving pain'
- ▶ Unlike large joint replacement, hand surgery for osteoarthritis is focused on pain relief as opposed to functional improvement.

Kloppenborg, M., Kroon, F. P., Blanco, F. J., Doherty, M., Dziedzic, K. S., Greibrokk, E., ... & Maheu, E. (2019). 2018 update of the EULAR recommendations for the management of hand osteoarthritis. *Annals of the Rheumatic Diseases*, 78(1), 16-24.

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## Basal Joint Arthritis

- ▶ The thumb carpometacarpal (CMC) joint possesses little stability from skeletal architecture relying on ligaments and muscles to allow the motion necessary for forceful grasp and fine pinch.
- ▶ Deterioration of the ligaments allow metacarpal translation on the trapezium with shear stress forces leading to cartilage degeneration.
- ▶ Trapeziectomy is the most common initial surgical intervention.

Consider This

Judd, A. L., Weiss, A. P., Crisco, J. J., Hagert, E., Wolf, J. M., Glickel, S. Z., & Yao, J. (2013). The thumb carpometacarpal joint: anatomy, hormones, and biomechanics. *Instructional course lectures*, 62, 165-179.

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### Trapeziectomy with Ligament Reconstruction And Tendon Interposition (LRTI)

- ▶ Removal of the trapezium.
- ▶ Flexor carpi radialis (FCR) insertion relocated to first metacarpal.
- ▶ Portion of tendon utilized to reconstruct anterior oblique ligament.
- ▶ Remaining “anchovy” is placed in space from excised trapezium.

Wajon, A., Vinycomb, T., Carr, E., Edmunds, I., & Ada, L. (2015). Surgery for thumb (trapezometacarpal joint) osteoarthritis. *Cochrane database of systematic reviews*, (2).

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### Trapeziectomy Rehab

```

    graph TD
      A[Month 1  
Spica cast  
Thumb IP ROM] --> B[Month 2  
Spica splint  
Wrist and thumb ROM  
Isometric strengthening]
      B --> C[Months 3-6  
Gradual return to activity and strengthening]
  
```

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### Distal Radius Fracture

- ▶ Low energy trauma in older individuals or high force impact in younger individuals can lead to distal radius fracture.
- ▶ Physicians attempt to achieve anatomic reduction in stabilizing fracture segments.
  - ▶ Inclination
  - ▶ Dorsal tilt
  - ▶ Radial length

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### Volar Locking Plate

Earlier post operative mobility | Nerve palsy  
Tenosynovitis  
Tendon rupture  
Hardware prominence

Saving, J., Encosson, A., Ponzer, S., & Navarro, C. M. (2019). External Fixation Versus Volar Locking Plate for Unstable Dorsally Displaced Distal Radius Fractures—A 3-Year Follow-Up of a Randomized Controlled Study. *The Journal of hand surgery*, 44(1), 16-22.  
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### Intra-medullary Nail

Minimal soft tissue dissection  
Less hardware irritation  
Earlier mobility | Nerve palsy

Calkins, M., & Ipek, D. (2018). Use of Volar Locking Plate Versus Intra-medullary Nailing for Fixation of Distal Radius Fractures: A Retrospective Analysis of Clinical and Radiographic Outcomes. *Medical science monitor : international medical journal of experimental and clinical research*, 24, 602-613. doi:10.12659/msm.908762  
Jain, R. W., & Sathya, A. (2015). Defining the role of intra-medullary nailing for fractures of the distal radius: a systematic review. *The bone & joint journal*, 97(10), 1370-1376.

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### External Fixation

- ▶ Potential complications include
  - ▶ Nerve palsy
  - ▶ Pin infection
  - ▶ Loss of fracture reduction

Saving, J., Encosson, A., Ponzer, S., & Navarro, C. M. (2019). External Fixation Versus Volar Locking Plate for Unstable Dorsally Displaced Distal Radius Fractures—A 3-Year Follow-Up of a Randomized Controlled Study. *The Journal of hand surgery*, 44(1), 18-26.

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### Tight Cast Syndrome

- ▶ Closed reduction with casting is the prevailing method of management for distal radius fractures in pediatric cases.
- ▶ A poorly applied cast can result in swelling, pain, and potential progression to compartment syndrome and Volkmann's contracture.

>8 cast index value  
Loss of reduction

<8 cast index value  
Tight cast syndrome

Turgut, A., Erkuş, S., Koca, A., Payzner, L., Çiçek, A. O., B. Kalenderer, O. (2018). Analysis of the factors causing tight cast syndrome after closed reduction and casting of pediatric distal radius fractures. *Acta orthopaedica et traumatologica turcica*, 52(5), 329-333.

