Biomechanics and the Total Ankle Arthroplasty

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David C. Hatch Jr, DPM, AACFAS
Saguaro Surgical Tucson, AZ
Conflicts of Interest

- No Conflicts of Interest
Learning Objectives

- Review anatomic and biomechanical principles of the lower extremity
- Understand how principles of lower extremity biomechanics influence total ankle arthroplasty planning.
- Understand the influence of the total ankle arthroplasty on lower extremity biomechanics in patients with ESAA.
- Review procedural staging in the correction of lower extremity biomechanical abnormality
Biomechanics and the Total Ankle Arthroplasty

1970s - Introduced as alternative to arthrodesis

Highly Variable - cement, constraint, fixed, mobile

Complications - loosening, subsidence, impingement, osteolysis

3 years $\rightarrow$ 0% failure, 100% satisfaction
5 years $\rightarrow$ 33% failure, 100% loosening
15 years $\rightarrow$ 40% failure, 19% satisfaction

Kitaoka and Patzer 1996
Biomechanics and the Total Ankle Arthroplasty
Principles of LE Anatomy and Biomechanics

A. Heel strike (initial contact)
B. Loading response (foot flat)
C. Midstance
D. Terminal stance (heel off)
E. Preswing (toe off)
F. Initial & Mid-swing
G. Terminal swing

Stance Phase (60%)
Push Off
Swing Phase (40%)

Double support (10%)
Single support (40%)
Double support (10%)
Single support (40%)

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Principles of LE Anatomy and Biomechanics

- HIP
- Knee
- Ankle
- STJ
Principles of Lower Extremity Anatomy: HIP, Femur

125° - 130°

10° - 15°

D. Paley et al. 1994; Carson et al. 1984
Principles of Lower Extremity Biomechanics: HIP

Ball and Socket Joint: Greatest ROM of Lower Extremity

Required in Gait:
Sagittal plane: 40° (30° flexion, 10° extension),
Transverse plane: Some internal rotation
Frontal plane: Some adduction

Forces
5.74 x BW walking, 10.01 x BW running

Giarmatzis et al. 2015
Principles of Lower Extremity Anatomy: Knee

Complex yet Relatively Unstable
MCL (r valgus/abduction)
LCL (r varus/adduction)
ACL (r anterior translation)
PCL (r posterior translation)

Tibiofemoral Angle
Normal 164° - 173°
Genu Valgum < 164°
Genu Varum > 173°
Principles of Lower Extremity Biomechanics: Knee

Ginglymus/Arthrodial joint (glides/rolls)
Biaxial, triplanar, screw-home

Required in Gait:
Sagittal plane: 60° flexion required in normal gait, 115° required for ADL
Progression along midline ~3° Varum

Forces
3x BW walking

“BASIC ORTHOPAEDIC BIOMECHANICS. ED. 2.”; Krackow 1983
Principles of Lower Extremity Anatomy: Ankle

- **Distal Tibia (plafond):** concave, open ant/post
- **Talar Dome:** convex, wider anterior vs posterior → greater stability in dorsiflexion
- **Articulation:** >90% congruity, 1mm displacement → 42% reduction of incongruity
- **Medial joint:** tibia and comma
- **Lateral joint:** fibula and triangle, larger, more distal, posterior

Barnett and Napier 1952; Hicks 1953; Ramsey and Hamilton 1976; Lloyd et al. 2006
Principles of Lower Extremity Anatomy: Ankle, cont.

**Medial:** Deltoid ligaments resist eversion of the talus and limit plantar/dorsiflexion.

**Lateral:** Anterior/Posterior talofibular and Calcaneofibular ligaments resist inversion and A/P displacement of talus

**Syndesmosis:** Anterior/Posterior inferior tibiofibular and syndesmotic ligaments resist tibiofibular diastasis

**Capsule:** surrounds ankle, incorporates many ligaments
Additional Stabilizing Forces

Extrinsic muscles of the foot crossing the ankle joint.

Dorsiflexion limited by triceps surae, posterior talofibular and posterior tibiotalar ligament.

