Flexor Tendon Rehabilitation
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Curtis National Hand Center
Baltimore, MD
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Keys to successful treatment
- Doing the wrong thing can lead to injury
- Not doing enough of the right thing can cause poor outcomes
- Use the following resources
  - Mentors
  - Surgeons
  - Protocols
  - Evidence

Tendon healing
- Extrinsic healing
  - Adhesion formation between tendon and surrounding tissue
  - Potenza and Peacock (1960-70s)
    - Tendons healed by fibroblastic response (adhesions)
    - Tendon cells were incapable of proliferating
    - "One wound" concept = tendon healing through adhesion formation

Factors that affect tendon healing
- Age
- Individual biochemical response
- Nutrition
- Mechanism/type of injury
  - Crush or untidy laceration
  - Associated fractures or blood vessel injury
  - Controlled stress

Tendon Healing

Tendon healing
- Tendons ability to heal without adhesions
- Intrinsic vascularity and synovial diffusion
- Fibroblasts needed for healing
  - Supplied by the endotenon and epitenon
  - Tenocytes appearing at 2-3 weeks

Gelberman et al., Manske et al., Lundborg et al. (1980s)
Controlled Stress

- Promotes intrinsic healing
- Encourages longitudinal orientation of adhesions
- Decreases joint stiffness

Physiologic response

- Improved tensile strength
- Improved tendon excursion
- Improved repair site cellularity
- Enhanced nutrition and intrinsic healing via synovial fluid
- Reorganization, elongation, and reorientation of extrinsic scar

Consideration for application

- Type of injury
- Zone of injury
- Repair technique
  - Number of strands
  - Epitendinous suture
  - Ensure strong enough repair for controlled stress
- Patient factors
  - Age, cognitive status, adherence

Precise transmission

- Provide enough stress to move tendon a controlled amount
  - 3-5 mm as determined by Gelberman and Duran
- Avoid gapping or rupture

Tensile Strength
**Tendon tensile strength**

- Decreases during the first week following a repair
  - Mason & Allen, 1941
- Progressive increase after the first 2-3 weeks
- Increase in strength proportional to the amount of stress provided
- Immediate controlled stress to the healing tendon facilitates a reversal of the initial weakening process
- Maximum collagen synthesis occurs at 3 weeks

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**Estimated repair strength**

*Strickland, 1993*

<table>
<thead>
<tr>
<th>Strands</th>
<th>0 week</th>
<th>1 week</th>
<th>3 weeks</th>
<th>6 weeks</th>
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</thead>
<tbody>
<tr>
<td>2</td>
<td>2500gm</td>
<td>1250gm</td>
<td>1700gm</td>
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<td>4500gm</td>
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**Tensile Stress on Repaired Flexor Tendons**

- Passive motion: 750 g
- Light grip: 2250 g
- Strong grip: 7500 g
- Tip pinch—index FDP: 13,500 g

- This is the repair strength needed to be maintained throughout healing
- Reflects upward adjustments of 25% for frictional forces, and 25% for edema
- Forces on FDS 2-7X less than FDP

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**Normal Tendon**

<table>
<thead>
<tr>
<th></th>
<th>Passive motion</th>
<th>Light grip</th>
<th>Strong grip</th>
<th>Tip pinch—index FDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Force</td>
<td>500 g</td>
<td>1500 g</td>
<td>5000 g</td>
<td>9000 g</td>
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</tbody>
</table>

**Repaired Tendon**

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<tr>
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**Passive, protected digital extension**

*Up to 400g of force*

- Urbaniak et al., 1975; Schuind et al., 1992; Lieber et al., 1996-1999; Groth, 2004

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**Active wrist flexion/Extension**

*Up to 300g of force*

- Schuind et al., 1992

*Up to 400g of force*

- Schuind et al., 1992

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<td>4300gm</td>
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Active straight fist

Up to 1100 gm of force

Greenwald et al., 1994

Groth, 2004

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<td>430gm</td>
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Active hook fist

Up to 1300 gm of force

Greenwald et al., 1994

Groth, 2004

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Active composite fist

400-4000 gm of force

Urbaniak et al., 1975

Schuind et al., 1992;

Greenwald et al., 1994

Evans, 1997

Silva et al., 1998

Gelberman et al., 1999

Boyer et al., 2001

Groth, 2004

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Active, isolated joint motion

