3-D Scan or Cast for Orthotics That is the Question?

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To Scan or Not To Scan?

Costs

- The cost differential of 3-D scanning vs. traditional plaster strip casting.
- According to a study by Payne, the costs for the plantar cast method vary from $27.94 (lowest estimate) to $49.60 (highest estimate).
- The costs for the optical scan vary from $3.30 (lowest estimate) to $10.00 (highest estimate) 1

Costs

- The costs do not include the initial costs of purchasing an optical scanner, nor the costs of maintaining an internet connection.
- Some 3-D scanners may typically cost between $1,200 and $2,500 , and some as high as $15,000.
- In many cases orthotic labs may provide the scanner at no cost

Time Savings

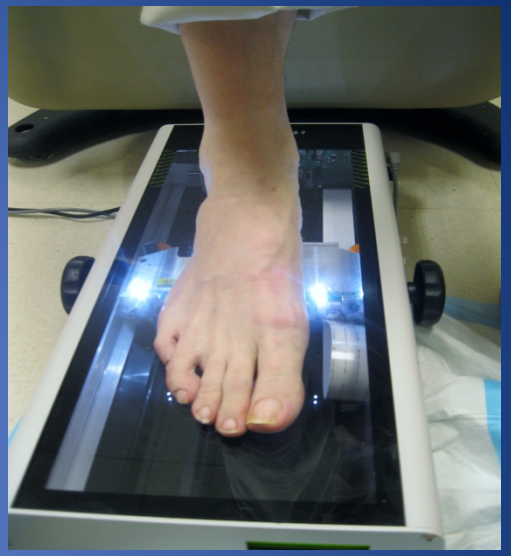
- The time estimates are even more impressive.
- The study showed that the total time involved with a plaster of Paris casting takes approximately 11 minutes while the optical scan takes 2 minutes. 1.
- Time savings also involve the immediate transmission of the digital data to the orthotic lab, compared to the time involved with packing and shipping of the plaster casts, and the worry of the casts being crushed, or lost in the mail.
- Inquiring the lab as to the whereabouts of the casts can be exacerbating, when faced with the delays in getting the orthotics into production.

3-D Scan vs Plaster Casting

- The custom-fabricated orthotic is only as good as the molding process used to create it.

Digital Technology

- If digital technology is utilized in the fabrication of a custom foot orthotic, the laser or scanning system must create a three dimensional foot image from points directly from the foot itself or from a direct model of the foot.
- The scanning technology must not use computer algorithms, extrapolations, or interpretations to calculate shapes and contours from two-dimensional pressure readings. 2.



3-D Scanner Technology

- When utilizing the 3-D scanner for capturing a 3-D model of the foot, there are three acceptable types of 3-D digital scanners:
- Laser triangulation (red light), which uses a laser light to measure the distance between the laser source and the foot to create an accurate model of the foot.
- Structured light (white or infrared light), which uses the same trigonometric triangulation used in laser scanning, however, instead of using laser light, the scanner projects a light pattern onto an object and calculates the distance to the light source.
- Contact digitization, which uses a three-dimensional pin matrix to capture the contours of the plantar aspect of the foot.

Evidence –Based Studies

- A 3-D scanning method developed through advanced optoelectronic technologies has been employed to collect anthropometric data. 3, 4,5 .
- A study by Lee and Wang compared the precision and accuracy of four foot dimension measurement methods.
- Looking at the precision and accuracy evaluation results, utilizing the 3D scanning method to collect the foot dimensions had better performance than the digital caliper, digital footprint and ink footprint methods.
- Based on the findings, the study supported the use of 3D scanning method for collecting foot anthropometric data 5.

