Flexor Tendon Update

Guidelines…Not a Cookbook!
Objectives

• Realize differences in surgical technique affect therapy programs

• Understand timing of each protocol to advance therapy programs

• Understand the advantages and disadvantages of each protocol

• Understand what needs to be communicated to each patient in order for the patient to have a successful outcome

• Gain exposure to options for addressing complications
Anatomy

Is everything!
Flexor retinaculum (transverse carpal ligament)

Ulnar artery and nerve

Palmaris longus tendon

Median nerve

Flexor carpi radialis

Flexor pollicis longus

Abductor pollicis longus

Extensor pollicis brevis

Radial artery

Hamate

Trapezium

Capitate

Trapezoid

Extensor carpi ulnaris

Extensor digiti minimi

Extensor digitorum

Extensor indicis

Extensor carpi radialis longus

Extensor carpi radialis brevis
Flexor Tendon Zones

- Hand I-V
  - Zone II most common site for injuries.
  - Known as “No Man’s Land”
- Thumb I-III

Fig. 49-1. Zone classification of flexor tendon injuries.
Pulleys
Anatomy of the FDS and FDP
History and Examination

"I have no idea what's wrong with you, so this is going to be very expensive."
Patient History

• Age/name
• Occupation **
• Handedness **
• Onset of symptoms/mechanism of injury/previous injury
• Nature/course of symptoms/sensory changes
• Nature of pain/pain rating
• Activities increase/decrease pain
• Functional limitations **
• General health
• Goals
Observations

• Bone & soft tissue contours
• Patterns of movement
• Any deformities (joints, intrinsic hand wasting, etc)
• Sympathetic changes
• Open wounds and wound care
• Edema
Teamwork!

- What structures were repaired?
- Was a reduction tenoplasty performed?
- Were one or more pulleys vented?
- What repair method was used (size and number of core strands), and how does this limit extend of permissible loading?
- Was an epitendon suture used?
- If tested intraoperatively, was tendon gapping observed with finger extension?
- Was active flexion tested in surgery?
- Was a digital nerve or digital artery repaired?
Surgical Techniques: An Overview

• Why do we care?
  • Strength of the repair
  • Tendon gapping
  • Pulley integrity
  • Friction at the repair site

All of these affect our rehabilitation plan!
Zone 1 flexor tendon repair

Tendon-to-bone attachment!!
Flexor Tendon Zones

Zones II-III

Zone II = No Man’s Land
A: Tsuge

B: Modified Kessler

C: Augmented becker

D: 4-strand savage

E: 4-strand cruciate

F: 6-strand savage
Flexor Pollicis Longus Tendon Reconstruction Using the Pulvertaft Weave

The purpose of this procedure is to restore the function of the thumb after a complete rupture injury to the flexor pollicis longus (FPL) tendon. In order to reconstruct the ruptured tendon, the palmaris longus (PL) is harvested and fastened to the proximal stump of the ruptured tendon in a complex method known as the Pulvertaft Weave (shown here). Ultimately, the graft is completed when the other end of the PL tendon is fed distally through the flexor tunnel of the thumb and sutured to the distal stump of the FPL tendon.

1. A curvilinear incision is made on the volar surface of the wrist to expose the underlying tendons.

2. The PL tendon has been removed from the wrist. It is woven with a tendon passer instrument through the FPL tendon, which has also been fixed at its distal end.

3. To complete the pulvertaft weave, the PL tendon is passed 3 times through the FPL and secured with sutures. The distal junction between these two tendons is streamlined with a “fish-mouth” incision made on the end of the FPL.
• Core suture methods used in different units: (A) modified Pennington suture (*lateral view*), (B) 4-strand double Tsuge suture. Both (A) and (B) are used in the Mayo Clinic. (C) Eight-strand Gelberman-Winters suture used in Washington University in St Louis (MO). (D) Cruciate repair used in the Hospital of Special Surgery, New York (NY). The interlocking peripheral suture is also shown. (E) A modified Strickland, a 4-strand repair made up of a locking Kessler repair and a horizontal mattress suture, used in the Stanford University Medical Center. (F) Strickland suture. (B–F) The repair in anterior view
Pulleys

ANNULAR (A) AND CRUCIATE (C) PULLEYS OVER FLEXOR TENDONS
Fig. 5. Venting major pulleys reduces constriction to the tendon and reduces the chances of impingement of the repair site to the pulley rims. The A2 pulley can be vented to 1/2 to 2/3 of its length; a portion of this pulley is kept.

