Foot Orthosis Fabrication: Processes and Technology

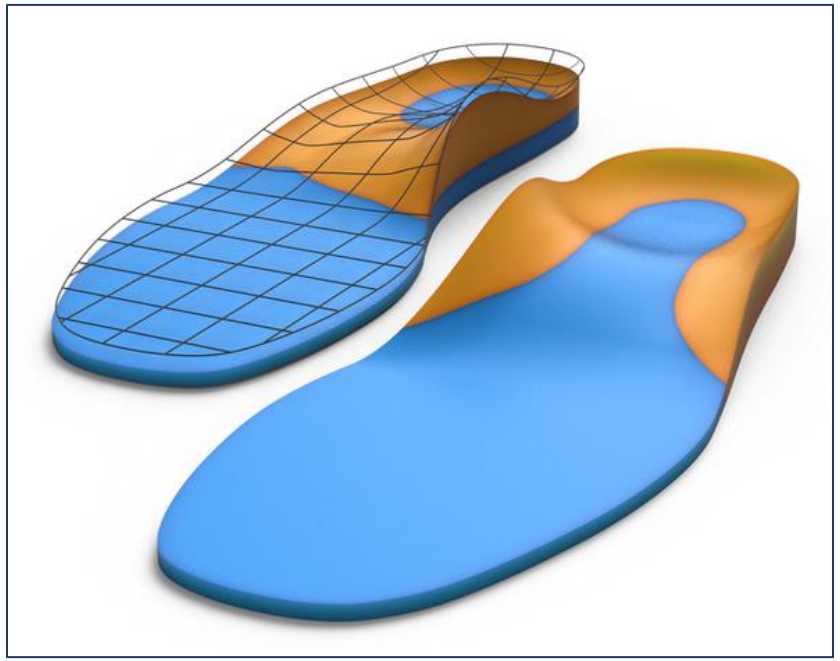
In this module…

- Traditional foot capture techniques
- Emerging foot capture technology
- Traditional cast modification Vs. digital 3-D modeling
- Traditional fabrication methods Vs. computer-aided manufacturing

A Word on Technology…

Exploring New Technologies

- Take this opportunity to learn what's out there.
- Keep an open mind.
- Technology for technology's sake?
  - How does it make your life better or easier?
- How customizable is the technology?
  - Is that even important to you?

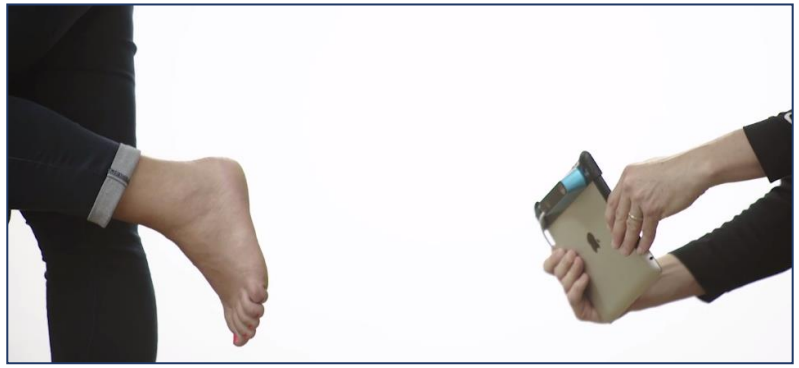


Exploring New Technologies

- In-house Vs. Outsourcing
  - Expectations
  - Communication
  - Support
- Stay flexible
  - Open Technology Vs. Closed Technology
- What do you value and what fits the bill for your practice?
  - Fast and Good won’t be Cheap
  - Cheap and Good won’t be Fast
  - Fast and Cheap won’t be Good

Be a Realist.

There is still, and will be, a place for “old school” processes.



Traditional Foot Capture

NWB Plaster Slipper Cast

- “Suspension technique”
- Taken in a STJN position with the midtarsal joint locked against the hindfoot.
- Patient lying prone with foot extended past end of table.
- Hold the foot by applying pressure only to the 4th and 5th MTHs with the thumb while holding STJ in neutral with the opposite hand.
- Finished cast should:
  - Have a straight lateral border.
  - Have skin lines visible in plaster.
  - Not have any visible air pockets.
  - Show the 5th toe in line with the 5th metatarsal.
  - Not have the impression of the thumb extending medially beyond the 4th MTH. If it does, the midtarsal joint most likely was not locked against the hindfoot.
  - If any of these points are incorrect, the cast should be retaken.

Foam Impressions

- Semi-weightbearing technique
  - Patient is seated
  - CPed positions the leg so that it is perpendicular to the floor from the front and side views. Knee and ankle are both at approximately 90°.
  - The pedorthist places one hand on the top of the knee and positions the other on the foot so that the thumb and forefinger are on either side of the talar head and the palm of the hand covers the dorsum of the foot. When molding the left foot, the right hand should be on the foot and vice versa.
  - The pedorthist pushes the foot down into the foam with equal pressure on the foot and knee.
  - The finished impression should:
    - Show that the entirety of the foot is at the same depth in the box.
    - Have the forefoot and hindfoot in the same plane, hopefully neutral.
    - Replicate the plantar contours, prominences and deformities of the foot.
    - If any of these points are incorrect, the mold should be retaken.
- Full weightbearing technique
  - This method is wildly inconsistent as the pedorthist has no control over the placement or positioning of the foot, nor the angle/alignment at which it is being depressed, nor the amount of force being applied. Simply put, it is not an accurate form of foot capture and therefore its use is discouraged.

