Foot Imaging for Custom Functional Foot Orthoses
An Evidence Based Approach

Lawrence Z. Huppin, DPM

Medical Director, ProLab Orthotics: Napa, California
Private Practice: Seattle, Washington
Disclosure

- Medical Director: ProLab Orthotics
- No financial connection to scanner manufacturer
- Tested and evaluated digital casting technology. No compensation.
- Currently using Sharpshape scanner in my office
In the beginning...
Goals

- Review the literature to determine evidence based medicine (EBM) criteria for foot imaging
- Evaluate current foot imaging techniques to determine if EBM criteria met
- Review and recommend digital foot scanners based on their ability to meet the EBM criteria for capturing foot images
- Demo a Scanner
Questions to Ask

- What do I need to capture to make a clinically effective foot orthosis?
- Will a particular digital imager capture this information?
- Can you achieve optimum clinical outcomes?
Casting vs. Scanning Cost

- **Costs**
  - Podiatrist time calculated = $100 - $150 / hr (AUD).
  - Cost of plaster for two feet was $6.60 (AUD)
  - Cost of shipping plaster casts avg $3.00 (AUD)

- **Time**
  - Time for the taking of the plaster casts is from 11 minutes (low estimate) to 16 minutes (high estimate).
  - Time for taking of the optical scan was 2 minutes

Casting vs. Scanning Cost (AUD)

- **Casting**
  - At $100 / hr: $28 - $36
  - At $150 / hr: $37 - $49

- **Optical Scanning**
  - At $100 / hr: $3.30 - $6.60
  - At $150 / hr: $5 - $10

Part I:
EBM Foot Imaging Criteria for Optimum Clinical Outcomes
EBM Casting Criteria

1. The foot image must be captured in a NWB, STJ neutral position
2. The 1st ray should be plantarflexed to the end of its range of motion during casting.
3. The posterior heel must be captured to allow frontal plane correction of the orthosis (FF:RF balancing)
4. The foot image must obtain a precise 3D representation of the foot’s plantar aspect
Comparison NWB plaster vs. SWB foam

- NWB plaster casting was superior to foam box SWB casting as SWB casting resulted in artificial varus
  - McPoil, TG; Comparison of three methods used to obtain a neutral plaster foot impression. Phys Ther. 1989

- NWB casting - good agreement with the clinically measured FF:RF. SWB Foam impressions had poor FF:RF agreement and the SWB foot resulted in an artificial increase in varus
  - Davis I; A comparison of 4 methods of obtaining a negative impression of the foot.. JAPMA. 2002
Therefore, any imaging technique that does not allow NWB casting is invalid
Decreased 1\textsuperscript{st} MPJ dorsiflexion resulted when 1st ray plantarflexion was limited.

When the first ray was allowed to plantarflex there was an increase in available first MPJ dorsiflexion.

Roukis, et. al. Position of the First ray and Motion of the First MTP. 1996 JAPMA
Rearfoot Eversion and Hallux Dorsiflexion

- “Eversion of the Rearfoot will lower the maximal hallux dorsiflexion”
  - No Wedge: 85.91
  - 3° Wedge: 68.23
  - 5° Wedge: 58.80
- First Ray Dorsiflexion
- Hallux Dorsiflexion Decreased

Harradine, Bevin: The Effect of Rearfoot Eversion on Maximal Hallux Dorsiflexion; 2000
If the foot image captures the 1\textsuperscript{st} ray in a dorsiflexed position, orthosis will hold it in the same Position = decreased 1\textsuperscript{st} MPJ motion.

To maximize 1\textsuperscript{st} MPJ DF capture 1st ray in maximally plantarflexed position.

NWB foot imaging is essential to capture the first ray in this position.

Therefore, any imaging technique that does not capture the position of the 1\textsuperscript{st} ray in a plantarflexed position is invalid.
Effect of Forefoot and Rearfoot Wedging on Plantar Fascial Strain

- 6 degree wedges
  - Medial and Lateral
  - Forefoot and Rearfoot
- Plantar fascial strain measured with transducer

Forefoot Lateral Wedges

Forefoot Medial Wedges

Fig. 4
Plantar Fascia Strain

- Decreased with lateral forefoot wedge
- Increased with medial forefoot wedge
- Rearfoot wedges had no significant effect

*The most effective way to decrease strain on the plantar fascia is to evert the forefoot*

-Kogler, et al, JBJS, 1999

*Therefore, any imaging technique that does not capture the posterior heel is invalid*
EBM 4: The foot image must capture a precise 3D representation of the plantar aspect of the foot

- Total contact, rigid orthoses decrease metatarsal head force most effectively
  - Mueller, 2006, Phys Ther

- Orthoses that conform closely to the arch reduce plantar fascial tension
  - Kogler, 1996, JBJS
Orthotic Arch Contour and Plantar Fascial Strain

- Measured tension in plantar aponeurosis via strain gauge
- Compared five orthoses and shoe only

Kogler GF: Biomechanics of longitudinal arch support mechanisms in foot orthoses and their effect on plantar aponeurosis strain. Clin Biomech, 1996
Orthotic Arch Height

- Arches that conformed tightly to arch of foot decreased tension
- Orthoses that gapped from arch no difference or increase tension

Kogler GF, 1996
“...the orthoses which decreased plantar aponeurosis strain [had closer] surface contours of their medial and central regions and the angles related to the their arch shape were more acute”

Kogler GF, 1996
EBM 4: The foot image must capture a precise 3D representation of the plantar aspect of the foot