Up to 1900 gm of force

Schuind et al., 1992

Groth, 2004

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Factors That Affect Flexor Tendon Repair Outcomes

- Mechanism/Type of Injury
- Multiple digits/concomitant injuries
- Age
- Patient motivation/socioeconomic factors
- Nutrition... smoking may cause vasoconstriction
- Timing of repair, timing of therapy
- Controlled Stress (mobilization)
  - Without tendon gaping and rupture

Factors that Cause Resistance to Flexor Tendon Gliding

- Surgical repairs
- Tendon bulkiness
- Smoothness of tendon gliding surface
- Healing responses of the tendons
- Presence of intact annular pulleys
- Edema formation
- Adhesion formation
- Joint stiffness
- Extensor tendon tethering
- Splints and bandages and speed, frequency and methods of postoperative care

Wu YF and Tang JB. Hand Clinics. 2013

****Amount of scar formation****
Factors that Cause Resistance to Flexor Tendon Gliding- cont’d

- Extreme flexion progressively increases resistance to tendon motion. It causes:
  - Impingement of repair sites to the sheath or pulley rims
  - Increase in the bulkiness of tendon
  - Narrowing of the tendon gliding tunnel
  - Increase in the tethering of the extensor mechanism
  - Tightening of the capsule of the digital joints
  - Increase of the compression of edematous subcutaneous tissues

Suggest:
- Only midrange active motion in the low-resistance range in the early post-operative period

Protocols

Key Concepts

- The therapist MUST
  - Understand concepts of applying controlled stress
  - Know the type of injury and repair performed
- No single protocol is appropriate for all repairs
  - Surgeon/therapist interaction is vital to this process
- Literature will vary with regard to timing

Types of Protocols

- Immobilization
  - Little to no controlled stress on a repaired tendon
- Early passive mobilization
  - Controlled stress on the healing tendon with active IP extension and passive flexion
- Early “active” mobilization
  - Higher level of controlled stress on repaired tendon
  - Gentle contraction of the repaired musculotendinous unit
  - Results in proximal gliding of the repaired tendon

Protecting the repair

- Joints supported in flexion
- Puts flexor tendon on slack
- Prevents gapping or rupture through excessive traction on the tendon

Treatment Progression

- If adhesions are significantly limiting tendon gliding
  - PROGRESS treatment
- If tendon gliding is good
  - PROTECT the tendon from resistance and potential rupture for a longer period of time
- How do you know??

Wu YF and Tang JB. Hand Clinics. 2013
Measurement

Strickland & Glogovac, 1980

\[
\frac{\text{Active PIP + DIP flexion – extension lag}}{\text{175°}} \times 100
\]

= % of normal active PIP and DIP motion

Excellent: 85-100%
Good: 70-84%
Fair: 50-89%
Poor: <50%

Immobilization

- Rationale/Used for:
  - Children (those under age 10-12)
  - Cognitively impaired
  - Non-adherent patients (????)

- EXTRINSIC HEALING

Immobilization

- Intermediate Stage (3 to 6 weeks)
  - Orthosis modified to wrist neutral
  - Removed for hourly exercises to include:
    - Passive flexion and extension of fingers with wrist in 10 ° extension
    - Active flexion: hook, straight, and full fist.
    - Synergistic motion

  - BE GENTLE...immobilized tendon is generally weaker

Immobilization

- Early stage (up to 4 weeks)
  - Dorsal blocking orthotic or cast
    - Wrist 10-30° flexion
    - MPJs 40-60° flexion
    - IPs in extension
  - If therapy is provided:
    - Passive flexion of the digits
    - Mobilization of uninvolved joints
    - Wound/scar management

Cifaldi-Collins & Shwarze, 1991

Immobilization

- After 3-4 days, assess tendon gliding
  - Measure full MP/PIP/DIP flexion passively and actively
  - If >50 ° difference is present, move to the late stage
  - If <50 ° difference noted, continue with intermediate phase of the program until 6 weeks post-op
Immobilization

- **Late Stage** (5 to 6 weeks)
  - D/C dorsal blocking orthosis
  - Add serial extension splinting
  - Begin *gentle* blocking exercises
  - After 1 week of gentle blocking, may initiate light resistance
    - If tendon gliding is good, delay any resistance

