Introduction to Foot Orthoses

In this session…

- Definition of a foot orthosis
- History of foot orthoses
- Categorization
- Foot capture
- Materials
- Objectives and considerations
- Terminology
- Methods of manufacture
- Prefabricated foot orthoses

What is a Foot Orthosis?

- AKA: foot orthotic, arch support, shoe insert, “insole”

- “A foot orthosis is a medical device employed to support and align the foot, to prevent or correct foot deformities, or to improve the functions of the foot.”
  - From Foot Orthoses: Principles and Clinical Applications by Kent Wu, MD, 1990.
- “An orthosis is a total contact, multidensity, removable inlay that is directly molded to the patient’s foot or a model of the patient’s foot and made of materials suitable for the patient’s condition. The orthosis, which achieves total contact with the plantar surface of the foot, is composed of a shell and posting. The shell is the layer of material next to and in contact with the foot. Posting is the material that fills the space between the shell and the shoe.”
  - From Introduction to Pedorthics (Chapter 18: Fabricating Shoe Modifications and Foot Orthoses by Roger Marzano, CPO, CPed), 1998
- “An orthosis is a device that provides correction, support or protection to a part of the body.”
  - From Contemporary Pedorthics by Wayne Decker, CPed and Stephen Albert, DPM, CPed, 2002

History of Foot Orthoses

- Documented use of foot orthoses goes back over more than two centuries.
- In 1781, a Dutch physician called Petrus Camper published one of the first books on foot deformities and described use of foot orthoses to manage flat feet in children.
- In 1885, orthopedic surgeon Royal Whitman created what is considered by many to be the first modern foot orthosis. His so-called “foot brace” was made of 18–20-gauge steel.
- Dr. William Scholl came out with a much lighter, more flexible metal support called the Foot-Easer in 1910.
- In 1950, podiatrist Benjamin Levy developed the “Levy Mold” which was a molded cork and leather footbed with medial longitudinal arch support and a toe crest.
- 1958 saw podiatrist Merton Root began work on his now ubiquitous “Root Functional Orthosis”.
- The UCBL was developed in 1967 in the Biomechanics Laboratory at UC-Berkeley.
- In 1992, Kevin Kirby, DPM introduced the “Kirby Skive”, a widely used technique for correcting heel alignment in a foot orthosis.

Categorization

- Foot orthoses can be categorized by several criteria or characteristics:
  - Prefabricated or custom made
  - Materials used
    - Soft
    - Semi-rigid
    - Rigid
  - Goals/Objectives
    - Corrective
    - Accommodative
    - Protective
  - Method of manufacture
    - Additive – 3-D printing
    - Subtractive – CNC milling
    - Vacuum formed – materials added in layers and then sanded off (subtracted) to achieve final dimensions
  - Orthotic theory
    - Total contact
    - Functional
  - Specialty devices
    - UCBL
    - Partial foot prosthesis (toe filler)

Foot Capture

- All custom foot orthoses begin with an accurate model of the patient's foot. There are numerous methods available to capture a three-dimension representation of the foot.
  - Digital
    - 2-D scanning
    - 3-D scanning*
  - Physical
    - Foam impression*
    - Plaster cast*
    - Fiberglass cast
    - Wax
    - Sand and wax

* These three are the principal methods used today

Which foot capture method is best?

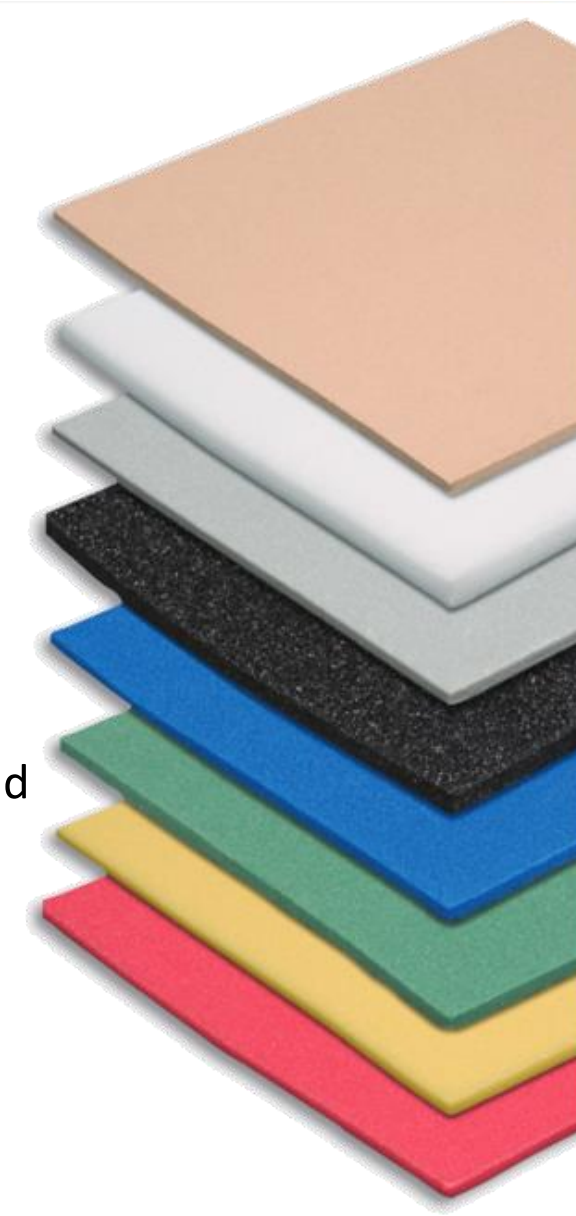
- Guldemond, et al, *Casting methods and plantar pressure: Effects of custom-made foot orthoses on dynamic plantar pressure distribution.* JAPMA 2006 Jan-Feb;96(1):9-18.
- McPoil TG, et al, *Comparison of Three Methods Used to Obtain a Neutral Plaster Foot Impression.* Phys Ther. 1989 Jun;69(6):448-52
- Laughton, et al, *A comparison of four methods of obtaining a negative impression of the foot.* JAPMA 2002 May;92(5):261-8.
- Leung AK, et al, *Orthotic design and foot impression procedures to control foot alignment.* Prosthet Orthot Int. 2004 Dec;28(3):254-62.
- Trotter LC, Pierrynowski MR, *Ability of foot care professionals to cast feet using the nonweightbearing plaster and gait-referenced foam casting techniques.* JAPMA 2008 Jan-Feb;98(1):14-8.
- Ki SW, et al, *Comparison of plantar pressure distribution patterns between orthoses provided by the CAD-CAM and foam impression methods.* Prosthet Orthot Int. 2008 Sep;32(3):356-62
- Carroll M, et al, *Reliability of capturing foot parameters using digital scanning and the neutral suspension technique.* Journal of Foot and Ankle Research. 2011;4(9).

- Levac K, Casting Techniques: A Review of Literature. 2010.
  - Range of variability between forefoot and rearfoot relationship was as much as 16.5^{o}
  - Such results raise the question of the necessity of accurate casts (***WHAT?!?***)
  - Clinicians are responsible to research the pros and cons of different casting methods

- There's been ample research conducted on capture methods. The one thing they agree on is that there is no one universally superior method. Essentially, the best method for you is the one a) with which you are most comfortable doing, and b) that gives you the best results.

