Biomechanics of the Diabetic Foot: 
*Forces Encountered*

Paul J Kim, DPM, MS, FACFAS  
Associate Professor  
Georgetown University School of Medicine  
Director of Research  
Division of Wound Healing & Hyperbaric Medicine  
Department of Plastic Surgery  
MedStar Georgetown University Hospital
Research & Consulting

- Nothing to disclose relevant to the lecture
- I am totally biased
Jack of All Trades

“We are born with two feet …and one is not a spare”
-B. Kalman (Amputee)
Soft Tissue of the Diabetic Foot

- Is different
- “diabetes” “foot” “soft tissue” “changes” = 63 indexed publications
- “diabetes” “foot” “soft tissue” “differences” = 25 indexed publications
- “diabetes” “foot” “ulcer” = 7467
Achilles Tendon of the Diabetic Foot

- Less mobility demonstrated in joints in the hand and the feet
- Achilles tendon undergoes overall thickening with general structural disorganization


Achilles Tendon of the Diabetic Foot

• Glycation induced collagen cross-linking is directly associated with the increased matrix stiffness
• The Achilles tendon of Charcot patients demonstrate decrease elasticity and a decrease tensile strength


Achilles Tendon of the Diabetic Foot

  – Examined the wound healing potential of the Achilles tendon in the diabetic rat model vs. control after an acute trauma

Impaired inflammatory response and angiogenesis in the diabetic rat Achilles tendon

Forces

• The geometry of the diabetic foot wound tells you what forces are at work

• 2 types of forces
  – Sagittal force
  – Shear force
    • Transverse
    • Frontal
Forces

• Sagittal plane (Peak Plantar Forces)
  – Between the foot and the shoe/ground
  – Easier to measure

• Transverse/Frontal plane (Shear Forces)
  – Between the underlying structures (bone) and the plantar soft tissue structures
  – Between the plantar soft tissue structures and the shoe/ground
  – Harder to measure
Sagittal Forces
Sagittal Plane Forces

- Restricted ankle joint motion (equinus) contributes to the development and chronicity of diabetic foot ulcers by increasing plantar pressures.

Armstrong DG, Lavery LA. Elevated peak plantar pressures in patients who have charcot arthropathy. JBJS 1998.
Sagittal Plane Force

- Wound Shape
  - Circular
- Cause
  - Bony deformity
  - Tendon Overpowering
Peak Plantar Pressures - DM


Lavery LA, Armstrong DG, Boulton AJM. Ankle equinus deformity and its relationship to high plantar pressure in a large population with diabetes mellitus. JAPMA. October 2002;92(9):479-482.

Lack of Consensus for Sagittal Plane Measurement

Sagittal Plane Force
Wound Geometry

Circular

Georgetown University Hospital Center for Wound Healing
Peak Sagittal Pressures
Shear Forces
Shear Force

- Wound Shape
  - Oval, Elliptical

- Cause
  - Rubbing (classic blister)
    - Poorly fitting shoes
    - Loose dressings
Transverse Plane (Shear) Force
Frontal Plane (Shear) Force
Wound Geometry

Oval, Elliptical
Practical Assessment for Shear Forces
Practical Assessment for Shear Forces
Shear Forces- DM PN

- 6 DM PN patients
- Shear measured during ambulation
- From 3.9-7.2 N/cm² (highest 1st met head, lowest 4th met head)

Lack of Consensus for Shear Measurement

Sagittal & Shear Forces

- 12 patients with DM and PN
- Sagittal and Shear measured during the initiation of gait
- Custom built transducer array

Conclusions

• The foot cannot tolerate excessive, chronic stress
• Sagittal and shear forces play a detrimental role
• Regardless of the treatment rendered, unless you address the forces (sagittal, shear) the wound will not heal or will recur or relocate