Planning Recipient:
- Fixation
- Vascular Access
- Biomechanics
- Limb Alignment
- Osteotomy

Planning Transplant:
- Bone Length
- Pedicle Length
- Paddle Use
- Paddle Location
Fixation Options:
- Plates
- Screws
- External Fixation
- K-wires
- Ilizarov

INDICATIONS
VASCULARIZED FIBULA

- PROMOTES UNION
- AUGMENTS SOFT TISSUE
- VALUABLE OPTION IN COMPLEX CASES
Free Functional Muscle Transfer for Upper Extremity Reconstruction

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Disclosure

• There are no conflicts of interest for this presentation and nothing to disclose

Functional Free Muscle Indications

• Deficiency of critical motor function with no suitable tendon transfer options
• No suitable rotational muscle transfer
• Soft tissue defect requiring coverage in combination with functional loss
Free Functional Muscle
Contraindications

• Relative Contraindications
  – Age > 45 years
  – Obesity (weight of limb to be moved by transfer)

• Absolute Contraindications
  – Medical comorbidities: DM, cardiac disease, vascular disease, autoimmune disease

Functional Free Muscle
 Goals (Manktelow)

• Supply a useful range of motion

• Provide adequate strength for functional activities

Functional Free Muscle
Pre-requisites

• Motivated patient
• Supple passive range of motion
• Suitable recipient site motor nerve and vessels
• Good soft tissue coverage and underlying tissue bed for tendon gliding
Surgical Technique: Key Points

Achieve optimal muscle resting length

Surgical Technique: Key Points

• Establish strong & appropriately-located origin and insertion

Surgical Technique: Key Points

• Minimize Ischemia Time
  – Irreversible muscle loss increases with time
  – Non-linear relationship
Surgical Technique: Key Points

• Nerve Considerations
  – Recipient site nerve should be motor fibers
  – Neurorrhaphy should be done as close as possible to transplanted muscle

Donor Muscle Considerations

• Muscle Type
  – Pennate (stronger)
    • Rectus femoris

Donor Muscle Considerations

• Muscle Type
  – Strap (better excursion)
    • Gracilis
    • Latissimus Dorsi
Donor Muscle Considerations

• Muscle Excursion
  – Ideally 6-7 cm of muscle excursion to produce functional range of flexion of fingers and elbow

Donor Muscle Options

• Gracilis
• Latissimus
• Rectus femoris
• Pectoralis Major
• Medial gastrocnemius
• Tensor fascia lata
• Serratus Anterior

Functional Free Muscle Indications

• Functional reconstruction after:
  – Trauma
  – BPBP
  – Volkmann’s
  – Tumor
  – Congenital deficiencies
Traumatic C5-C6 BPI
3 years post injury
CONGENITAL:
5 year old Arthrogrypotic

PROM

LATISSIMUS

LATISSIMUS

LT
Free gracilis for finger flexion 10 month follow up

Volkmann's Contracture
4 year old 2 years S/P SCH Fx

Flexor Origin Slide to correct contracture
1 year after flexor origin slide

Nerve Graft
Independent fascicular territories of gracilis

Cable grafting of severely compromised median nerve

Functional results at one year
Harvesting Gracilis with a Skin Paddle

[Images of surgical procedures]
Options for Thumb Opposition

- Tendon transfer
- Huber muscle tranposition
- Functional free muscle
  - Serratus
  - Gracilis
  - Medial plantar flap with adductor hallucis
Functional Free Muscle Transfer

- Demanding procedure
- Meticulous technique
- Experience in microsurgery

Immediate Reconstruction of finger flexion after severe Compartment Syndrome with liquifactive muscle necrosis

Immediate Functional Reconstruction

Flexor Tendons

Median Nerve
Think about your reconstructive options
Thank you
Medial femoral condyle free flaps

Allen T. Bishop, MD

MFC flaps

- Versatile flap for:
  - Periosteum: corticoperiosteal flap
  - Bone: small segments
  - Cartilage: Osteoarticular graft
  - Skin: composite or buoy flap