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### Scaphoid Fracture

- ▶ Healing is complicated by the tenuous blood supply of the scaphoid bone with proximal pole fractures at risk for delayed union, nonunion, avascular necrosis.

Herbert Fracture stability

MAYO Fracture location

Russe Healing potential

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### Scaphoid Fracture Stabilization

- ▶ ORIF or percutaneous pins or headless screws are placed.
- ▶ Bone grafting may be incorporated to bridge the fracture defect.
- ▶ Dorsal approach may allow for more accurate placement but may risk injury to extensor pollicis longus, extensor indicis, and extensor digitorum to the index finger.

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### Fracture Healing

- ▶ Scaphoid fracture healing occurs at a slower rate than other sites in the body.

1-5 days  
Inflammatory  
Osteogenic cells proliferate

4-40 days  
Reparative  
External callus formation

25-100 days  
Remodeling  
Internal and external callus bridge deficit

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### Scaphoid Fracture Rehab

- ▶ To diminish the risk of non-union, rehabilitation progressive slowly minimizing activities with vibration exposure and fall risk.

Immediate Post-op

Bulky dressing with stabilization followed by suture removal and cast

Weeks 2-6  
Cast or spica splint  
Finger and elbow AROM  
Lifting restriction 1-2 lbs  
Edema control

Week 8-10  
Wean splinting  
Scar massage  
Wrist and thumb A/AAROM  
Lifting restriction 5 lbs

Week 10+  
Discharge splint  
Strengthening  
Work conditioning

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### Perilunate Fracture Dislocations

- ▶ Alignment of the lunate is critical for correct geometry of the carpal arcs necessary for hand function and stability.
- ▶ FOOSH injuries in extreme pronation and ulnar deviation hyperextended wrist results in combined fractures and dislocations of carpals.

Lesser Arc L S Greater Arc

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### Mayfield Carpal Instability Stages

- 1
  - Scapholunate ligament disruption
  - Terry Thomas Sign
- 2
  - Capitulunate joint dislocation
  - Lunate remains aligned with radius
- 3
  - Lunotriquetral interosseous ligament disruption
  - Midcarpal dislocation
- 4
  - Dorsal radiolunate ligament injury
  - Lunate dislocation

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### Perilunate Management

- ▶ Closed reduction of the carpus followed by direct primary fracture stabilization with K-wire placement and ligament repair.
- ▶ When fracture stabilization and open reduction are unsuccessful carpectomy and arthrodesis are necessary.

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### Perilunate Post-op

- ▶ Approximately 2 weeks following surgery, the post operative splint is replaced with a short arm cast then weaned to a removable splint.
- ▶ Monitor for median nerve palsy, fracture non-union, and Kienbock's Disease.
- ▶ Despite early management many patients experience long term stiffness, weakness, osteoarthritis, in latent carpal instability.

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### Scapholunate Instability

- ▶ During functional use of the hand the scaphoid and lunate demonstrate translational kinematic motion exerting high levels of shear stress on cartilage.

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Stromps, J. P., Eschweiler, J., Knoke, M., Rennekampff, H. O., Radermacher, K., & Palkus, H. (2018). Impact of scapholunate dislocation on human wrist kinematics. *Journal of Hand Surgery (European Volume)*, 43(2), 179-186.

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### Kienbock's Disease

- ▶ Osteonecrosis of lunate often following trauma.

- Stage 1
  - Blood supply disrupted, normal X-ray or evidence of lunate fracture.
- Stage 2
  - Sclerosis of lunate
- Stage 3
  - Collapse of lunate and carpal shift
- Stage 4
  - Adjacent carpal and wrist arthritic changes

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### Kienbock's Surgery

- ▶ Revascularization surgery utilizes a vascularized graft from an adjacent hand bone or portion of the radius into the location of the deteriorated lunate.
- ▶ Radius or ulnar osteotomy may be indicated to alleviate axial loading forces at the wrist.
- ▶ Proximal row carpectomy or arthrodesis can maintain partial wrist motion and alleviate pain.

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### Casts and Splints

- ▶ Casts may be utilized to rigidly stabilize surgical repair sites.
- ▶ Splints utilized for post operative stabilization allow some expandability to accommodate swelling and visualization of the wound.
- ▶ Splints wearing schedule can be modified protect the wrist and hand as the patient regains functional use of the hand.

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### Thumb Spica Splint

- ▶ Extends from just distal to the IP joint of the thumb to the mid forearm.
  - ▶ Forearm neutral and wrist extended or neutral with thumb wineglass position and slight MCP and IP flexion.

