Stress Fractures of the Foot
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Jones Fractures

I. Definition = fracture of the metaphyseal-diaphyseal junction at or distal to the 4th and 5th metatarsal articulation

II. Zones 1-3
a. Zone 1 – Tuberosity avulsion fractures – typically oblique fracture line
b. Zone 2 – True Jones fracture – transverse fracture line
c. Zone 3 – Diaphyseal stress fractures
d. Zones 2 & 3 have guarded potential for healing related to vascular watershed area and factors placing added load to this area; often treated the same

III. Treatment of Jones fractures
a. Nonoperative
   i. NWB for 6 wks (Torg)
   ii. 72-75% heal in 5 months
   iii. 50% fail to heal or refracture (Quill)

b. Operative
   i. Indications (threshold decreasing?)
      1. Athlete with acute or stress fx
      2. Nonunion
      3. Refracture
      4. Acute or stress fracture in presence of cavovarus foot/lateral overload
   ii. Operative goals
      1. Expedite healing
      2. Quicker recovery
      3. Easier rehab
      4. Decreased risk of refracture
   iii. Surgical technique
      1. Axial screw fixation is the gold standard but no studies with Level 1 or 2 evidence
         a. Popularized by J DeLee
         b. Plates work but are prominent and require removal with subsequent risk for refracture
      2. Low morbidity – percutaneous technique in primary situations
a. Open bone grafting for revisions

3. Select largest screw that “comfortably” fits canal
   a. I prefer “solid” screw but no definitive answer on cannulated vs not – controversial and conflicting lab studies
   b. Studies only suggest screw must be larger than 4.0 (Porter, AJSM ’05)
   c. Headless variable pitch screw has less pull out strength but equal bending strength to 6.5 cancellous lag screw (Sides SD, FAI, 2006)
   d. Jones fracture-specific screws now available – solid type with strength advantages (Nunley, FAI ’09)

4. Surgical technique
   a. Outpatient; regional anesthesia; calf tourniquet optional
   b. Enter the canal “high and inside” on the tuberosity – need to account for “curved” diaphysis
      i. “Hug the cuboid”
      ii. Blunt dissection to protect sural nerve
   c. Cannulated assisted
      i. Option to use a solid 3.2mm drill bit to “ream” the canal free-hand once the proximal canal is opened with a cannulated system
      ii. Prevents perforation of cortex or cutting across guide wire
         1. Advance on reverse drilling
      iii. Adjusts for less than ideal entry site
   d. Tap to determine screw diameter and length
      i. 4.5, 5.5, 6.5mm – partially threaded
      ii. Most men require a 5.5mm screw to obtain distal intramedullary cortical purchase
      iii. Excessively large diameter screw may distract fracture site
      iv. Threads just past the fracture
         1. Longer screw may attempt to “straighten” bone and lead to lateral gapping (Horst F, FAI ’04)
      v. Headless variable pitch screw has less pull out strength but equal bending strength to 6.5 cancellous lag screw (Sides SD, FAI, 2006)

5. Option to inject biologic (DBM + bone marrow aspirate) or stem cells (Murawski, AJSM ’11)
a. Consider if lateral/plantar gap present after screw insertion
b. Aspirate from iliac crest or tibia – need 2-4cc volume

iv. Typical postop management
1. NWB 1-2 weeks, then walker boot for 2-4 wks
2. Pool therapy/bike good cross-training rehab tools
3. Run in stiffened shoe/orthosis once clinically nontender
4. Return to play when nontender – usually 6-8 weeks (x-ray healing lags behind)