Ya Fang Wu, Jin Bo Tang

**Tendon Healing, Edema, and Resistance to Flexor Tendon Gliding : Clinical Implications**


http://dx.doi.org/10.1016/j.hcl.2013.02.002
Bowstringing

**Diagram**

- **Diagram A**
  - Metacarpal
  - Proximal phalanx
  - A1, A2, A3, A4, A5
  - Palmar aponeurosis (PA)
  - Distal phalanx

- **Diagram B**
  - Metacarpal
  - Proximal phalanx
  - PA
  - Distal phalanx
  - Middle phalanx

**Text**

The absence of the A1 and A2 pulleys allow the tendons to bowstring away from the MP joint during flexion.
Fig. 2. The digital “extension-flexion test” consists of three parts. (A) Step 1: to make sure gapping does not occur at the repair site at full extension of the repaired digit. (B) Step 2: make sure that the tendon glides in the range of mild to moderate flex... 

Jin Bo Tang

**Outcomes and Evaluation of Flexor Tendon Repair**

Hand Clinics, Volume 29, Issue 2, 2013, 251–259

http://dx.doi.org/10.1016/j.hcl.2013.02.007
Zone II repair without gapping
Time for Teamwork to Begin!

- Patient Education
- Operative report
- Surgeon discussion
- Therapist communication
Back to Physiology
Definition of Apoptic cells

- Called *programmed cell death*,

- More commonly called *apoptosis* (from a Greek word meaning “falling off,” as leaves from a tree).
Fig. 2. Fifty percent to seventy percent of the total cell population in adhesions are apoptotic. The next highest proportion of apoptotic cells is seen in the tendon-adhesion gliding interface (40%–60%), and the fewest apoptotic cells are seen in the tendon c...

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_Tendon Healing, Edema, and Resistance to Flexor Tendon Gliding: Clinical Implications_

Fig. 6. (A) Percentage contribution of different factors to resistance to tendon motion. (B) Structures causing resistance to tendon gliding. Note that some factors can be eliminated during surgery: restrictive pulleys constitute about 30% of the total resistance.

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**Tendon Healing, Edema, and Resistance to Flexor Tendon Gliding : Clinical Implications**


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Fig. 7. The active digital motion creates a dynamic loading situation in which tendons are consistently subjected to changing forces from digital extension to flexion. Extreme flexion of the fingers greatly increases resistance to flexor tendon gliding. Ther ef...

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Tendon Healing, Edema, and Resistance to Flexor Tendon Gliding : Clinical Implications


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Early Active Motion for Flexor Tendon Repairs in Zones II-III

• History of Flexor Tendon Rehabilitation
• Early Active Motion
• Considerations for Surgeon and Therapist
History of Rehabilitation
Flexor Tendon Repairs

Immobilization

1950's

1960's

1970's

1980-1990's

2010's

Early Passive Mobilization

Early Active Motion

1950's

1960's

1970's

1980-1990's

2010's
History of Rehabilitation
Flexor Tendon Repairs

1950’s
1960’s
1970’s
1980-1990’s
2010’s

Immobilization

Early Passive Mobilization

Early Active Motion
Immobilization Protocol

• Children

• Patients with low compliance
# Flexor Tendon Rehabilitation

## Immobilization

<table>
<thead>
<tr>
<th>Immobilization program</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>0 to 3-4 weeks</strong></td>
</tr>
<tr>
<td>○ Cast or dorsal</td>
</tr>
<tr>
<td>protective splint in</td>
</tr>
<tr>
<td>wrist and MCP</td>
</tr>
<tr>
<td>joint flexion and</td>
</tr>
<tr>
<td>IP joint full extension</td>
</tr>
<tr>
<td>○ Dorsal protective splint replaces cast</td>
</tr>
<tr>
<td>○ Splint modified to bring wrist to neutral</td>
</tr>
<tr>
<td>○ Hourly: 10 repetitions of passive digital flexion and extension with wrist at 10° extension</td>
</tr>
<tr>
<td>○ Hourly: 10 repetitions of active tendon gliding exercises</td>
</tr>
<tr>
<td><strong>3-4 weeks</strong></td>
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<tr>
<td>○ Hourly: 10 repetitions of passive digital flexion and extension with wrist at 10° extension</td>
</tr>
<tr>
<td><strong>4-6 weeks</strong></td>
</tr>
<tr>
<td>○ Dorsal blocking splint discontinued</td>
</tr>
<tr>
<td>○ Gentle blocking exercises initiated 10 repetitions, 4-6 times daily added to passive flexion and tendon gliding</td>
</tr>
<tr>
<td><strong>6-8 weeks</strong></td>
</tr>
<tr>
<td>○ Gentle resistive exercise begins and progresses gradually</td>
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</tbody>
</table>
History of Rehabilitation Flexor Tendon Repairs

