**Flexor Tendon Case Conundrums**

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  - Yale – molecular biochemistry & biophysics
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  - Washington University – orthopedic residency
  - Philadelphia Hand Center – hand fellowship & practice
  - Passion for research, family
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**Faculty**
- Jeffrey A. Greenberg, MD
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  - Indiana Hand to Shoulder Center – hand fellowship & partner
  - ASSH – practice division director
  - AFSSH – board of trustees
  - AAHS – former board member
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**Breaking News...**

**Every Day...**

**Every Month...** *Something New... Flexor Tendons*

**Conundrum...**
- A problem or puzzle which is difficult or impossible to solve.
  - Mystery
  - Enigma
  - Head-Scratcher
  - Dilemma

**Conundrum...**
- Webster Dictionary
  - An intricate or difficult problem

- Oxford Dictionary
  - A confusing and difficult problem or question
Flexor Tendons → Conundrum!

- Anatomy
- Surgery
- Therapy
- Outcomes
  - Not straight-forward
  - No simple or direct path
  - No easy answers
  - Not predictable
  - No guarantees
  - Problem-solving, decision-making critical
  - Cannot “let your guard down”...
  - Favorable outcome

Topics – Conundrums!

- Zones I & II FTRs
- Anatomical & Surgical Challenges within each Zone
- Preferred Surgical Approach & Rationale [case examples]
- Therapy Case Examples - Conundrums
  - Problem-solving & decision-making
- Questions & Answers

Q&A – End of all Presentations

Zone I Flexor Tendon Repairs

- Zone I
  - Subzones
  - Tendon excursion
  - Repair options
- Therapy Case Examples
  - “Conundrums”
  - Button
  - Partial FDP repair
  - Bone anchors
- Outcomes

Zone I – Moiemen & Elliott [JHS – Br. 2000]

- 1A – Very Distal FDP Tendon (<1 cm)
- 1B – Zone 1A to Distal Margin of the A4 Pulley
- 1C – FDP within A4 pulley

Digital Level Anatomy

- Tendon Excursion
  - Active Excursion FDP in Zone I
    - Maximum of .7 – 1 mm per 10° motion
    - ± 5 – 6 mm
  - Passive FDP Excursion in Zone I
    - ± .3 mm per 10° motion
    - 1 – 2.5 mm

Hand to Shoulder Therapy Center
Types of Injury – Zone 1

- Lacerations
- Ruptures
- Avulsions
  - Leddy & Packer Types I, II, III
  - + Type IV & V

Repair Options

- End to End Repair
- Button
- Anchor

Repair Options

- Core Sutures
  - 2–4–6 Strand Repairs

Repair Strengths - Estimates

- Core Sutures – 2 Strand 20N
- Core Sutures – 4 Strand 40N
- Core Sutures – 6 Strand 60N
- + Peripheral Running Suture ≥ 7N
- 3-0 vs. 4-0 Suture + 10-15N
- Button 45N
- Anchor – Micro 70N
- Anchor – Mini 45N

Program Choices - Passive

- Early Passive Motion Program
  - Modified Duran
    - 2-strand repairs
  - Stronger repairs – concerned for quality of repair
  - Persistent edema, limited passive flexion – unable to add early active motion

Hand to Shoulder Therapy Center
Program Choices – Active

- Early Active Motion
  - ≥ 4 strand repairs
  - Button
  - Anchor

- Place & Hold
  - Synergistic wrist motion

- Short Arc Active
  - AROM

- Place & Hold

Key Points – Establish therapy program

- Detailed Understanding → Surgery
  - Type of repair – know repair strength
  - Quality of the repair
  - Other repaired structures
  - Venting of pulleys – A4, A5

- Patient – Current Medical History
  - Impact – delay healing

- Baseline Initial Therapy Evaluation
  - Edema – joint stiffness – pt. impression

Zone I Flexor Tendon Repairs

- Challenges – Therapy
  - Limited tendon gliding – DIP joint level
  - Risk of DIP joint flexion contracture

Conundrums – Zone I FTR

- Zone I Repair – Button

- Zone I Repair - Anchors

- Zone I Partial Laceration & Repair

Case Example – Button

- 21 y/o Female Student
- Lacerated FDP – DIPJ Level (volar plate)
  - Left index
- Less than 5mm Stump of the FDP
- Profundus Repair – Button
- UDN Repair

Zone I FDP Repair – Button

- Points of Interest – Surgery
  - Button ~ 45N strength
  - Postop – nail bed infection (required antibiotics)

- Points of Interest – Course of Therapy
  - Persistent & notable erythema
  - Persistent edema
  - Limited passive flexion
  - Slow gains with active flexion
- **Zone I FDP Repair - Button**
  - Therapy – 3 Days Postop
  - Modified Duran Passive Program

