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Conservative management for thumb CMC osteoarthritis

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Learning Objectives:

- Participants will be able to identify normal thumb mechanics and signs related to osteoarthritis of the thumb CMC
- Participants will be able to state 3 functional limitations related to thumb osteoarthritis
- Participants will be able to identify at least 3 evidence based methods of treating thumb CMC pain and to improve functional use

Hand osteoarthritis

- Osteoarthritis- (OA) a degenerative condition of a joint cartilage and bone causing pain and stiffness
- The most common site of OA is in the hand
- The most commonly described symptoms are pain, loss of grip strength and loss of hand function
- Currently there is no cure for hand arthritis

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The Thumb

- A pillar of the hand
- Contributes to nearly 40 - 60% of hand function
- Essential for power grip and precision
- Largest cortical area than other digits
- Complex anatomy & biomechanics

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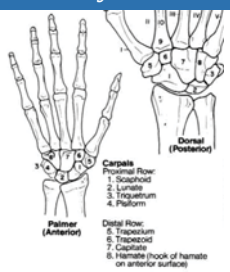
Anatomy – Thumb Complex



- Occupies the most radial position of the hand.
  - Distal phalanx
  - Proximal phalanx
  - 1st Metacarpal
  - Trapezium
  - Scaphoid

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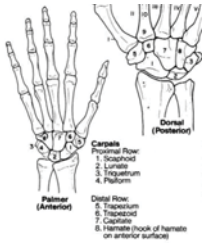
Terminology



- Interphalangeal joint (IP)
- Metacarpal phalangeal joint (MP)
- Carpal metacarpal joint (CMC)
- Scaphoid-trapezium joint (ST)

IP Joint

- Is a simple hinge joint
- Surrounded by collateral ligaments on both the radial and ulnar sides- prevents movements in a lateral direction
- Has 2 motions
  - Flexion- produced by the flexor pollicis longus
  - Extension- produced by the extensor pollicis longus

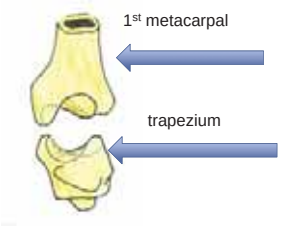
MP Joint

- Loose hinge joint
  - Has flexion, extension, slight rotation and abduction which improves precision pinch functions
- Collateral ligaments – radial & ulnar
- Tough & flexible accessory collateral ligaments.
  - These attach to a strong volar plate

All are important to provide stability to the thumb as gripping and pinching occurs

The First Metacarpal

- Articulates with trapezium
- Provides unique circumduction
- Ability to oppose each 4 fingers
- Attachment site for 3 muscles



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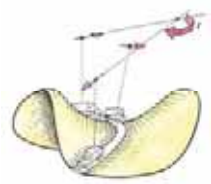
The Trapezium- A Carpal Bone

- A saddle type of configuration
- Concave & convex articulating surface in different planes
- Permits two planes of motion



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The Trapezio-Metacarpal Joint-AKA CMC

- Positioning thumb in space
- Responsible for rotation & opposition
- This joint has the most mobility of all the digits

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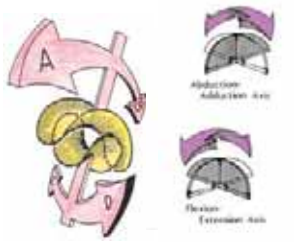
CMC Kinematics

- Camshaft effect during opposition
- Components of supination with extension
- Pronation with flexion



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CMC

- Inherently unstable because of its anatomic location
- Lacks **strong** supporting ligaments
- Lacks fixed axial base

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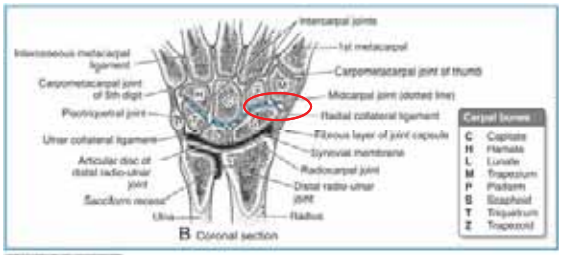
Scaphoid-Trapeizum Joint



