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A Guide for the Prosthetic Management of

Partial Foot Amputations

A comprehensive model for the prosthetic management of partial foot amputations designed to:

- Resolve acquired limb length and postural deficits
- Facilitate return to fluid symmetrical gait
- Protect and preserve the residual foot

The challenges posed by partial foot amputations are inter-related, and must be managed by a comprehensive plan that addresses all the issues in one integrated solution.

Introduction

This illustrated guide was developed in response to requests from medical educators, prescribers, as well as orthotic and prosthetic practitioners seeking a comprehensive prosthetic model to manage partial foot amputations.

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Reimbursement Codes

Any reference to reimbursement codes are based on suggestions from practitioners using these techniques and are not suggested by Allard or validated by any reimbursement agency.

Applicable Amputation Levels

The concepts in this guide apply to any partial foot amputation that has the potential of developing callus formations at the distal residual foot. It is also applicable for patients for whom gait is difficult secondary to the loss of the propulsive lever arm of the foot.

Incidence and causes of partial foot amputation

The incidence rate of partial foot amputation were many times larger in cohorts with diabetes (94.24 per 100,000 people) compared to those without (3.80 people without)[1]. The leading causes of partial foot amputation[2] are:

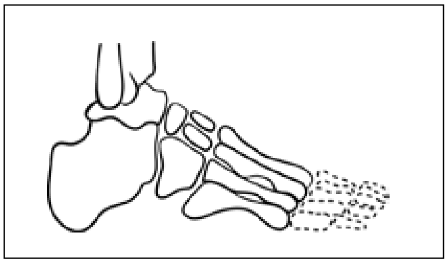
1. Diabetes (many diabetic patients also have peripheral vascular disease)
2. Peripheral vascular disease (in the absence of diabetes)
3. Trauma (most often lawnmower injuries and motorcycle trauma)
4. Chronic infections (primarily osteomyelitis)
5. Tumors
6. Congenital abnormalities

With the dual epidemics of obesity and diabetes, it is thought that the incidence of partial foot amputations will continue to increase.

References
1. Dillon et al, A systematic review describing incidence rate and prevalence of dysvascular partial foot amputation;...., Syst Rev 6, 230 (2017)
2. James W. Brodsky, Charles L. Salzman, Musculoskeletal Key (n.d.) Amputations of the Foot and Ankle. https://musculoskeletalkey.com/amputations-of-the-foot-and-ankle/

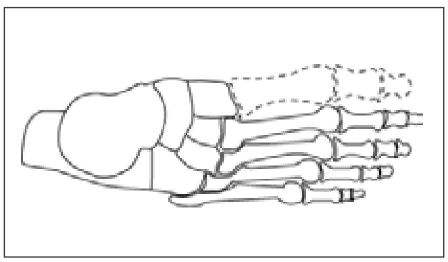
Levels of amputation

Levels of amputation correlated to anticipated limb length loss and resultant proximal compensations.



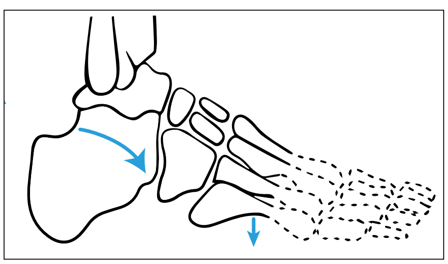
Toe Amputation with Hallux Intact

Toe amputation is the most common partial foot amputation (PFA). If the great toe is still intact the loss of propulsion is not as severe so it is usually sufficient to support the residual foot with a carbon foot plate with toe fillers to prevent drifting of residual toes.



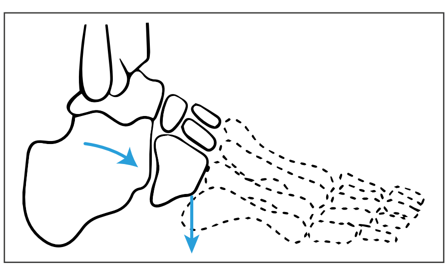
Toe Amputation including Hallux

If the great toe is disarticulated, either alone or in conjunction with other toes, the propulsive lever arm becomes deficit, resulting in loss of propulsion and the creation of shearing forces that lead to callus formation. Propulsion during gait has to be restored to minimize proximal compensations.