- **Zone I FDP Repair – Button**
  - Passive Intrinsic Stretch – Therapy Only
  - 3 Weeks Postop
    - Left on passive program!
    - Orthosis – wrist 30° extension
    - Place & hold exercise

- **Coban™ ... No Coban?**
  - JHS (Am) July, 2012
  - Coban™ - ↑ WOF
  - Preference: leave Coban™ in place
  - Clinical experience – edema resolves more quickly, difficult for patient to apply
    - Risk patient straightening finger or applying Coban™ too tight, too loose
  - 3 ½ Weeks Postop
    - AROM within orthosis

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**Hand to Shoulder**
**Therapy Center**
**Zone I FDP Repair – Button**

- Thermal Ultrasound

- AROM – Immediately following US

**Ultrasound**

- Cited Benefits
  - Decrease inflammation
  - Promote, accelerate tendon healing
  - Prevent adhesions
  - Increase motion
  - Non-thermal benefits
    - May be of greater value in adhesion prevention

- Definitive Evidence
  - Lacking in detail

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**Zone I FDP Repair - Button**

- 4 Weeks Postop
  - Place & hold exercise – out of orthosis

**Zone I FDP Repair - Button**

- 5 Weeks Postop
  - Hook fist exercise
    - Passive & active

**Zone I FDP Repair - Button**

- 5 Weeks Postop
  - IPJ elastic straps for passive flexion

**Zone I FDP Repair - Button**

- 6 Weeks Postop
  - Discontinue dorsal blocking orthosis
  - Buddy tapes
Zone I FDP Repair - Button

- 6 Weeks Postop
  - Blocking exercises
  - Passive extension PIPJ only – not DIPJ

Patient Education - Precaution

- Buddy Tapes
  - Reminds the patient to be cautious

- Avoid Pinching
  - Note: FDP force quickly ↑ 20N - 120N, well beyond current strength of a repair

Zone I FDP Repair - Button

- 8 Weeks Postop
  - Hand exersiser & putty
    - Goal → increase tendon excursion

Zone I FDP Repair - Button

- ROM – 12 Weeks Postop
  - MP 0/85
  - PIP 0/105
  - DIP 5/40
  - Note: blocked motion 45° - 50°

Case Example

- 14 y/o Boy
- Lacerated Right Ring Finger FDP, UDN
- Cut Hand on Ceiling Tile
- 60% Repair – Profundus & UDN
FDP Repair (+60%) – Zone I

- Points of Interest – Injury & Surgery
  - Laceration through DIP (volar plate/UCL)
  - 4 strand repair 4-0 supramid
  - 6-0 prolene epitendinous suture
  - UDN repair

- Points of Interest - Therapy
  - Early AROM
  - Exercise orthosis – hand based
  - DIP flexion contracture
  - PIP hyperextension

Partial Tendon Lacerations Literature

- < 50%
  - Typically, surgery not necessary
  - May trim the tendon

- ≥ 50%
  - Surgery recommended
    - Stronger tendon
    - Decrease risk of triggering
    - Increases tendon gliding

Therapy-Partial Tendon Repairs

- Early AROM – Tenodesis & Synergistic Movement
  - Favorable gliding excursion
  - Less severe adhesions
  - Improved tendon strength

- No Orthosis or Hand-Based Orthosis – with Exercises

- Forearm Based Dorsal Blocking Orthosis – between ex sessions/night

Partial Tendon Repair – Zone I

- 3 Days Postop
  - Bulky dressing removed
  - Light dressing

Partial Tendon Repair – Zone I

- Custom-Fabricated DBO

- Modified Duran Passive ROM Exercises

- Early Active ROM Exercises
  - Dorsal blocking orthosis – hand based
  - Tenodesis motion, place & hold exercises

- Forearm Based DBO – between ex/night
Partial Tendon Repair – Zone I

- 10 Days Postop
  - Suture removal
  - Scar massage – lotion [3 days later]

- 3 ½ Weeks Postop
  - Intrinsic stretch – passively, passively with active flexion & place & hold – slowly removing the hand

- 4 Weeks Postop
  - No orthosis – active place & hold
  - AROM – wrist & digits (gentle digital extension)
  - Gently mobilize adhesions distally

Hand to Shoulder Therapy Center
Partial Tendon Repair – Zone I

4 Weeks Postop
- AROM - Hook-fist exercise

6 Weeks Postop
- Slight PIPJ hyperextension
- Oval 8 ring – block hyperextension with exercise

7 Weeks Postop
- Discontinued forearm based dorsal blocking orthosis (young/active/+ROM)
- Buddy tapes

7 Weeks Postop ~ 3 times a day
- Extension orthosis
- DIPJ 30° (30°)

8 Weeks Postop
- Passive extension DIPJ – MP & PIP flexed
- PIP joint only flexed

LMB – dynamic extension DIPJ
- DIPJ 30° (25°)

Hand to Shoulder
Therapy Center
Partial Tendon Repair – Zone I

- ROM – 10 Weeks Postop
- Right Ring Finger
  - MP 0/90
  - PIP +5/110
  - DIP 7(0)/80

Case Example [J.S.]