Early passive mobilization

Early Passive Mobilization

- **Rationale:**
  - Promoting *synovial diffusion for healing*
  - Inhibit dense adhesion formation
  - Facilitate a stronger repair at an earlier stage
- Two main protocols
  - Duran & Houser
  - Kleinert

“Original” Duran & Houser

- 0- 4 ½ Weeks
  - Orthosis
  - Dorsal block with wrist in 20° flexion, and MPs in a relaxed state of flexion:
    - *Orthosis ends at PIP joints to allow full IP extension*
    - *Rubber band traction to the injured finger (loosely) during the day*
  - Between exercises stockinette is applied over the fingers and pinned to forearm
    - All fingers resting in flexion within stockinette to prevent impulsive grasping

“Original” Duran & Houser

- Exercises: 6-8 repetitions, 2x/day within orthosis that blocks MP in flexion
  - Passively extend DIP while PIP is held passively in flexion
  - Passively extend PIP while DIP rests in flexion

“Original” Duran & Houser

- 4 ½ Weeks
  - Replace dorsal block with a wrist band with rubber band traction
  - Exercises: 10 repetitions every 2 hours as previous
  - Add gentle active extension against the rubberband traction.
"Original" Duran & Houser

- 5 ½ Weeks:
  - Hourly exercises: 10-12 repetitions
  - Remove wrist band and nail suture for rubber band attachment
  - Active flexion is initiated: gentle blocking, FDS gliding, and composite fist
  - Passive flexion of all joints
  - IP passive extension with MP flexed

- 6 Weeks
  - Begin gentle PIP extension
  - Dynamic splinting if needed

- 7 ½ Weeks
  - Initiate gentle resistance
  - No strong resistance to the tendon for another 2-4 weeks

"Modified" Duran

- Eliminate the rubber-band traction
- Extend the DBS hood to the fingertips
- Strap the fingers in IP extension at night
- Exercises:
  - Passive flexion: isolated and composite
  - Active IP extension
  - Passive protected extension
  - Protected tenodesis in therapy if appropriate

"Original" Duran & Houser

Modified Kleinert Protocol

- Dorsal blocking orthosis
  - Wrist in 45° flexion
  - MPs 40° flexion
  - IPs allowed full extension
  - Volarly applied “PFT” (postoperative flexor tendon)

Protected Tenodesis

Passive composite flex with wrist extension 20-30 degrees followed by passive wrist flexion; fingers extended passively by tenodesis effect
Modified Kleinert Protocol

- The PFT is a prefabricated orthosis
- Rubber band traction runs from the fingernail, under a rolling bar at the palm, to a coiled lever at the forearm.
- Coiled lever and rolling bar on the PFT
- Designed to minimize resistance within the rubber band during IP extension

Modified Kleinert Protocol

- Exercises: 20 repetitions per hour
- 0-4 to 6 weeks
  - Active IP extension against rubber bands
- 3-6 weeks
  - Remove orthosis for wrist motion at 4 weeks
  - Begin gentle active flexion
- 6 weeks
  - Discontinue orthosis
  - Add differential tendon gliding exercises
- 6-8 weeks
  - Begin gentle resistance

Washington Regimen

- Dorsal blocking orthosis
  - Wrist at 20-45° flexion
  - MPs at 40-60° flexion
  - IPs allowed full extension
- A safety pin is applied to the palmar strap at the distal palmar crease, and on the forearm strap
  - A nylon line is run from the fingernail of the injured finger(s) only, under the safety pin at the DPC, attaching to 2 rubber bands
  - One rubber band is cut, so that it is only a single strand
  - One rubber band with exercise; 2 at rest

Washington Regimen

- Full finger flexion to the distal palmar crease strap is attempted with singular rubber band traction

Washington Regimen

- 0-3 weeks
  - Therapist performs protected passive flexion and extension
  - Active extension against traction x10 reps, hourly
  - Rubber band traction on 24 hours/day
- 4 weeks
  - Discontinue rubber band traction
  - Begin active flexion with an active hold in flexion for 10 seconds, passive flexion, and active extension