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Advanced OA of STT joint

CMC Stabilizers- Extensive Ligament Network

- What is the role of a ligament?
  - Limits and regulates the range and direction of joint motion
  - Contributes to normal alignment of the joint
  - Helps control and disperse forces produced by activated muscles

Role of ligaments

- Cadaver studies suggest that CMC joint ligament innervation may correlate with proprioceptive and neuromuscular changes in OA pathophysiology
- Afferent information from the ligament mechanoreceptors can influence neuromuscular control
- The precise role of mechanoreceptors in supporting ligaments versus supporting muscles in the thumb CMC joint has not been determined.

Ligaments- The Stabilizers of the Thumb

- 7 ligaments stabilize the 1st metacarpal
- 9 ligaments stabilize the trapezium
- *Anterior oblique ligament (AOL) or Beak ligament* on the palm side holds the thumb as it twists on the trapezium
- *Dorsal radial ligament* prevents the thumb from slipping off the carpal bones

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AOL or Beak Ligament

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Beak and Dorsoradial Ligaments

Anterior View

Posterior View

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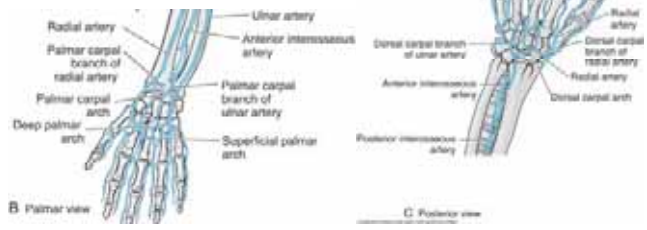
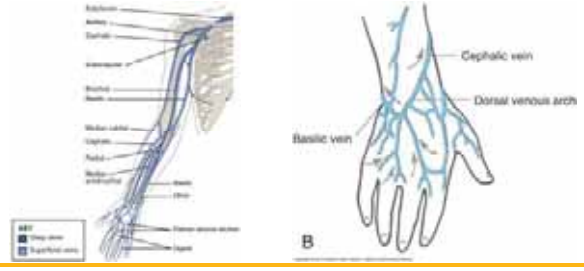
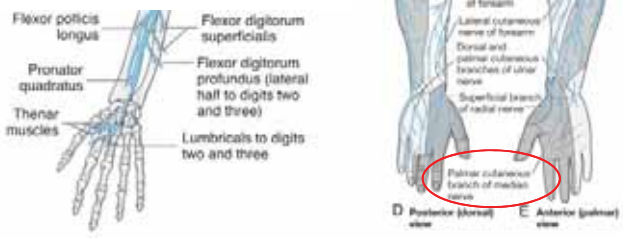
Blood Supply



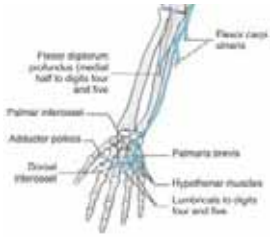
Venous Return



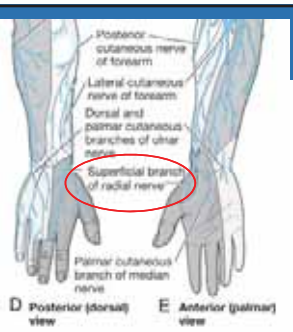
Median Nerve



Ulnar Nerve



Radial Nerve



8 Thumb Muscles Intrinsic and Extrinsic

- Flexor pollicis longus
- Extensor pollicis longus
- Extensor pollicis brevis
- Abductor pollicis longus
- Abductor pollicis brevis
- Adductor pollicis
- Opponens pollicis
- Flexor pollicis brevis

