How Extensor Tendons Differ from Flexor Tendons

- Anatomy more complex
- Tendons are flatter, more superficial, largely extrasynovial
- Can rapidly adhere to underlying bones and joints
- Often heal with a lag secondary to longer excursion pull
- Weaker than digital flexors

Dorsum of hand revealing extensor tendons of Zones 5-7

Muscle/Tendon Functions

- MP Extension: RN
  - Extensor Digitorium Communis (PIN)
  - Extensor Indicis Proprius (PIN)
  - Extensor Digitii Quinti Minimi (PIN)

Muscle/Tendon Functions

- PIP extension: UN, MN, RN
  - Interossei: UN
  - Lumbricals: MN & UN
  - ED, EIP, EDM: RN
- DIP extension: RN
  - DIP extension is the combined action of ED, lateral bands, and tenodesis effect of spiral oblique retinacular ligament
  - The terminal extensor tendon serves to extend the DIP joint in synchrony with the PIP joint
Muscle/Tendon Functions: Thumb

- Thumb CMC extension/abduction: RN
- 3. Abductor Pollicis Longus (PIN)
- 4. Extensor Pollicis Brevis (PIN)
- 5. Extensor Pollicis Longus (PIN)
- Abductor Pollicis Brevis (Median N)

- Thumb MP extension:
  - Extensor Pollicis Brevis
- Thumb IP extension:
  - Extensor Pollicis Longus

Extensor Tendon Healing

- Vascular mesenteries, called mesotendons, (similar to the vinculae in flexor tendons) carry blood to the extensor tendons from branches of the radial and ulnar arteries and vessels of the deep palmar arch.
- Synovial fluid also provides nutrition to the extensor tendons, especially under the extensor retinaculum.

Digital Extension

The extensor mechanism is comprised of both extrinsic and intrinsic systems.

- The extrinsic system is radial nerve innervated.
- The intrinsics are median and ulnar nerve innervated.
- The precise length relationships between the central slip, lateral band, terminal tendon, and the interweaving of fibers make restoration of extension difficult.

Supporting Ligaments: ORL

- **Oblique retinacular ligament (ORL)**
  - Origin: on the flexor tendon sheath at P1
  - Insertion: dorsally on P3, lateral to the terminal extensor tendon
  - Taut w/PIP extension
  - Assists the initial motion of DIP extension

Supporting Ligaments

- **Transverse retinacular ligament** extends from the lateral bands to the flexor tendon pulley, encompassing the PIP laterally. It prevents dorsal displacement of the lateral bands and provides additional stability to the PIP joint.
Supporting Ligaments

- **Triangular ligament**
  - is located over the dorsum of the middle phalanx, and serves to support the lateral bands in place dorsally, preventing volar displacement. It connects the converging lateral bands over the dorsal middle phalanx.

Lumbrical Action

- Extend the IP joints and simultaneously flex MCPs of the 2-5th digits
- Extend IP joints when MCPs are flexed due to their insertion into extensor expansion

Interossei Action

- **Dorsal Interossei:**
  - Abduct I, M, R
  - Assist in flexion of MCP joints and extension of IPs
- **Palmar Interossei:**
  - Adduct I, R, S
  - Assist in flexion of MCP joints and extension of IPs

Extensor Tendon Zones: Digits

- Zone 1: DIP joint
- Zone 2: Middle phalanx
- Zone 3: PIP joint
- Zone 4: Proximal phalanx
- Zone 5: MPs
- Zone 6: The dorsal hand, distal to the extensor retinaculum
- Zone 7: Extensor retinaculum
- Zone 8: Proximal to the retinaculum
- Zone 9: Intramuscular portion of tendon
- Zone 10: Forearm muscle bellies

Extensor Tendon Zones: Thumb

- Zone T1: IP joint
- Zone T2: Middle phalanx
- Zone T3: MP joint
- Zone T4: 1st metacarpal
- Zone T5: Carpus

ZONES 1 & 2
Pathoanatomy

- Closed rupture or laceration of terminal extensor tendon over DIP
- Mallet, cricket, baseball finger, drop finger
- Unable to actively extend DIP joint, but passively correctable when acute.
- Most common cause is sudden flexion force to extended finger but can be a trivial incident.