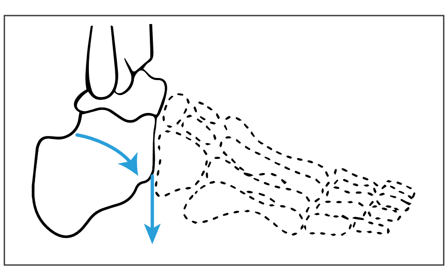
Transmetatarsal amputations

Transmetatarsal amputations (TMA) result in not only shearing forces second- ary to loss of the propulsive lever arm, there is also an acquired limb length deficit of approximately 1cm. Prosthetic intervention should include restoring the calcaneal inclination angle to neutral to restore ankle neutral posture. See more later in this guide.



Lisfranc

It is estimated that Lisfranc and higher PFAs result in 100% loss of power crossing the ankle. This leads to compensations including hip hike and trunk sway to pick the limb up off the floor, and trunk torque in the 4th rocker to initiate swing to advance the limb through space. The anticipated acquired limb length deficit is approximately 1.5cm.

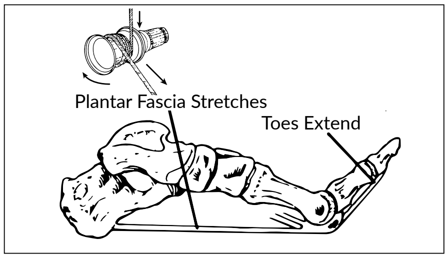


Chopart

Chopart amputations are associated with complete loss of the propulsive lever arm. The ankle ends up in plantarflexion as the anterior aspect of the calcaneus reaches the floor. This plantarflexed posture leads to the appearance of a large bulbous heel. Limb length loss at this level can be anticipated at about 3cm.

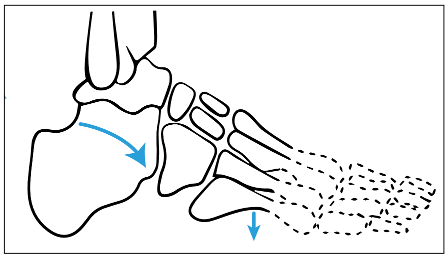
There are limb length losses, postural deformities, and functional deficits that occur secondary to partial foot amputations that must be corrected to help preserve the residuum and to restore gait function.

Partial foot challenges



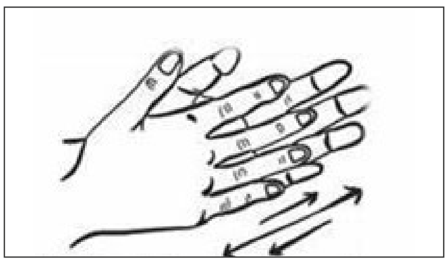
Loss of windlass mechanism

The windlass mechanism occurs when the heel comes up off the ground in the 3rd rocker. That dorsiflexes the great toe and tightens the plantar fascia, making the foot a more rigid propulsive lever arm. Without the great toe, shearing forces occur leading to callus formation, and the foot remains too flexible to be an effective propulsive lever arm.



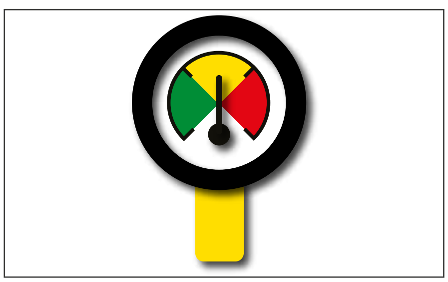
Loss of propulsive lever arm

The foot is a lever arm for torque. Reducing the length of the lever arm results in two consequences. The first is the appearance of gait compensations similar to hemiplegic gait. The second is that the calf group muscles now overpower the too-short lever arm, causing shearing between bones and connective tissue in the residuum leading to callus formation.



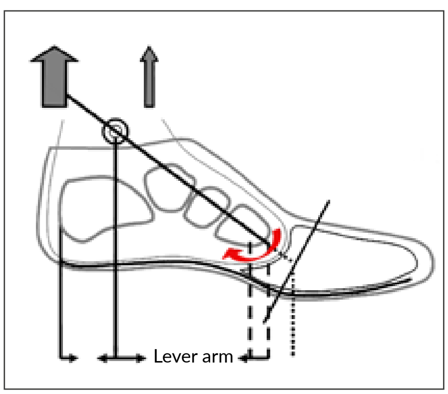
Friction

Friction can occur when there is movement between the skin and another object like the inside of a shoe or a prosthetic socket that's too large. It is destructive to the foot in that it can lead to skin abrasions or blistering. This damage to soft tissue, especially in an insensate foot, can lead to the onset of wound formation and ulceration.



