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Decoding and Understanding Transtibial Gait Biomechanics and Gait Deviations

Jared Howell, MS, CPO, FAAOP
Director, Baylor College of Medicine
Orthotics and Prosthetics Program

Foundational Objectives

• Articulate the key differences that make the amputated/prosthetic side unique when compared to the sound limb
• Develop an understanding of TT mechanical structure and alignable components.
• Learn about standard transtibial (TT) alignment parameters
• Develop baseline competence in identification of transtibial gait patterns.
So you have had a TT amputation, now what?

3 Underlying Mechanical Principles

Anatomical Changes Following TT Amputation

- Loss of Gastroc/Soleus Insertion
  - Reduces efficacy of gait
  - Reduces active knee extension
  - Poses risk to posterior compartment of the knee

- M/L Stability can be altered depending on mechanism of injury/cause of amputation
Soft Tissue Considerations

- In a socket all motion is transferred to the most proximal contact area
- The soft tissue of the residual limb takes the entire force of the body.
- The socket moves around the limb as a central axis.

Joint Considerations

- The foot and the ankle are particularly helpful in the dissipation of force during stance phase.
- The loss of the foot and the ankle means that forces are transferred to the proximal joints in the limb and spine.
Biomechanical goals

• 3 main biomechanical goals for TT prosthetics
  – Allow for maximum load bearing capacity on the limb
  – Promote knee flexion throughout stance phase
  – Provide optimal M/L stability throughout stance phase

Maximum Limb Loading

• How do you increase the load bearing capacity of the limb?
  – total contact
  – Increase surface area that is loaded
  – load the pressure tolerant areas more
    • relieve pressure sensitive areas
  – flex socket to improve loading
Maximum Limb Loading

• Total Contact
  – Load as much surface area as possible
  – prevent Verrucous hyperplasia
  – Increase proprioception

Maximum Limb Loading

• Increase surface area
  – How can you do this?
  – Increase trim lines (the shorter the limb, the more proximal the trimlines)
  – Joint and Corset
Maximum Limb Loading

- Pressure Tolerant areas

- Pressure intolerant areas
Maximum Limb Loading

• Flex socket (3 reasons)
  • Reason 1 is to maximize limb loading

Decoding Alignment

• The spatial relation of the ground contact (foot) to articulating parts (knees/ankles), to the interaction with the body (socket)
  • Bench Alignment
  • Static alignment
  • Dynamic Alignment
Alignable Components

Socket
Pylon
Ankle
Foot
Suspension

How is this alignment changed?

One set of Screws = angular change

Top and bottom screws = translational change
Prosthetic gait is 100% dependent on position of the ground reaction force in reference to the joints of the body.
Normal vs. Symmetrical

• Reason 2 and 3 deal with sagittal control
  #2 encourage knee flexion moment at heel strike
  #3 discourage knee extension moment at terminal stance
Sagittal Control

• 3 ways to encourage knee flexion
  – socket flexion
  – A-P placement of socket relative to the foot
  – Heel/toe durometer/flexibility

Sagittal Control

• A-P placement of socket relative to the foot
  – How does this promote knee flexion at IC?
  – How does this discourage an extension moment at terminal stance?
Sagittal Control

• A-P placement of socket relative to the foot

For a SACH foot
  – Textbook bench alignment is the foot bolt to be 37mm posterior to midline of the socket
  – final range is 18-65mm

For a Dynamic foot
  – Socket midline is set up typically between the first and second third of the foot. or per manufacturer’s recommendation

Test Your Knowledge

• Heel/Toe durometer or flexibility
  – Heel stiffness or durometer acts as the dorsiflexors. How?
  – What does the heel do?
    • Shock absorption
    • Hip and knee extensors control this shock absorption (greater activity required)
  – If it does not absorb shock, where does it get translated?
    • into abrupt knee flexion
Sagittal Control

– a cushioned heel will reach foot flat sooner, progressing the GRF anterior to the knee quicker
  • creating which moment?
    flexion, or extensions (circle one)
– The shorter the limb, the more cushioned heel, the less external knee flexion moment
– A stiff heel will create a more posterior GRF
  • creating which moment?
    flexion, or extensions (circle one)
– A stiff heel may also present as a rapid external rotation of the foot