Mallet Fracture Classification

- I: Closed w/ or w/o bony avulsion
- II: Direct laceration at DIP (open)
- III: Trauma w/loss of skin, tendon, bone
- IV: Significant dorsal lip fracture

Mallet Fracture (Avulsion)

Nonoperative Management

- Continuous DIP splinting 6-8 weeks in slight hyperextension
  - Alumafan
  - Stack splint
  - Thermoplastic splint
- Bony mallet: DIP 0°
- PIP should not be immobilized in splint
- Weaning schedule

Mallet Finger/Swan Neck Deformity

Sequence of a Swan neck deformity due to distal tendon rupture.

- Extensor tendon slides proximally due to loss of the distal insertion.
- Slack on the ORL and lateral bands allows them to displace dorsally into PIP hyperextension.
- DIP continues to flex further due to increased difficulty flexing the PIP joint.

If Swan Neck Deformity Develops

- Utilize a swan neck splint that limits PIP full extension by 10-15°
- Can be used concurrently with DIP splint if PIP hyperextension is noted
- Prevents lateral bands from tightening dorsal to the axis of motion and helps the extension force to go distally to the DIP joint

Combination figure 8 splint with mallet splint
Operative Management
- Used with more complex injuries
  - Open injury
  - Bony fracture fragment >30% of articular surface
  - II-IV on classification scale
- Usually undergoes direct repair of tendon.
- Pinned in 0° extension following repair

Therapy Post Surgery
The physician will determine the appropriate time to begin motion.
- Pinned and splinted for the first 5-6 weeks.
- Motion is initiated gently when the pin is removed.
- Progressive flexion of 5°/week while maintaining full active extension
- DIP extension splinting between exercises and during heavier activities continues for 3-6 weeks following initiation of motion.

Therapy for Chronic, Untreated Mallet Fingers
- Regain full passive DIP extension
  - Serial static splinting/casting
  - Splint finger in continuous extension for 8 weeks
  - Follow weaning protocol
  - If unsuccessful, surgery or pinning may be indicated

Surgical Options for Chronic Deformity
- Abbreviato procedure
- ORL reconstruction
- Fowler Tenotomy
- DIP fusion

Origins of Boutonniere and Swan Neck Deformities
Boutonniere: a flower worn in a button hole (P1 button holes up through central slip defect)
Swan neck: looks like a swan’s neck
Boutonniere Deformity

Sequence of a Boutonniere deformity:
1. Central slip ruptures
2. Head of P1 button holes through central slip defect
3. Lateral bands move more volarly, laterally, increasing their flexion force
4. Increased tension in lateral bands causes increased extension force at DIP, causing hyperextension

Boutonniere: Closed Injury

- Passively the PIP joint can be extended, but actively, it is unable to extend.
- The deformity may take place gradually over the course of several weeks.

Boutonniere: Open Injury

Open laceration over PIP joint/proximal phalanx may include injury to any combination of:
- Central slip
- Lateral bands
- Oblique fibers of the dorsal hood
- Transverse retinacular ligament

Splinting for Boutonniere Deformity

- Safety Pin Splint
- Serial Casting
- PIP Extension Splint

Fixed Boutonniere Versus PIP Flexion Contracture

- In a PIP flexion contracture (pseudoboutonniere), the DIP joint remains passively flexible.
- In a true boutonniere deformity, the DIP joint cannot be passively flexed due to oblique retinacular ligament (ORL) tightness
  - Can test for ORL tightness

Swan Neck Deformity

- Postural collapse deformity
- Can begin at MP, PIP, or DIP joints
Swan Neck Deformity

Four possible causes:
- Terminal tendon rupture
- PIP hyperextension from lax volar capsule 2nd to synovitis or rupture of volar plate
- FDS rupture (loss of dynamic PIP stabilization)
- Intrinsic tightness 2nd to MP pathology

Splinting for Swan Neck Deformity

Oval 8 splint

Thermoplastic Figure 8

Boutonniere Deformity of Thumb

- Pathology begins at MP joint
- Most common thumb deformity in RA

Swan Neck Deformity of the Thumb

Pathology begins with subluxation of 1st CMC joint

Treatment of Closed Injury Boutonniere: Immobilization

**Acute/Subacute (1 - 8 Weeks)**
- Flexible - treat as an acute closed injury
- PIP extension splinting for 8 weeks
- Allow full active DIP flexion !!!
- Open or closed with stiff joint
- Regain extension of PIP first, then initiate static splinting

**Chronic (More than 8 Weeks)**
- Flexible PIP - longer immobilization
- Stiff PIP - first regain mobility, then begin the countdown

Treatment of Open Injury w/Repair
Early Controlled Passive Mobilization

An outrigger splint supports the PIP at 0° with rubber band traction. Allows a controlled amount of flexion beginning a few days post surgery.