Evidence Based Studies

- An advantage of using the 3D scan is that it allows a large number of participants to be scanned quickly and the measurement is robust and efficient. 6.
- A previous study has indicated that using the digital footprint to collect foot dimensions is reliable. 7. Mall et al. compared the foot dimensions collected using optical techniques and caliper measurements and reported that using he optical techniques was as reliable as the caliper measurements , while concomitantly the measurement time was reduced. 8.
- In another study, DeMits et al. evaluated the validity of 3D scanning measurements using comparisons with X-ray and manual instruments.
- They results showed that 3D scanning provided good validity when scanning health participants. 9. In cases of abnormal feet, the 3D scan can also be used to screen for foot deformities before the presence of foot erosions. 10. The study also showed good validity and reliability compared with clinical measurements. 11.

3-D Scanning for Foot Deformities

- The 3D scanner has a role in the prescription of foot orthotics and customized shoes intended to accommodate deformities related to the foot.
- Scanning technology can be used for research and clinical assessments of various medical conditions 5.
- Conditions that require custom shoes and insoles such as diabetic peripheral neuropathy, rheumatoid arthritis, psoriatic arthritis, can also benefit from the 3D scanner, in addition to tradition impression casting technique.

3-D Scan Research

- Borchers et al investigated a laser scanner intended to assess its potential for generating the data needed for the design of custom shoes intended to reduce the risk of ulceration in insensate feet.

- Their study revealed that compared to a standard shoe last, the hallux and the 5th metatarsal head both protruded outside last shape, both areas common for developing irritation and development of diabetic ulcerations. 12.

3-D Scan Evidence

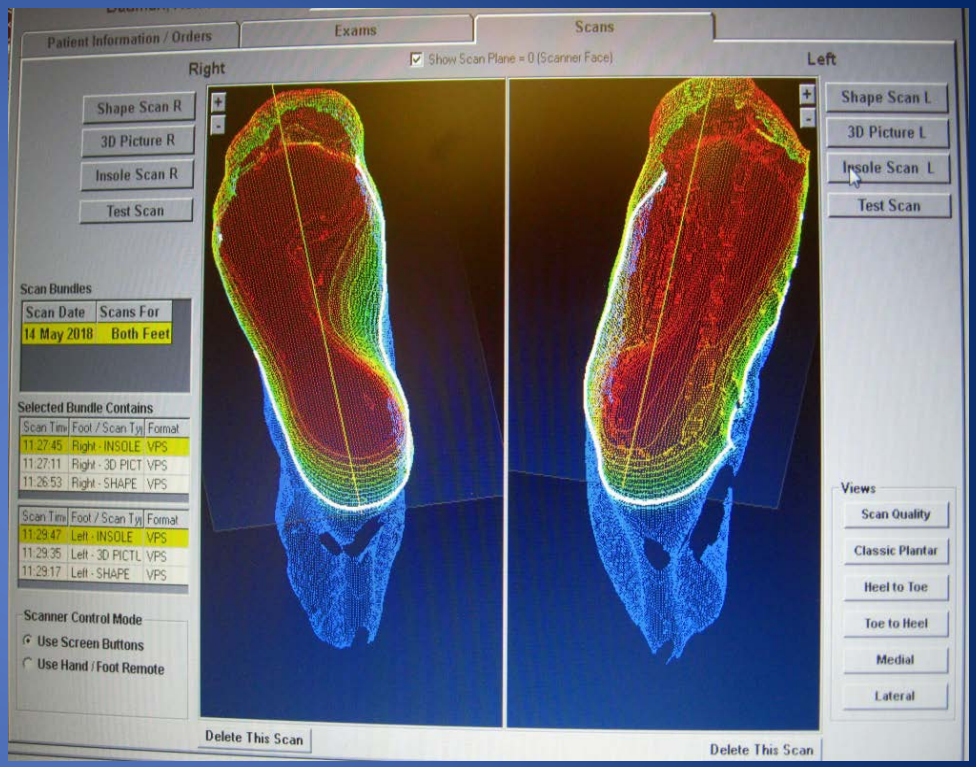
- Kouchi and Mochimaru described the development of the Infoot 3D foot digitizer. 13.
- They investigated the validity and reliability of the 3D scanner compared to manual measurements for rheumatoid arthritic patients.
- They determined that the device was a fast and reliable method of obtaining 3D anthropometric data of the foot. 11, 13.