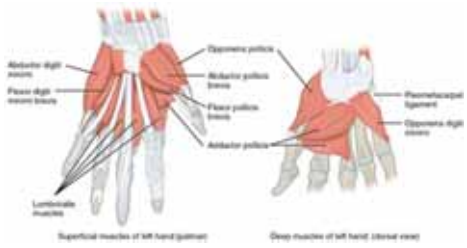
Moving the Thumb

- Extension (radial abduction)- both Radial nerve, extrinsic
  - Extensor pollicis longus
  - Extensor pollicis brevis
- Flexion
  - Flexor pollicis longus- Median nerve, extrinsic
  - Flexor pollicis brevis – intrinsic
    - Superficial head- Median nerve
    - Deep head- Ulnar nerve

Moving the Thumb

- Abduction (palmar abduction)
  - Abductor pollicis longus- Radial nerve, extrinsic
  - Abductor pollicis brevis- Median nerve, intrinsic
- Adduction
  - Adductor pollicis – Ulnar nerve, intrinsic
- Opposition
  - Opponens pollicis – Median nerve, intrinsic

Muscles of the Thumb



Finger Muscle that Moves the Thumb

- 1st Dorsal Interosseous
- This is a bipennate muscle that has 2 action:
  - Abducts the index finger to the thumb
  - Brings the thumb in towards the index finger providing more stability at the CMC

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Mechanism of Opposition

- Mechanism – Complex
- Different group of muscles act at various intervals of motion
- Movement occurs in three components

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Mechanism of Opposition

- Projection – performed by abductor pollicis brevis
- Adduction – transverse fibers of adductor pollicis
- Rotation & pronation – oblique fibers of adductor, superficial flexor pollicis brevis & finally opponens pollicis

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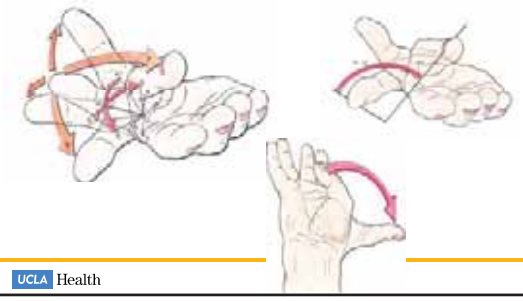
Mechanism of Opposition



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What is considered functional range of motion of the thumb?

- The FROM of the hand joints was evaluated for each subject by recording the hand posture while performing a set of ADL's selected to cover all the areas of the ICF chapters most directly related with hand function

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Static postures used to determine the active range of motion of the hand joints

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ADL's selected

- Reading
- Writing
- Talking on phone
- Computer use
- Handling a book
- Using a key
- Opening a door
- Turn on faucet
- Brushing teeth
- Putting toothpaste on a toothbrush
- Combing hair
- Cutting food
- Using a spoon

Conclusion:

- Functional active range of motion was 5 to 28 degrees *less than* available AROM depending on the joint and movement performed.






Forces Generated with Tip Pinching

	IP	MP	CMC
Tip pinch	2.36	4.45–6.61	6.44–13.42
Lateral shear	0.19–0.27	1.87–2.08	1.42–2.10
Axial rotation	1.21–2.63	2.38–6.61	7.83–23.6

The amount of force applied to the cmc to stabilize a load was between ***6-24* times the applied load depending on the posture of the thumb

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The Colditz Tear Test

The progressively imbalanced posture of the left thumb is observed as increasing thicknesses of the paper are torn

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Arthritic Changes of the Thumb

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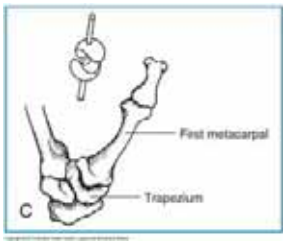
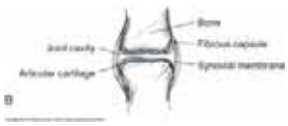
Healthy Joint Space



Slow Deterioration as Arthritis Progresses



Later Stages

Pathomechanics of CMC

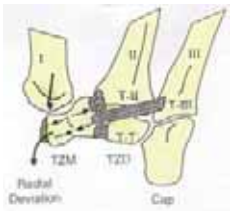
- What causes arthritis of the thumb CMC?
  - The forces that are placed through the tip with pinching are magnified 6-24 times as they travel through the joints on the way to the CMC
  - The joint is inherently unstable due to its anatomical location
  - It has a relatively poor ligamentous stability
  - Over time, after repetitive and sustained loading the joint begins to wear down and ligament stability is challenged