- Early Passive Mobilization
  - 1950’s
  - 1960’s
  - 1970’s

- Early Active Motion
  - 1980-1990’s
  - 2010’s

Immobilization
Kleinert Protocol

- DBS wrist 30° flexed, MCPs 50-70° flexed
- Dynamic traction bands to flex fingers
- Active extension of digits within DBS 50 times/hour
- 3 weeks continue with splint, begin place and hold
- 4 weeks wrist brought to neutral, tendon gliding exercises, restricted active range of motion of the wrist
- 5-6 weeks d/c splint
- 6 weeks may start PROM for extrinsic tightness and static progressive splinting
Kleinert Continued

• 6 weeks may start PROM for extrinsic tightness and static progressive splinting

• 6 weeks unrestricted AROM, blocking, NMES, light functional activities

• 7 weeks Unrestricted AROM, PROM, light grip and wrist strengthening

• 8-12 weeks progressively return to prior function
Pros and Cons of Kleinert type protocols

Advantages
- Can be used with any surgical repair technique
- Good for any zone
- EMG: resistance to extensors during active motion causes flexor relaxation = safer mobilization

Disadvantages
- Promotes IP flexion contractures!
- Uncomfortable splint and difficult to don
- Need patients who are fully competent to don/doff splint
History of Rehabilitation
Flexor Tendon Repairs

Early Passive Mobilization


Immobilization → Early Active Motion
Modified Duran Protocol

• Developed and used by the Indiana Hand Center

• Uses passive flexion, active extension within the limits of a DBS

• Relies on exercise to provide differential gliding between the FDS and FDP

• Allows for more “cheating” or unintentional active motion of the tendons

• Easier to rupture with unintentional active motion
Modified Duran Protocol

• Start at 3 days post op
• DBS wrist at 20° flexion, MCPs 70° flexion, IP’s full extension
• Passive flexion at each joint and composite flexion w/ active extension within the splint
Modified Duran Protocol

- Passive DIP flexion
- Passive PIP flexion
- Passive composite finger flexion
Modified Duran Protocol

• 1-3 Weeks:
  • DBS with wrist in 20 degrees of flexion, MPs 40-70 degrees of flexion, IP at 0
  • Hourly repetitions of passive flexion (individual and composite flexion)
  • Reverse blocking
  • Wrist motion in splint
Modified Duran Protocol

- Wrist motion in the splint
Modified Duran Protocol

- **3-1/2 weeks:**
  - begin AROM in the splint, place and hold

- **4 weeks:**
  - begin FES, US if needed

- **4-1/2 weeks:**
  - AROM with the DBS off, tenodesis motion, hook/claw positions, composite fist with wrist flexion and extension
  - Continue DBS between exercise sessions
Modified Duran Protocol

• Place & Hold exercise: 50% fist initially
**Base joint flexion**
1. Straighten your wrist and point your fingers and thumb upward.
2. Bend the base joints (knuckles) of your fingers while keeping the end and middle joints and your wrist straight, forming a "tabletop."
3. Hold for ______ seconds.
4. Relax for ______ seconds.
   • Do ______ repetitions.
   • Do this exercise ______ times a day.

**Middle and end joint flexion**
1. Straighten your wrist and point your fingers and thumb upward.
2. Bend the end and middle joints of your fingers while keeping the base joints (knuckles) and your wrist straight.
3. Hold for ______ seconds.
4. Relax for ______ seconds.
   • Do ______ repetitions.
   • Do this exercise ______ times a day.

**Flat fist**
1. Straighten your wrist and point your fingers and thumb upward.
2. Bend the base joints (knuckles) of your fingers and then the middle joints of your fingers to bring your fingertips to the base of your palm.
3. Hold for ______ seconds.
4. Relax for ______ seconds.
   • Do ______ repetitions.
   • Do this exercise ______ times a day.

**Full fist**
1. Straighten your wrist and point your fingers and thumb upward.
2. Make a fist by bringing your fingers to the middle of your palm and place your thumb against your index and middle fingers.
3. Hold for ______ seconds.
4. Relax for ______ seconds.
   • Do ______ repetitions.
   • Do this exercise ______ times a day.
Modified Duran Protocol

• 6 weeks:
  • discontinue splint; start extension splinting, buddy taping to the adjacent digit as needed
  • blocking exercises prn (not recommended for fifth digit as it may rupture)

• 8 weeks:
  • begin gentle progressive strengthening

• 10-12 weeks:
  • resume normal activities
Blocking Exercises

DIP joint

PIP joint
Pros and Cons of the Modified Duran Protocol

Advantages

• Can be done with a 2 strand repair or higher
• Good for any zone, but most typical for zone II
• Biggest gains in motion are seen from 3 ½-7 ½ weeks

Disadvantages

• Tendon “buckles” in sheath because tendons should pull, not push
• Does the FDS & FDP differentiate in gliding?
• Do you strap at over the fingers or leave free?
Indiana Early Active Mobilization (Tenodesis Program)

3 days: 2 splints

- **DBS**: wrist 20° flexed, MCP’s 65-70° flexed, IP’s neutral

- **Tenodesis splint**: dynamic wrist hinge DBS, which allows full flexion and limits wrist extension to 30°, MP’s 70° flexion.