Periosteal flap

- Better than vascularized bone in certain locations and situations
  - Clavicle
    - 50% nonunion with fibula
    - Failed grafting of nonunion
    - Radiation necrosis
  - Forearm: radius and ulna non-union
  - Structural allograft nonunions
    - As a “patch” to form bone in larger nonunion sites
Vascularized Corticoperiosteal flaps:

- Conform to the shape the recipient bone*
- Robust production of subperiosteal new bone **
- Improve local vascularity


2 Blood vessels supply MFC

MFC Blood Supply: Descending Genicular Artery*

- Present in 89%
- 1.5mm diameter (1.0-2.0)
- Saphenous branch (to skin in 79%)
- Usually the dominant blood supply

*Yamamoto H, A. T. Bishop A. Y. Shin et al
J Hand Surg Eur Vol 2010 35: 569
MFC Blood Supply
Superomedial Genicular Artery

- Present 100%
- Origin: 5.2 cm proximal to knee
- 0.78 mm dia. (0.38-1.4)
- Anastomosis with descending genicular a.

*Yamamoto H, A. T. Bishop A. Y. Shin et al
J Hand Surg Eur Vol 2010 35: 569

Blood supply of the medial femoral condyle
Bone nutrient vessels

- Highest # of nutrient vessels in distal-posterior quadrant-preferred for graft harvest

*Yamamoto H, A. T. Bishop A. Y. Shin et al
J Hand Surg Eur Vol 2010 35: 569

Periosteal flap technique

Elevation of vastus medialis exposes condyle, descending genicular vessels
Periosteal flap technique

Osteotome used to lift periosteal flap containing fragments of cortical bone

* Mean flap size 4.75 x 5.75 cm

Surgical Technique

Graft elevated on descending genicular pedicle
**Surgical Technique**

- Deep surface includes periosteum and thin layer of bone
- Dominant vascular pedicle

**Periosteal flap technique**

Flap is thin enough to bend: conforms to recipient site

**Periosteal flap: clavicle**

Periosteal flap: Clavicle

- Flap wrapped around clavicle, radius or ulna, secured with heavy sutures

Periosteal flaps

- Clavicle
  - 100% union
  - 2 path. fractures after radiation
  - 1 infected nonunion
  - Time to union 5 months


Femoral allograft nonunion
Case:
Femoral allograft nonunion

MFC Vascularized bone graft:
Treatment of scaphoid nonunion
Case 5

17 year-old male with 1-year-old injury

Humpback deformity
Some density changes
DISI

MRI: diminished vascularity of the proximal pole
Case 5

Density changes suggestive of AVN proximal pole

Exposure of medial condyle

Exposure of medial condyle
Case 5: 4 months

Union Rates

ICSRA
N = 10

MFC
N = 12

100%

p = 0.039
Osteoarticular MFC Flap

- Uses in the wrist:
  - Replacement of damaged proximal surfaces of scaphoid and lunate
16 cases of proximal scaphoid replacement with 14 mo. Follow-up
- Healing in 15
- 12 with complete pain relief
- No SL instability


Conclusions

- MFC grafts provide superior results in treating scaphoid nonunions with AVN and humpback deformity
- Cortico-periosteal flaps allow salvage of recalcitrant nonunions of clavicle, forearm and allograft-host nonunions
- The Osteochondral MFC flap is a new, promising method for irreparable damage to cartilage and subchondral bone

Thank You
Toe-to-Hand Transfers

Neil Jones MD
Chief of Hand Surgery
Professor of Orthopedic Surgery
Professor of Plastic and Reconstructive Surgery
University of California - Irvine
Shriners Hospital Los Angeles

I have nothing to disclose

- Ultimate functioning free flap
- Osteocutaneous flap
- Mobile joints
- Sensate
- Growth in children
Great Toe or Second Toe
Vascular Anatomy

- Dorsalis pedis artery - First dorsal metatarsal artery (FDMA)
  - "Long" transfer
- First plantar metatarsal artery (FPMA) + vein graft
  - "Short" transfer

- Key point is to understand the relative size and dominance of the dorsal and plantar arterial systems
- Proximal - distal dissection of FDMA
- Identify FDMA in 1st web space and dissect retrogradely

Preoperative Investigations

- Preoperative angiogram?
- Doppler mapping of FDMA

Toe-to-Hand Transfers
Preoperative Investigations

- Preoperative angiogram?
- Doppler mapping of FDMA

Great Toe or Second Toe
Vascular Dissection

- Key point is to understand the relative size and dominance of the dorsal and plantar arterial systems
- Proximal - distal dissection of FDMA
- Identify FDMA in 1st web space and dissect retrogradely
First Dorsal Metatarsal Artery (FDMA)

- Superficial to muscle
- Through the muscle
- Deep to muscle

Relative position of FDMA with respect to the muscle may be evaluated by Doppler mapping.