Scanning Technology for Foot Capture

Scanning Techniques: Weightbearing

Patient standing in angle and base of gait on scanner while practitioner maintains desired foot position

Pros

- Accommodative shape can be achieved with accuracy
- Full fat pad expansion/soft tissue displacement is captured

Cons

- Lower arch profile
- Reduced arch contour
- Cannot control hypermobility
- Increased width
- Portability of scanner

Scanning Techniques: Non-weightbearing

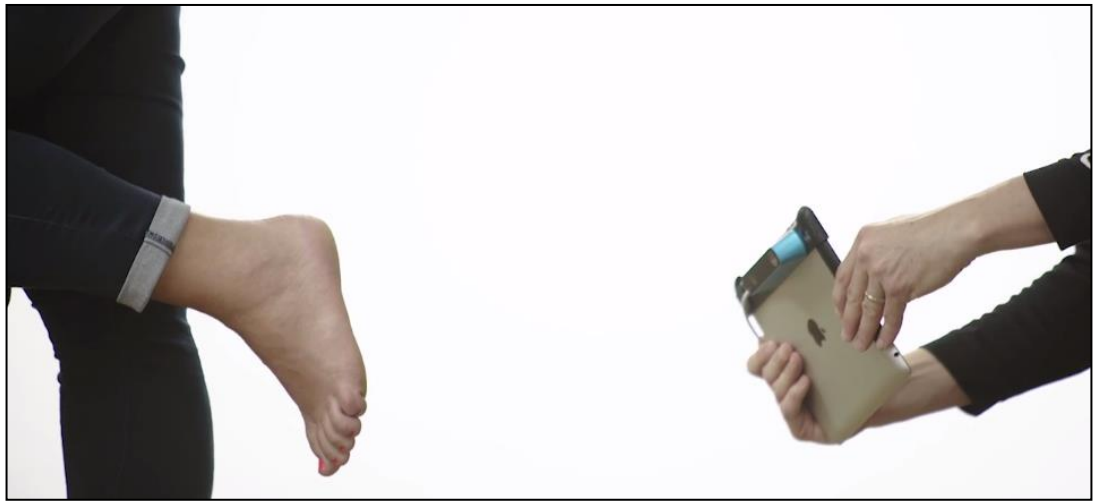
Patient either seated, lying or standing with knee on chair. Typically, handheld scanners used for NWB.

Pros

- Greater arch height and contour
- May be desirable for flexible devices
- Good option for strictly accommodative devices

Cons*

- Very difficult, if not impossible, to balance HF to FF
- Shortened overall foot length
- Subjective fat pad expansion and digital compensation
- Plantarflexed forefoot
- Exaggerated lateral longitudinal arch



* Most of these can be remedied in the modeling process, but it tends to be subjective and quite variable.

Scanning Techniques: Non-weightbearing

Scanning Techniques: Semi-weightbearing

Patient partially loaded (with desired positional correction)while seated

Pros

- Easiest to maintain positional alignment/correction
- Easiest to design from due to combination of good foot topography and moderate level of fat pad capture
- Produces a more functional device without so much subjective interpretation

Cons

- Portability of scanner

Types of Scanners

Contact 3-D Scanning

Is this “outdated” tech?