IV. Complications of intramedullary screw fixation
a. Infection
b. Sural nerve injury
c. Distal cortical perforation (not “high and inside” or screw too long)
d. Prominent screw head – (not “high and inside” – entered too lateral)
e. Recurrent fracture/nonunion (often with hardware failure)
   i. Not a new problem
      1. Wright AJSM ’00
      2. Larsen AJSM ’02
      3. Anderson: our own review noted a 8% nonunion rate in elite athletes – often asymptomatic
   ii. Athlete/parents must understand this risk when early postop play decisions are made (accelerated rehab)
   iii. CT scan often necessary to confirm degree of nonunion
       1. Need to differentiate from a persistent plantar-lateral gap
   iv. Be critical of index surgery
      1. Type/size/length of screw
         a. Small cannulated screws may bend/break
         b. Long screws may “stress shield” proximal metatarsal or create lateral gapping
      2. Location/direction of fracture
         a. Axial screws for transverse fractures
         b. Bicortical screws may be better for very proximal oblique fractures
      3. Foot posture
         a. Cavovarus/metatarsus adductus creates lateral overload
   v. Observe/protect if asymptomatic
      1. Okay to play and may do well if well positioned and fitted screw of adequate size
   vi. If symptomatic refracture - manage initially with rest/stimulator
1. Other options available include injection of biologic or high energy shockwave (Furia et al, JBJS ’10)
   a. Helpful if time constraint
vii. Persistent or unstable nonunion: open bone grafting and screw exchange
   1. Place larger solid screw
   2. Autogenous bone graft
      a. Prefer non-weightbearing location due to risk for stress fracture
         i. Iliac crest – use power trephine
   3. +/- address lateral overload (depends on index technique)
      a. 1st metatarsal or calcaneal osteotomy
      b. Use bone removed for bone grafting of nonunion
   4. Bone stimulator postop
   5. Extended period of non-weightbearing (usually 6 weeks)
   6. Repeat CT at 10-12 weeks to assess union
   7. RTP when fully united by CT and asymptomatic
   8. Results: Hunt/Anderson AOSSM 2011. Successful revision in 20/21 athletes; one refracture; all RTP at avg of 12.3 weeks
viii. Failed revision surgery - reassess for hindfoot varus/lateral overload; consider Vitamin D deficiency
   1. Dorsiflexion 1st metatarsal or calcaneal osteotomy or both
   2. If normal foot posture?
      a. Anecdotal reports of cuboid osteotomy and plantar condylectomy of 5th metatarsal

**Bibliography**

Navicular Stress Fractures
I. Incidence increasing? Perhaps awareness is!
   a. 1st description by Towne in 1970 in middle distance runner
   b. Over 200 cases now reported
      1) Torg 21 JBJS 82
      2) Fitch 20 JBJS 89
      3) Khan 86 AJSM 92
II. Anatomy
   a. Rigid structure
      i. Dense ligamentous attachments to cuneiforms
      ii. Three separate and flat articulations with the cuneiforms allow for little motion
      iii. Significant swivel motion occurs at talar side
   b. Blood supply
i. Arterial
   1. Dorsal – dorsal pedis
   2. Plantar – medial plantar

ii. Central one-third relatively avascular

III. Fracture characteristics

   i. Demographics/incidence
      1. Avg. age 21 yrs. (14-45 y/o)
      2. Time to diagnosis 4.6 mo.
      3. Males 68-80%
      4. Bilateral 5%
      5. Sport speciality
         a. Track and field 62%
         b. Football (contact sport) 19%
         c. Basketball 11%

   ii. Etiology
      1. Abnormal mechanics of structural foot
         a. Cavus vs. planus vs. metatarsus adductus
         b. Controversial – never proven
      2. High concentration of forces with muscle contraction at push-off
      3. Endurance sports (overuse?)
      4. Explosive athletic events (pole vault – push-off leg)
      5. Achilles contracture may increase midfoot stresses
      6. Cam lesion on talus?
         a. Impingement on anterior ankle may increase forces on navicular

   iii. Diagnosis
      1. Insidious onset of vague pain
         a. Dorsal/medial
         b. Confused with ankle pathology
      2. Recurrent symptoms after strenuous activity
      3. Prolonged symptoms
      4. Exam
         a. No deformity or swelling
         b. Occasional (50%) limitation of subtalar/ankle motion
         c. Percussion test over navicular may elicit pain
         d. Pain with single limb hop
         e. Torg – majority of his patients with short 1st MT, metatarsus adductus, and tenderness to palpation over lateral one-half of navicular

