Tendon Transfers
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Goal
- Restore balance
- Indications
  - Nerve injury
  - Paralyzed muscle
  - Damaged tendon/muscle
  - CNS lesion
- Consider
  - Action
  - Functional gain

Mechanical considerations
(Barad)
- Strength: ability to generate tension
  - Number of muscle fibers
  - Cross-sectional diameter of all fibers
- Muscle will lose a grade following transfer
- Variability
  - Muscle 2x stronger than another
  - Greatest force at resting length

Leverage
- Leverage: “The power of a lever moving about a point”
- Torque/movement: Force X moment arm
- Moment arm: perpendicular distance form the axis = the lever
- Drag:
  - Internal resistance
  - Friction

Principles: Relative Strength

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Strength Relative to FCR/Muscle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brachioradialis</td>
<td>2.0</td>
</tr>
<tr>
<td>Flexor carpi ulnaris</td>
<td>2.0</td>
</tr>
<tr>
<td>ECRL, ECRB, ECU, PT, FPL</td>
<td>1.0 (each tendon)</td>
</tr>
<tr>
<td>FDS, FDP</td>
<td></td>
</tr>
<tr>
<td>EDC, EIP, EDQ</td>
<td>0.5 (each tendon)</td>
</tr>
<tr>
<td>APL, EPB, PL</td>
<td>0.1 (each tendon)</td>
</tr>
<tr>
<td>Interossei</td>
<td>2.7 (total/combined)</td>
</tr>
<tr>
<td>Lumbricales</td>
<td>0.6 (total/combined)</td>
</tr>
</tbody>
</table>

Mechanical Considerations
- Actual strength of a muscle does not change
- Direction of force changes
- Blood and nerve supply are not affected by transfer
- Muscles adapt tension to demand:
  - Strong muscle will atrophy
  - Weak muscle will hypertrophy
Potential excursion –
  - Free from restrictions
  - Based on number of sarcomeres
  - Intact limb –
    - Very few muscles achieve full potential

Excursion – Required

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Excursion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interossei</td>
<td>3 cm</td>
</tr>
<tr>
<td>Wrist flexors and extendors</td>
<td>3 cm</td>
</tr>
<tr>
<td>EPB, APL</td>
<td></td>
</tr>
<tr>
<td>BR, lumbricals, thenars</td>
<td>4 cm</td>
</tr>
<tr>
<td>Finger extendors</td>
<td>5-6 cm</td>
</tr>
<tr>
<td>Finger flexors</td>
<td>6-7 cm</td>
</tr>
</tbody>
</table>

Available Excursion

- Excursion permitted by the surrounding connecting tissue
  - Usually assessed during surgery
  - Varies
  - Can be decreased by too much dissection Scar

Preoperative Planning

- Purpose:
  - Identify assets
  - Limitations
  - Determine goals for pre-op treatment
  - Patient education for post op
  - Precautions
  - Protocols
  - Expectations

Hand/UE Evaluation

- Observation – watch functional use or limits of affected limb
- History/Physical
- Grip/Pinch – watch for substitution or motor signs (i.e., Froments); watch for abnormal grasp patterns
- Sensibility

Preoperative Treatment

- Stretch opposing muscles to prevent contracture
  - FDS – stretch with wrist ext

- Splinting
  - Goals
    - To temporarily restore balance externally for an imbalance internally
    - To prevent deformity or to correct existing joint contractures
**SPLINTING**

- To prevent
  - over-stretching
  - adaptive shortening
  - compensatory patterns
- Increase function

**Preoperative Treatment**

- Joint and Soft tissue mobilization to maintain ROM
- Muscle training and strengthening
  - isolate muscle that will be transferred
  - biofeedback and/or FES can be used to isolate the muscle and give feedback to the patient
  - minimize loss of strength during immobilization

**Postoperative Treatment of Common Transfers for Peripheral Nerve Injury**

- Communicating with the Surgeon/Op Report
  - Specific muscle/tendon units
  - **Anatomical route**
  - Site of tendon suture or anastomosis
  - How did the wound bed look?
  - What is the potential for tendon scarring?
  - Was a tendon graft used? From where?
  - Ideal to go to operating room

**Stages of Postoperative treatment  General guidelines**

- **Protective Stage/Early Stage**
  - Protect transfer
    - Generally, immobilized in protective post-op cast for 1-4 weeks; usually 3 weeks.
    - Transfer is immobilized so tension on the juncture site is minimized
    - Control edema
    - Prevent stiffness in uninvolved joints

- **Mobilization/Intermediate Stage 4–8 weeks**
  - Protect transfer between exercises with thermoplastic splints
  - Activate transfer being careful not to over-stress tissue
    - Active motion will tear some adhesions and prevent others from forming.
    - Monitor early motion making sure desired position is maintained
**Mobilization/Intermediate Stage 4-8 weeks**

- Short frequent exercise sessions
  - Limit fatigue of transferred tendon.
- Always be aware of avoid overstretching.
- Sometimes
- Limited arc /isolated joint motion
- Dynamic splint with stop blocks
- Can use biofeedback and/or electrical stimulation (at sub-tetany contraction) at 4-5 weeks post-operatively.