Pathomechanics of CMC

- Some muscles start to become overused (adductor pollicis) and others are no longer recruited with pinching tasks
- Over time ligaments fail to properly support the joint and it subluxes
- As the thumb continues to be used for functional use, it will start to develop abnormal mechanics up the chain involving MP and IP mechanics
- MP can start to hyperextend and IP hyperflex with pinching

Articular Changes at the CMC Joint

- Greater loads on the thumb progressively cause ligamentous laxity



Articular Changes at the CMC Joint

- Zigzag collapse of the thumb is associated with radial deviation & extension
- Forces magnified by the adductor pull at MP & extensor & abductor pull at the radial CMC

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Classification of CMC

- Stage I
  - Precedes cartilage degeneration
  - May see joint space widening if the patient has synovitis

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Classification of CMC OA

- Stage II
  - Small osteophytes
  - Subchondral sclerosis
  - Subluxation less than 1/3 rd of metacarpal base
  - Joint narrowing

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Classification of CMC OA

- Stage III
  - Prominent trapezial osteophytes
  - Subchondral sclerosis
  - 1/3rd subluxation of metacarpal base

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Classification of CMC OA

- Stage IV
  - Loss of total joint space
  - Trapezial osteophytes
  - Subluxation of MC base and subchondral cyst

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Positive Shoulder Sign

- Dorso-radial prominence
- Adduction contracture
- MP hyperextension

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Factors Associated with Thumb OA

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Thumb OA

- It can begin at any age
- It is more common in women than men
- Generalized laxity & joint hyper-mobility - associated factors in younger females
- Hereditary component , connective tissue disorders
- Previous trauma to the joint
- Activities or jobs that put high stress on your thumb

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Spiral of Thumb Pain and Loss of functional use

- Ligament laxity can cause instability
- Instability can cause deformity
- Effective thumb use requires both flexibility and stability

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Loss of joint position sense

- Looked at 29 thumbs with CMC OA and 29 'healthy thumbs'
- Performed an active joint position test which was used to measure proprioception function
- For comparison, participants with unilateral CMC OA were matched against themselves, whereas those with lateral CMC OA were age matched with a healthy participant.

Active joint position test

- Measurement of the target position for carpometacarpal joint position sense test.
- With participant's vision occluded, the examiner passively placed her or his thumb CMC joint into 30° of abduction.
- Measurements were recorded using the goniometer placement shown

Results

- Data analysis was performed to compute the mean error of JPS between the 2 groups
- The mean positional error measured from subjects with CMC OA was 9.53 degrees compared with 1.32 degrees for the age-matched healthy subjects.

What does this mean ?

- Results of this study suggest the JPS test may be clinically useful for evaluating SM function and setting rehabilitative goals for patients with CMC OA for the purpose of restoring optimal function.
- There is no consensus of how to effectively treat this deficit with the thumb yet
- It is fair to extrapolate that fine motor coordination can be impaired based on these findings

Functional Deficits

- Opening jars
- Turning keys
- Opening gas cap on car
- Removing credit cards from machines
- Opening water bottles
- Picking up grocery bags
- Loss of sleep
- Difficulty driving
- Difficulty gardening
- Pain with food preparation

Functional Deficits

- Difficulty writing, texting, using the computer
- Difficulty opening packages, jewelry clasps
- Difficulty using tools-screwdriver
- Turning door knobs
- Pain with holding a book or newspaper
- Using scissors
- Needlepoint, knitting, crochet
- Shaking hands

Evidence based conservative management strategies

What are the patient's goals?
Pain reduction?
Improved functional use?
Grip strength?

What Does the Evidence Say?