   5. Imaging
a. Plain radiographs often inconclusive (33% sensitive, 24% sensitive with incomplete type))
   i. Dorsal spur on navicular pathognomonic? (controversial)
b. Tc scan 100% sensitive (even early)
c. CT – need sag/axial recons, very helpful in defining fx/location/extent; consider serial studies as may be negative initially
d. MRI – notes early edema and extent but difficult to define fx or healing; do not confuse edema for AVN or OCD

b. Fracture occurs in sagittal plane (usually oblique – dorsolateral to plantarmedial)
   i. Central 1/3 vascular watershed – fx between lateral 1/3 and medial 2/3
   ii. Begins at dorsal cortex - 80% of fx lines are incomplete
   iii. Saxena classification (1,2,3): based on propagation of fx from dorsal cortex to plantar

IV. Treatment – no level 1 or 2 evidence
a. Incomplete/nondisplaced
   i. Strict NWB x 6 wks, then protected WB x 6 wks - 89% success (Torg, JBJS, 1982; Kahn, Am J Sports Med, 1982)
      1. Return to play in avg. 4-5.6 months
   ii. Torg meta-analysis (AJSM ’10): recommended NWB cast immobilization in all nondisplaced fractures
   iii. In athlete, consider early percutaneous fixation
      1. Watch closely for incomplete fracture line propagating from dorsal cortex
         a. MRI and bone scan positive before CT may show development of fracture
      2. Early fixation assists with rehab (pool, bike, etc)
         a. Dedicated athletes will seldom tolerate the lengthy period of nonop Rx & NWB - Lee & Anderson, Foot Ankle Clin N Am, 2004
b. Complete
   i. Nondisplaced
      1. Percutaneous screw fixation from lateral to medial, perpendicular to fracture line
      2. Two cannulated 4.0-4.5 mm screws; titanium to assist with future MRI?
      3. Make certain that the screws do not penetrate the medial cortex
         a. Prominent screws can irritate the posterior tibial tendon
b. Screw removal may result in refracture

ii. Displaced
   1. ORIF +/- bone graft
   2. Dorsal longitudinal incision
      a. Use fluoro intraop to identify fracture and assist with placement of incision

iii. Delayed or nonunion
   1. ORIF + bone graft

iv. Postop management like that for incomplete fx
   1. Repeat CT at 12-14 weeks to assess union
   2. RTP when union present and asymptomatic
   3. Okay to play with asymptomatic partial union
   4. Saxena/Fullem FAI ’06: avg RTP was 4.1 mo with ORIF using 2 screws (2.9-5.3 mo)

v. Results/conclusions
   1. Results variable and poorly followed (about 75% heal with extended period of NWB)
   2. Often second surgery necessary
   3. Have high index of suspicion and be aggressive
      a. Early fixation of athlete
      b. Surgery for persistent pain
      c. McCormick et al paper: worst results/more nonunions in those with complete and displaced fractures (AJSM ’11)

c. Complications
   i. AVN with progressive collapse/fragmentation
      1. Observe
      2. May require t-n fusion or inlay graft from talus to cuneiform
   ii. Delayed/nonunion
      1. ORIF with bone graft
      2. Vascular pedicle graft (Gilbert, Nunley JBJS ’04)
   iii. Arthritis
      1. Shoewear modifications
         a. Good arch contact/support
         b. Rigid sole or insole
      2. Fluoroscopic directed injection of cortisone/Marcaine and follow response
         a. Eventual arthrodesis
            i. Naviculo-cuneiform
            ii. Talo-navicular
Bibliography