- 22 y/o Male
- Accidental Knife Laceration at Work
- Right Middle Finger – FDP Zone I & RDN
- Surgery [4 days post injury]
  - FDP advancement – micro anchors [≤70N]
  - RDN repair

Points of Interest

- Surgery
  - Slow wound closure [three months]
- Therapy
  - Slow recovery of motion
  - PIP joint flexion contracture

Micro Anchors – Zone I FDP

- 6 Days Postop
  - Indiana passive motion program

- Initial Challenge
  - Wound closure – persistent drainage
Micro Anchors – Zone I FDP

- 6 Weeks Postop – limited active flexion
  - MP joint blocking orthosis – all day for over a month

Micro Anchors – Zone I FDP

- 7 Weeks Postop – limited active flexion
  - Thermal ultrasound

Micro Anchors – Zone I FDP

- 8 Weeks Postop – PIPJ flexion contracture
  - Safety pin splint

Outcome – 3 Months

- MP: 0/95
- PIP: 5(0)/110
- DIP: 10(5)/60

Outcomes - FDP End to End Repair

- Zone I Flexor Digitorum Profundus Two Strand Repair
  - 41 digits
  - 28 digits end to end repairs
  - PIPJ 91°
  - DIPJ 47°

APS – 2012

- 2 Strand Repair
- 14 Digits
- 9 Excellent & 5 Good Results
  - Strickland criteria (> 125° combined PIP & DIP)
Outcomes - FDP End to End Repair

- Zone I Flexor Digitorum Profundus
  Four Strand Repair
  - Active mobilisation following single cross grasp four-strand flexor tenorrhaphy (Adelaide repair)
  - Full length article
  - M. J. Sandow and M. McMahon
  - Department of Orthopedics and Trauma, and Physiotherapy Department, Royal Adelaide Hospital, Adelaide, Australia

- Four Strand Repair
  - 14 digits
  - Early AROM program
  - 6 excellent, 5 good, 2 fair, 1 poor (Strickland Criteria)
  - Average TAM 130°
  - With digital nerve repair
  - Average TAM 150°
  - Without digital nerve repair

Outcomes - Buttons vs. Anchors

- JHS (A) 2006
  - Comparison of Pullout Button Versus Suture Anchor for Zone I Flexor Tendon Repair
  - Wren V. McCallister, MD, Heidi C. Ambeau, MD, Leonard I. Katolik, MD, Thomas E. Trumble, MD
  - From the University of Washington Hand Center, Department of Orthopaedics and Sports Medicine, University of Washington Medical Center, Seattle, WA.

- Buttons & Micro Anchors
  - Therapy Program
    - Combined Modified Duran + Early AROM Program (Indiana Program)
  - 26 Patients: 13 Buttons 13 Anchors
  - Button: AROM PIPJ 5°/99° 3°/104°
  - Anchor: AROM DIPJ 10°/57° 8°/57°
  - JHS (A) 2006

Outcomes - Micro Bone Anchor

- JHS (E) 2013
  - The outcomes of zone 1 flexor tendon injuries treated using micro bone suture anchors
  - S. Nag, S. George and D. E. Bepple
  - Surgical Center for hands and Plastic Surgery, Metropolitan Hospital, Swansea, UK

  - 42 Zone I FDP Repairs
  - Average PIPJ ROM 5°/96°
  - Average DIPJ ROM 8°/48°
  - One Rupture
  - Mean QuickDASH Score 13.5
  - 81% Satisfied with Outcome

- JHS (E) 2013
Zone I FDP Repairs

- Customize the Rehab Program
  - Based on the individual
- Every Visit – Assess Therapy Program
  - Adjust based on progress or lack thereof
- Realize… Zone I Repairs – DIPJ Level
  - Difficult to achieve excellent flexion ≥ 40°
- Flexion Contractures Common
  - DIP joint or PIP joint level
  - 5° - 10°

Zone II Flexor Tendon Repairs

- Challenges - Therapy
  - Limited tendon gliding – PIP joint and DIP joint level
  - PIP joint flexion contracture – particularly in the presence of laceration into the volar plate

Case Example

- 17 y/o Male, High School Student
- Laceration Left Long FDS/FDP Zone II
- Surgery: 7 days post injury
  - FDS repaired
  - 8 strand FDP repair 4-0 looped double Kessler stitch
  - 6-0 prolene epitendinous stitch
- Therapy: 2 Days Postop