- i. Modalities
- ii. Joint protection principles
- iii. Adaptive equipment
- iv. Topicals
- v. Stretching/ strengthening/ stability exercises
- vi. Orthotics

Modalities- Moderate to Weak Evidence

- Heat and cold can be used for short term pain reduction
- Paraffin wax baths combined with exercise is effective for short term effects
- Magneto-therapy improves pain and function at short term follow up
  - How does this work? The mechanism of action is based on the flow of electrical charges and the movement of the ions within the cell

Joint Protection Principles

- Includes education in altering working habits, use of proper joint and body mechanics by applying ergonomic principles, use of assistive devices, and modifying functional performance and environment
- Goal- to reduce loading on articular cartilage, strengthen muscle support, and improve shock-absorbing capabilities of joints.

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Joint Protection Basics

- Respect pain – be mindful of when your hands are starting to hurt, and change positions, take a break or stretch
- Avoid sustained postures when using your hands and thumbs. Ex. Texting, holding a newspaper or book
- Use the bigger joints to do the work- carry bags on your forearms rather than in your hands. Push yourself up from a seat with your palms, not your knuckles.

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Joint Protection Basics

- Use adaptive devices/equipment when possible
- Maintain joint motion and muscle strength – stay active!
  - It may be the last thing you want to do when you are in pain, but if you don't exercise muscles become weak and pain can increase. Not moving your joints makes them more stiff, weak muscles cannot support your joints.

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Adaptive Equipment

- Book holders, playing card holders, jar openers, Dycem, large handled utensils, foam over pens, toothbrushes, electric toothbrushes, easy action scissors, EZ-dose pill boxes, compression gloves, rocker knife,

Arthritis Foundation Ease of Use®

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Topicals

- Volteran
  - Contain the prescription NSAID diclofenac, approved by FDA
- Salon Pas patches
  - Contains methyl salicylate
- CBD oils - Cannabidiol
  - Act at peripheral sites and bond to the CB1 and CB2 receptors. Local analgesic actions of agonists for CB2 receptors include the inhibition of mast cell function and inflammatory pain.

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Topicals

- Biofreeze- contains menthol 3.5%
- Capsacin
  - Derived from hot chili peppers
  - Interacts with sensory afferent receptors and desensitizes the channels
  - There was a 38% improvement with 0.025% capsaicin patch in comparison to 25% relief with placebo. The analgesic effect lasted throughout the 4–8 weeks of follow-up.

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Stretching Exercises-

- Web space release of the tight adductor
  - Use a chip clip 3-5 minutes
  - Or manual release

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Frequency? Duration?

- More than 2-3 times a week with most gain noted with daily stretching
- Soft tissue stretches more effectively when it is warmed
  - Hot packs, hot water, paraffin baths, light aerobic warm up
- Intensity: go to the point of mild discomfort or tightness
- Time: older persons may benefit from longer time frame stretching- 30-60 seconds

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Stability Exercises

- Utilizes the muscles of the thumb to provide proper and stable position of the thumb.
  Must be able to identify and recruit:
  - Opponens Pollicis
  - Abductor Pollicis Brevis/Longus
  - Extensor Pollicis Brevis
  - Flexor Pollicis Brevis
  - 1st Dorsal Interossei

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The Position of Stability is a "C" Shape

- This places the CMC in the best alignment to accept loads
- Activates muscles responsible for stabilizing the CMC

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Adding Some Resistance

Start with thumb in adduction

Move thumb out into abduction

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Find your 1st Dorsal Interosseous

- Place a rubber band around all fingers
- Keep all fingers straight and move index towards the thumb
- Palpate this muscle in the 1st web space

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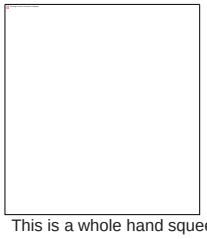
Stability Exercises

- Similar to the way the rotator cuff of the shoulder provides stability to the shoulder
- *Muscle re-education* necessary prior to strengthening
- May require Functional Electrical Stimulation
- Need to be done in pain-free manner

Stability Exercises



This is a whole hand squeeze – isometric contraction

Activating your Opponens Pollicis

Roll your thumb so your thumbprint is on the surface of a bottle or tennis ball

Stability Exercises

- Isometric contraction-
  - To encourage thumb pronation
  - Index and middle fingers lifted off the ball with bunny ears- activating the 1st dorsal interosseous
  - Both muscle groups stabilize the CMC

Stability Exercises

- While supporting the CMC in proper alignment
  - Gentle thumb isometric pinch
  - Index finger presses up into extension and then abducted away from the middle finger.