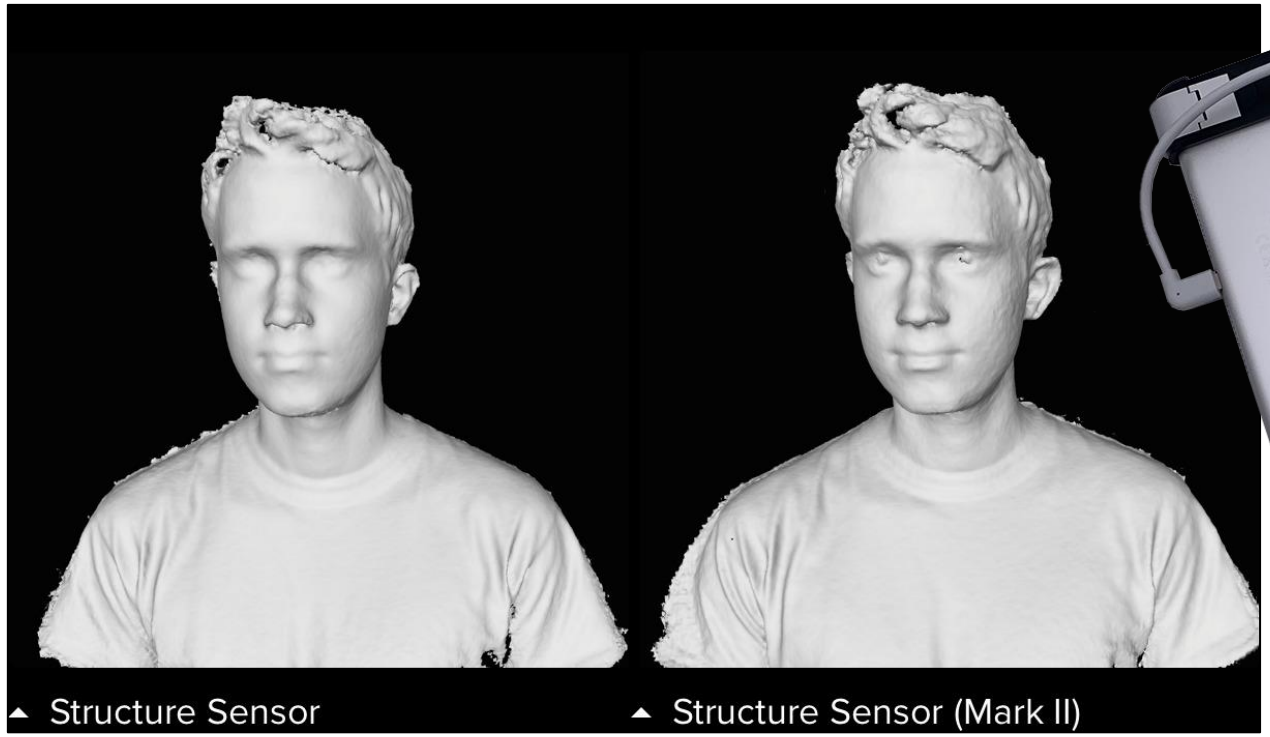
Structured Light Scanning

- Infrared light
  - The Structure projects a unique infrared pattern of dots out in front of it, and the infrared camera uses that pattern of dots to visualize the shape and distance of objects.
- White light
  - Projects line shadows onto a 3-dimensional surface. Two sensing cameras are used to view variances and use algorithms to construct a 3-D model.
- Blue light
  - Advanced version of white light tech. Produces more accurate results as it filters out interference from ambient light. Lower margin for error.
- Laser
  - Measures how long it takes laser light beams to reflect back from objects. More cumbersome and slower. Higher margin for error due to overlapping data.