Sagittal Control

• Socket flexion/extension
  – During stance, what moment acting against the limb does a flexed socket create?
  – What moment acting against the limb does an extended socket create?
The Affect of Poor Alignment

- Poor Alignment is just as detrimental to the health of the limb as a poor fitting socket
- Any open wounds need to be treated quickly and efficiently and should involve all members of the health care team

Transtibial Gait
Sagittal Control

• Heel stiffness

External Rotation of the Foot at Heel Contact

Sagittal Control

• Heel/Toe durometer or flexibility
  – Toe stiffness acts as what muscles?
  – too stiff creates what moment?
  – too soft creates what moment?
Sagittal Control

• Early Drop off and excessive dorsiflexion

  - Rapid loss off support in late stance
  - what excessive moment is being experienced?
  - Where will they experience discomfort?
  - They may feel this discomfort and not show physical signs of early drop-off
  - name 4 possible causes:
**Sagittal Control**

- Delayed progression/Halted gait/foot slap cushioned heel

**Sagittal Control**

- Delayed progression
  - Can create hyperextension
  - Requires much more energy
  - Name 4 possible causes
Sagittal Control

- Hyperextension

Flexion Moment
- Socket is anterior to foot
- Socket too flexed
- Toe lever is too soft
- Heel is too stiff

Extension Moment
- Socket is posterior
- Socket is too extended
- Toe lever is too rigid
- Heel is too soft
Sagittal Control Alignment Review

- Bench alignment
  - 5 flexion in socket
  - center of weight (sagittal midpoint at MTP) falls at 37mm anterior to SACH bolt, or between the first and second thirds for a dynamic foot
  - foot 5-7 degrees external rotation
- Static Alignment
  - Weight centered over foot. The patient does not feel like they are falling backwards or forwards
- Dynamic alignment
  - smooth rollover
  - no early drop-off or delayed progression

Medial-Lateral Stability

- Promote M/L stability during stance
  - create a varus moment at the knee for many reasons
    - mimics NHG and therefore:
      - Narrows base of support
      - Lowers energy expenditure (determinant of gait)
    - Loads pressure tolerant areas of the limb
    - lateral collateral ligament is less prone to injury
      - More flexible and stronger
Medial Lateral Alignment

Socket Adduction in closed chain  

Medial-Lateral Stability

• Proper Abduction of the socket
  – Bench Alignment: depends on the limb. based on line obtained during casting
  – Mimics NHG
  – provides varus alignment
  – Not always ideal (Genu Valgum vs Genu Varum)

• Lets look at outset/inset
Medial Lateral Stability

• Forces that are applied

\[ \Sigma M = 0 \]
\[ F_{GRF} \cdot dx = (FP \cdot dy_2) + (FD \cdot dy_1) \]

What variables do we have control of?
Which force is greater, prox or dist?

If the proximal force is too great, what variables can we change?

As $d_1$ decreases what happens to the distal force?

How can you fix this problem?

The shorter the limb, the less the foot is inset

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**Medial Lateral Stability**

**Varus Moment**
- Inset foot
- Socket abduction
- Associated pressures
  - Proximal Medial
  - Distal Lateral

**Valgus Moment**
- Outset foot
- Socket adduction
- Associated pressures
  - Proximal Lateral
  - Distal Medial

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![Continued](image-url)
Medial Lateral Stability

• Excessive Valgus/Varus

Excessive Varus Moment

Medial Lateral Stability

• Excessive Abduction/Adduction

Excessive Ab/Adduction of the Socket
M/L Alignment Review

• Bench Alignment:
  – 12mm inset of midfoot to midline at MPT
  – adduction depends on the limb, based on line obtained during casting

Let’s review

• List three reasons why we flex the socket?

• With an excessive varus moment, where are the pressures experienced?

• With an excessive valgus moment, where are the pressures experienced?

• With an excessive flexion moment, where are the pressures experienced?

• With an excessive extension moment, where are the pressures experienced?
the end.

Questions?