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### Volar Splint

- ▶ Volar splint begins in the palm at the MCP joints and extends to the forearm proximal to the elbow.
  - ▶ Forearm and wrist in neutral or slight extension.

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### Ulnar and Radial Gutter Splints

- ▶ Ulnar gutter the runs from the DIP or MCP of the pinky and ring finger along the ulnar aspect up to the mid-forearm.
- ▶ Radial gutter the runs from DIP or MCP of the index and middle finger along the radial aspect to mid-forearm.
- ▶ For both forearm neutral with slight wrist extension, MCP 50° flexion, PIP and DIP slight flexion.

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### Sugar Tong Splint

- ▶ A U-shaped splint that runs from the dorsal aspect of the knuckles, around the elbow, along the volar forearm stopping at the MCP joints.
  - ▶ Elbow flexion at 90 degrees, forearm neutral and wrist neutral or slight extension.

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### Adaptive Equipment

- ▶ Utilization of equipment to perform functional and work tasks can minimize unnecessary stress on joints and decrease musculoskeletal demands to execute the task.

External Pressure	Internal Pressure
Odd shaped objects	Extremes of range of motion
Slippery surfaces	Excessive grip pressure
Tightly fit objects	Sustained positions
Small handles/objects	
Cold objects	

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- Longer lever arm**
  - Decreases muscle power and torque requirements
- Larger surface area**
  - Use palm and proximal upper extremity force
- Increase circumference**
  - Allows use of larger joints and decrease force requirement
- Use alternative joints**
  - Eliminate workload on hands
- Add stability and decrease friction**
  - Reduced muscle power and endurance requirement

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### Smoking and Healing

- Increased infection rates are noted in smokers following closed and open hand fractures.
- Electronic cigarettes have been shown to decrease hand microvascular circulation.

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Pywell, M. J., Wardworth, M., Kwasnicki, R. M., Chadha, P., Hettiaratchy, S., & Halsey, T. (2018). The effect of electronic cigarettes on hand microcirculation. *The Journal of hand surgery*, 43(5), 432-438.  
Minhas, S. V., & Catalano III, L. W. (2019). Comparison of open and closed hand fractures and the effect of urgent operative intervention. *The Journal of hand surgery*, 44(1), 55-e1.

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### Conclusion

- Research continues to explore innovative surgical techniques to restore hand kinematics and muscle function following injury.
- Understanding the complex hand anatomy will allow clinicians to understand physician protocols and apply rehabilitation techniques to restore functional hands use.

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- Which of the following changes resulting during hand surgical interventions does NOT impact biomechanics?
  - Altered hand geometry
  - Restoration of vascular supply
  - Shifted muscle-tendon paths
  - Joint congruency changes

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- How is WALANT surgery different than traditional surgery?
  - Higher cost
  - Surgical time is longer
  - No tourniquet is utilized
  - Warm arm compresses are applied

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- What surgical procedure relocates donor nerves to a target muscle or skin region to restore innervation?
  - Transfer
  - Decompression
  - Grafting
  - Repair

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4. Which of the following is NOT one of the “6P’s” when monitoring for a Compartment Syndrome?
- A. Poikilothermia
  - B. Paresthesia
  - C. Pallor
  - D. Pressure

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5. Zone I Flexor Tendon Repairs are performed on injuries located \_\_\_\_\_.
- A. Near the tip of the finger
  - B. Close to the metacarpal phalangeal joint
  - C. In the palm
  - D. Near the wrist crease

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6. Needle Aponeurotomy (microscopic punctures in the palmar fascia) is used to treat which condition?
- A. Carpal Tunnel Syndrome
  - B. Dupuytren’s Contracture
  - C. Scaphoid Necrosis
  - D. Trigger Finger

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7. Which of the following is NOT a position used in tendon gliding exercises?
- A. Table Top
  - B. Hook
  - C. Opposition
  - D. Straight Fist

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8. Trapeziectomy is performed on what joint?
- A. Thumb Carpometacarpal
  - B. Scapholunate
  - C. Distal Radioulnar
  - D. Interphalangeal

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9. A volar locking plate is utilized during open reduction internal fixation to stabilize a fracture of what bone?
- A. Lunate
  - B. Radius
  - C. Trapezium
  - D. Ulna

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10. What is the name of the U-shaped splint that runs from the dorsal aspect of the knuckles, around the elbow, along the volar forearm stopping at the MCP joints?

- A. Thumb Spica
- B. Ulnar Gutter
- C. Sugar Tong
- D. Radial Gutter

127

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