Sesamoid Stress Fractures
I. Incidence unknown, relatively uncommon
   a. Suggested that 1% of all running injuries are to the sesamoid and that 40% of those are stress fractures (30% sesamoiditis)
II. Sesamoid characteristics
   a. Medial (tibial)—larger/longer, more distal with greater WB forces
   b. Lateral (fibular)—smaller, rounder, lies more proximal
   c. Lie within conjoined tendons, connected by intersesamoidal ligament, suspended by collateral ligaments
   d. Form articulating joint with MT head, separated by intersesamoidal ridge (crista)
   e. Blood supply—medial plantar artery
   f. Ossification—9 to 11 years, often multiple areas
   g. Congenital partition of tibial sesamoid 10—33% (10x greater than fibular), bilateral 25—85%
   h. Function
      i. Dissipate forces
      ii. Elevate MT head—↑ mechanical advantage of FHB
iii. Protect FHL, maintain its direct pull

III. Mutliple etiologies for Sesamoid Pain
   a. Sesamoiditis
      i. A diagnosis or a symptom?
      ii. Pain with negative x-rays and equivocal MRI
         1. A diagnosis of exclusion
         2. R/o bursitis or flexor tendinitis
      iii. Often history of overuse or trauma
   b. Fracture
      i. Acute vs. stress
      ii. Typically tibial sesamoid
      iii. Transverse fracture line; usually mid-waist
         1. Differentiate from a bipartite
            a. Obtain comparison xray
            b. Bipartite often with smoother, rounder edges
            c. Total size with bipartite is larger than single sesamoid would be
      iv. Association with MP dislocation (Jahss Type II)
   c. Degenerative
      i. Chondromalacia
      ii. Osteophytes
      iii. Don’t forget about gout
   d. Osteochondrosis
      i. Unknown etiology
         1. Crush injury
         2. Stress fracture
         3. AVN – more often in fibular
      ii. Painful fragmentation/cyst formation/flattening
      iii. X-ray changes may follow symptoms by 6-12 months

IV. Diagnostic evaluation – stress fracture
   a. History
      i. Pain localized to plantar hallux MP with weightbearing
      ii. Impact worsens
      iii. Often no recall of precipitating event
         1. Participation in running sports/aerobics
   b. Clinical exam
      i. Specific location of pain/tenderness
         1. Plantarmedial – tibial sesamoid
         2. Plantar – fibular sesamoid
      ii. Often no or minimal swelling/warmth/erythema
iii. Compression pain, grind test (+) only if associated problems at metatarso-sesamoid articulation
c. Radiographic
   i. Standing AP/lateral foot views
      1. Comparisons
   ii. Axial/tangential sesamoid view
      1. Assess for fracture line/displacement
      2. R/o focal arthrosis/plantar osteophyte/bony prominence
   iii. Oblique sesamoid view
      1. Helpful for fracture of tibial sesamoid
   iv. Always place marker (B-B) on skin overlying site of tenderness – helps to differentiate which sesamoid involved (or does not correlate with sesamoid location if flexor tendon problem)
d. MRI
   i. Excellent tool to confirm/localize pathology
   ii. More edema expected in fractured sesamoid vs bipartite
   iii. Assesses sesamoid viability, joint degeneration, tendon continuity
e. Bone scan
   i. 3 phase helpful
      1. Like MRI expect more uptake in fractured sesamoid vs bipartite
   ii. Pinhole images to differentiate between sesamoids
      1. Make certain that you know which is indeed the problematic one
f. CT
   i. Better look at fracture location and configuration
   ii. Delineates degree of metatarso-sesamoid arthrosis
   iii. Assesses fracture healing
V. Nonoperative treatment – stress fracture
a. Acute presentation
   i. RICE = rest, ice, compression, elevation
   ii. Avoid NSAIDs due to bone healing issues
   iii. Boot or cast – rigid sole/off loads
      1. Toe spica extension with joint in mild plantarflexion if displaced
      2. Weight-bearing as tolerable?
b. Chronic
   i. NSAIDs
   ii. Modify training/activity programs
1. Play as pain allows

iii. Orthoses and shoewear modifications

1. Off-the-shelf plates to limit dorsiflexion (e.g., “Scott” turf toe plate or carbon fiber; full length or forefoot only)
2. Custom-made with Morton extension to limit hallux MP ROM
3. Metatarsal pad just proximal to symptomatic sesamoid
4. Maintain low heel height