Washington Regimen

- 5 weeks
  - May be allowed out of orthosis for hygiene and light activity
- 6 weeks
  - Discontinue orthosis
- 8 weeks
  - Add blocking if needed
  - Gradual increase in use and resistance
  - Heavy lifting above 5lbs not allowed until after week 12 post-op
### Zone I Protocol: LEAF

- **Limited extension active flexion (LEAF)**
  - Evans, 1990
- **Rationale:**
  - Place the repaired FDP tendon in a shortened position
  - 4.5mm proximal to normal resting length
  - Decrease gap formation
- **Therapy initiated at 24 – 48 hours post op**

### Zone I Protocol: LEAF

#### Weeks 0-4

- **Exercises- 10-20 reps/hour:**
  - Passive DIP flexion to 75° in orthosis
  - Passive composite flexion
  - Passive IP flexion with MPs resting at 30° in orthosis (modified hook position)
  - Full active PIP extension while other hand holds MP’s at 90° flexion
  - With distal strap extension, place and hold PIP joint flexion of injured finger

### Zone I Protocol: LEAF

#### Weeks 0-4

- In therapy, orthosis removed for:
  - Passive wrist tenodesis
  - Slow repetitive motions to loosen finger
  - Short arc motion (SAM) place and hold against 15-20g of force in the following position:
    - Wrist extension = 20°
    - MP flexion = 75-80°
    - PIP flexion = 70-75°
    - DIP flexion = 40°

### Zone I Protocol: LEAF

#### Weeks 3-4

- Discontinue DIP dorsal blocking gutter
- Add gentle place/hold flexion

#### Week 4

- Add synergistics, hook fist, and gentle DIP blocking for FDP glide
- Orthosis remolded to wrist neutral

#### Week 4 ½

- May begin DIP extension orthotic PRN

### Zones III through V

- Repairs are most commonly placed in the preferred Zone II protocols
- Less complications and better results
  - Do not have the tight pulley/sheath system
  - Adhesions are often less dense
- Watch intrinsic scarring and/or paradoxical extension in zone III
Early “active” mobilization

“What” is Early Active Motion?

• Place and hold
  – ½ fist, whole fist
  – Optional tenodesis splint
• Active fist
  – 1/3 first 1-2 weeks, increasing to 2/3 the third week.
    Full ROM at week 4-5.
  – Full IPJ flex and ext with MCP extension blocked at
    60-80° flex
  – Finger method?
• Active initiation of fist to 50% with PROM to full
  fist
• Active fist with 45° MPJ, 45° PIPJ and 45° DIPJ

Indiana Protocol

• Repair technique
  – Tajima core suture plus horizontal mattress
  – Equal to 4 strand repair plus epitendinous suture
• Criteria
  • Motivated, understanding patients
  • Minimal to moderate edema which does not
    restrict passive flexion
  • Minimal wound complications

Indiana Protocol

• Week 0-4
  – Dorsal blocking orthosis
  – Wrist 20° flexion, MPs 50° flexion, IPs
    allowed full extension
  – Worn continuously
    • Once hourly: remove and apply hinged wrist
      splint
    • Immediately reapply dorsal blocking splint after
      exercises

Indiana Protocol

• Synergistic orthosis with hinge
  – Allows full wrist flexion and 30° extension
  – MPs blocked at 60° flexion
  – IPs allowed 0° extension

Indiana Protocol

Week 0-4

• Passive:
  – 15 reps of passive flexion/extension to the PIP joint,
    then the DIP joint, then entire digit
• Apply synergistic orthosis for 25 reps of
  place/hold
  – Passively flex digits & simultaneously extend wrist
  – Gentle place/hold contraction for 5 seconds
  – Simultaneous wrist flexion with digit extension to
    orthosis
Indiana Protocol

- Week 4:
  - Discharge synergistic orthosis
  - Continue dorsal blocking orthosis between exercise
- Exercises
  - Synergistic motion: 25 reps every 2 hours
  - Add light active finger flexion and extension
  - Avoid combined finger and wrist extension

Indiana Protocol

- Week 5
  - Exercises
    - Continue week 4 exercises
    - Add tendon gliding and hook fisting
- Week 6
  - Discontinue dorsal blocking orthosis
  - Exercises
    - Continue previous exercises
    - Add blocking exercises
    - Do not perform blocking exercises to the small finger FDP