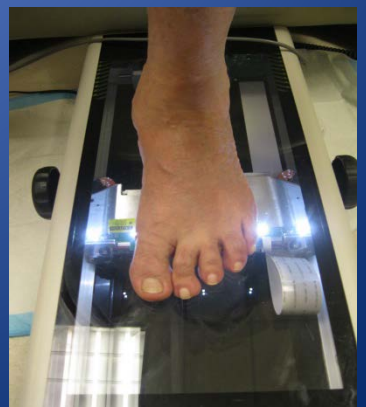
3-D Scan Measurement

- Another use of the 3D scanner is for measuring surface area of the foot .
- Traditionally, it has been an estimated percentage of total body surface area. 14.
- The 3D scanning system provides a means to increase the accuracy of the measurement by taking into account many parts of the foot surface that may be omitted utilizing previous, physical measuring techniques such as wrapping. 15.

3-D Scan

- The 3D scanner may be used as a means for creating a base line reproduction of the foot, particularly for the athlete or for the neuropathic diabetic patient.
- Repeated scans over a period of years can help determine changes in the foot, and how their prescription orthotics may be modified, taking into consideration those physiologic changes.
- These scans will be saved indefinitely in cases where the patient has changed foot physicians, or moved locations.





3-D Scan

- The 3-D digital foot scan creates a full-color 3D digital cast or impression.
- This process incorporates a weight-bearing process, where the patient rests one foot, or both feet on the sensor plate with the knee bent at 90 degrees.
- The assistant clicks a button to begin the process, and a computerized image of the foot is taken. It is important to note that some pressure mapping systems only provide a 2-demensional representation of the foot.
- The computer then extrapolates, or “guesses” the remaining details of the foot to create the 3D cast.

3-D Scan Criteria

- Optical scanning systems can be further split into two categories, those that capture the plantar arch only and those that capture the plantar arch and the posterior heel.
- The criteria proposed herein favors the latter type of system.

3-D Scanning and Ski Orthotics

- You step onto a special scanner that uses air pressure to raise lots of little plastic pegs until they impact the entire bottom of your foot at different points, which in turn creates a highly accurate and detailed 3-D model of the bottom of your feet, including arch, heel, toes, and ball, along with where and how much pressure you are exerting.
- This model is fed into a very precise computer controlled lathe that generates a pair of orthotics designed to take whatever natural flaws you have in your foot and remedy them into a neutral stance.

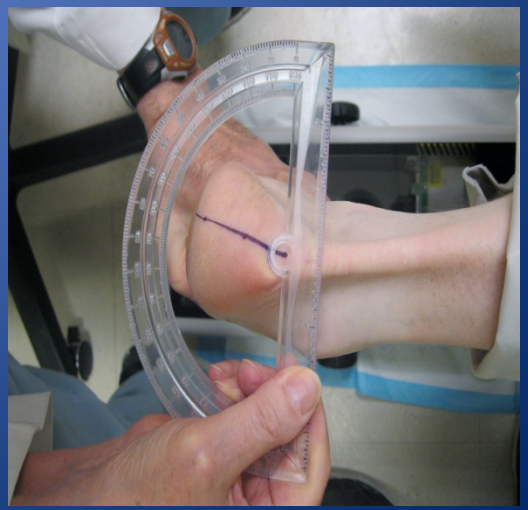
One foot at a time is scanned and 3-D modelled using this computer controlled footbed scanner.

Casting

- The traditional approach to custom made functional foot orthoses is to initially take a plaster cast of the foot. 17, 18.
- Plaster casting has been shown to be widely used in the fabrication of foot orthoses, but has been shown to have some reliability issues. 19.
- Despite the issues of reliability, reviews of outcome surveys have shown they are clinically successful. 20.