- Studies support total contact orthoses for:
  - Plantar fasciitis
  - Metatarsalgia
  - Neuroma
  - Diabetic ulcerations
  - Functional hallux limitus
  - Tarsal Tunnel Syndrome

Therefore, any imaging technique that does not capture a true 3D image of the foot is invalid
EBM Casting Criteria

1. The foot image must be captured in a NWB, STJ neutral position.
2. The 1st ray should be plantarflexed to the end of its range of motion during casting.
3. The posterior heel must be captured to allow frontal plane correction of the orthosis (FF:RF balancing).
4. The foot image must obtain a precise 3D representation of the foot’s plantar aspect.
Part II
Techniques to Capture the Image of the Foot

- Techniques that **Do Not** Meet EBM Criteria
- Techniques that **Do** Meet EBM Criteria
Techniques That Do Not Meet EBM Criteria

- Contact Digitation
- Foam Box
- Pressure Plates / Mats
- Greyscale Pixilation
Techniques That Do Not Meet EBM Criteria

- Contact Digitation
  - Does not capture Posterior Heel
  - SWB leads to dorsiflexion of 1st ray
Techniques That Do Not Meet EBM Criteria

- Foam Box
  - SWB leads to dorsiflexion of first ray
Techniques That Do Not Meet EBM Criteria

- **Pressure Plates/Mats**
  - Does not allow NWB
  - WB dorsiflexes 1\textsuperscript{st} ray plantarflexion
  - Does not capture Posterior Heel
  - Does not capture 3D Image of foot
Ability of Footprints to Predict Arch Height

- Hawes, 1992
  - measurements obtained from the footprints were invalid as a basis for predicting or categorizing arch height.

- Chu, 1995
  - 49% of arch height variance can be explained by digital footprints

- McPoil, 2006
  - Plantar surface contact area can explain only 27% of medial longitudinal arch height
“..the clinician cannot predict the vertical height of the medial longitudinal arch on the basis of the amount of foot plantar surface area in contact with the ground during walking.”

McPoil, 2006
Techniques That Do Not Meet EBM Criteria

- **White Light Scanners**
  - Does not allow NWB
  - Does not allow 1\textsuperscript{st} ray plantarflexion
  - Does not capture Posterior Heel
  - Does not capture 3D Image of foot
Techniques That Do Not Meet EBM Criteria

- Plantar Digitizer
  - Virtual 3D Technologies
  - Did not capture Posterior Heel
Techniques That Do Not Meet EBM Criteria

- Ipad

Fast
Portable
Accurate
Techniques That DO Meet EBM Criteria

- Plaster Casts
- STS Sock
- Laser Scanning
Ideal Scanner Functionality

- Meets all EBM Criteria
- Allows Use of all Prescription Variables
  - Medial and lateral heel skives, Inversion, Sweet spots, Medial flange
- Cost and Time Efficient
- High Degree of Reliability
- Strong Support Infrastructure
- Intuitive Software
Laser Scanners

- Meet EBM Criteria
  - Bergmann
  - Sharp Shape
  - Veriscan
  - iQube
Optical Scanners That Do Meet EBM Criteria

- Bergmann Laser Scanner
  - Advantages
    - Meets EBM
  - Disadvantages
    - Single lab production
    - 15+ sec
    - BIG! Not portable
Optical Scanners That Do Meet EBM Criteria

 SharpShape
- Meets EBM
- <5 sec
- Portable
- Multiple Labs

Disadvantages
- Support –
  - 2 person company
- Wires
- Kinda ugly
Optical Scanners That Do Meet EBM Criteria

- Veriscan
  - Advantages
    - Meets EBM Criteria
    - 3.6 sec
    - Portable
    - Multiple labs
  - Disadvantages
    - Support
      - 3 person company
Optical Scanners That Do Meet EBM Criteria

• Advantages
  – Meets EBM Criteria
  – Portable
  – Multiple labs
  – Large, innovative company

• Disadvantages
  – Larger
  – Cord placement
  – Expensive
Summary of Units That Meet EBM Criteria and All Functionality recommendations

- Three viable units on market
  - **Sharp Shape** is available and works well. Small company
  - **Veriscan** is very good technology, but currently has very questionable support
  - **iQube by Delcam** has new unit coming out that has great potential. Delcam is very responsive to feedback
Cost

- Pricing Models
  - Purchase or lease outright
  - Subsidized by labs (cell phone model)
    - May limit labs that can be used

<table>
<thead>
<tr>
<th>Unit</th>
<th>Price</th>
<th>Ongoing Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharp Shape</td>
<td>$2900</td>
<td>$0</td>
</tr>
<tr>
<td>Veriscan</td>
<td>$3200</td>
<td>$3.00 per pair</td>
</tr>
<tr>
<td>iQube</td>
<td>$2900</td>
<td>$120 per month</td>
</tr>
</tbody>
</table>
Scanning vs. Casting Savings / Mnth

- Based on
  - $150 per hour
    - Average casting cost = $43
    - Average scanning cost = $7.5
  - Full schedule

<table>
<thead>
<tr>
<th>Pairs / Month</th>
<th>Savings / Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$355</td>
</tr>
<tr>
<td>15</td>
<td>$532.50</td>
</tr>
<tr>
<td>20</td>
<td>$710</td>
</tr>
<tr>
<td>25</td>
<td>$887.50</td>
</tr>
</tbody>
</table>
Summary

- Imaging Based on Evidence Critical for Achieving Best Clinical Outcomes
- Many Imaging Techniques Being Marketed to Podiatrists
- Digital Casting has Potential to Increase Efficiency and Decrease Cost
- Must Critically Evaluate All New Technology