Great Toe or Second Toe Harvest

Dissection of extensor and flexor tendons

Tibial and fibular digital nerves

Deep peroneal nerve

Saphenous vein

Great Toe or Second Toe Anatomy
Toe-to-Hand Transfers
Surgical Technique

- Bony osteosynthesis - 90-90 intraosseous wiring
- Flexor and extensor tendon repairs, possible tendon grafts, tendon transfers
- Digital nerve repairs, possible nerve grafts, end-to-side nerve transfers
- Venous anastomosis (end-to-end)
- Arterial anastomosis (end-to-end or end-to-side)
- Tension-free closure - liberal use of skin grafts
- Pulse-oximetry for post-operative monitoring

Toe-to-Thumb Transfers
Surgical Technique

Post-traumatic
Congenital
Toe-to-Thumb Transfers

- Great toe
  "Wrap-around" great toe
  "Trimmed" great toe
- Second toe
- Partial toe

Toe-to-Hand Transfers

Post-Traumatic Reconstruction

- Isolated thumb amputations
  - from the metacarpal base to the mid-point P1, with intact CMC joint and thenar muscles
- Multiple digit amputations
- Multiple digit and thumb amputations
- Metacarpal hand
Post-Traumatic Reconstruction of the Thumb

Indications for Toe-to-Thumb Transfers

- Isolated thumb amputation (from CMC joint to mid-proximal phalanx)
- Thumb and multiple finger amputations
- Amputation of all five digits - "metacarpal hand"

Toe Transfers and the Level of Amputation

Great toe or variations

Second toe transfer

Great Toe Transfer

- Reasonably similar appearance to thumb
- Can be debulked secondarily
- Best IP joint flexion
- Most significant donor defect in the foot
“Wrap-around” Great Toe Transfer
Morrison 1984, Baechen modification

- Minimizes donor defect in foot
- Soft tissues and nail and distal phalanx are transferred to minimize resorption of bone graft
- Intervening length made up by iliac crest bone graft
- Excellent appearance
- No IP joint motion
- No growth in children

Thumb Amputation through Proximal Phalanx
“Wrap-around” Great Toe Transfer
Trimmed Toe Transfer
Wei, Upton 1988

- Reduces width of P1 and P2, but preserves IP joint motion

Thumb Amputation base of Proximal Phalanx

“Trimmed” Toe Transfer
Second Toe Transfer
Yang 1977

- Narrower than a thumb
- Less satisfactory appearance
- Tend to develop DIP joint flexion deformity
- Relatively inconspicuous donor site

Thumb Amputations
Proximal to mid-Metacarpal

- Second toe provides length of second metatarsal
- May require preliminary soft tissue coverage and secondary opposition tendon transfer
Isolated Thumb Amputation just distal to CMC joint

Second Toe to Thumb Transfer

Second Toe to Thumb Transfer

4 years old
Crush Injury Thumb

Immediate Custom Toe-to-Thumb Transfer

Immediate Custom Toe-to-Thumb Transfer
Custom Toe-to-Thumb Transfer

- Minimize the amount of tissue harvested from the foot
- Make the toe transfer the same size as the contralateral normal thumb

Post-traumatic Reconstruction of the Fingers

Indications for Toe-to-Hand transfers

- Multiple amputated fingers with a thumb present  U4 R1
- Amputation of all 5 digits  R5

Toe Transfers for Post-Traumatic Reconstruction of the Fingers

Either:

- Single second toe transfer
- Bilateral second toe transfers
- Combined second-third toes
Amputation of Thumb and all 4 Fingers
“Metacarpal Hand”

4 years old

Metacarpal Hand

Either:

- Great toe for thumb reconstruction and combined second-third toes for finger reconstruction
- Bilateral second toes for thumb and finger reconstruction

Staged Double Second Toe Transfers
Reverse Radial Forearm Flap (Lu 1982)
"Metacarpal" Hand
8 year old with burns

Right Great Toe-to-Right Thumb Transfer

Right Great Toe-to-Right Thumb Transfer
Combined 2nd-3rd Toe Transfers for Finger Reconstruction

Great Toe and Combined 2nd-3rd Toe Transfers to Right Hand

Toe-to-Thumb Transfers

Results

- Success > 97%
- Sensation: 2pd < 10mm in 50% patients (better than contralateral toe!)
- MCP joint motion 25°, IP joint motion 29°
- Grip strength 80-100%, key pinch 65-169%
- Pinch strength: second toe < 50% great toe
- Appearance: wrap-around and trimmed toe > great toe > second toe
- Donor foot: gait analysis close to normal
Decisions in Post-Traumatic Toe Transfers

Conclusions

- Harvest the minimal amount of bone and soft tissue from the foot to minimize morbidity in the donor foot
- Second toe has most inconspicuous donor site
- Trimmed toe and Morrison wrap-around variations provide the best appearance of the reconstructed thumb

Decisions in Post-TraumaticToe Transfers

Conclusions

- Explain all the options to the patient, both conventional and toe transfers
- Explain the morbidity of each donor site
- Show pre-operative and post-operative photographs
- Have patient meet with a patient who has had a similar reconstruction
- Individualize the reconstruction, don’t depend on an algorithm!

Toe-to-Hand Transfers

- Post-traumatic
- Congenital
Toe Transfers for Congenital Absent Thumbs

Morphological Indications

No guidelines for referral of children with congenital absent thumbs for consideration of microsurgical toe-to-thumb transfers (Jones 2013)

- Absent thumb only, distal to CMC joint
- Absent thumb with only 1-2 ulnar fingers
- Absence of all 5 digits

Absent Thumb, Index and Middle Fingers

Congenital Constriction Ring Syndrome

- Only right great toe is available

Congenital Constriction Ring Syndrome

Only right great toe is available
Congenital Constriction Ring Syndrome
“Wrap-Around” Great Toe-to-Thumb Transfer

5 years postop

Toe-to-Hand Transfers for Finger Reconstruction
Indications
- Normal thumb but four absent fingers - U4R1
- Symbrachydactyly
- Transverse failure of formation
- Congenital constriction ring syndrome
- Ulnar longitudinal deficiency
Toe Transfers for Finger Reconstruction

- Second toe into ring or small finger position (ulnar side of hand allows grasp and pinch)

- Two second toes into middle and small finger positions allows 3-point pinch

- 2 stage procedure

- Simultaneous one stage procedure

Thumb but Absent Fingers

- 2 second toes into middle and small finger positions sequentially

- Simultaneous one-stage procedure

Simultaneous Double Second Toe Transfers
Symbrachydactyly
Thumb but absent fingers U4R1

Second Toe-to-Small Finger Transfer

7 years postop
Toe-to-Hand Transfers for Finger Reconstruction

**Indications**

- Complete absence of all 5 digits – R5

  - Prosthesis
  - 2 second toe transfers into thumb and small finger positions
  - Two-stage procedure or simultaneously

Complete Absence of all 5 Digits R5

- 2 second toe transfers into thumb and small finger positions
- Two-stage procedure or simultaneously

1st stage Second Toe Transfer into Thumb Position
Staged Double Second Toe Transfers

Toe-to-Hand Transfers for Congenital Hand Anomalies

Conclusions

- All children have regained subjective sensibility
- MTP joint motion better than PIP and DIP joint motion
- All but 2 children have improved pinch and grasp function
- Toe-to-thumb transfers have better function than toe-to-finger transfers
- Epiphyses remain open
- Growth is equal to contralateral toe
- Very high parental satisfaction
Toe-to-Hand Transfers for Congenital Absent Digits

Conclusions

- Embryological classifications are not helpful in guiding reconstruction.
- Morphological and radiographic anatomy of the hand and level of absence of the digits are the most logical criteria for conventional or microsurgical reconstruction.