Plaster Casting

- Before a custom-made foot orthotic can be fabricated, an involved process involving capturing a three-dimensional foot shape, an orthotic design process, and finally a manufacturing process.
- The cast is the capture of foot structure and foot position.
- The fabrication of a foot orthotic first requires both an accurate evaluation of the foot structure, and a precise neutral impression of the foot morphology.



Plaster Casting

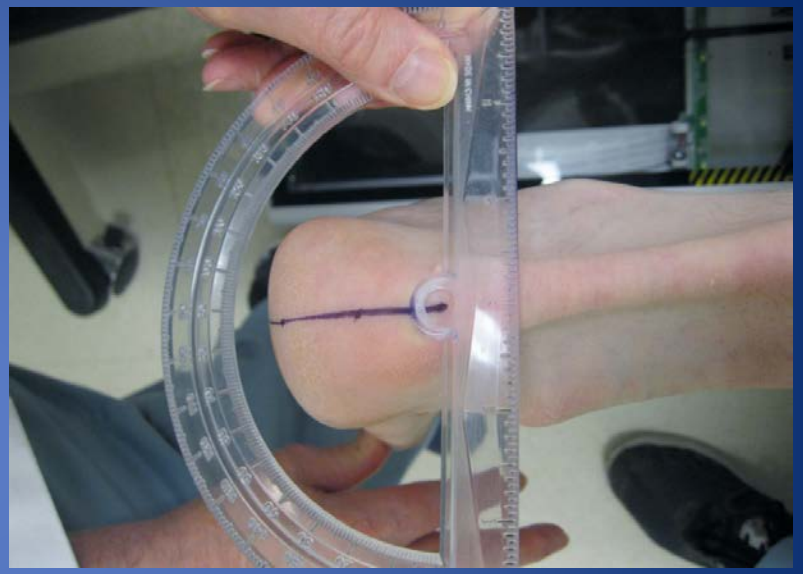
- This plaster neutral foot impression is to replicate the patient's forefoot-to-hindfoot alignment that would occur at the midstance phase of the gait cycle. 21.
- At the midstance instance, the subtalar joint should be in a neutral position, which is neither pronated nor supinated. 17.
- Concomitantly at midstance, the midtarsal joint becomes fully locked, causing the plane of the metatatrsal heads to be placed in a position that is perpendicular to the bisector of the calcaneus. 22.

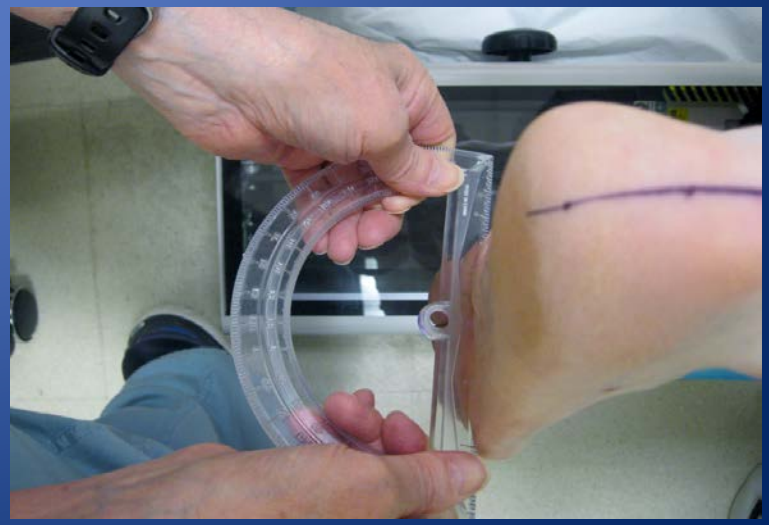
Plaster Casting

- The normal forefoot to hindfoot alignment at midstance phase of gait should be 90 degrees.
- To duplicate the midstance phase of the gait cycle, the neutral plaster impression should be performed with the subtalar joint in neutral and the midtarsal joint fully locked.
- It has been shown that the principle cause of incorrect positioning of the foot when taking the neutral plaster impression is the failure to fully lock the midtarsal joint. 23.