Materials

- Materials are covered more thoroughly in the "*Materials Science*" module.
- Generally speaking, foot orthosis materials can be roughly broken into two categories:
  - Rigid
    - Thermoplastics
    - Resins
    - Carbon graphite composites
  - Soft (accommodative)
    - This is somewhat of a misnomer as materials in the "accommodative" grouping are available in a wide range of densities and firmness. Many could more appropriately be called *semi-rigid*.
    - Ethylene vinyl acetate (EVA)
    - Cross-linked polyethylene foams (CLPE)
    - Polyurethane foams (PU foams)
    - Cork composites
    - Neoprene



Objectives of Foot Orthosis Treatment

- Relieve pain
- Correct alignment
- Accommodate deformity
- Offload high pressure areas
- Redistribute peak plantar pressures
- Reduce shear and friction to prevent neuropathic ulcers
- Support medial longitudinal arch
- Provide shock attenuation on heel strike

Formulation of Treatment Plan

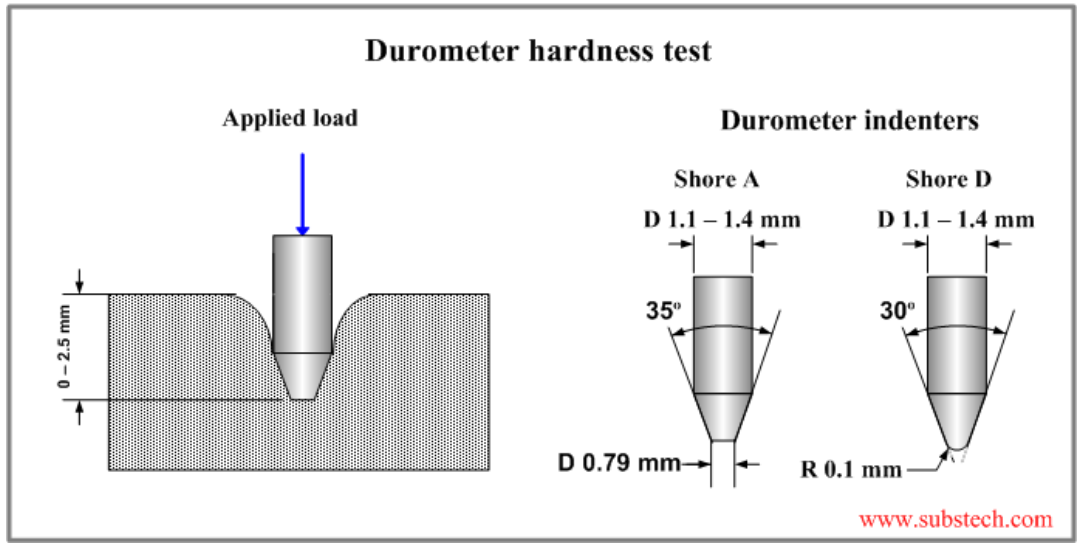
- Considerations / Selection Criteria
  - Diagnosis
  - Prescription
  - Physical exam/foot assessment
  - Patient history
    - Foot specific issue(s)
    - What's been tried to date?
    - Systemic concerns/conditions
  - Prognosis
  - Expected length of usage
  - Activities and/or occupation
  - Applicable footwear requirements (not any and all footwear desires)
  - Cost/coverage (?)

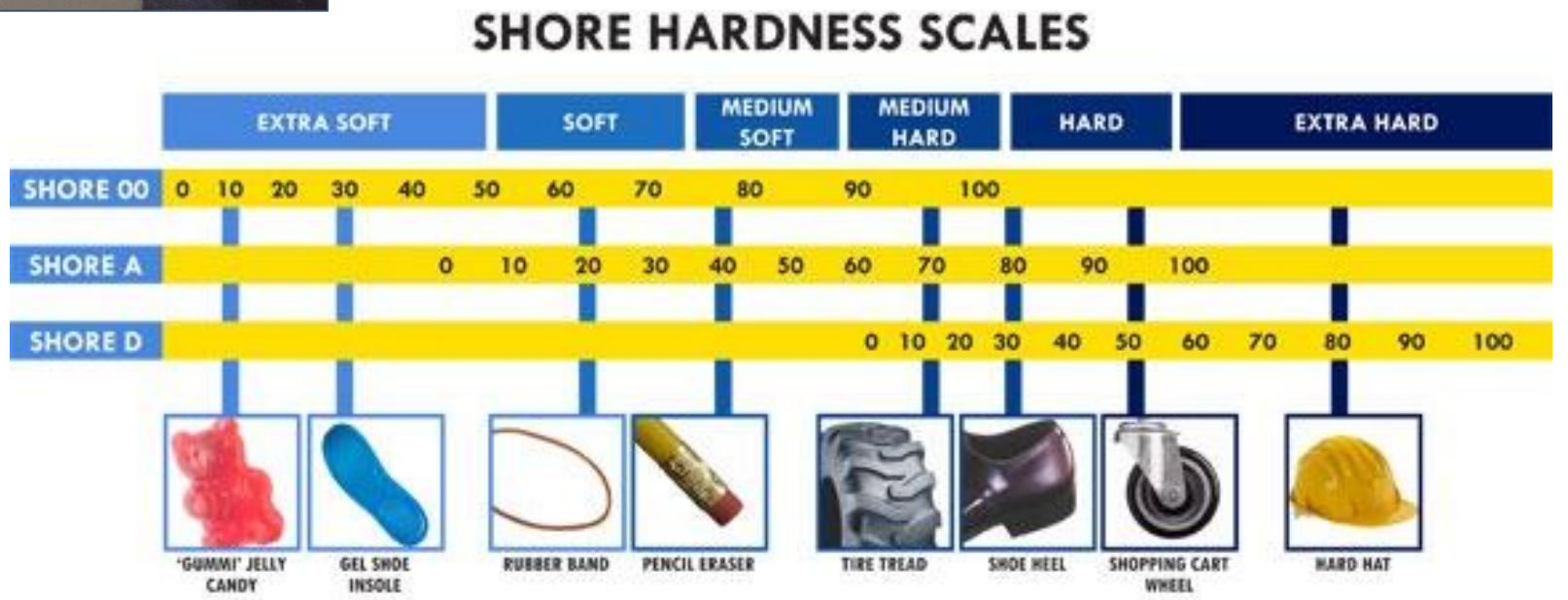
Foot Orthosis Terminology

Durometer

- What exactly is a Shore A durometer mean?
  - Hardness may be defined as a material's resistance to permanent indentation. The durometer scale was defined by Albert F. Shore, who invented the durometer device in the 1920s.
- How do you physically measure a material's hardness?
  - The different Shore Hardness scales measure the resistance of a material to indentation. A ‘Shore Hardness' gauge has a needle on a spring protruding from one end. The needle is placed against the rubber or plastic and pressure is applied. Once the gauge is pressed firmly against the material and the needle has penetrated as far as it can go, the measurement needle will indicate the corresponding hardness measurement.