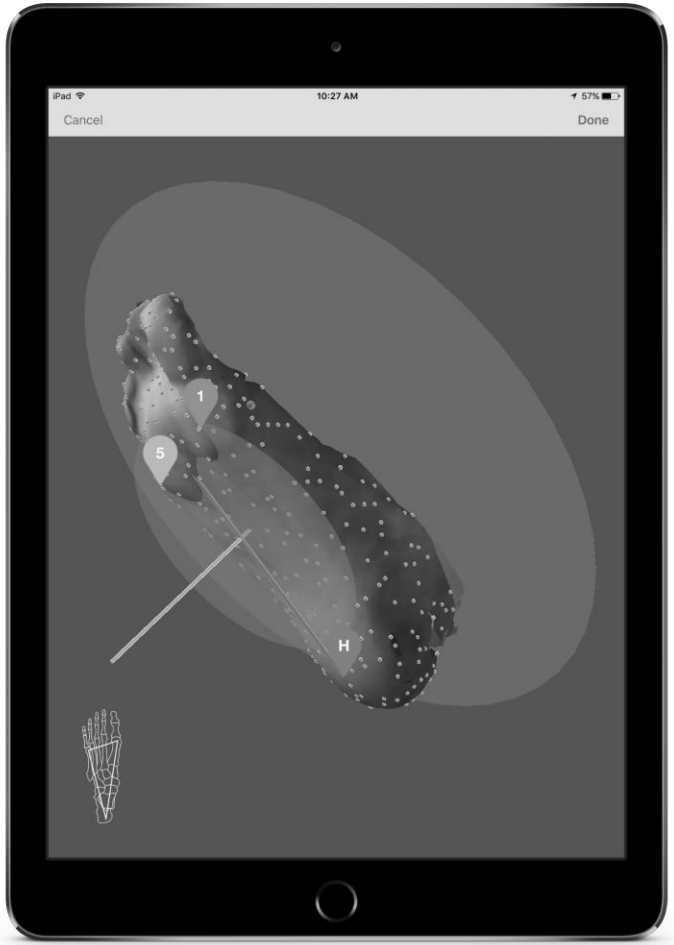
Laser Scanning

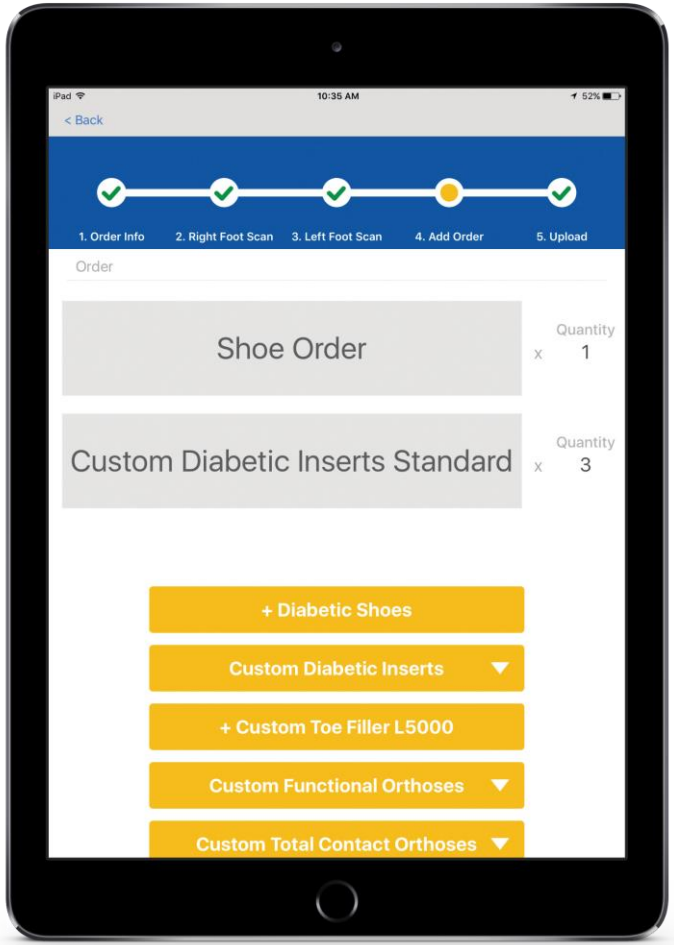
- LiDAR
- Laser triangulation

Structure® Sensor



Comfort Scan Mobile™ app





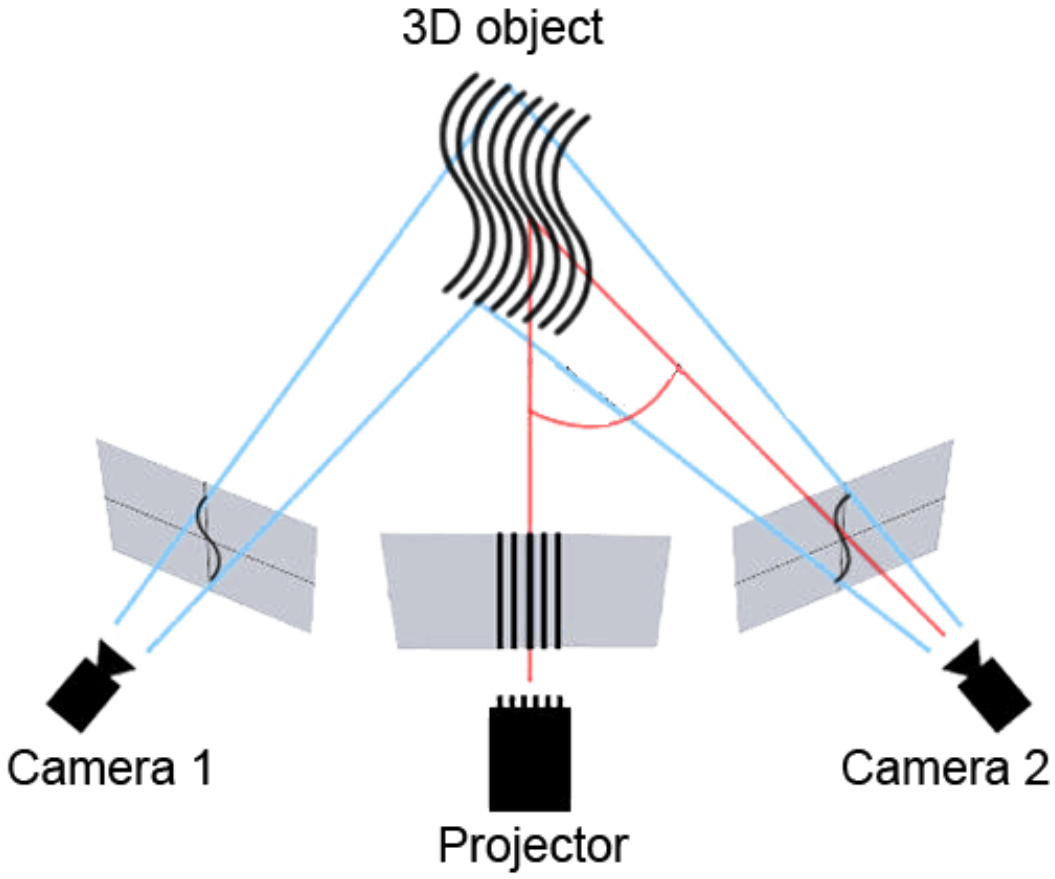
TrueDepth® Scanning

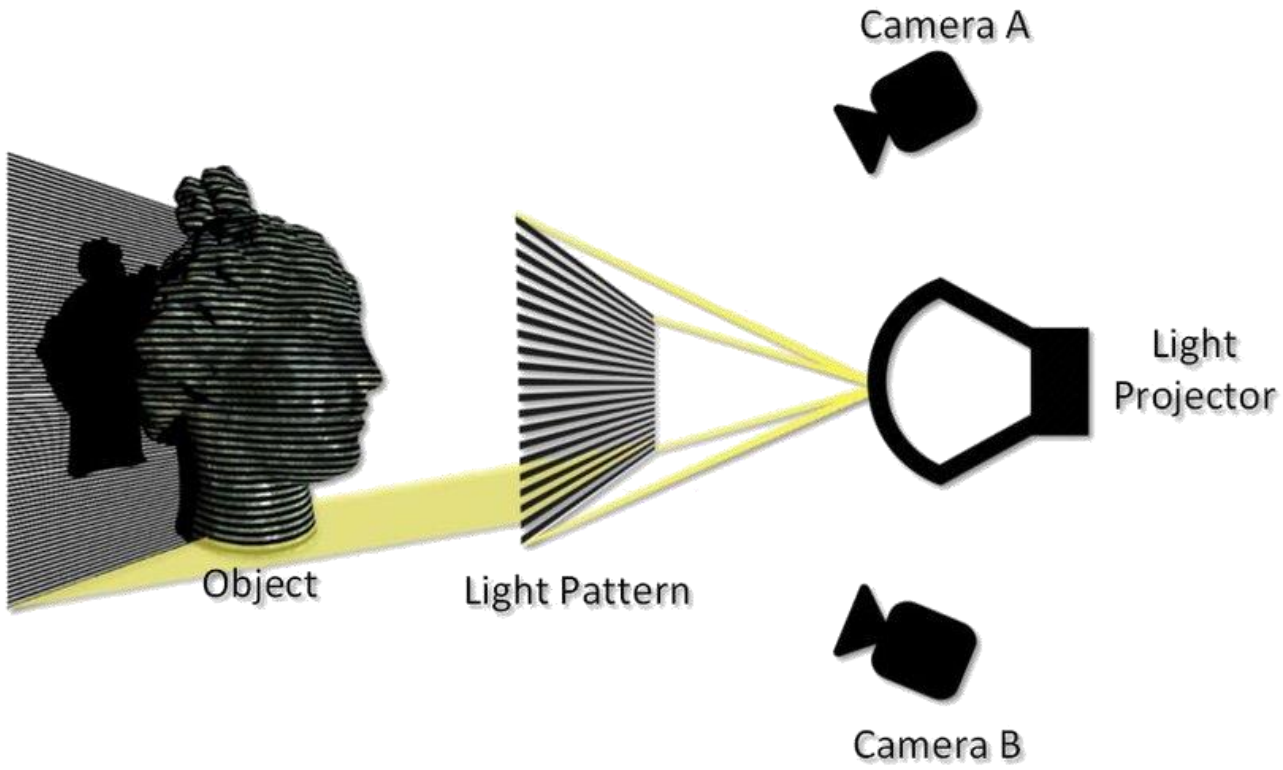
- iPhone
- Is technically LiDAR
- Can only be utilized for plantar scan or foam boxes
- Not movement tolerant

White Light Scanners

- Very precise
- Movement tolerance
- Expensive

White Light Scanning





Photogrammetry Scanning

- Multiple cameras take 2D pictures of the foot and the software constructs a 3D model.
- Some are just traditional flatbed scanners.
- The key here is the software, not the hardware.