Pressure

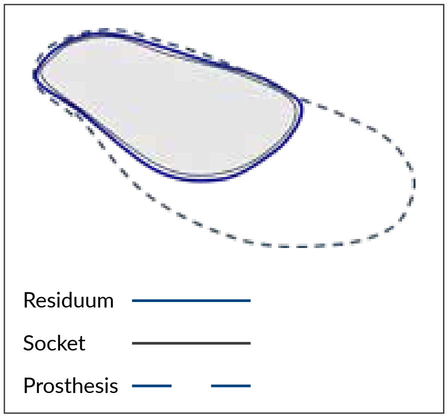
There are two kinds of pressure. One is constant pressure when the residuum is fit into a prosthetic socket or a foot that is fit into a shoe. Devices that are too small can lead to constant pressure that can lead to cell death and wound formation. The second is intermittent pressure that occurs when walking. The weightbearing surfaces should be as broad and intimately fitting as possible to minimize pressure on soft tissue.



Shearing Forces

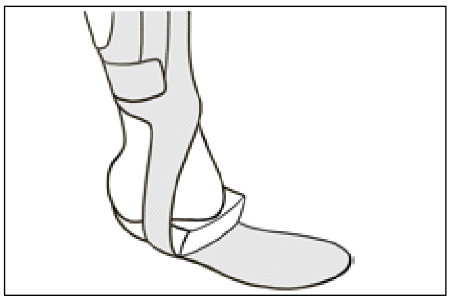
Shearing is perhaps the most destructive of foot challenges, and is the most difficult to manage. It occurs when the propulsive lever arm becomes too short and calf group muscles overpower the shortened lever arm, causing bone to move within the foot, disrupting connective tissue. The only solution to the resultant callus formation is to restore the length of the propulsive lever arm.

Solutions to challenges



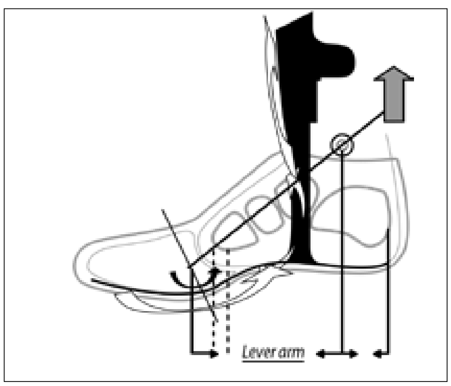
Managing friction and pressure

The solution to managing friction and pressure is to capture an image of the residual foot using a scan, plaster, or an STS sock. While a slipper cast works, a more proximal cast may help create a better model for assuring proper alignment. An intimately fitting socket will protect the residuum from friction and pressure. That same socket then serves as a foundation onto which posting is added to manage improvements in functional biomechanics and to resolve any acquired limb length deficit.



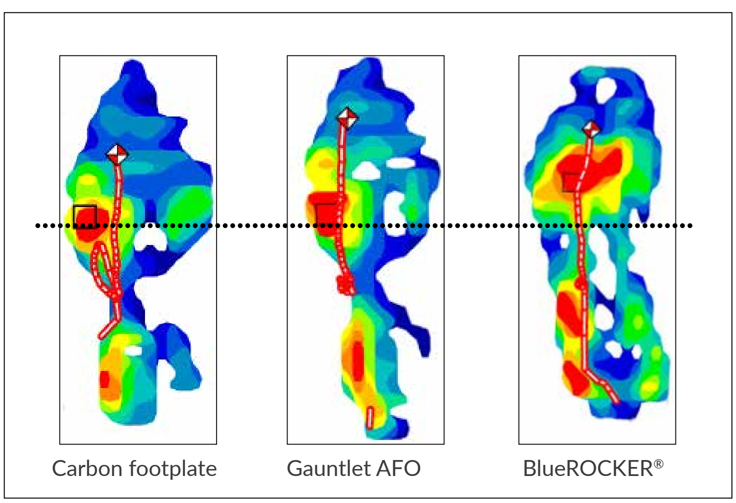
Restoring limb length

To restore limb length and to restore the ankle back to its neural posture, a wedge or post is used to support the anterior aspect of the socket to restore the calcaneal inclination angle to as close to the sound side angle as possible. This also minimizes any acquired bulbous heel deformity typically seen in more proximal levels of partial foot amputations. Any residual limb length deficit can be managed by posting under the posterior aspect of the socket.



Restoring the propulsive lever arm

A carbon composite superstructure is used to help restore the lever arm that is required for propulsion in the 4th rocker. The lever arm of the footplate feeds into the lever arm of the lateral strut. Those forces are distributed over a very broad pretibial shell to minimize pressure on soft tissue. As the tibia progresses over the foot that's fixed to the ground, potential energy is loaded into the system. As the heel comes up off the ground, that energy is returned in the form of powered motion that helps propel the foot off the floor and initiate swing.