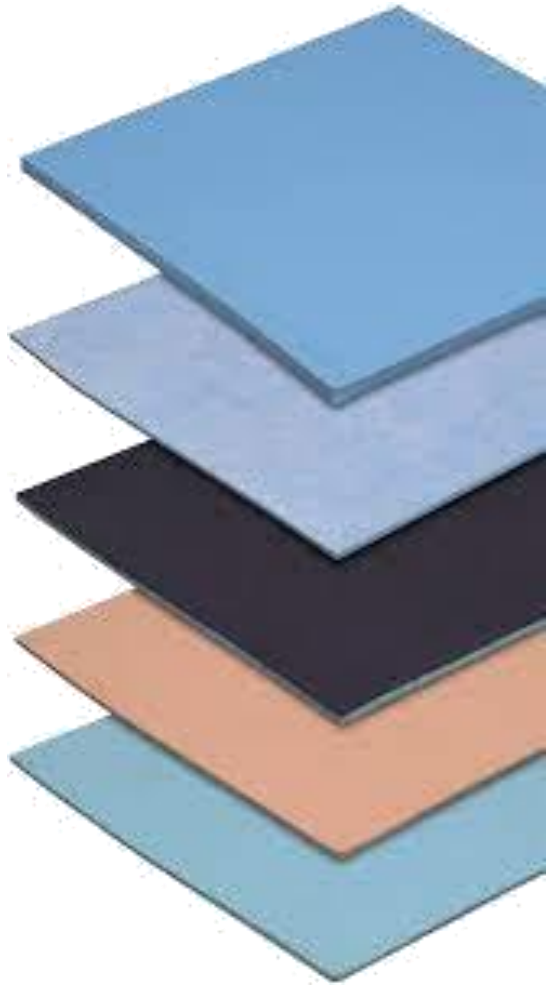
Shore hardness testing

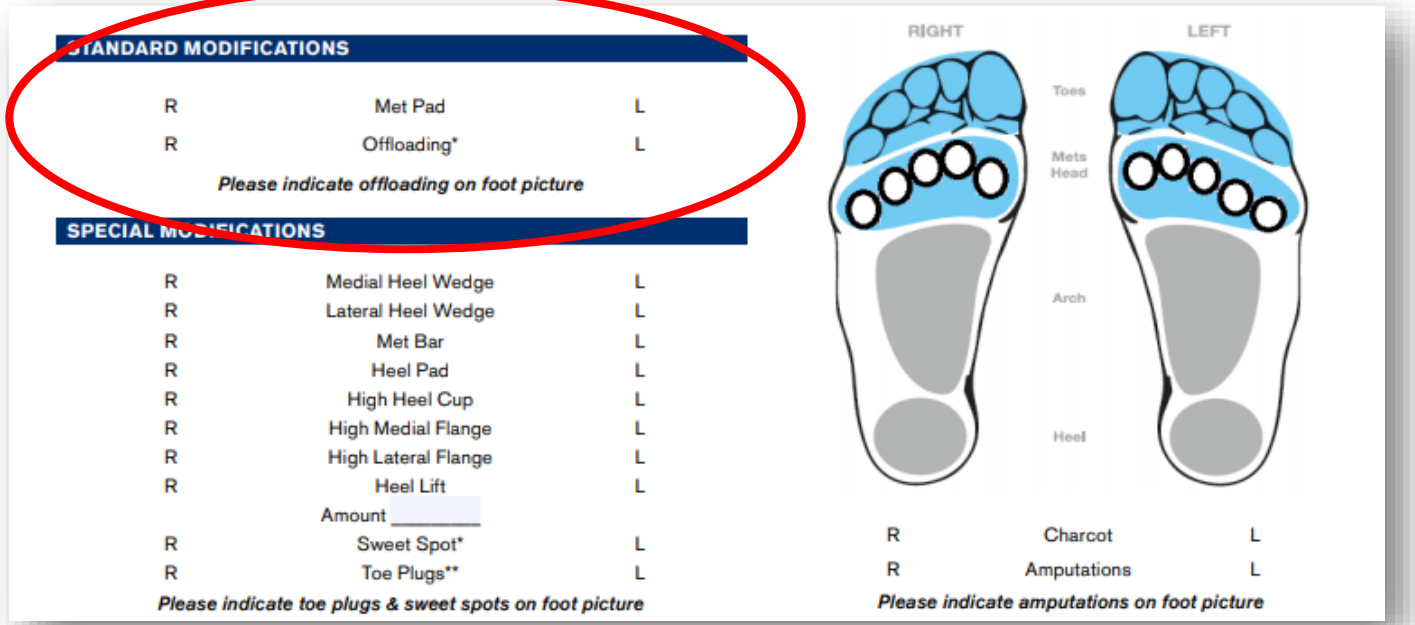




Shore a durometer

- Poron® 3
- Plastazote® #1 15
- AliPlast™ 23
- P-Cell™ 20-25
- Plastazote® #2 25
- UcoLite™ 35
- Medium Pelite 37
- EVA soling 45
- Multicork 55-60
- Plastazote® #3 60
- Ripple soling 75





STANDARD MODIFICATIONS

R		L
R	Met Pad	L
R	Offloading*	L

Please indicate offloading on foot picture

SPECIAL MODIFICATIONS

R		L
R	Medial Heel Wedge	L
R	Lateral Heel Wedge	L
R	Met Bar	L
R	Heel Pad	L
R	High Heel Cup	L
R	High Medial Flange	L
R	High Lateral Flange	L
R	Heel Lift	L
	Amount _____	
R	Sweet Spot*	L
R	Toe Plugs**	L

Please indicate toe plugs & sweet spots on foot picture

R		L
R	Charcot	L
R	Amputations	L

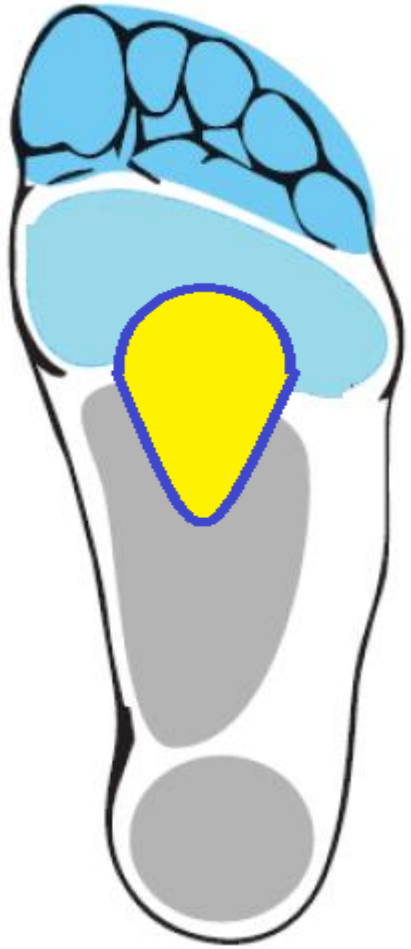
Please indicate amputations on foot picture

