BIOMECHANICS OF ANKLE FRACTURES
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Significance of Ankle Fractures
- Most common weight-bearing Fx
  - 70% of all Fxs
- Incidence is increasing
- Bimodal distribution
  - Men 15-24
  - Women over 60
- Not related to osteoporosis
- Related to obesity
ANATOMY

- The ankle is a complex joint consisting of three distinct functional articulations:
  - Tibia & fibula
  - Tibia & talus
  - Fibula & talus
- Tibia and fibula form a mortise that creates a constrained articulation for talus.
- Articular surface of distal tibia (plafond) and mortise is wider anteriorly to accommodate trapezoidal talar dome.
- Provides some intrinsic stability especially during weight bearing.

ANATOMY CONT.

- Each articulation reinforced by a group of ligaments.
  - Posterior/ Syndesmotic ligaments
  - Medial collateral ligaments
  - Lateral collateral ligaments
  - Crucial determinants of appearance of ankle Fxs.
- Ankle stability is provided by a combination of three factors.
  - Osseous architecture
  - Ligaments
  - Joint capsule
**Syndesmotic Ligaments**

- 5 ligaments:
  - Anterior inferior tibiofibular (AITFL)
  - Posterior inferior tibiofibular (PITFL)
  - Transverse tibiofibular (ITL)
  - Posterior intermalleolar (IML)
  - Interosseous Membrane

**Medial Collateral Ligaments**

- Superficial Deltoid (1)
  - Post. Tibiotalar, Tibiocalcaneal, Tibionavicular
  - Restrains Int. Rotation
  - Not important in Fx biomechanics.
  - Does not need repair.
- Deep Deltoid
  - Deep Post. Tibiotalar
  - Deep Ant. Tibiotalar
- Plantar Calcaneonavicular (Spring) (2)
  - Important in flatfoot.
- Deep plantar ligament (3)
  - Secondary Arch restraint.
Lateral Collateral Ligaments

- Anterior talofibular ligament (2)
  - Weakest: Damage almost all ankle sprains.
  - Restrains ant. Translation and Int. rotation of talus.
- Calcaneofibular Ligament (3)
  - Damaged ~25% ankle sprains.
  - Restrains varus angulation of ankle and subtalar joint.
- Posterior talofibular ligament
  - Damaged ~5% ankle sprains.

Tibiotalar Motion

- Fibula needed for lateral stability and maintainance of congruence between talus and plafond.
- Normal: Flexion /Extension:
  - Need minimum of 10° dorsiflexion and 20° plantarflexion for normal gait.
  - Lateral talar shift of 1mm decreases surface contact by 40% and 3mm shift decreases contact by >60%.
Tibiotalar Motion

- As ankle dorsiflexes, it externally rotates.
- As ankle plantarflexes, it internally rotates.
- Because talus is wider anteriorly dorsiflexion, causes lateral mall. To rotate externally (11°).
- Syndesmosis scarring may interfere with or cause painful ankle dorsiflexion.

Subtalar Motion

- Rotation of the ankle (and proximal limb) in relation to fixed foot accommodated by subtalar joint >> tibiotalar motion.
- Stiffness of subtalar joint interferes with ankle movement and gait.
- Open chain: Foot and calcaneus rotate on fixed talus.
- Closed chain: Talus rotates on fixed foot and calcaneus.
Ankle Biomechanics

Without axial load, main stabilizers against anterior, varus and internal rotation stress:
- In plantar flexion: ATFL
- In neutral: CFL

In dorsiflexion: Inferior tibiofibular joint ligaments play increasing role in stability.

Deltoid ligament (particularly deep deltoid) protects against valgus and external rotation stresses.

Posterior ligaments: Little studied, probably because posterior displacement and forced dorsiflexion are uncommon mechanisms of injury.

Ankle Biomechanics

Well recognized that injury patterns associated with ankle Fxs are more complex than simple lateral displacement of the talus in the mortise."