Managing shearing

Instead of shearing resulting in callus formation at the distal aspect of the residuum, those forces are directed and absorbed by the BlueROCKER® composite lever arms so the skin at the distal residuum is protected. As this one case study shows, the shearing forces that occurred during propulsion now occur distal to the residuum

The challenges posed by partial foot amputations are inter-related, and must be managed by a comprehensive plan that addresses all the issues in one integrated solution.

Patient assessment

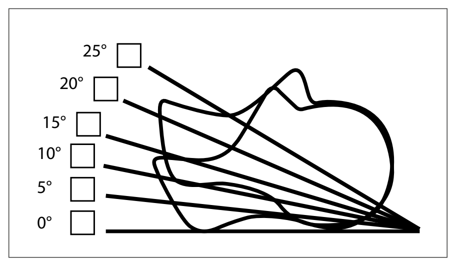
Ankle neutral posture

Ankle neutral posture is associated with a calcaneal inclination angle (CIA) of approximately 30°. The CIA is the visual bisection of the calcaneus in the sagittal plane and is usually measured using a goniometer. That angle can be lower with feet that tend to be more pronated, and can be higher in more supinated feet. Ankle neutral posture and limb length are both lost when supportive boney structures of the foot are lost. The following is an estimation of the CIA associated with different levels of amputation. Check the sound side CIA for each patient's reference to neutral.

Ankle neutral, CIA ± 30° | TMA, CIA ± 20° | Lisfranc, CIA ± 15° | Chopart, CIA ± 00°

Static weightbearing CIA posture

This is a baseline measurement, taken with the patient in a static weightbearing bipedal stance. This documents the involved side CIA prior to any intervention. There is usually a correlation of more proximal amputation levels having a lower inclination angle. Document the findings.

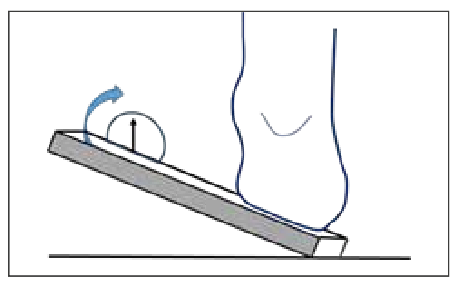


Static posture

Weightbearing ankle ROM

There are two techniques available to assess ankle range of motion (ROM) in the sagittal plane. Both must be done in weightbearing to unlock the ankle as much as possible. One is to use an inclinometer board as illustrated to determine maximum CIA and correlate that to the CIA on the sound side to determine available ankle ROM.

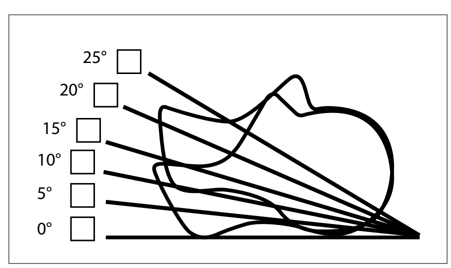
The other technique is to position different height wedges under the anterior aspect of the residuum while patient is in bipedal stance. Add wedges to find maximum CIA and ankle dorsiflexion ROM. Compare this to the sound side CIA to determine available ankle ROM.



Inclinometer board

Determine fabrication order

If an inclinometer board was used to find ROM, add that angle to the static CIA to determine maximum ROM towards dorsiflexion. If wedges were used, subtract the static CIA from the maximum ROM CIA to determine the fabrication wedge order. In either case, the prosthetic fabrication wedge should bring the CIA as close to the CIA on the contralateral side as possible.