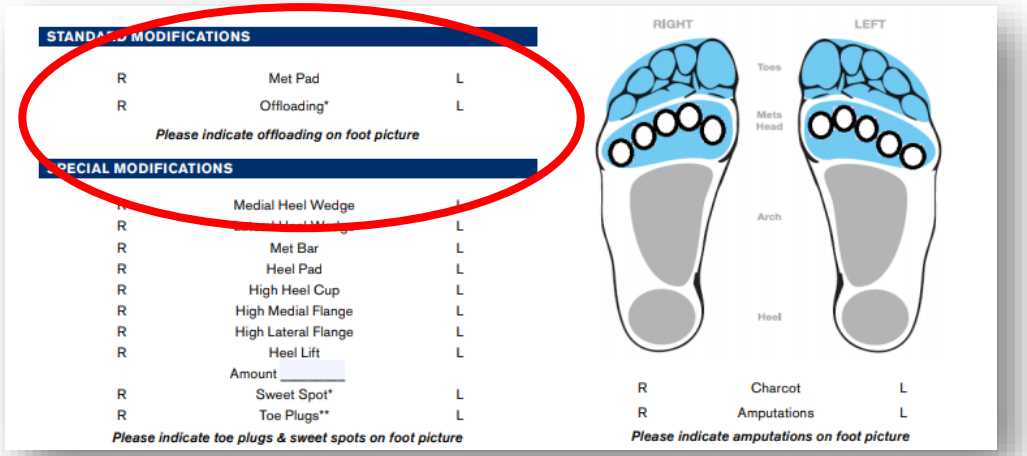
Met Pad

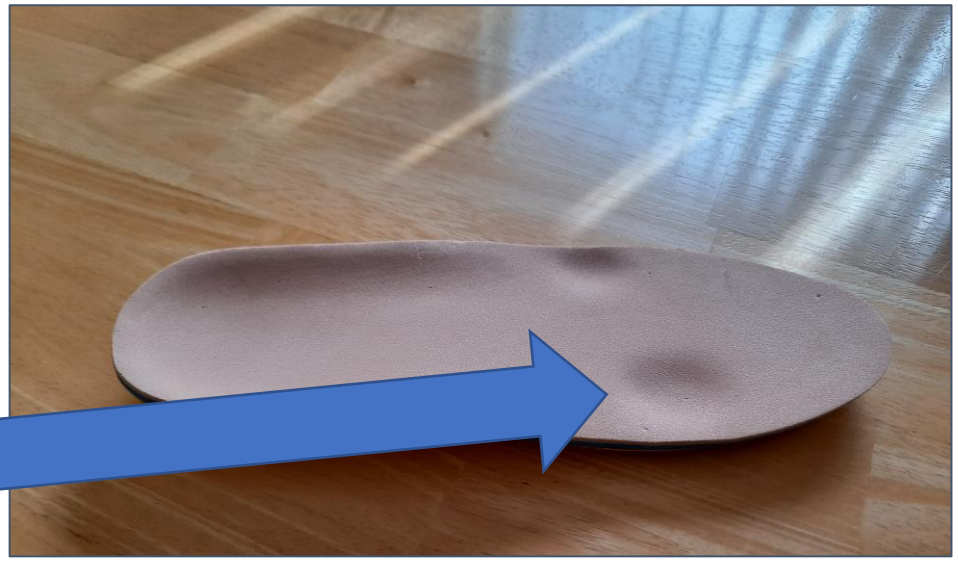
Transmetatarsal arch – supported by the met pad

Based on study – Optimal placement is 6.1mm – 10.6mm proximal to the apex of the metatarsal head

Used for: metatarsal pain, ulcerations, callouses

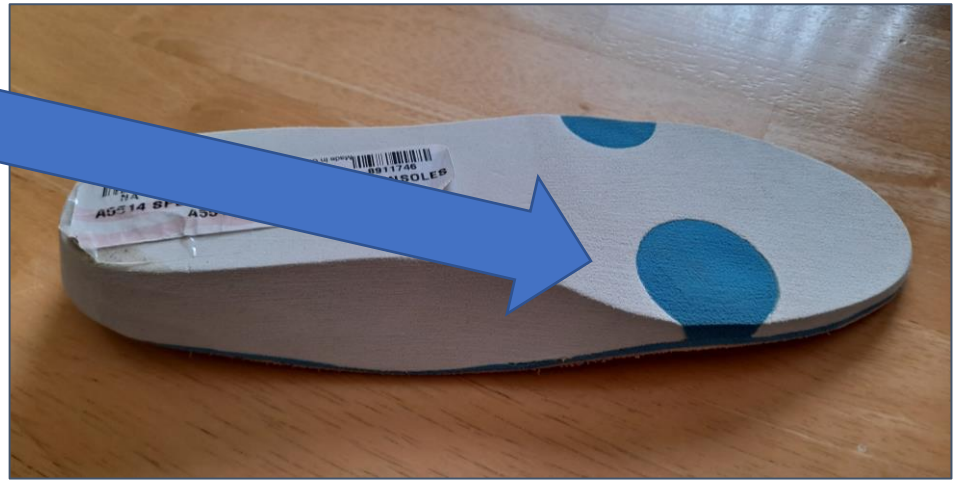






Offloading – Depression in the insert

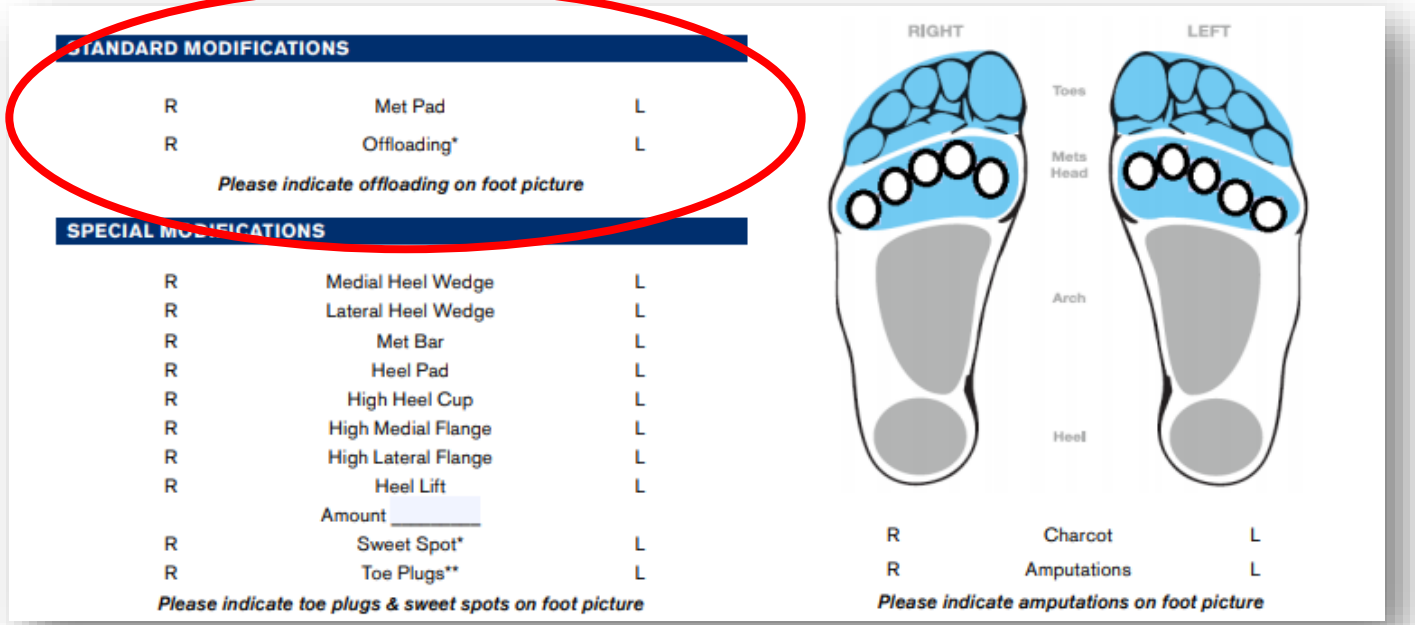
Sweet Spot – Cutout in base backfilled with softer foam



