The inability to answer FAQ’s concerning biomechanics / orthotics is a missed opportunity to educate the patient.

A general understanding of foot biomechanics, gait analysis, and foot orthotic terminology can enhance patient satisfaction.

You get to choose the topics for discussion.

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The goal of today’s question and answer session is to provide you with basic biomechanics knowledge.
Medial (inside of foot) anatomy

Lateral (outside of foot) anatomy

Key Point
If the foot is unstable: bones, ligaments, tendons, muscles and skin get stretched or twisted or bent or compressed causing damage and pain

Phases of the Gait Cycle

Medial ligaments of the foot

Lateral Ligaments of the foot
Contact is from Heel Strike to Opposite foot Toe Off

Midstance is from Opposite foot Toe off to Opposite foot Mid-Swing or Heel Unweighing

Terminal Stance is from Heel unweighing to Opposite foot Heel Strike

Propulsion or Pre-swing is from Opposite foot Heel Strike to Toe Off

The unstable foot is forced to bend during terminal stance causing soft tissues to be stretch on the bottom of the foot and bones to be compressed on the top of the foot.
Examination of the foot usually begins with the bisection of the back of the heel.

The subtalar joint or rearfoot position will dictate the range of motion of the joints in the forefoot.

The forefoot ROM is greater when the STJ is pronated and less when the STJ is supinated.

Non Weight-bearing and Standing Evaluation of the Foot

Examination of the foot usually begins with the bisection of the back of the heel.

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Supination Lag

Pt. seated  Feet plantarflexed

“Bring soles together”

The pronated and supinated foot can be assessed using the resting calcaneal stance position.

Pronated  Supinated

“Too Many Toes Sign”

The maximum pronation test provides a guideline to prescribe the amount of control required for the orthotic to stabilize the foot.
Re-supination test provides a guideline to prescribe the appropriate amount of control.

If the arch does not rise after lifting the toe this signifies a loss of ligamentous integrity in the spring and deltoid ligaments.

The single leg raise or tip toe test will quickly demonstrate if the midfoot is unstable.

The lack of leverage & pain inhibits heel lift.
NWB and standing tests help to determine how much foot compensation motion needs to be controlled or encouraged.

The subtalar neutral position provides a starting point to help in describing foot pathology.

The subtalar neutral position was determined by trial and error by casting the foot in different STJ positions.

What is forefoot varus, forefoot valgus and rearfoot varus and the compensations they cause in the foot.

Compensated Rearfoot Varus
Compensated Forefoot varus

Compensated Forefoot valgus

Key point

The forefoot and rearfoot angular relationships can be compensated by foot joints. Depending on the amount of compensation the foot will be stable or unstable during terminal stance.

The most common question you will be asked is if the orthotic will fit in every shoe. Your answer must outline that you have to make compromises to the orthotic prescription to allow it to fit in a dress or casual shoe.
The role of footwear must be discussed to get the maximum benefit from orthotic intervention.

Shoe Volume vs. Orthotic prescription variables

Key point

Footwear can greatly affect the efficacy of foot orthotics

Therapeutic footwear is any regular extra width or depth off-shelf footwear or modification to footwear that is intended to respond to a prescription for foot or gait-related issues. It can act in an accommodative or a functional manner depending on the outcomes desired, and the design approach taken.

An example of therapeutic footwear would be a correctly fitted motion control running or walking shoe.
Orthopaedic footwear is the same as therapeutic footwear except will provide more depth, width and choice of material and styles to accommodate more deformity and extremely high risk category feet. *An example of orthopaedic footwear would be a correctly fitted Drew shoe.*

Custom footwear is indicated when a foot can not be accommodated in therapeutic or orthopaedic footwear. Custom footwear is fabricated using a custom shoe last produced using a cast of the foot above the ankle. Custom footwear requires a complex assessment with multiple follow up fittings and adjustments.