- Follow Modified Duran exercises in DBS

- Use dynamic wrist splint for tenodesis with place and hold
History of Rehabilitation
Flexor Tendon Repairs

Immobilization

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Early Active Motion for Flexor Tendon Repairs in Zones II-III

- History of Flexor Tendon Rehabilitation
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- Considerations for Surgeon and Therapist
Early Active Motion (EAM)

• What is EAM?
  • Early Active Motion is active contraction of the injured flexor muscle to promote increased glide of the tendon and decreased adhesions
  
  • Lacerations at the middle phalanx with the FDP lacerated will benefit the most from EAM to increase the glide of the FDP
Early Active Motion
Which Patients?

• 4-strand repair

• WALANT (wide awake local anesthesia no tourniquet surgery)

• Easily glides through pulley

• Compliant patient

• Minimal edema

• Good PROM
Early Active Motion
Splinting Considerations for Zone II-III

Wrist: Neutral

MP: 45 degrees flexion

IPs: In full extension*

*IP’s at 30 degrees of flexion with digital nerve repair
Early Active Motion
Splinting Considerations At the IP joints

Free
Tetragrip to increase support for PIP extension
Stockinette as a reminder not to use hand
Splint cage, to allow incidental motion
Early Active Motion
Day 3-5

• Light dressing

• Compression as needed for edema X-span & Tetragrip

• Exercises

Passive Flexion/Active Extension in the splint
Early Active Motion
Day 3-5

• Wrist Tenodesis in the splint

• Place & Hold with MPs PIPs and DIPs all at 45 degrees of flexion
  • Full flexion could lead to a tendon gap

• Progress to active range of motion of digits at one finger width per week
  • Instructed patient to “SCRATCH” the finger
    • Increased activation of the FDP
Early Active Motion
Day 3-5

**SCRATCH**

**Week 1** to index finger

**Week 2** to long finger

**Week 3** to ring finger

**Week 4** to small finger or full fist
Early Active Motion
Day 3-5  A Closer look at the exercise
Early Active Motion

• Day 10-14
  • Begin scar management 24-48 hours after suture removal

Advance “scratch” exercises
Early Active Motion
Weeks 3-4
Early Active Motion

• Week 4
  • Consider NMES and/or Ultrasound

• Week 4.5
  • Remove splint for exercise sessions
    • Tenodesis
    • Hook fist
  • Composite fist followed by MP extension followed by IP extension
  • Composite fist with wrist flexion/extension
Early Active Motion

- Week 5.5
  - Discontinue splint
  - Consider extension splinting for PIP extension lag
  - Fabricate relative motion flexion splint for day time use with a PIP extension lag
PIP joint contracture splinting options
Early Active Motion

• 6 weeks
  • Passive extension exercises
  • Blocking exercises
    • (Caution with small finger as can cause rupture)

• 8 weeks
  • Strengthening with putty hand exerciser
  • No heavy hand use
Early Active Motion

• 10-12 weeks
  • Use hand for all activities of daily living

• 14-16 weeks
  • Heavy weighted hand use is allowed
Early Active Motion for Flexor Tendon Repairs in Zones II-III

- History of Flexor Tendon Rehabilitation
- Early Active Motion
- Considerations for Surgeon and Therapist
Early Active Motion

Other Considerations

- Use adhesion grading system to move up the pyramid

**Absent:** Greater than or equal to 5 degree discrepancy between digital active and passive flexion

**Responsive:** Greater than or equal to 10% resolution of active lag between therapy sessions

**Unresponsive:** less than 10% resolution of active lags between therapy sessions

Early Active Motion
Other Considerations

• “The safe zone for a typical four-strand repair with a 40-N (9-lb) breaking strength is actually within a much smaller range, perhaps between 5 and 10 N (1-2 lb).”

• Critical factor
  • Gapping
• Post Operative-
  • Safe zone narrow
    • Damaged tendon sheath
    • ↑ Stiffness
Function, Function, Function

- Activities to increase FDP gliding
Magic Therapy
Questions & Discussion