Cushioning placed directly below the metatarsal heads (possibly slightly distal)

Transferring weight bearing away from the affected area

Used for: metatarsal pain, ulcerations, callouses



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R	Toe Plugs**	L

Please indicate toe plugs & sweet spots on foot picture

R	Charcot	L
R	Amputations	L

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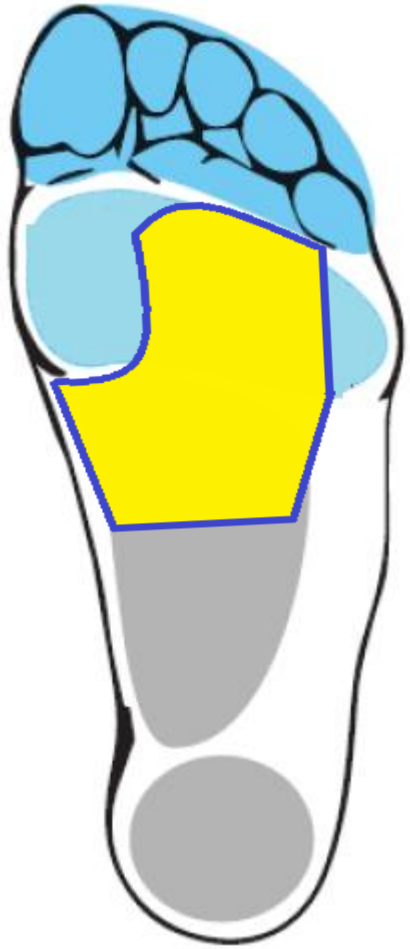
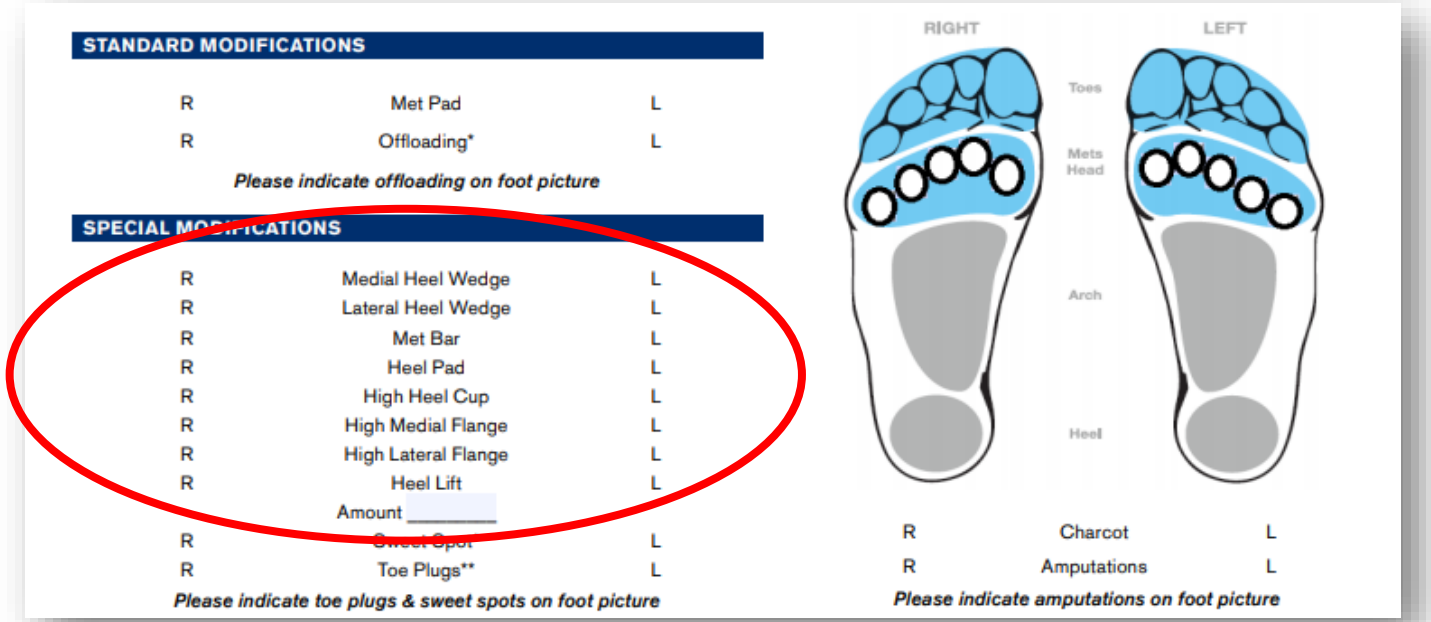
Offloading - Dancer pad

Transferring weight bearing away from the affected area by *loading up the lesser metatarsals*