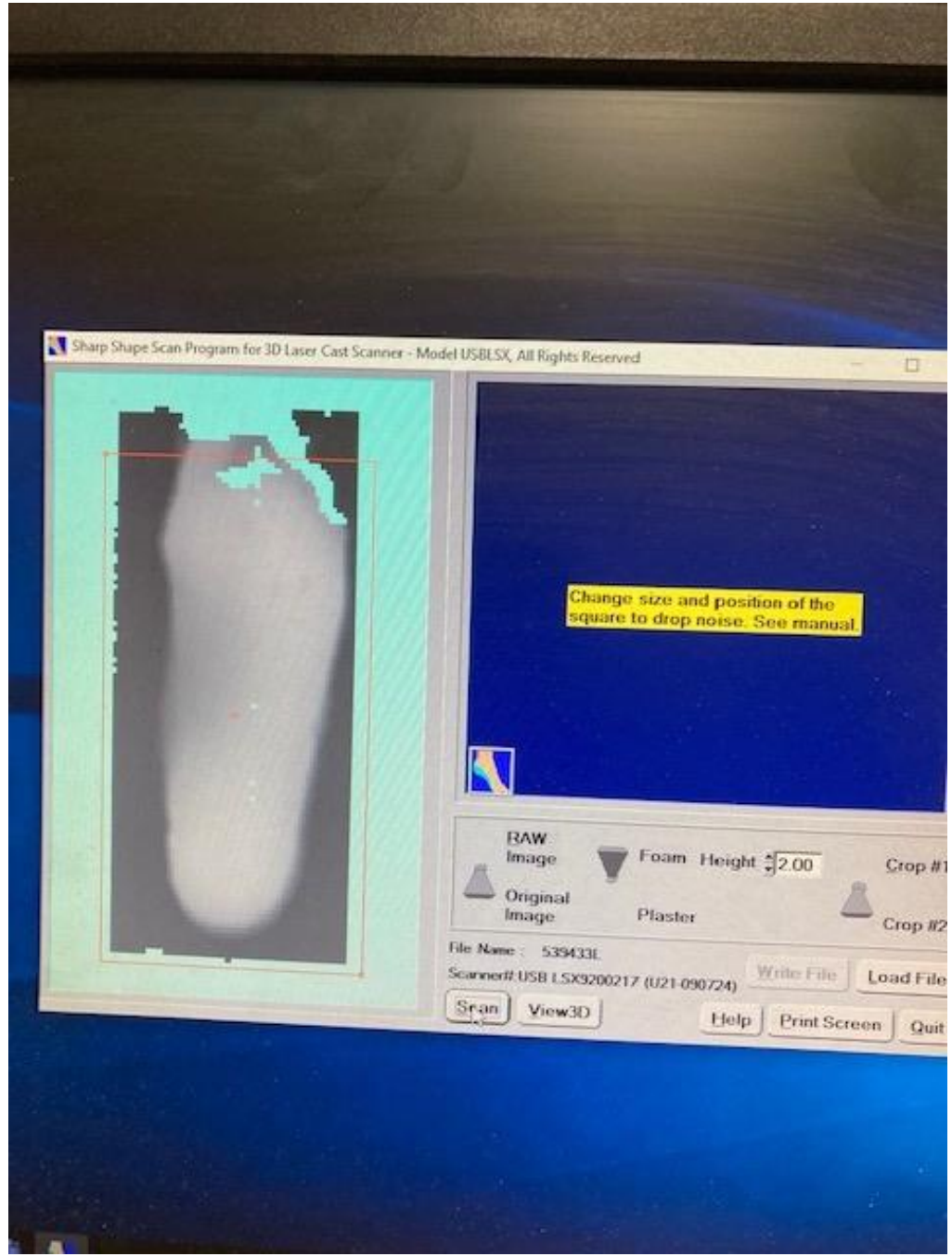
Tips for a great Scan

- Scan either Neutral or Corrected position. (ie. Invert/Evert foot)
- Loading amount critical & consistency key. Semi-Weight bearing appear to give our clients the best results.
- Labs need to know if scans are; Full WB, Non-WB, Semi WB. Minimal Lab interpretation is ideal.
- There is no perfect technique. Personal experience and desired patient outcome influence technique used.
- Seated or standing scans can both work well
- Capturing foot morphology in the desired position of function is the key.
- 3 Point Contact with flat bed scanner - 1st , 5th and heel.

iOrthotics

Combo…


Turn off after work!


Sharp Shape Scan Program for 3D Laser Cast Scanner - Model USBLSX, All Rights Reserved
Change size and position of the square to drop noise. See manual.
RAW Image
Original Image
Foam
Plaster
Height
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Crop #1
Crop #2
File Name :
539433L
Scanner#:USB LSX9200217 (U21-090724)
Write File
Load File
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Print Screen
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Orthotic Design

Traditional Cast Modification

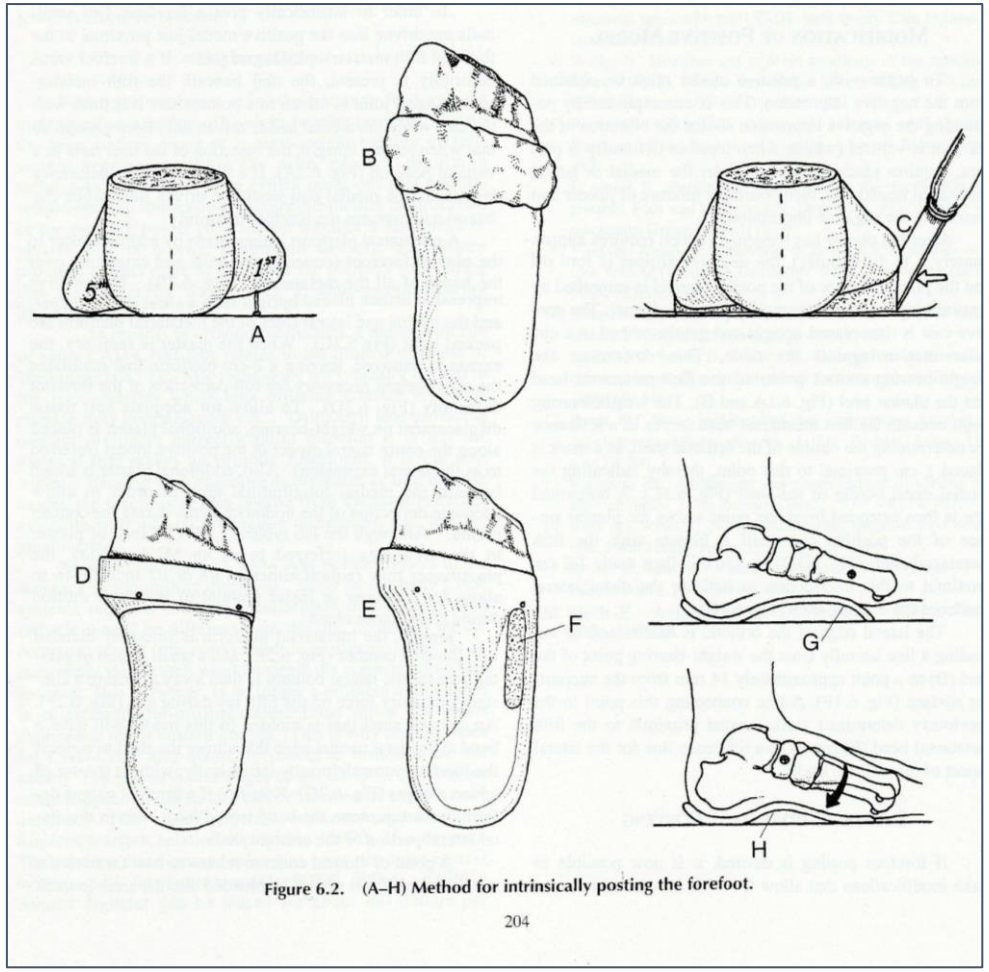

Figure 6.2. (A–H) Method for intrinsically posting the forefoot.