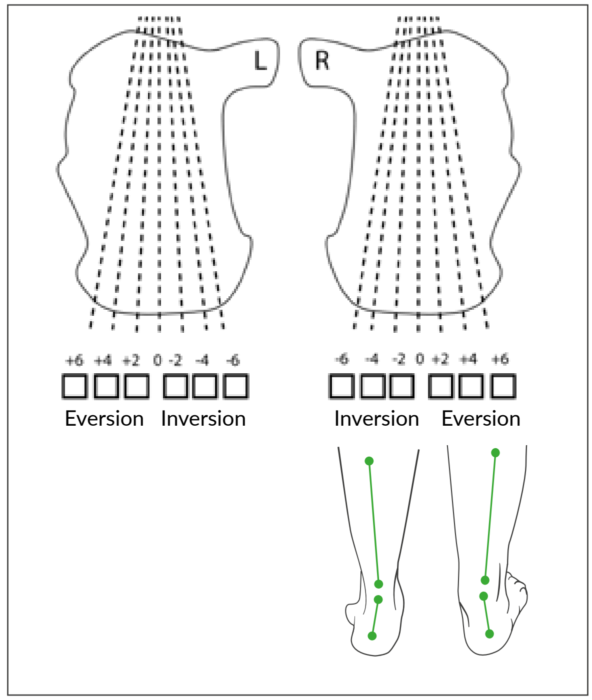
Fabrication Order

Patient assessment, cont'd

Calcaneal frontal plane inversion-eversion

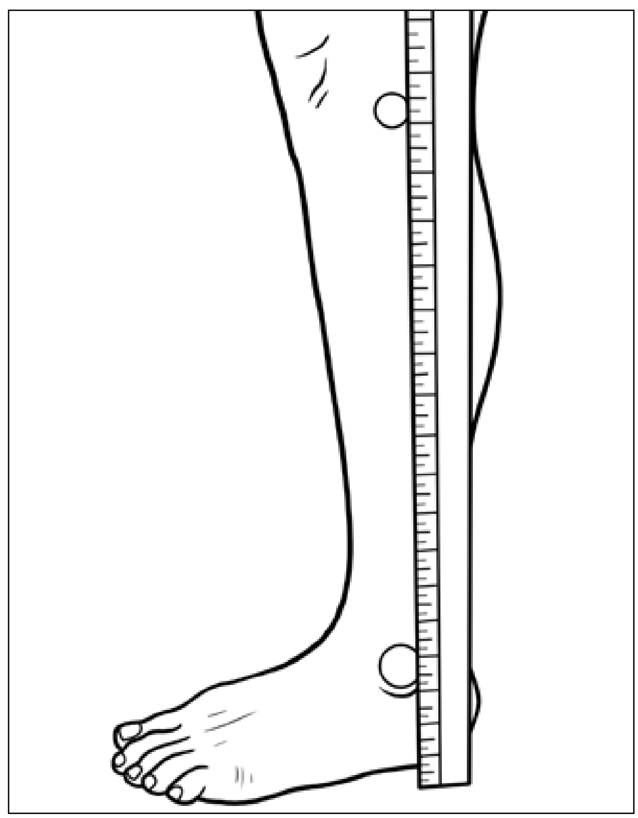
Calcaneal weightbearing posture is usually a visual assessment of the inversion/eversion posture in the frontal plane. A minus (-) reading indicates an inverted calcaneus associated with a more rigid supinated foot that is still locked and isn't reaching subtalar neutral. A plus (+) reading indicates the subtalar joint has gone through neutral and the foot is now unlocked in some degree of pronation.

Any minus (-) reading usually indicates a need for a lateral post to help unlock the foot to pass through neutral. Any reading in the +2 ro +6 range is functional and doesn't need posting. Any reading past +6 is usually corrected with a medial post to decelerate excessive pronation.



Limb length

Compare limb length of the involved side to the sound side by measuring from the fibular head to the floor. As previously discussed, the involved side will typically be shorter than the sound side, depending on the level of amputation. Restoring the CIA will help restore limb length and, at more proximal levels of amputation, help reduce any acquired bulbous heel deformity.



”A thorough and accurate patient assessment is critical in preparation for defining the prosthesis.”

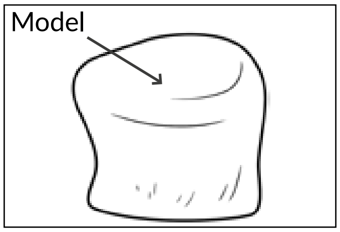
- Robert Meier, CO

Fabrication

Fabricating a partial foot prosthesis is a skilled task. The following are steps that can be used to achieve success. Each fabricator must rely on his/her own earned experience and knowledge in selecting materials, thicknesses and durometers.

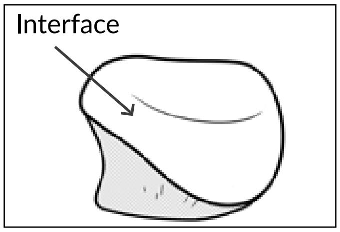
Positive model

A positive model of the residuum is made by milling the scan or filling the cast with plaster. Once it's set, the cast is removed and the positive model is prepared by removing any ridges and positioning imprints that might have occurred during casting. Mark the dorsal trim lines.