Used for: metatarsal pain, ulcerations, callouses





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R	Charcot	L
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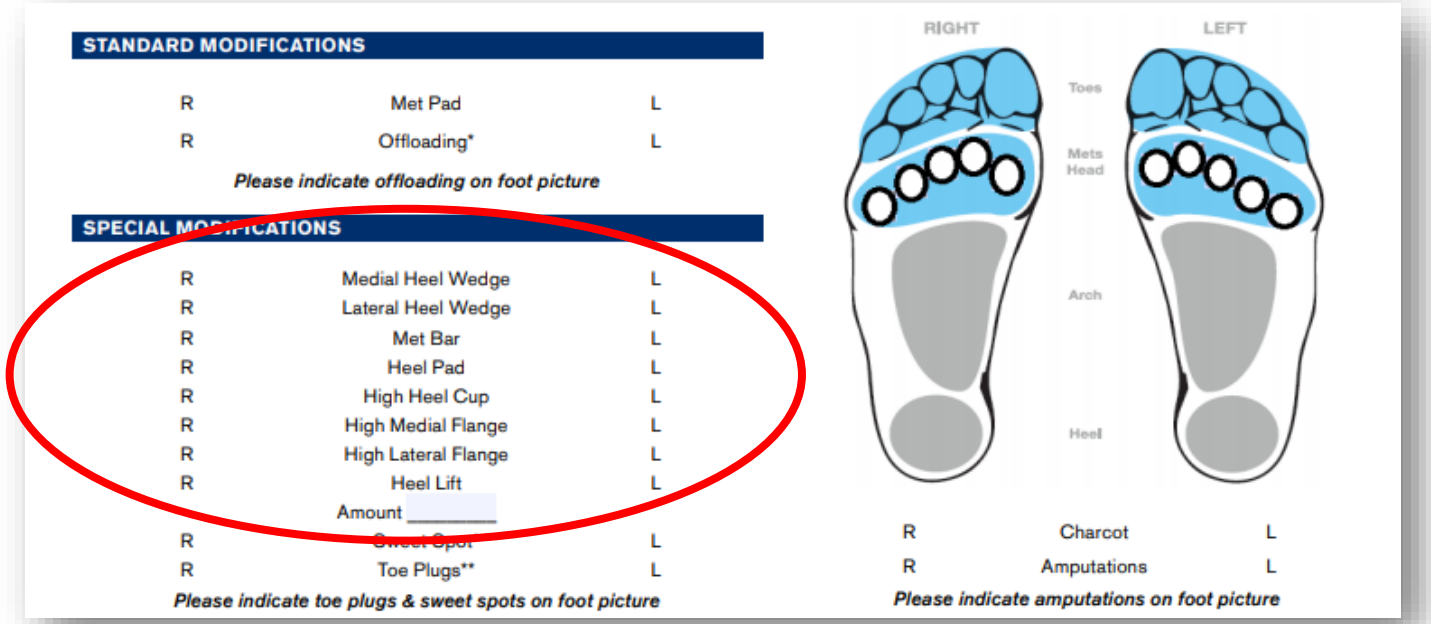
Wedges