Forefoot Considerations

- There are also forefoot deformities which can also alter the normal forefoot-to-hindfoot alignment and contribute to abnormal movement patterns of the foot. 21. 24.
- Two of those forefoot deformities include a forefoot varus or forefoot valgus.





Casting Rule #5

- *The negative cast must capture a perfect representation of the plantar aspect of the foot while the foot is held non-weightbearing in subtalar neutral position.*

Various Casting Methods

- **Plaster casting slipper casting**
- **Impression foam**
- **3D digital scanner.**
- **All of these methods can be successful if they are performed properly.**
- **The foot care profession must be skilled in performing the various casting methods.**

Neutral Plaster Casting

- The three most common methods used to obtain a neutral plaster foot impression are:
- the supine non-weight-bearing method (S),
- the prone non-weight-bearing (P) method,
- the sitting semi-weight-bearing (SW) method.
- In a study by Mcpoil et.al. the same forefoot –to-hindfoot alignment can be obtained by using either the non-weight-bearing, or the prone non-weight-bearing methods,
- However not with the semi-weight-bearing method. A difference in the degree of forefoot deformity can also be expected between the left and right feet. 25.

Neutral Plaster Casting

- Valmassey described the advantages and disadvantages of all three impression techniques.
- He suggested that the variation in forefoot-to-hindfoot alignment in the semi-weight-bearing method is used for obtaining a neutral foot impression in comparison with the prone non-weight-bearing, and supine non-weight-bearing methods. 25, 26.
- It has been shown that the difference is caused by the inability to fully local the midtarsal joint when the foot is in a semi-weight-bearing position.
- This can also be a problem when utilizing the 3D scanner as well.

Positioning of the Foot During Casting

- Positioning the foot for plaster casting is important for reproducing the sagital contour.
- You should be able to assess the cast that was taken, and compare it to foot shape, and any idiosyncrasies of the rearfoot or forefoot.
- During the casting process it is important to remember not to allow the forefoot to plantarflex, which will cause the cast to have a higher lateral arch than the foot.
- There are some advantages to casting which can allow the practitioner to slightly plantarflex the first metatarsal, and dorsiflex the hallux for a functional or structural hallux limitus.
- Balancing the forefoot to correct various degrees of forefoot varus is another advantage to the casting technique.
- Remember, a gastro-soleus equinus can also have an effect upon neutral plaster casting particularly with the knee extended, versus a cast performed with the foot in partial weight-bearing.

CAD-CAM- vs. Foam Impression

- Comparing different plaster impression casting techniques to the foam box casting devices, Ki, et al. compared the plantar pressure distribution patterns between foot orthoses by the CAD-CAM system and the foam impression method.
- Their results showed that a pressure distribution pattern, with the exception of the mid forefoot region, similar to the one provided by the foam impression method.
- They noted that peak pressure and the pressure-time integral in the midfoot regions were lower in the CAD-CAM approach than in the foam impression approach. 29.

3-D Printing and Orthotics : A Roundtable

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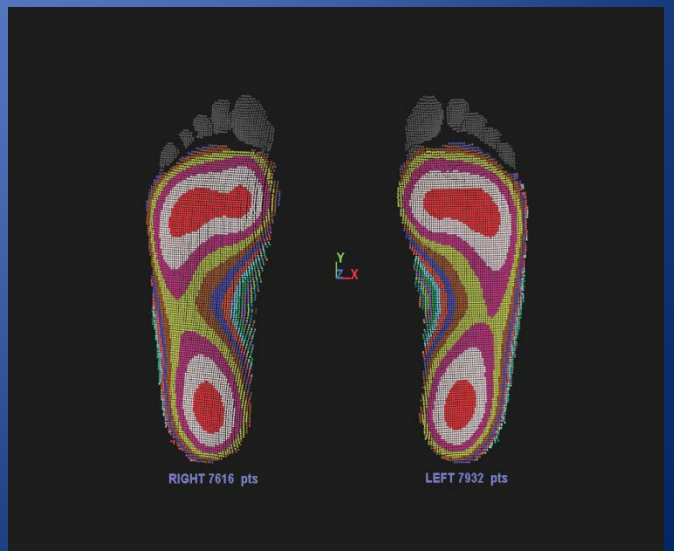
The most common current methods for 3D printed foot orthoses are selective laser sintering (SLS) and fused filament fabrication (FFF), both of which work by raising the temperature of a thermoplastic material to the point that the molecules flow together and bond Hewlett-Packard uses polyamide 11 (PA 11) or polyamide 12 (PA 12),