Probably explains why recent literature suggests that correlation between Lauge-Hansen Mechanism and reality is only moderate.**

*JBJS 1996; 78-A
**J Orthop Trauma 2010 Aug;24(8):477-82
Abnormal Tib/Talar Mortise Motion

- Inversion (Abduction)
- Eversion (Adduction)
- External Rotation
  - Usually eversion injuries accompanied by degree of external rotation.

Inversion (Adduction)
Eversion (Abduction)/ External Rot.

Effect of Initial Ankle Position
Classification Systems

Biomechanical concepts make ankle Fx appearance & classification understandable.

- Lauge-Hansen
  - Supination external rotation (SE)
  - Supination adduction/inversion (SA)
  - Pronation external rotation (PE)
  - Pronation abduction/eversion (PA)

- Danis-Weber
  - A: Inferior to Synd. Ligs.
  - B: Through Synd. Logs.
  - C: Superior to Synd Ligs.

- AO Classification

Classification: Lauge-Hansen

- System takes into account
  1. Position of the foot at the time of injury;
  2. Direction of the deforming force.
- Based on cadaveric studies
- The patterns may not always reflect clinical reality.
LAUGE-HANSEN: SE
40-70% of Malleolar Fxs.

- **Stage 1:**
  - Rupture of AtibFib ligament OR
  - Wagstaffe-Leforte (Ant. fibula) Fx AND/OR

LAUGE-HANSEN: SE

- **Stage 2:** Oblique or spiral Fx of the lateral malleolus (Weber B).
LAUGE-HANSEN: SE

- **Stage 3:**
  - Rupture of PI Tib Fib ligament OR
  - Avulsion Fx of posterior malleolus (Volkman).

LAUGE-HANSEN: SE

- **Stage 4:**
  - Transverse (sometimes oblique) Fx of medial malleolus OR
  - Tear deep deltoid ligament.
LAUGE-HANSEN: SA
10-20% of Malleolar Fxs

- Stage 1:
  - Transverse Fx of lateral malleolus, at or below the level of AITibFib ligament (Weber A) (tip or above ATFL) OR
  - Tear of ATFL, often accompanied by CFL tear.

LAUGE-HANSEN: SA

- Stage 2:
  - Oblique to vertical Fx of medial malleolus.
LAUGÉ-HANSEN: PE
5-20% of Malleolar Fxs

Stage 1:
- Transverse Fx of the medial malleolus OR
- Rupture of the deltoid ligament.

Stage 2:
- Rupture of the AiTibFib ligament OR
- Tillaux/Chauput AND/OR Wagstaffe Fx.
- Rupture inferior Interosseous membrane.
LAUGE-HANSEN: PE

- **Stage 3: Oblique/Spiral** Fx of the fibula **above** the level of the syndesmosis (Weber C).
  - Tearing of interosseous membrane can lead to Maisonneuve B.

- **Stage 4:**
  - Rupture of the PiTibFib ligament OR
  - Fx of the posterior malleolus.
LAUGE-HANSEN: PA
5-20% of Malleolar Fxs.

- **Stage 1:**
  - Transverse Fx of the medial malleolus or
  - Rupture of the deep deltoid ligament.

LAUGE-HANSEN: PA

- **Stage 2:**
  - Rupture of the AtibFib & PdTibFib ligaments OR
  - Tillaux-Chauput AND/OR Wagstaffe Fxs.

- Note: Inerosseous membrane INTACT!

Interosseous Membrane
LAUGE-HANSEN: PA

- **Stage 3**: Oblique Fx of fibula at level of syndesmosis.

PRONATION-DORSIFLEXION

- **Stage 1**: Transverse Fx of the medial malleolus.
- **Stage 2**: Fx of the anterior lip of the tibia.
- **Stage 3**: Oblique Fx of the supramalleolar aspect of the fibula.
- **Stage 4**: Rupture of the PiTibFib ligament or Fx of the posterior malleolus.
Conclusion

- Malleolar Fractures depend on:
  - Position of foot at initiation of trauma.
  - Motion of ankle that causes trauma.
  - Ligamentous anatomy
  - Strength of bones.
- Fracture forces can be predicted based on radiographic appearance of fracture.