Stability in the rear foot

Used to reduce pronation and supination



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R	Amputations	L

Please indicate amputations on foot picture

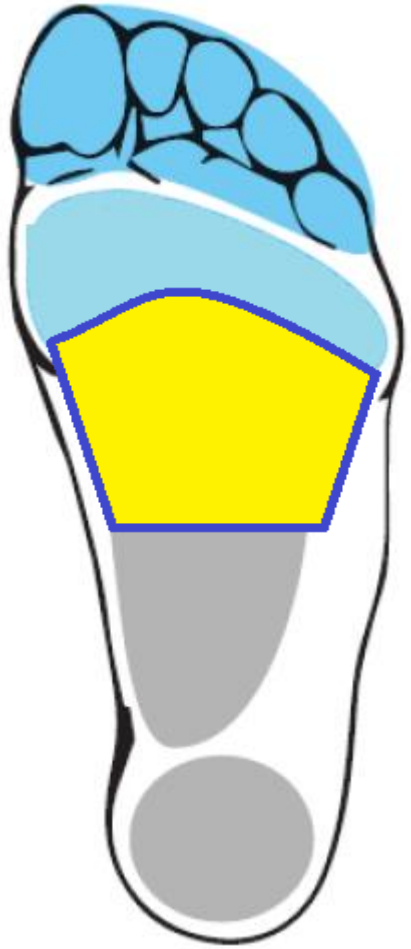
Met Bar

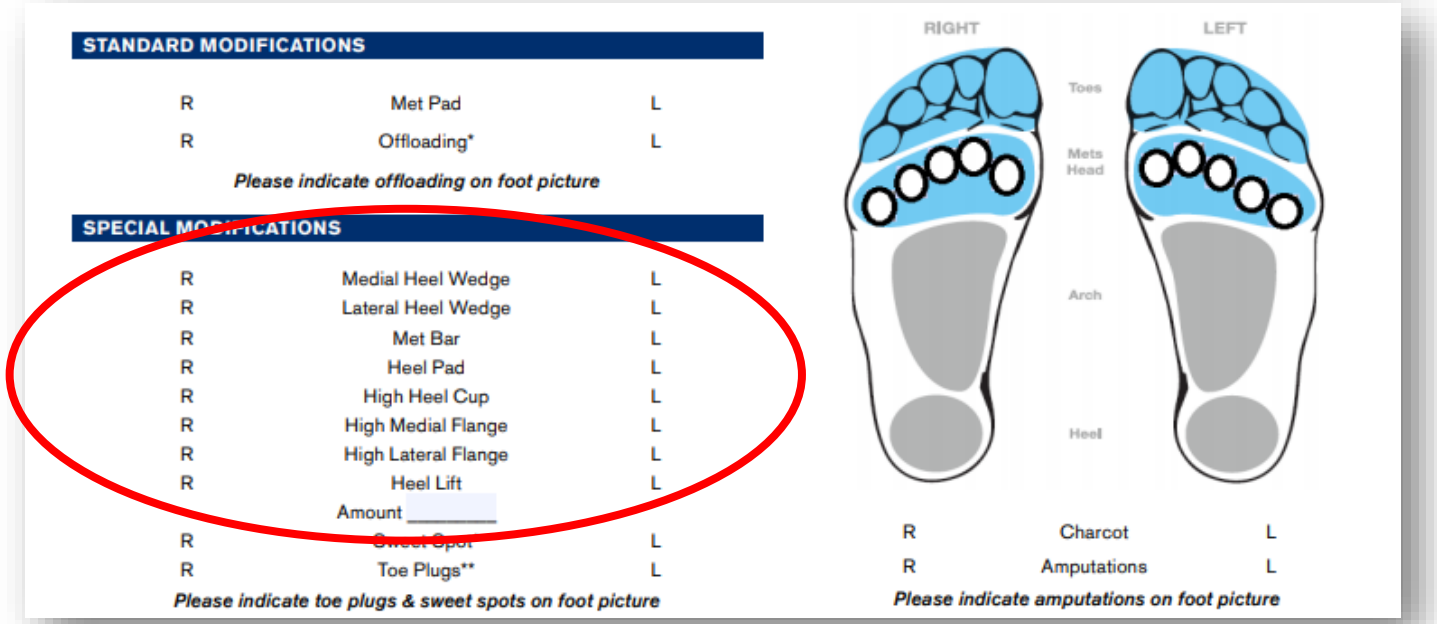
Placed proximal to the metatarsal heads

Transferring the weight bearing surface to the shafts of the metatarsals

Creating a “shelf” like system to offload

Used for: metatarsal pain, ulcerations, callouses





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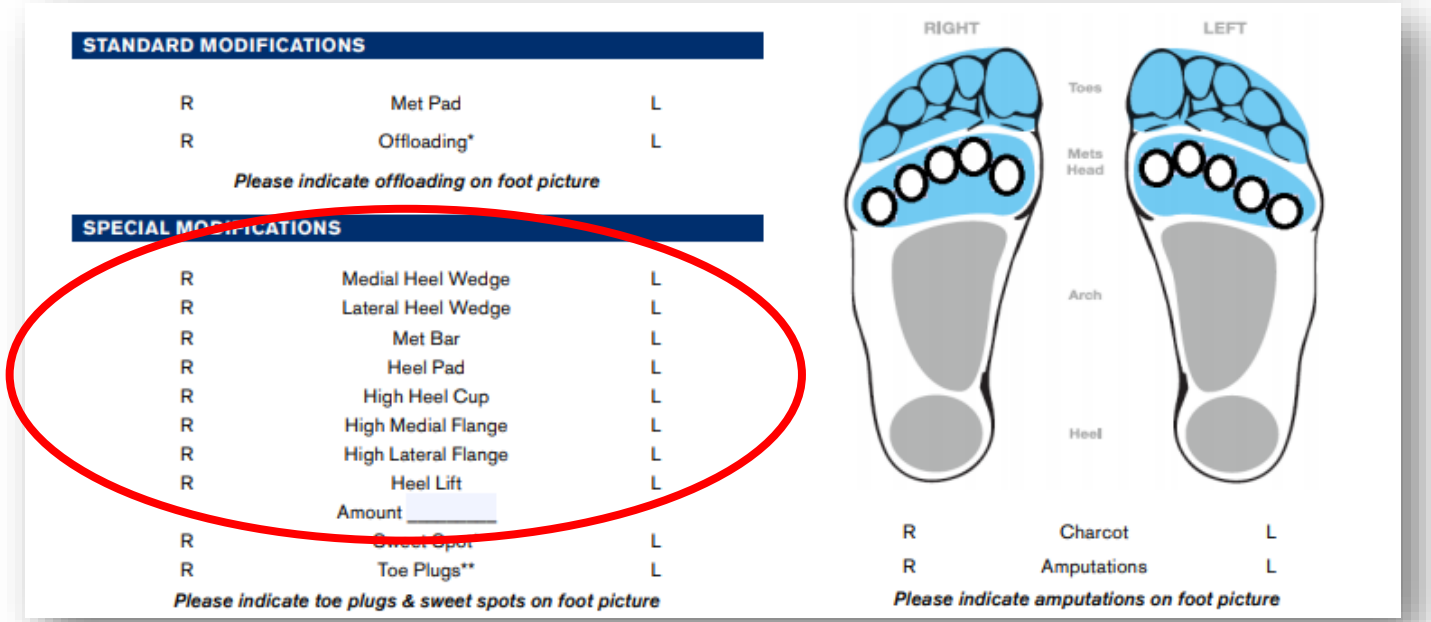
R	Charcot	L
R	Amputations	L

Please indicate amputations on foot picture

Heel Pad vs Heel Lift

Heel Lift: an addition to the orthosis to put the foot at a higher pitch than the shoe offers
Used for: ROM limitations, tendonitis or a LLD

Heel Pad: soft padding added between the base and top cover laye rs
Used for: heel pain, plantar fasciitis



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R	Amputations	L

Please indicate amputations on foot picture

Flanges/Heel Cup

Milled deeper base layer

More padding and protection

Used for: Charcot foot, PTTD, overpronation, supination

Arch Fill vs Arch Fill

- Arch fill on positive model

Is this a REORDER? ☐ Yes, ☐ No. ☐ Order 1 pair c

Customer Reminder: In support of federal requirements, yo

CAST CORRECTIONS

Arch Fill

R	Normal	L
R	Increased	L
R	No Fill	L

REQUIRED DETAILS

Side: Right Left Bilateral

STANDARD SELECTIONS - comes with a pseudo s

Casual
Poly pro shell - ball length
1/8" EVA top cover – full length

Dress
Poly pro shell - ball length

- Arch fill on orthosis

- Traditional Functional Foot Orthoses
  - aka Functional Orthotics (FFOs)
  - aka Podiatric Orthotics
  - aka Rigid Orthotics

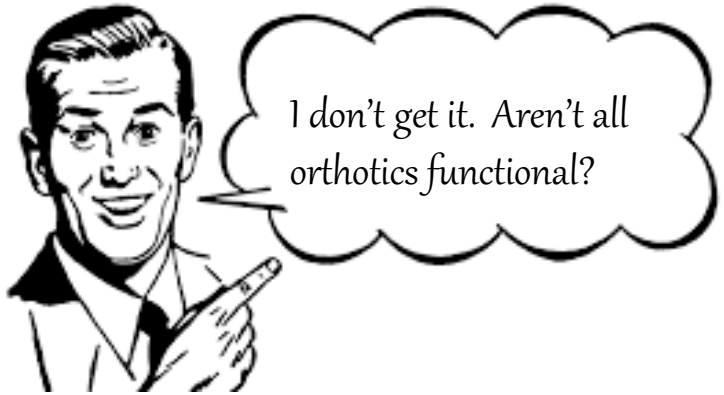
- Total Contact Foot Orthoses
  - aka TCOs
  - aka TCIs (Total Contact Inserts)
  - aka Semi-rigid Foot Orthoses

Traditional “Functional” Orthoses

func·tion·al

adjective

1. of or having a special activity, purpose, or task; relating to the way in which something works or operates.
2. designed to be practical and useful, rather than attractive.



Pros and Cons

Pros

- Shell materials are long-lasting.
- Do not typically take up much space in shoes, allowing a greater variety of shoe selection.
- Can be very lightweight.
- Are not total contact.

Cons

- Not easily adjustable in office.
  - Except for some polycarbonates like Exos®
- Not forgiving.
- May be contraindicated for the insensate foot.
- Suspect “scientific” presumptions.
- Are not total contact.

Podiatric-specific FO Modifications

- Reverse Morton's Extension
  - Extension of shell material under 2-5 MTHs
  - Increase motion at 1st MTPJ

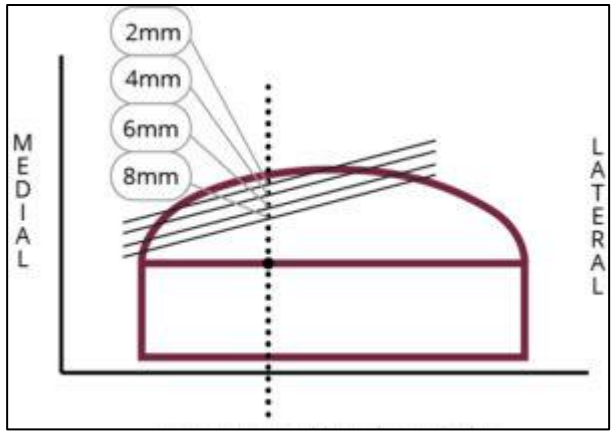
Figure 1c. Reverse Morton's extension with ⅛-inch EVA platform second through fifth metatarsals.

Figure 1d. Rigid Morton's extension from carbon graphite plate.

- Morton's Extension
  - Extension of shell material under 1st ray
  - Reduce motion at 1st MTPJ

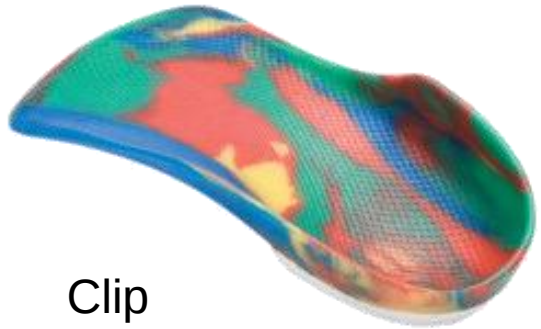
Podiatric-specific FO Modifications

- Kirby Skive
  - Material is removed from the medial heel of the positive model to create a sort of intrinsic wedge



- Flanges and Clips
  - Vertical medial or lateral extensions from the footplate to provide additional supinatory or pronatory control.