**Mobilization Stages**

- Mobilize surrounding soft tissue to increase available excursion
- Add scar management
- Gradually incorporate transfer motion into functional activities

**Stages**

- Resistive/Late stage 8-12 weeks
  - Add resistance to transfer
    - Strengthen gradually and avoid substitution patterns
    - Add putty
  - Restore passive motion
    - Gentle passive stretches watching effect on transfer (be careful not to over stretch!)
    - Focus on hand function

**Tips to Get the Transfer working**

- Try light functional tasks – opposition
- Facilitate by incorporating motion of transferred muscle in activity
- Use biofeedback
- Use training splints

**Straps and splints with re–ed**

**Tendon Rupture due to Trauma**

- EPL rupture post fracture
  - Use of Extensor indicis to the EPL
  - Easy to activate transfer
  - Commonly used

- Taping used for facilitation
- Re–ed = blocks full flexion
**High Median Nerve Injury**

*Extrinsic muscles Affect:*
- Pronation - Pronator Teres and Quadratus
- Wrist flexion - Flexor Carpi radialis
- Wrist radial deviation
- Finger flexion - FDS all; FDP index and middle
- Thumb flexion - Flexor Pollicis longus

*Intrinsics affected:*
- MP flexion Index and Middle - Lumbricales 1 & 2
- Thumb flexion - FPB
- Thumb opposition - opponens pollicis

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**High Median nerve transfers**

- Less common
- With high median nerve injury – fewer motors to choose from

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**High Median Nerve Injury Deficits**

**Transfers for High Median Nerve Palsy**

<table>
<thead>
<tr>
<th>Needed Function</th>
<th>Preferred Transfer</th>
<th>Other Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opposition</td>
<td>EIP to APB + EPL</td>
<td>EDM or PL</td>
</tr>
<tr>
<td>FPL Thumb Flexion</td>
<td>BR to FPL</td>
<td>ECRL</td>
</tr>
<tr>
<td>Finger Flexion</td>
<td>FDP of index, middle to ring, small</td>
<td>ECRL to FDP index and small</td>
</tr>
<tr>
<td>Forearm Pronation</td>
<td>Zancoli biceps rerouting</td>
<td>Radius derotational osteotomy (rare)</td>
</tr>
<tr>
<td>Sensibility</td>
<td>Flag flap</td>
<td>Neurovascular cutaneous island pedicle from ring</td>
</tr>
</tbody>
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**AIN Neuropathy**

*Anterior Intertosseous Nerve or Pseudo AIN*

- Direct trauma to the AIN - Fracture/compartment syndrome
- Originates off the MN 5-8 cm distal to the medial epicondyle
- Pseudo AIN
  - Parsonage–Turner syndrome / Brachial plexopathy
  - Affects the fascicles more proximally

**AIN tendon transfer**

*Brachioradialis to FPL*

FDP of RF/MF to index side to side
Loss of thumb opposition (APB, OP, FPB)
Loss of palmar sensation thumb, index, middle and radial border of ring fingers

Goal: restore thumb opposition
- Common motors chosen for this transfer:
  - FDS of II or IV
  - EIP
  - palmaris longus (Camitz)
  - abductor digiti minimi
  - extensor digiti minimi

Ideal line of pull for transfer is toward the pisiform
Transfers which pass distal increase thumb flexion
Transfers which pass palmar and radial increase thumb abduction

EIP transfer
- Doesn’t require a pulley
- Can be used with scarring of palmar forearm muscles and/or tendons
- Need to extend tendon length by including 1 cm of extensor hood with EIP tendon
**Opponensplasty**

- **FDS ring transfer**
  - Pulley should be distally based FCU pulley or proximal border of palmar fascia
  - Adequate power and excursion for abduction
  - May weaken residual grip

**Rehabilitation**

- **Week 4** begin AROM of thumb and other joints out of splint
- **Light grasp**
  - Prehension tasks
- **Week 6**
  - d/c splint
  - A/PROM
- **Week 8**: PRE’s

**Low Ulnar Nerve Injury**

- Wartenberg’s sign – eccentric abduction of 5th finger due to unopposed EDQ and paralysis of palmar adductors
- Froment’s sign – substitution of FPL for adductor pollicis and first dorsal interosseus; positive if patient flexes IP joint with key pinch