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Cast Modifications: Intrinsic Forefoot Posting

A. Two small nails driven into cast just proximal to 1st and 5th MTHS

B. Plaster added to cover nails to create MT platform

C. Medial and lateral sides of MT platform filled in with plaster

D. A 2cm platform created to maintain correction of forefoot varus/valgus
   - At this point, the arch fill is performed. Typically ¼' of plaster is added to medial longitudinal arch.

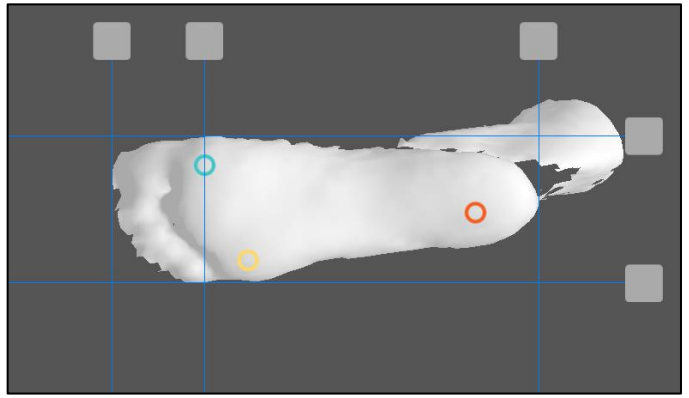
E. Metatarsal platform blended into arch fill

F. A small region of plaster removed beneath lateral column to ensure pronatory force on 5th ray

From: Foot Orthoses. Michaud, TC. 1997 ©Thomas Michaud

Digital Modeling

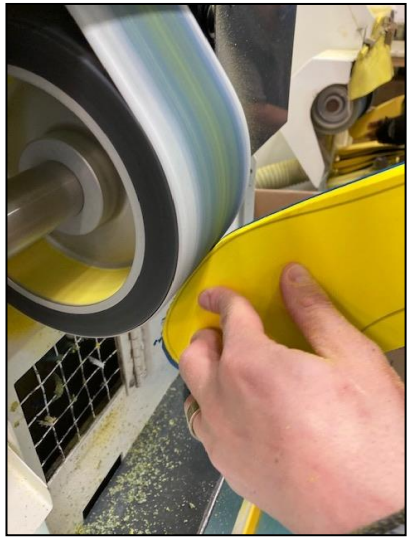
- How involved do you want to be?



Methods of Manufacture

Traditional Vacuum Forming

Subtractive Manufacturing



Traditional Vacuum Forming

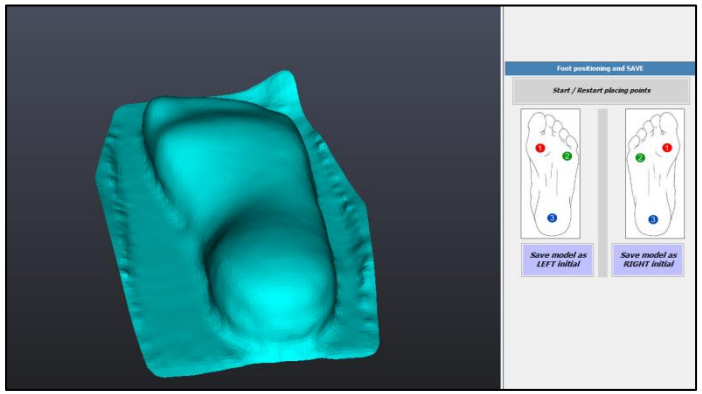
- Pros
  - Ability to mold deep heel cups and high flanges
  - More options in material selection
  - Plenty of time for smoke breaks
- Cons
  - Inefficient
  - Labor intensive
  - Expensive