Points of Interest

- Surgery
  - 8-strand repair
  - Middle finger (favorable – 1 tendon excursion)
- Therapy
  - Negligible edema (two days postop)
  - Supple PROM (two days postop)
  - Excellent – early active flexion
  - Negligible scarring
  - Fair hair, fair skinned

8 Strand FDP Repair – Zone II

- Dorsal Blocking Orthosis
  - 3 days postop
8 Strand FDP Repair – Zone II

- Modified Duran PROM Program

8 Strand FDP Repair – Zone II

- Tenodesis Orthosis & Exercise Program
  - 5 days postop

8 Strand FDP Repair – Zone II

- Week 5
  - Tenodesis orthosis discontinued
  - Continue place & hold exercise

8 Strand FDP Repair – Zone II

- Week 6
  - Transitioned from place & hold to AROM
  - Continued dorsal blocking orthosis between ex/night

8 Strand FDP Repair – Zone II

- Week 7
  - Discontinued DBO except at school until 10 weeks postop
  - Buddy tapes
  - Active extension exercises (no passive)

8 Strand FDP Repair – Zone II

- ROM Measurements:
  - 2 Days po: MP x/70 PIP x/80 DIP x/35
  - Week 1: MP x/90 PIP x/100 DIP x/55
  - Week 2: MP x/90 PIP x/95 DIP x/60
  - Week 3: MP x/85 PIP x/100 DIP x/45
  - Week 4: MP x/85 PIP x/100 DIP x/60
  - Week 6: MP 0/90 PIP 0/105 DIP 0/50
  - Week 8: MP 0/90 PIP 0/105 DIP 0/65
  - Week 9: MP 0/90 PIP 0/105 DIP 0/70
8 Strand FDP Repair – Zone II

- Final Visit – Week 9
  - Precautions: avoid tight grasp, sports, lifting objects ≥10 lbs for four months

Case Example [A.F.]

- 13 y/o Girl; Fell & Cut Finger on Glass
- Left Middle Finger
- FDP Laceration thru A3 Pulley [zone II]
- Surgery [9 days post injury]
  - Six strand repair – 3-0 suture
  - Peripheral epiteninous repair
- Therapy [5 days post surgery]
  - Indiana early motion program

Therapy

- 5 Days Postop
  - Dorsal Blocking–PROM
  - Tenodesis–Place & Hold

- 7 Days Postop
  - Thumb (flexor pollicis longus)

Weeks 1 – 3

- Limited Participation in Therapy Initially
- ROM:
  - MP x/75 x/75 x/80
  - PIP x/95 x/95 x/95
  - DIP x/35 x/30 x/30

- Modify Therapy Program
  - Opportunity to improve active flexion

Out of Orthoses

- Set Goals – Active Flexion
  - Markings in the palm

13 years old!

Treatment Program “Modifications”

- Advanced Therapy Program 1 Week
  - Out of orthoses – active motion at 3 weeks
  - Added blocking orthoses at 5 weeks
  - Discontinued protective DBO at 5 weeks
  - Began resistance at 6 weeks
    - Foam piece (cylinder shape)
    - Putty
    - Hand exeriser
Blocking Orthoses - Exercise
- Buddy Tapes
  - 4 weeks postop
- Hand Based MPJ Block
  - 5 weeks postop

Blocking Orthosis – 6 Weeks
- Oval 8
  - Wore all day

7 Weeks Postop
- Increase Tendon Gliding
  - Putty & hand exerciser

Outcome – 11 Weeks Postop
- ROM - Left Middle Finger
  - MP 0/90
  - PIP 0/110
  - DIP 0/55 [65] — [blocked motion]

Discharge Visit – 3 Months
- ROM – Left Middle Finger

Outcomes – Short Arc
- Zhou X., et al JHS European 2017
  - 54 Digits
  - 6-Strand M-Tang Repair + Peripheral Suture
  - Therapy
    - Passive flexion + short arc active flexion
  - 80% Excellent or Good Category
  - No Ruptures
Outcomes – Place & Hold
- Trumble et al. JBJS American 2010
- 4-Strand Repair + Peripheral Suture
- Indiana Program [Modified Duran/Place & Hold]
- 54 Digits
- Averaged 156° Excellent Category
- Rupture Rate: 3.8% [two small fingers]

Outcomes – P&H + Short Arc
- Savvidou & Tsai J Hand & Microsurgery Jan-June 2015
- 51 Digits
- 6-Strand Double Loop + Peripheral Suture
- Passive - Place & Hold - Short Arc Active
- 81% Excellent or Good Category
- Rupture Rate 1.9%

Therapy for Flexor Tendons
- Customize Home Program
- Carefully Monitor Active Flexion
  - Adjust therapy program – no gains
- Protective Orthosis (wrist) initial 6 wks
- Exercise Orthosis (with or without wrist)
- Passive Extension – Isolate Indiv. Joints
- Pause...Small Fingers
  - No blocking
  - More caution with advancing program