Early Controlled PROM

Thomes: hand-based splint
- MP in flexion and the PIP supported in full extension with a dorsal outrigger.
- 30° PIP flexion, and added 10° per week for the next 3 weeks when the splint was discontinued.

Walsh: hand-based splint
- MP in extension and PIP supported in full extension with a dorsal outrigger.
- PIP joint was allowed 30° flexion for the first 3 weeks, and then the splint was discontinued.

Early Controlled Active Short Arc of Motion

Proposed by Rosalyn Evans, OTR, CHT
- Follows belief that 3-5 mm glide is necessary to prevent adhesions
- Zone III, IV protocol
  - Volar static extension splint
  - Two exercise splints

Evans Protocol/Template Splints

Exercise Template 1: 30° PIP flexion, 20° DIP flexion
Exercise Template 2: PIP 0°, DIP free (if lateral bands repaired, then 30° only)

Classification of Results

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<th>Classification</th>
<th>Group I (33 Digits)</th>
<th>Group II (26 Digits)</th>
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<td>5 (19%)</td>
<td>5 (19%)</td>
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<td>Good</td>
<td>11 (28%)</td>
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<td>35% to 59%</td>
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<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td>Poor</td>
<td>1%</td>
<td>1%</td>
</tr>
</tbody>
</table>

Classification of Results comparing Group I and Group II (Strickland-Gloudey Formula)
Chronic Boutonniere Treatment
Achieve full passive PIP extension using dynamic, static-progressive, serial-static splints or casts.

Perform aggressive DIP flexion actively and passively with the PIP supported in full extension to stretch the ORL.

Operative Management of Chronic Boutonniere Deformities
- A: Anatomic repair
- B: Reconstruction using lateral bands (Littler technique)
- C: Reconstruction using both lateral bands
- Terminal tendon tenotomy: resection of tendon distal to insertion of central slip

Treatment Considerations
- Crush injuries
- Tendon excursion length
- Both wrist and digits must be splinted
- Proximity to retinaculum

ZONES 5 & 6

Sagittal Band Rupture
- The sagittal bands prevent bowstringing of the ED during extension, centralize ED at midline during flexion
- Rupture is usually atraumatic, involving radial fibers
- Can cause ED to sublux ulnarly and can cause incomplete extension

Sagittal Band Splinting
Splint to immobilize a sagittal band rupture
Sagittal Band Repair Techniques

Intertendinous Connections

- Juncturae Tendinum
- Proximal laceration
- Distal laceration
- EIP, EDM - may need to splint only involved finger

Intertendinous Connections

**Proximal:** the injured finger as well as the adjacent finger(s) should be supported in full extension to prevent the juncturae from placing tension on the portion of the tendon distal to the repair.

**Distal:** flexion of the adjacent finger(s) will not adversely affect the repair, as the juncturae will pull the portion of the extensor tendon proximal to the repair more distally, taking tension off the repair.

Splint for a Distal Juncturae Laceration

Treatment Protocols

**Four Protocols:**

- Immobilization
- Controlled passive motion
- Controlled early active motion
- Immediate Controlled Active Motion: Zone 4-7 (ICAM, Relative Motion)

Immobilization Protocol

- **Splint #1:** Wrist 40-45° ext, MP & IP 0° ext, full time for 3 weeks
- **Splint #2:** wrist 40-45° ext, MP 0° ext, IP free in daytime for weeks 3 to 6. Wear splint #1 at night
Early Passive Motion (Reverse Kleinert)
- Initiate therapy 24 hours to 3 days post-op
- Splint for 6 weeks
  - Wrist 40 - 45° ext
  - MP, IP in dynamic ext slings resting at 0° ext
  - Volar flexion block to allow 30° flex in I & M, 40° in R & L

Controlled Early Active Motion
- Splint position
  - Wrist held in 20° ext, MP/IP at 0°
  - MP moves actively from 30° flex to 0° ext
- MP increases weekly to 45°, 60°, 90° flexion
- Can be combined with early passive motion protocol
  - Based on minimal active tension, place/hold concept, and tenodesis

Zones 4-7
Immediate Controlled Active Motion (ICAM, Wyndell Merritt Method)
- Forearm-based wrist splint with a yoke orthosis with the involved MP in 15-20° greater extension relative to uninvolved joints.
- Reduces extended position of the wrist to enhance tendon excursion and glide zone IV-VII repairs.