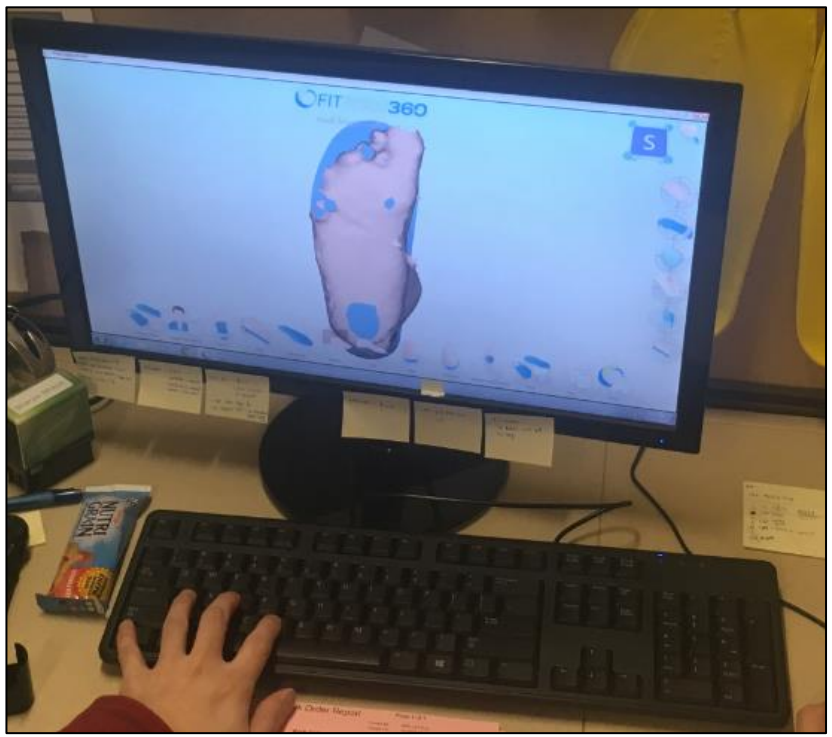
Computer Numerical Control (CNC) Manufacturing

Subtractive Manufacturing

CNC ROUTER MANUFACTURING

- 3-axis milling/carving


Foot positioning and SAVE
Start / Restart placing points
Save model as LEFT Initial
Save model as RIGHT Initial


FIT 360
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FREEDOM
MACHINE TOOL
by DMS


FREEDOM
MACHINE TOOL
by DMS


Techno CNC
LC 3


CAUTION: SHARP

Milling/CNC

- Pros
  - Most efficient method*
  - Infinitely more repeatable than vacuum-forming
  - Ease of adding intrinsic relief/posting
- Cons
  - Learning curve for design software
  - CAD/set-up time
  - Equipment is more expensive

*30 prs/hr

3-D Printing

Additive Manufacturing

3-D Printing

- Pros
  - Limitless design capabilities
  - Locally variable density
  - Technology constantly expanding and improving

- Cons
  - Growing, but limited selection of materials
  - Initial equipment expenses
  - CAD/set-up time
  - Tediously slow to do in-house without a printer farm.

- **The biomechanical effects of 3D printed and traditionally made foot orthoses in individuals with unilateral plantar fasciopathy and flat feet**
  - Ho M, Nguyen J, Heales L, Stanton R, Kong PW, Kean C. The biomechanical effects of 3D printed and traditionally made foot orthoses in individuals with unilateral plantar fasciopathy and flat feet. Gait Posture. 2022 Jul;96:257-264. doi: 10.1016/j.gaitpost.2022.06.006. Epub 2022 Jun 11. PMID: 35709609.
- **Research question:** How effective are 3D-printed FOs (3D-Print) compared to traditionally-made (Traditional) or no FOs (Control), in changing biomechanical parameters of flat-footed individuals with unilateral plantar fasciopathy?
- **Methods:** Thirteen participants with unilateral plantar fasciopathy walked with shoes under three conditions: Control, 3D-print, and Traditional. 2 × 3 repeated measures analysis of variance (ANOVAs) with Bonferroni post-hoc tests were used to compare discrete kinematic and kinetic variables between limbs and conditions. Waveform analyses were also conducted using statistical parametric mapping (SPM).
- **Results:** There was a significant condition main effect for arch height drop ($p = 0.01$; $\eta p^2 = 0.54$). There was 0.87 mm (95% CI [-1.84, -0.20]) less arch height drop in 3D-print compared to Traditional. The SPM analyses revealed condition main effects on ankle moment ($p < 0.001$) and ankle power ($p < 0.001$). There were significant differences between control condition and both 3D-print and Traditional conditions. For ankle moment and power, there were no differences between 3D-print and Traditional conditions.
- **Significance:** 3D-printed FOs are more effective in reducing arch height drop, whilst both FOs lowered ankle plantarflexion moment and power compared to no FOs. The results support the use of 3D-printed FOs as being equally effective as traditionally-made FOs in changing lower limb biomechanics for a population of flat-footed individuals with unilateral plantar fasciopathy.

- **Novel 3D-printed foot orthoses with variable hardness: A comfort comparison to traditional orthoses**
  - Walker KJ, Przestrzelski BT, Kaluf B, Driggers NH, Ballard WD 2nd, Pruett TC, Hoeffner SL, DesJardins JD. Novel 3D-printed foot orthoses with variable hardness: A comfort comparison to traditional orthoses. Med Eng Phys. 2023 May;115:103978. doi: 10.1016/j.medengphy.2023.103978. Epub 2023 Apr 7. PMID: 37120178.
- Both the 3D-printed and the traditionally fabricated foot orthoses demonstrated statistically significant increases in comfort when compared to the factory fabricated shoe insert. Additionally, the two orthosis groups were not significantly different from each other in comfort rankings both regionally and overall, at any time point. The similar comfort achieved by the 3D-printed orthosis to the traditionally fabricated orthosis after 7 days and 14 days emphasizes the potential of the future use of the more reproducible and adaptable 3D-printed orthosis manufacturing methodology.

The End