Frequency ? Duration?

- Individually prescribed
- American College of Sports Medicine recommends:
  - 40-50% of maximum pain free effort for 5 seconds – 10-15 repetitions every other day

Hands on Lab

- Short opponens orthotic fabrication
- Kinesiotaping

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Goals of Orthotic Use:

- Reduce pain and inflammation
- Rest and support the weakened structures
- Position the involved joints in optimum alignment
- Help prevent or minimize joint deformities
- Improve functional use of the hand

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Over the Counter vs. Custom Made

- Multiple studies found no difference in the type of brace used and its effects on pain relief
- Choose one the patient will wear and supports their condition

Pictures courtesy of Performance Health

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To Include the MP or Not ?

- Visual observation of patients pinch will help decide if the MP needs to be included to provide proper stability to the thumb with pinching
- Watch for MP hyperextension or collapse

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User perspectives on orthoses for thumb carpometacarpal osteoarthritis

- Purpose:

To investigate user perspectives and experiences with 2 types of CMC OA orthoses

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Results- 5 central themes were identified

- **Stabilizer**-to stabilize the joint to diminish pain- most common
- **Tool**-an assistive device to enable performance of heavy tasks
- **Healer**-an instrument to cure the osteoarthritis
- **Preventer**-to protect deterioration of the cartilage
- **Nuisance**- some did not find it useful in treating their symptoms

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Results

- Push- Ortho-Thumb –Brace was noted to have better appearance and ability to do more activities than it's counterpart.
- The custom made orthotic provided better support and ability to tolerate more strenuous activities
- The main theme was related to the users' understanding of the disease process and the working mechanism of the orthoses and affected the patterns of usage and orthosis preference.

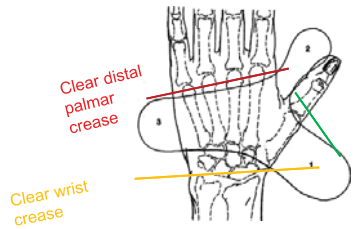
Conclusion

- *For clinicians, it is important to inquire after the patient's knowledge on disease processes and on their knowledge about orthosis working mechanisms because this seems to influence therapy adherence and patient satisfaction.*
- *…health professionals should take into consideration these user perspectives to optimize treatment adherence and individual treatment outcome.*

Orthotic Implications

- Need to clear the distal palmar crease to make a fist
- Need to clear the wrist crease to bend your wrist
- Need to clear the IP of the thumb to bend the tip

Orthotic Fabrication- Short Opponens



Needs to allow tip to bend and oppose index finger

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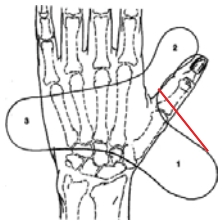
The Basic Pattern- add some room for the MP



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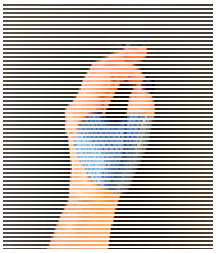
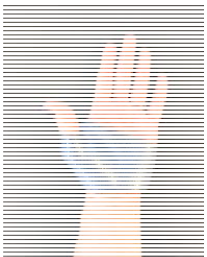
Orthotic Fabrication- Short Opponens





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Orthotic Material Used Today

- Aquaplast-T watercolors, 1/16" thick and is perforated (13%)
  - Coated for a temporary bond
  - Moderate resistance to stretch, moderate drape and good conformability
  - 100% memory
  - Ideal for hand / finger based orthotics or for ones that need frequent reheating