Accuracy of various scanning methods compare with the accuracy of traditional casting techniques?

- Three-dimensional scanners are generally accurate to within 1 mm or less.
- For all intents and purposes clinically no different than traditional casting methods in terms of capturing the shapes it is meant to capture.
- However, traditional methods such as plaster casting have the advantage of allowing the manipulation of soft tissues while capturing a model of the foot.
- Examples such as allowing the clinician to reshape the calcaneal fat pad, heighten the lateral arch or press into the groove of the tarsal tunnel (e.g. for a UCBL-type device) at the time of casting.

James McGuire, DPM

Accuracy of various scanning methods compare with the accuracy of traditional casting techniques?

- All major labs scan the foam boxes or plaster casts they receive.
- Few, if any, labs work with traditional plaster positive casts, saying the plaster process is not fast or efficient enough to keep up anymore.
- Most labs use CAD/CAM systems and scan the non-digital casts they receive.
- “Essentially no difference” in comparing scanned plaster casts or scanned foam boxes or foot scans with similarly casted feet in plaster of Paris.
- “Scanning is not the issue,” “Positioning by the practitioners is more important.”
- Bruce Williams, DPM

Conclusion

- Choose between 3D digital scanners versus the traditional plaster casting methods.
- As technology has advanced, replicating the foot in a digitalized manner, can now transmit immediately to the orthotics laboratory
- Plaster impression casts which easily can be crushed in boxes, lost or delayed in the mail, or thrown out inadvertently by the lab can now be eliminated.
- The 3D scan data can now be stored indefinitely, so that if a patient moves locations and needs a new foot specialist to continue their care, their biomechanical information will be stored at the lab, which offers continuity of care. Additional orthotics can be ordered at any time in the future without having to re-cast the patient.
- The process can increase efficiency in the office, allow the practitioner to speed up the orthotic process, which also allows the patient to spend less time in the office, and with cleaner feet.
- It allows the practitioner to spend more time for a gait analysis, and or a pressure mapping test.

Conclusion

- Does not eliminate the need for the traditional plaster casting for the fabrication of prescription orthotics.
- Does not preclude the need for a full biomechanical evaluation and measurement taking before casting or 3-D scanning.
- Measurements should be taken of the inversion/eversion of the sub talar joint, rearfoot neutral , calcaneal stance / forefoot neutral measurement, as well as assessing for equinus with ankle joint range of motion, mobility of the first ray, 1st ray position, dorsiflexion of the hallux, and assessing foot type off weight bearing and fully weight- beared.
- Those measurements should be included whether it is with a 3-D scan or plaster casting.

Conclusion

- Knee position should be assessed for genu valgum or genu varum, as well as the gait pattern, whether the patient demonstrates in-toe, out-toe or rectus gait pattern.
- Pressure gait analysis with a Mat Scan. This can help to determine if there is a limb length discrepancy, or asymmetry between the two feet or limbs. Those results can be sent to the lab as well with the 3-D scan or the plaster casts.
- Athletes with certain foot types, and rearfoot /forefoot imbalances can benefit from a foot impression which can offer exact contour, and better locking of the midtarsal joint, while preventing the rearfoot from supinating or pronating.
- Consider plaster casting in some cases for the insensate Charcot arthropathy patient.
- Have plaster splints available when assessing the foot, and decide whether to 3D scan or impression cast is preferred.

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