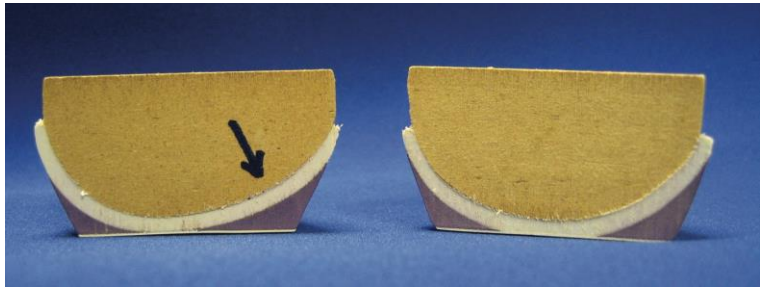
Flange



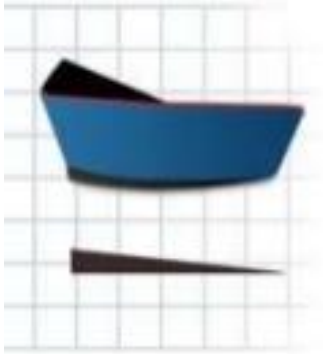
Clip

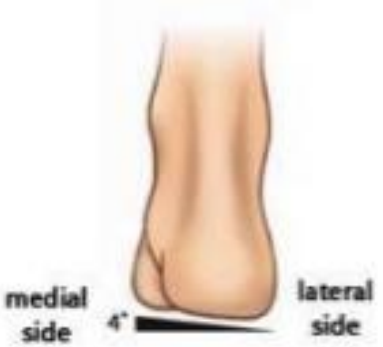
Skive vs Wedge vs Post

- Skive:
  - The cast or positive model is modified.
  - Material is removed from the cast or positive 3D model under one side of the heel.
  - Ex: Medial heel skive = Material removed from underside of medial heel.



- Wedge:
  - The FO itself is modified.
  - Additional material added to the underside of the orthosis. May be external/extrinsic (readily apparent) or it may be built-in/intrinsic (not visible).
  - Ex: Medial heel wedge = Thickness under medial aspect of the heel is greater than the lateral aspect.
- Post: Another name for a wedge

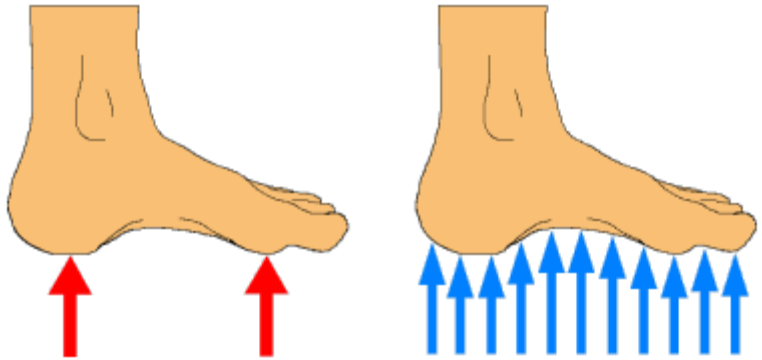




- Functionally speaking, a wedge and a skive are two ways to skin the same cat. Just depends on your training/discipline.

The Total Contact Concept

- Unlike traditional FFOs, these devices achieve total contact with the plantar surface of the foot.



Pros and Cons

Pros

- Total contact function
- Can be supportive/corrective; can be accommodating; can be both at the same time.
- Endless material combinations
- Overall, easier to adjust
- Applicable for *all* conditions

Cons

- Do not last as long as FFOs (12-16 mos.)
- Take up more room in shoe than FFOs

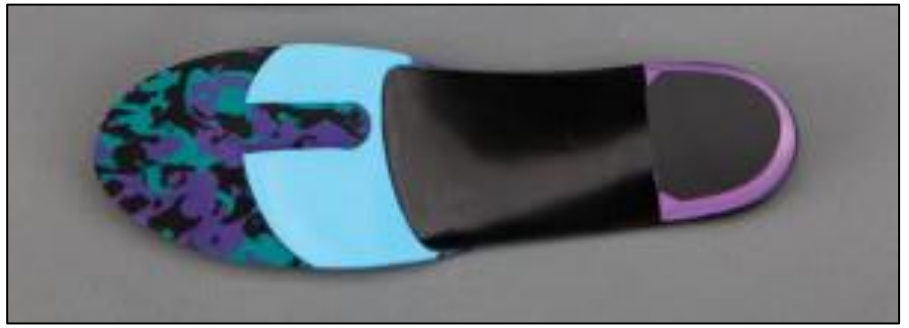
Modifications and Add-ons

Intrinsic

- Built into either the positive model and/or the device itself.
- Not easily adjustable.
- Clean, finished aesthetics

Extrinsic

- Added externally to the finished orthotic device.
- Simpler to adjust, move or correct as it is not built into the device itself



Modifications and Add-ons

Intrinsic

- Heel wedges
- Heel skives
- Posts
- Metatarsal pads
- Offloads
- Extended flanges or clips

Extrinsic

- Heel wedges
- Forefoot wedges
- Posts
- Metatarsal pads
- Metatarsal bars
- Dancer’s pad
- Additional cushioning
- Cutout for offloading

Methods of Manufacture

Fabrication Processes

- There are three principal methods of manufacture used in foot orthoses today.
  - Traditional vacuum forming
  - CNC milling
  - 3-D printing

Traditional Vacuum Forming

- Pros
  - Ability to mold deep heel cups and high flanges
  - More options in material selection
  - Tried and true traditional method
- Cons
  - Inefficient
  - Labor intensive
  - Expensive

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

- 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
  - Comparatively slow…

Prefabricated Foot Orthoses

- Lower cost alternative
- Can be customized
- Available in countless material and design feature configurations

- Considerations
  - Prescription
  - Deformity
  - Peripheral neuropathy
  - Age
  - Duration of usage
  - Appropriateness of device
  - Insurance coverage

Tran K, Spry C. Custom-Made Foot Orthoses versus Prefabricated foot Orthoses: A Review of Clinical Effectiveness and Cost-Effectiveness [Internet]. Ottawa (ON): Canadian Agency for Drugs and Technologies in Health; 2019 Sep 23. PMID: 31714699.

Key Findings

This review included two systematic reviews, one randomized controlled trial and one prospective cohort study. No cost-effectiveness studies of custom-made foot orthoses were identified.

The evidence showed no difference between custom-made and prefabricated foot orthoses for pain reduction or functional improvement after short-term (6 weeks), medium-term (12 weeks) and long-term (12 months) treatment in adult patients with plantar heel pain. There was also no difference between interventions for short-term self-reported recovery and patient satisfaction. Evidence on comfort was mixed.

The End