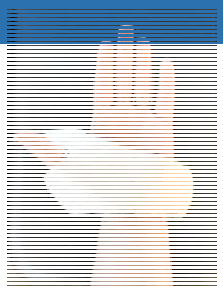
Drawing a Pattern

- Mark the proximal border just distal to the wrist crease
- Mark the distal border at the thumb IP flexion crease and distal palmar crease
- Connect the lines adding 1-1 ½ inches along the ulnar border

Connect the Lines and Cut it out

Refine the Pattern

- Cut it out and place it on the patients hand
- Make sure you are able to see the creases to allow full finger motion, thumb IP flexion and wrist motion



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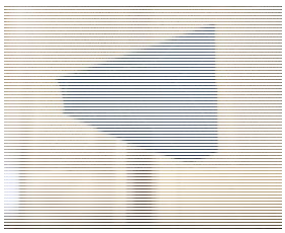
Trace and cut out the Pattern

- Trace the pattern on to the orthotic material
- Place the material in the splint pan for about 10-15 seconds, checking it frequently
- Remove the material and cut out the pattern

UCLA Health 101

2 Dips into the Pan



UCLA Health 102

Ready to Place on the Patient?

- Make sure your patient is positioned with elbow on the table, with thumb in abduction and opposing the index, making a “C” shape
- Dip the material in the splint pan again, after about 20 seconds, remove it , blot dry the water and gently form it on the patient

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Final Touches

- Assess the fit
- Make sure all creases are cleared and material is smooth along the edges
- Heat and adjust those areas for comfort
- Apply straps and Velcro

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Clinical Pearl

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Wearing schedule?

- Colditz recommended the CMC orthosis to be worn full time for the initial 2-3 weeks, followed by wearing the orthotic device during activities to prevent joint irritation or to reduce symptoms after such an irritation had occurred.
- She also mentioned wearing the orthotic when sleeping and on and off during the day with stressful activities.

Kinesiotape

What Does Kinesiotape Do?

- The lifting action of the Kinesiotape relieves pressure on pain receptors directly under the skin, allowing for both immediate and lasting relief.
- Chronic pain can be improved by the sensory stimulation of other types of nerve fibers.
- Provides gentle support to joints

Kinesiotape- Video

Taping for Joint Support

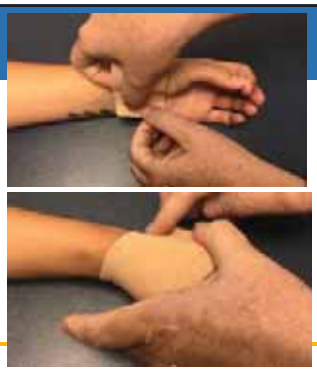
- Cut 2 strips about 4 inches long, round the corners
- Place the patients hand in neutral
- Remove backing of one strip of tape
- Anchor the first inch to the base of the thumb on the palmar side

Taping

- Position the CMC joint in abduction
- Pull the paper off the tape and lay it down with a 50-80% stretch to provide support
- Tack down the last inch near the 2nd metacarpal

Taping

- Position the 2nd strip of tape about 1/2" below the 1st strip
- Anchor the first inch or so
- Use 50-80% stretch across the joint
- Anchor the last inch across the 2nd metacarpal



UCLA Health 112

What's in your arthritis tool box?

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Arthritis tool box

- Skeletal model of the hand
- Patient educational handouts with images explaining the diagnosis and treatment options
- Samples of prefabricated orthoses in different sizes for determining proper fit

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Arthritis tool box

- Adaptive equipment such as spring-loaded scissors, jar openers, pens, and grips, etc. to relieve strain on arthritic joints
- Tubular silicone compression sleeves for protection of fragile or painful IP joints

Arthritis tool box

- Chip clip (spring-loaded clip used for keeping food bags closed) to apply pressure to a tight thumb adductor muscle in preparation for stretching
- Rubber bands for isometric CMC exercises while performing contract relax or gentle thumb extension exercises
- Self-adherent elastic tape used to support painful joints either via buddy taping or circumferential wrapping

Questions?