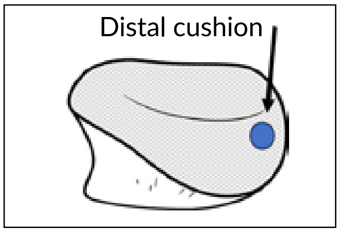
Interface

An interface material is heated and molded over the model. Generally a 25 to 35 shore A durometer material is recommended. A thickness of 1/8" is recommended to minimize movement of the residuum within the socket. This helps minimize shearing or friction that can occur if there is too much room in the socket.



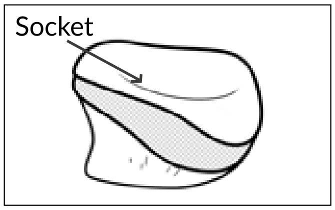
Distal cushion

If a distal cushion is called for, add that padding on top of the interface material. An additional 1/8" 25 durometer material is usually used to as extra pad- ding to protect a boney prominence, but different durometers and thicknesses can be used to manage specific areas of concern.



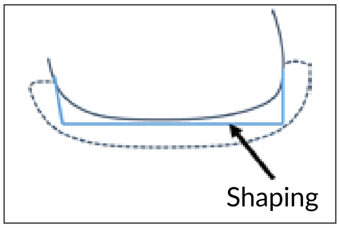
Socket

The socket is then molded over the interface material. This is usually 1/8" (3mm) copolymer although different materials and thicknesses can be used to address specific situations.



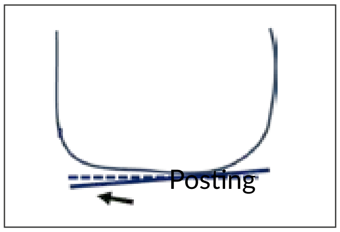
Shaping

A high durometer (nominally 60 shore A) 1/2" thick material is then formed to the bottom of the socket. After it has set, it is ground down to form a flat surface to prepare for the following step.



Frontal plane posting

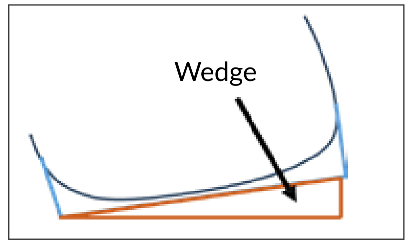
Any frontal plane (calcaneal inversion/eversion) posting is done at this stage. Because forefoot abductors/everters are typically lost with amputation, many partial foot amputations present with a rearfoot inverted posture. In this case, a lateral post can help facilitate function through subtalar neutral making gait more stable.



Fabrication, cont'd

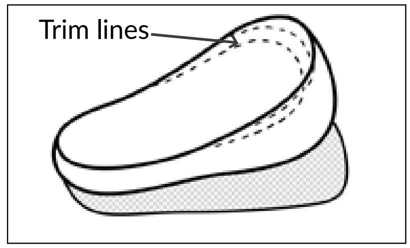
Sagittal plane posting

The socket is then wedged or posted to the prescribed calcaneal inclination angle to restore it to, or as close as possible to the CIA of the sound side foot. This is designed to restore the ankle to its neutral posture while resolving any acquired limb length deficit.



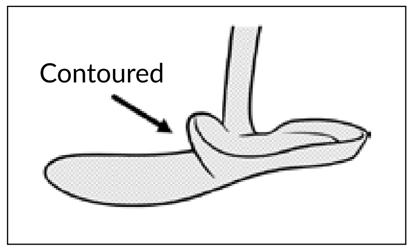
Trim lines

The posterior trim lines should look just like that of a biomechanical foot orthotic device. The anterior trim lines are determined to contain soft tissue and to act as the starting point for the filler prosthesis.



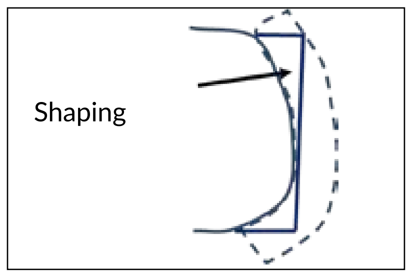
Contouring

The posted socket is now ready to be custom shaped to fit the contours of the composite superstructure. Shape to the contours around the lateral strut and to the curve of the footplate to assure these components function as a single integrated unit.



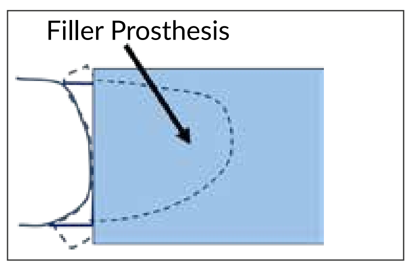
Shaping

The same high durometer shaping material used earlier is now used on the anterior aspect of the socket. After it is set, grind the anterior and lateral aspects flat to prepare for the addition of the filler prosthesis.