iv. Turf shoes modified by removing cleat under area of pain

v. Bone stimulator?
1. I have never seen it work for this entity

VI. Operative treatment

a. Options

i. ORIF

1. Anecdotal reports using tension band wire, cerclage suture, cannulated screws
   a. Australian series of 13 screws – 10 reportedly healed
2. Limited written series
      i. 9 fractures treated with Barouck screw; 5 tibial, all healed and back to activity by 3 months

ii. Bone grafting

1. Stress fracture nonunions - tibial
   a. Anderson/McBryde FAI '97
      i. Bone graft from met head
      ii. NWB postop cast for 4-6 weeks, then boot
         1. Avoid running for 12 weeks
      iii. 19 of 21 healed and returned to sport
      iv. Avoid if >2mm diastasis or gross motion between fragments

iii. Sesamoidectomy

1. Total
i. 26 sesamidectomies in athletes; 16 tibial; all but 3 RTP by 12 weeks

2. Partial
      i. Removed proximal pole in 6 feet, avg age 16; all tibial; RTP after 6 months; G/E in 5 of 6
   b. I reserve for those with one small fragment – difficult to reattach FHB
   c. Concern for chronic pain when one pole preserved – may not track well

b. Sesamoidectomy
   i. Tibial
      1. Medial/plantarmedial approach
      2. Avoid plantarmedial digital nerve
      3. Excise sesamoid from within joint or extra-articular
         a. Extra-articular approach allows for repair of overlying FHB after excision
            i. Longitudinal incision and reflection of overlying soft tissues (subperiosteal)
            ii. Repair defect side-to-side with absorbable suture (i.e. 4-0 Vicryl)
         b. Beaver blade (#69) a useful tool to circumferentially dissect around sesamoid
         c. Beware of the proximity to the FHL – must protect
      4. Consider transferring abductor hallucis tendon into large defects created by excision of bipartite or fractured sesamoids
         a. Dissect/release off of capsule at distal insertion
         b. Perform fasciotomy proximally to allow for rerouting of tendon to plantar aspect.
      5. Consider performing concomitant bunionectomy if significant hallux valgus present

ii. Fibular
   1. Approach – dorsal vs. plantar?
      a. Dorsal approach very difficult unless large IM angle with lateral subluxation of the sesamoid complex (i.e bunion/hallux valgus)
i. Risk for FHL/nerve injury

b. Plantar
   i. Curvilinear incision over fibular sesamoid but off of weightbearing pad of hallux MP joint
   ii. Identify and protect plantar lateral digital nerve
   iii. Allows for direct excision without disruption of adductor or FHL tendon
   iv. Allows for subsequent repair of FHB tendon (lateral head)
   v. Closure must carefully approximate skin edges to minimize hypertrophic scar formation

iii. Postoperative
    1. “Rigid” soft dressings to maintain plantarflexion and either varus (tibial sesamoidectomy) or valgus (fibular sesamoidectomy)
    2. WBTT in sandal or short walker boot for tibial sesamoidectomy
    3. NWB/heel touch for fibular sesamoidectomy
       a. Begin WBTT with sutures “in” at 10-14 days
       b. Suture removal at 3-4 weeks
    4. Removable bunion splints 2-6 weeks
    5. Gradual return to hard soled shoes
       a. Utilize turf toe plate in athlete
       b. No running for 12 weeks

iv. Results
       a. 24 tibial/13 fibular (dorsal approach)
       b. 4 tibial developed hallux valgus > 5 degrees
       c. Fibular: maximum varus 3 degrees
       d. 15 excellent, 5 good
    2. Fibular sesamoidectomy
          i. 12 patients - plantar approach
          ii. 9/12 very satisfied and 2/12 satisfied
          iii. All would do it again
          iv. 11/12 returned to pre-injury activity level
          v. No complications (scar, neuroma, etc)
Bibliography