- Thank you very much!
- Feel free to contact me
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References

1. S. de Raedt, M. Stilling, M. van de Giessen, G. J. Streekstra, F. M. Vos and T. B. Hansen. A three-dimensional analysis of osteoarthritic changes in the thumb carpometacarpal joint . J Hand Surg Eur Vol 2013

2. Valdes, K., & Marik, T. (2010). A systematic review of conservative interventions for osteoarthritis of the hand. Journal of Hand Therapy, 23(4), 334-351.

3. Bertozzi, L., Valdes, K., Vanti, C., Negrini, S., Pillastrini, P., Villafan, J. Investigation of the effect of conservative interventions in thumb carpometacarpal osteoarthritis: systematic review and metaanalysis. 2014: Disabil Rehabil; 1–19

References

4. O'Brien VH, Giveans MR. Effects of a dynamic stability approach in conservative intervention of the carpometacarpal joint of the thumb: a retrospective study. J Hand Ther. 2013; 26:44-51.

5. McGee, C., O'Brien, V., Nortwick, S., Adams, J., Van Heest, A. First dorsal interosseous muscle contraction results in radiographic reduction of healthy thumb carpometacarpal joint. JHandTher 2015

6.O'Brien VH, Giveans MR. Effects of a dynamic stability approach in conservative intervention of the carpometacarpal joint of the thumb: a retrospective study. J Hand Ther. 2013; 26:44-51.

References

7. Jack, J & Estes, R. (2010) Documenting Progress: Hand Therapy Treatment Shift From Biomechanical to Occupational Adaptation. American Journal of Occupational Therapy, January/February 2010, Vol. 64, 82-87. doi:10.5014/ajot.64.1.8

8. Spaans, A. J., van Minnen, L. P., Kon, M., Schuurman, A. H., Schreuders, A. R., & Vermeulen, G. M. (2015). Conservative treatment of thumb base osteoarthritis: A systematic review. *Journal of Hand Surgery*, *40*, 16–21

References

9. Halilaj, E., Moore, D. C., Laidlaw, D. H., Got, C. J., Weiss, A. P., Ladd, A. L., & Crisco, J. J. (2014). The morphology of the thumb carpometacarpal joint does not differ between men and women, but changes with aging and early osteoarthritis. *Journal of Biomechanics*, *47*, 2709–2714

10. Albrecht, Jan (2015) Caring for the painful thumb. More than a "splint" Printed by Corporate Graphics

References

11. DeMott, Lori (2017) Novel isometric exercises for the dynamic stability programs for thumb carpal metacarpal joint instability. Journal of Hand Therapy, 30, 372-375

12. Verónica Gracia-Ibáñez MSca,, Margarita Vergara PhDa, Joaquín L. Sancho-Bru PhDa,Marta C. Mora PhDa, Catalina Piqueras MD. (2017) Functional range of motion of the hand joints in activities of theInternational Classification of Functioning, Disability and Health. Journal of Hand Therapy, 30, 337-347

References

- 13. Adele Ouegnin OTD, OTR/L *, Kristin Valdes OTD, OTR/L, CHT. (2019) Joint position sense impairments in older adults with carpometacarpal osteoarthritis: A descriptive comparative study. Journal of Hand Therapy
- 14. Colditz JC.Dynamic loading posture of the thumb: The Colditz Tear Test. J of Hand Ther. 2013; 26,(4): 360–362

References

- 15. Johann S. Grüschke MD a,b , Heleen A. Reinders-Messelink PhD a,b , Anna E. van der Vegt MSc a , Corry K. van der Sluis MD, PhD, User perspectives on orthoses for thumb carpometacarpal osteoarthritis. (2019) Journal of Hand Therapy Vol 32. 435-443

- 16. Colditz JC. The biomechanics of a thumb carpometacarpal immobilization splint: design and fitting. J Hand Ther. 2000;13(3):228e235.

References

- 17. Verónica Gracia-Ibáñez, Margarita Vergara, Joaquín L. Sancho-Bru, Marta C. Mora, Catalina Piqueras, Functional range of motion of the hand joints in activities of the International Classification of Functioning, Disability and Health (2017) Journal of Hand Therapy. Vol 30. 337-347

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