Filler prosthesis

The plantar aspect of the filler prosthesis is shaped to the contour of the composite footplate and then adhered to the front of the socket. To minimize the number of laminations, it is considered best to use 1" 25 durometer shore A material and lay that flat in front of the socket.



Finalize shape

Grind the filler prosthesis to the length, width and sagittal plane profile of the sound side. The final shape should create an excellent fit of the completed prosthesis into the shoe.

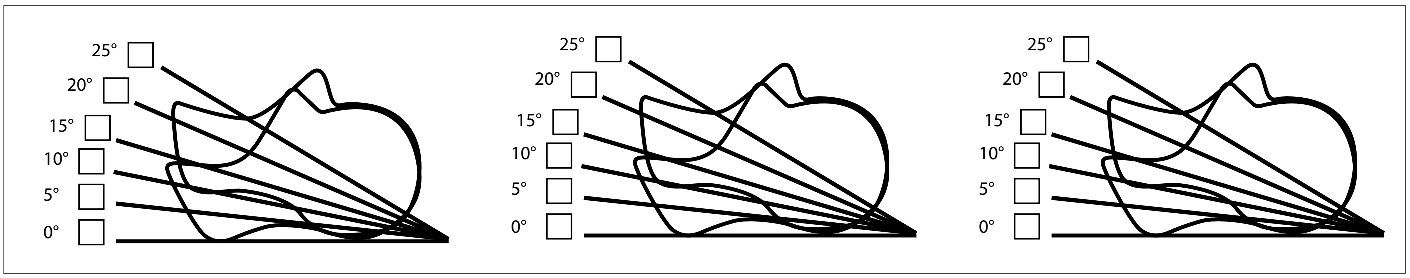
The definitive prosthesis: An Allard BlueROCKER® superstructure with socket and filler prosthesis.

Fabrication specifications

Restore neutral posture

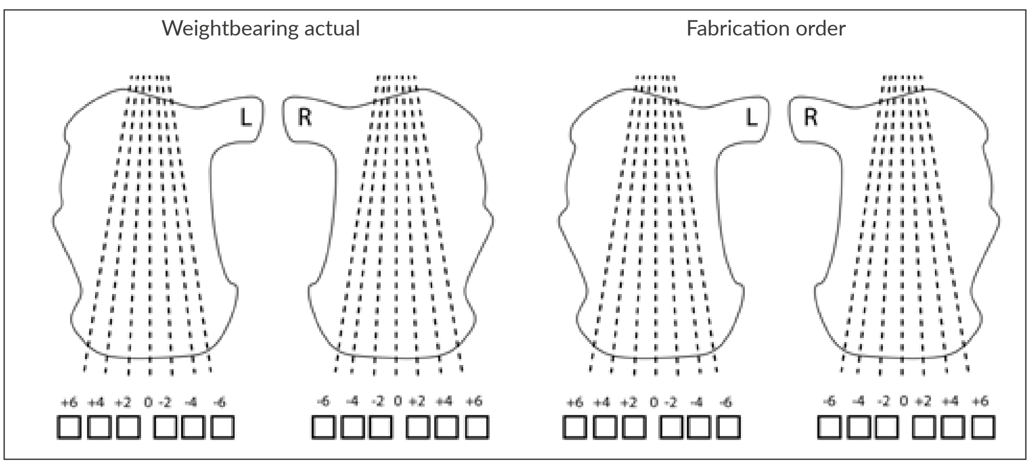
To restore both limb length and ankle neutral posture, use these graphs to document the full static weightbearing CIA, then the available ROM using an inclinometer or wedges, and then the angle at which the prosthesis should be posted during fabrication.

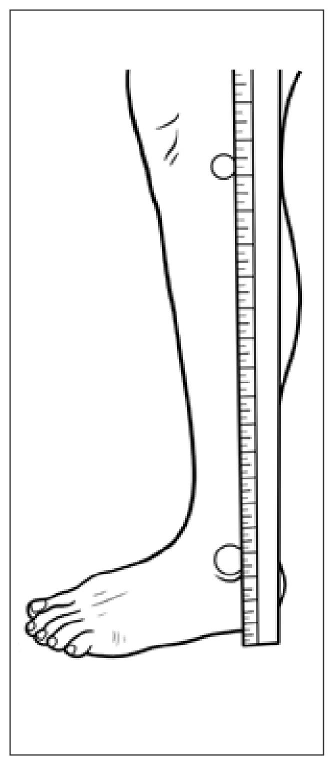
Static weightbearing | Available ROM | Fabrication order



Biomechanical function

To assure that the residual foot is functioning in supination during swing and into pronation during stance, document the static weightbearing frontal plane (inversion/eversion) calcaneal angle. Next, mark the degree of posting (if necessary) to be built into the prosthesis to help facilitate function through neutral.