Relative Motion Splint Program
- Phase 3 (36-49 days)
  - Wrist orthosis is d/c
  - Yoke orthosis is removed for digit ROM only and d/c when digit ROM is normal

Relative Motion Splint Program
- Phase 2 (22-35 days)
  - Yoke orthosis is worn continuously but wrist orthosis is removed for wrist AROM
  - If there is no lag, composite wrist and digit ROM is initiated
  - When wrist AROM is normal, wrist orthosis is d/c for light duty use

Relative Motion Splint Program
- Protocol (0-21 days)
  - Wrist and yoke orthoses are used continuously
  - Active digit flexion/extension are permitted, limited only by the relative extension of the affected digit
  - Full digit flexion and extension must be achieved before progressing to phase 2

Relative Motion Splint Program
- Phase 2 (22-35 days)
  - Yoke orthosis is worn continuously but wrist orthosis is removed for wrist AROM
  - If there is no lag, composite wrist and digit ROM is initiated
  - When wrist AROM is normal, wrist orthosis is d/c for light duty use

ZONES 7 & 8
Zone 7 - Compartments of the Extensor Retinaculum
- Area through which the extensors gain entrance to the hand.
- Compartment 1: APL & EPB
- Compartment 2: ECRL & ECRB
- Compartment 3: EPL
- Compartment 4: EDC & EIP
- Compartment 5: EDM
- Compartment 6: ECU
- Extensor retinaculum is a wide fibrous band that prevents bowstringing of the tendons across the wrist joint.
- *Remember: 22, 12, 11*

Zone 7: Wrist Extensor Tendon Lacerations
- Tendons are synovial at this point
- Adhesions similar to Zone 2 flexor tendon injuries
- Splint need not include IP joints
  - Wrist in 40° extension for 4 weeks. Fingers free if no digital extensors are injured.
  - Multiple repairs need differential tendon gliding.

Vaughn-Jackson Lesion
- Tendon rupture of ED to 4th & 5th fingers at ulnar styloid
- Often seen in RA
- Will require surgery
  - Tendon repair vs. transfer

Zone 8: Dorsal Forearm, Proximal to Extensor Retinaculum
- Splint as in Zone 7
- Extrinsic extensor tendon tightness is a common problem, frequently requiring later splinting to regain composite wrist and MP flexion.
Zones 9 & 10
- Splint wrist only
- Differential tendon gliding necessary

Thumb Extensor Tendons
Treatment Considerations
- Zones T-1 & T-2: similar to finger treatment
- Zones T-3 & T-4: watch for MP extension contracture
- Zone T-5: prone to adhesions at wrist; consider controlled early passive motion, controlled active motion or combination of both

Thumb Extensor Tendon Injuries
- Zone T-1
  - IP extension splinting and/or pinning in full extension
  - Splint for 8 weeks followed by gradual increase of flexion while maintaining full active IP extension.
- Zone T-2
  - Hand-based splint should immobilize MP and IP joints at 0°, with radial extension of the CMC joint

Thumb Extensor Tendon Injuries
- Zones T-3 & T-4
  - Splint should include the wrist at 30-40° extension, with MP and IP supported at 0°, slight CMC abduction

Zone T-5: Conservative Treatment
- Begin gentle motion at 3-4 weeks for conservative treatment.
- Dense adhesions form to the thumb extensors.
  - Tendon at this level is synovial
Early Controlled Passive/Active Motion Protocol: Thumb T5

Thumb IP will need 60° of flexion to achieve 5mm of tendon gliding with wrist in neutral & MP at 0°

Reverse Kleinert for Thumb

References

2. Rosen MI, Beach RM, Thompson DB: Relative tension and potential excursion of muscles in the forearm and hand. [Hand Surg. 6:208-219 1981]

Thumb T5: Early Controlled Passive/Active Motion

- 0-3 weeks
  - Dynamic extension splint with wrist in 30-40° extension and MP at 0°
  - A volar block allows 60° of IP flexion with MP at 0° between reps and at rest
  - 3 weeks
    - Remove volar block to allow IP flexion as tolerated
    - Add active thumb IP extension
- 4-5 weeks
  - Continue dynamic splinting at home
  - In therapy, begin gentle composite flexion/extension of thumb
- 5 weeks (1/c dynamic extension splint
  - Begin PROM to thumb as needed
  - If extensor lag is present, add night extension splinting

References

2. Rosen MI, Beach RM, Thompson DB: Relative tension and potential excursion of muscles in the forearm and hand. [Hand Surg. 6:208-219 1981]