**Opponensplasty**

- **PL transfer (Camitz)**
  - Provides best abduction
  - Most commonly used with severe carpal tunnel syndrome
  - Significant bowstringing occurs, may be objectionable cosmetically

**Low ulnar nerve palsy**

- Loss of thumb adduction (AdP, ulnar ½ of FPB)
- Clawing of ring and small fingers (Interossei muscles (4), lumbricals to ring and small, hypothenar muscles)
- Median nerve innervation of lumbricals to index and middle prevent clawing of these digits

**Zancolli lasso procedure**

- Slips of the FDS Middle finger form a loop around A1 and A2 pulley of RF, SF
  - “lasso”
  - MP flexion of RF and SF with MF
Brand ECRB transfer
Goal: restore intrinsic function of MP flexion; control claw deformity
- uses ECRB as a motor prolonged with palmaris longus free graft
ECRB is passed radially around radial side of forearm, extended by graft into 4 slips, passed through the carpal tunnel and volar to the deep transverse metacarpal ligament into the lateral band of the dorsal apparatus (Green’s Operative Hand Surgery)
Splint intrinsic plus with wrist for 3-4 weeks

Intrinsic plus transfer rehab
- Increase amount of extension at the MP gradually
- No unsupervised full ROM
- Easier to stretch transfer much later
- Avoid making a fist in the first few weeks – too much stress on transfer – flexors are strong
- 4–6 weeks – add blocked PIP, DIP extension
- 8 weeks begin gentle PRE’s

Splints after Transfer
• use lumbrical bar as a splint assist when progressing to light functional activities
• protect transfer from heavy use for up to 3 months post surgery, do not allow hyperextension at MP’s

Surgery – to restore thumb adduction
- Most transfers provide improved stability and improved pinch strength of 25–50%
  - Common motors include EIP, brachioradialis
Boyce uses Brachioradialis extended with free graft; lengthened tendon end is passed through interspace between 3rd and 4th metacarpals to insert on abductor tubercle of thumb.

Radial Nerve injury
Motor Deficits
- Elbow extension
- Wrist extension
- MP finger extension
- Thumb extension
- Supination
  - Biceps still intact
Radial nerve Low Injury – Posterior Interosseus Nerve

- Loss of ECU but will see extension in radial direction (ECRB, ECRL intact)
- Decreased strength in supination (supinator)
- Loss of EDC and thumb extension

Commonly used tendon transfers for radial nerve palsy

- Pronator Teres to ECRB/L to restore wrist extension

Commonly used tendon transfers for radial nerve palsy

- Palmaris Longus or FDS to EPL to restore thumb extension

Finger Extension

- FCR to EDC
  - Less strength than FCU
- FCU to EDC
  - Contraindicated in Posterior Interosseous Nerve Palsy (removes remaining ulnar wrist deviator)
  - Weakens power of finger flexion

Putty rolling exercise

Brand Transfer

- Thumb separate but all 4 fingers extend simultaneously
**Boyes Transfer**

- Separation of thumb/index extension and M/R/S F extension
- FDS (m) to EPL/ED (1) IF
- FDS (r) to ED (M/R), EDQ
- PT to ECRB

**Post-operative management**

- Splint
  - Elbow at 90 degrees
  - Forearm pronated maximally
  - Wrist extended (30–45)
  - MPx extended to neutral with IPs free
  - Thumb is held in radial abduction
- Mobilization exercises start at 3–4 weeks
- Protective splinting is continued for 3–4 more weeks for a total of approximately 8 weeks

**Gentle Protected active exercise**

- performed with support to the wrist in extension
- Designed to protect the tendon from composite flexion stretch
  - MP flexion/extension with IPs straight
  - IP flexion/extension with MP extension
  - Wrist flexion to neutral (from protected position)
  - Thumb IP flexion/extension with thumb in slight radial abduction
  - Elbow flexion/extension with forearm pronated
  - Forearm rotation with elbow flexed and wrist/fingers maintained in extension

- Avoid simultaneous wrist flexion/finger flexion until approximately 8 weeks post-op
- Resistance initiated around 8 weeks; ex. Velcro dowel board

**Tips to get transfer to work**

- Preoperative preparation pays off
- Functional and familiar tasks
- Use gravity eliminated plane
- Biofeedback / FES
- Ask the patient to perform the original motion of the transferred muscle
  - ex. FDS of ring for thumb opposition: block other fingers in extension and ask pt to bend ring finger at MIP
- Use training splints – lumbrical bar following intrinsic transfer as an assist