Indiana Protocol

- Week 7
  - Add passive extension exercises
- Week 8
  - Add light resistance
- Week 14
  - Return to normal activity

Pyramid of Progressive Force

- Pyramidal series of eight exercise levels in ascending order of increasing force
- The patient progresses up a level in the pyramid if the tendon is unresponsive
  - Unresponsive = < 10% resolution of active lag between therapy sessions
  - Continue progression until the tendon is responsive
    - > 10% resolution of active lag between therapy sessions

Pyramid of Progressive Force (Groth, 2004)

- The active lag is measured:
  - \[
    \text{active lag} = \frac{\text{Current DIP flexion} - \text{previous DIP flexion}}{\text{previous DIP flexion}} \times 100\%
  \]
  - Absent = < 5 degree discrepancy between active and passive flexion
  - Responsive = > 10% resolution of active lag between therapy sessions
  - Unresponsive = < 10% resolution of active lag between therapy sessions

**Note:** The figure likely contains a visual representation of the pyramid of progressive force levels, but the text description is sufficient to understand the progression and measurement criteria.
Other protocols

- Critical aspects
  - Partial release of A2 pulley or complete release of A4 pulley
  - 4-6 strand repair for FDP
  - Active motion under load tension, synergistic with wrist position
- DBS with wrist 20-30° flex, MPJ slight flex, IPJ ext.
- Therapy starts at 3-5 days post-op
- For 2.5 weeks RX includes PROM 10 reps f/u by 10 A fists in comfortable range 4 times a day
- From 2.5-5 weeks, wrist splinted in 30° ext and focus on PROM, AROM for 2/3rds of fist assistance as needed to achieve full fist to prevent rupture
- D/C splint and full AROM at 5-6 weeks

Delay full active flexion to week 5 if multiple fingers are repaired or if a late tendon repair or a primary tendon rupture.

Nantong
Tang, 2007

Other protocols

- Patients perform full range of motion during surgery to ensure no gapping or lack of glide
- Post op days 2-4: hand is elevated and splinted with wrist in comfortable ext, MPJ flexed to 80-90° and PIP/DIPJ extended
- Post op days 3-7: passive warm up of fingers followed by active mid-range movement: 45° flex of each of the MP, PIP and DIP with full IPJ extension. No place and hold.
- Finger wrap

Mass & Saint John
Coats et al., 2005; Clancy & Mass, 2013; Lalonde, 2013

Manchester Short Splint
Peck, 2014

- 62 forearm-based
- 40 Manchester short
- Significantly less flexion contracture at PIP at 6 and 12 weeks
- Significantly greater arc of flexion at DIP
- Greater proportion of excellent/good results
Studies to note

  - Severe edema in subcutaneous tissue and tendon as measured by circumference adds to resistance of tendon gliding by 2x-3x
  - Resistance to motion increased progressively for the first 4 days and remained consistent from days 4-7 therefore recommend best time to start motion is 4th to 7th day
  - Repetitive PROM of the digit as "warm up" greatly reduced the force and energy of the digital flexion
  - Tendon swelling is worse in a delayed repair so sheath release or venting may be necessary
  - Self adhesive tapes increase digital flexion energy 4x baseline and should be removed for exercise.
  - Adhesions do not form before day 9 so digital motion can be started as late as day 7-9

FPL Repair

- Goal is minimum of 30-40 degrees of IPJ motion
- Direct repair at all levels of injury may be possible as late as 3 to 6 weeks after injury but may need tendon lengthening because of proximal retraction is greater in FPL
- Rate of rupture of repair in Zone 2 of thumb is twice as common as Zone 1 likely secondary to zone of avascularity.
- Splint positioning usually includes wrist in 10-20° flexion and CMC and MCP in neutral. Typically the IPJ is dorsally blocked at 20-25°
- Treatment options include early passive, place and hold or early active based on the type of suture and should be guided by physician.

Take Home Message

- Measure...measure...measure
- Never follow a protocol blindly- use clinical judgment
- Start therapy close to post op day 5 and before post op day 10
- Make sure to do a passive warm-up of finger prior to exercises which can include passive modified tenodesis and passive modified hook.
- Always position the wrist in neutral or slight extension for active exercises
- When doing place and hold or AAROM start with a looser fist
- Monitor interossei tightness and retrain hook fist for differential gliding

Thank you!