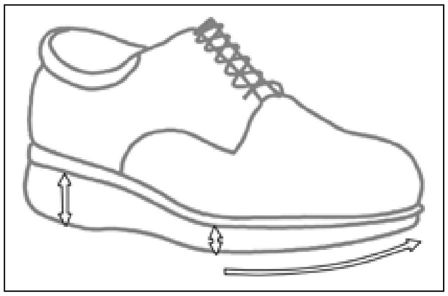




Limb length

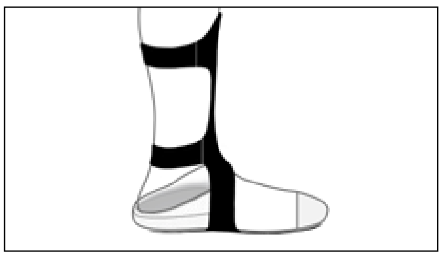
Finally document limb length on both involved and uninvolved sides, measuring from fibular head to floor. Any residual limb length discrepancy can be corrected during the fabrication process by adding posting underneath the posterior aspect of the socket.

Final steps



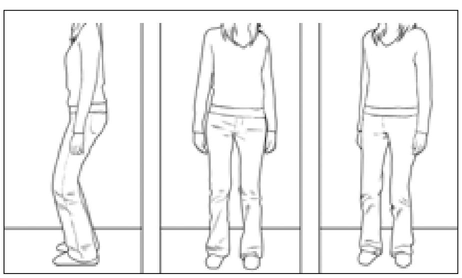
Shoe selection criteria

Footwear selection can have a big impart on the functional outcomes of partial foot patients. If the sole is not firm enough, the prosthetic intervention can not provide the energy return needed to restore propulsion. Therefore it is important that the shoe have a firm high durometer sole to facilitate the function of the prosthetic lever arms. Additionally, a shoe with a rocker toe is important to aid in the smooth transition from midstance to the propulsive phase of walking.



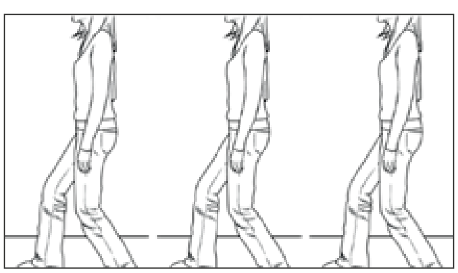
Alignment

Apply a strip of MikroFIX™ across the footplate at the strut junction, and the opposing strip across the plantar aspect of the socket in that same area. Place a strip of paper or thin plastic over the footplate strip and set the socket on top of the footplate. With the patient seated and the foot in the socket, align the pretibial shell to the tibial crest, moving the socket as necessary to achieve alignment. When alignment is achieved, pull the paper out from between the footplate and socket to fix the socket onto the footplate. The completed device can now be moved from shoe to shoe.



Gait training

Immediately after fitting the prosthesis, ask patients to stand with feet shoulder width apart. Ask them to do baby squats by slightly bending their knees while keeping their heels on the floor and the trunk in an upright posture. After a nominal set of 10, ask them to rotate their trunk without moving their feet and do 10 more. Then rotate the trunk in the other direction and do 10 more. This helps trigger the proprioceptive system to accept a different feeling created by the prosthesis.



Sequential lunges are also recommended to help patients acclimate to the new energy return prosthetic environment. This is walking with slightly exaggerated knee flexion with each step. The trunk should remain upright and head held high during this exercise. Gradually encourage a quicker cadence as the patient transitions to more normal gait.

It is common to see gait become more fluid and symmetrical as patients relax into their prosthesis.

About the author

Robert Meier is an ABC certified orthotist. He has specialized in closed chain functional biomechanics and gait for most of his 45-year career. Bob has earned 6 US patents involving closed chain biomechanics applied to spine and lower extremity applications. His focused interest in partial foot amputations began in 2012. He has since become globally recognized for his expertise in this specialty.

Notes:

Support for Better Life

Everyone should be able to live their life to the fullest, regardless of their mobility challenges. With innovative solutions developed in close collaboration with healthcare professionals and patients, we strive to provide Support for Better Life.

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