Plantarflexion limited by the anterior talofibular ligament, deltoid structure and talus/tibial contact.
Principles of Lower Extremity Biomechanics: Ankle

Ginglymous-type mortise joint with sagittal dominant triplanar motion

Axis: 8° from transverse, 20° - 30° from frontal and 82° from sagittal planes

Dorsiflexion → external rotation and abduction

Plantarflexion → internal rotation and adduction

Coughlin, Saltzman, and Mann 2013; Inman 1976; Stiehl 1991; A. Lundberg et al. 1989; Berry 1952
Principles of Lower Extremity Biomechanics: Ankle

Required in Gait:
Sagittal plane: 25° - 30° (15° - 20° plantar and 10° dorsiflexion)
    Max PF at toe-off, DF in swing
Transverse plane: 8.4° coupled with int/external tibial rotation

Forces
5x BW walking, 2-3x shear

McCullough and Burge 1980; Lundberg et al. 1989; Levens et al. 1948
Principles of Lower Extremity Anatomy: Talus/STJ

Anterior facet articulation: ant. Inf. head of talus and ant. sup. calcaneus

Middle facet articulation: prox/medial to ant. facet, articulates with sus. tali of the calcaneus

Sinus tarsi

Posterior facet: largest facet, post. ½ of inf. talus, sup. post. facet of calcaneus

Ligaments: TC Interosseous; anterior, posterior, medial and lateral TC ligaments

Bucholz 2012
Principles of Lower Extremity Biomechanics: STJ

Arthrodial joint, single axis triplanar motion

**Axis**: 16° from sagittal, 42° from transverse and 48° from frontal planes (distal/med/dorsal to proximal/lateral/plantar)

- **Low pitch** → greater frontal plane calcaneal motion
- **High pitch** → less frontal plane calcaneal motion

- **Medial dev** → more pronatory moment
- **Lateral dev** → more supinatory moment

Close and Inman 1953; Manter 1941; Wright et al. 1964; Bucholz 2012; Coughlin et al. 2013
Principles of Lower Extremity Biomechanics: STJ

GIFs created from: https://www.youtube.com/watch?v=7SK_O-NuFr4
Biomechanics and the Total Ankle Arthroplasty: Thorough Evaluation is KEY

Posttraumatic Extraarticular Deformity-
Trauma is a major cause of ESAA

Femoral neck - Coxa Vara/Valga, in/out-toed
Knee - Genu varum/Valgum, Q angle
Tibia - tibial varum/valgum, re/procurvatum, transverse plane rotation, tibiofibular stability
Ankle - Varus/Valgus deformity
Calcaneus/STJ - calcaneal fracture malunion, STJ rigidity/arthritis, deformity

Biomechanics and the Total Ankle Arthroplasty:

Paley 2002; Dodd and Daniels 2017

>10°
Biomechanics and the Total Ankle Arthroplasty

**Sequencing Procedures**

- 75% of patients with ESAA require additional procedure.
- 40% of patients with ESAA have significant deformity.

Biomechanics and the Total Ankle Arthroplasty

- 2004, Haskell, Mann: **24% misalignment** of prosthesis at 2 year follow up
- Addressed hindfoot alignment issues, addressed deformity and soft tissue
- 2011, Reddy, Mann: **14% misalignment** at 3.5 year follow up
- **42% improvement**

Haskell and Mann 2004; Reddy et al. 2011
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**GAIT IMPROVEMENT**
Gait does not reach the level of healthy controls. However, gait function is greatly improved compared to preoperative values.

**TEMPORAL-SPATIAL PARAMETER IMPROVEMENTS**
Increase stride length
Increased cadence
Increased walking speed
Decreased support times

Kane et al. 2017; Valderrabano et al. 2007; Brodsky et al. 2011; Queen et al. 2014
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ROM IMPROVEMENT
Increased knee, hip sagittal plane ROM
Improved ankle plantarflexion, dorsiflexion
Improved ankle inversion motion and stability
More stable eversion limits

FORCE IMPROVEMENT
Ankle power, plantarflexion and inversion moment, posterior and anterior ground reaction force

Valderrabano et al. 2007; Brodsky et al. 2011; Choi et al. 2013; Queen et al. 2012; Kane et al. 2017
Biomechanics of the Total Ankle Arthroplasty

1. **IS NOT** the equivalent to total knee or hip arthroplasty
2. **WILL NOT** return gait or LE biomechanics to “normal”
3. **BASELINE** is function and pain prior to procedure
   - Improvement on baseline is goal
   - Patient perception of wellness!


Biomechanics and the Total Ankle Arthroplasty

- Understand and evaluate patient LE anatomy for biomechanical influences on the ankle
- Consider surgical soft tissue or osseus correction of deformity
- Will staging procedures improve outcomes
- Consider and thoroughly discuss baseline/realistic expectations with your patients.
Thank you.

For a complete reference list, please contact: david@hatchfootandankle.com