Good, the Bad and the Ugly Sandal Choices
Orthotic design determinants

1. Determine the Patient:
   - Weight in lbs:
     - Active
     - Sports
     - Sedentary
     - Dress / Working / Boots / Sneakers

2. Choose a Style:
   - Spurr: For sneakers
   - Elastic: For dress shoes/leather
   - Intrinsics: For high heel and footed accommodations
   - Comfort: Usually full length
   - For extra depth shoes and sneakers

3. Pick a Material for the Main Body of the Orthotic:
   - Functional:
     - Thermoplastic: Good for most shoes, boots and sneakers
     - Graphite: Used for dress/high heel narrow shoes
   - Accommodative:
     - Plastazote: Excellent for general foot comfort and when multiple accommodations are required
     - Leather: Used with sneakers or extra depth shoes

The shape of the shell due to patient foot type and heel depth will dictate the flexibility of the shell.

Posting the shell increases the rigidity of the shell.

Orthotic design determinants

4. Would You Like?
   - Heel Cap
     - High
     - Low
   - Area
     - High
     - Low
   - Range
     - High
     - Low

5. Pick Necessary Accommodations:
   - Posting
     - Heels
     - "U" Shaped Pads
     - Raises
     - Drops

6. Choose a Top Cover:
   - None
   - Very Thin, Very Durable
   - Thin, Durable
   - Vinyl
     - Thin, Very Durable
   - EVA Type: Cushioning, Good for Comfort / Sports
   - Cloth Type: Good for Comfort / Sports
   - Plastazote: Very Conforming, Low Friction, Not Durable

7. Pick a Length:
   - To Heels
     - To Midleg
     - To Knee
     - To Ankle
     - To Socks:
       - Best when there is met pain and accommodation
     - To Ties:
       - For extra depth shoes and sneakers

Key point: Patient weight and activity level will influence orthotic material selection.
Corrective foot orthoses are casted in the subtalar joint neutral position.

The subtalar joint neutral plaster cast of the foot captures the forefoot to rearfoot relationship.

Balancing the forefoot via posting prevents the foot from compensating via pronating.

The inability to place the foot in the neutral position due to gross deformity or rigidity in the foot joints is the deciding factor in choosing an accommodative foot orthotic instead of a corrective foot orthotic.

Accommodative orthoses are casted in a semi-weight bearing or weight bearing position.

Develop a consistent orthotic dispensing procedure.
The front of the orthotic shell should not cross the metatarsal-phalangeal joints and follow the metatarsal formula.

Does the foot orthotic arch height match the contours of the plantar aspect of the foot?

Old orthotic

New orthotic

Is the prescribed rearfoot post correct?

Can you easily perform great toe dorsiflexion.

Patient denies any pressure points or sharp edges.

Most important explain the break in period to adjust to the foot orthotic.
A orthotic dispensing checklist helps to educate the patient what to expect during the break in period and beyond.

The traditional method of foot orthotic fabrication uses the 3-dimensional contours of the foot captured via plaster, foam or pin arrays. **Buyer beware** - non 3D methods have been used to produce custom foot orthotics.

**Key point**

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**Anatomical Volumetric Foot Model (AVFM).**

An AVFM captures a person’s 3-dimensional plantar foot anatomy using physical or digital means. A physical AVFM captures foot anatomy through direct contact to duplicate plantar foot anatomy using plaster or foam. A digital AVFM can be captured using a laser 3D scanners, stereo-digital 3D imaging systems, or pin array systems. Actual 3D data points must be taken directly from the foot to duplicate plantar foot anatomy.

**Sub talar joint neutral plaster casting.**

**Anatomical Custom Foot Orthotic (ACFO).**

An ACFO is made directly from an Anatomical Volumetric Foot Model (AVFM). The AVFM is modified as per the prescription with:
- medial and/or lateral arch fill,
- lateral column expansion,
- heel expansion,
- and intrinsic forefoot and/or rearfoot corrections.
Extrapolated Volumetric Foot Model (EVFM).

A digital model that approximates 3D plantar foot anatomy through application of mathematical models using pressure data, or temperature data, or light data to form the digital model. These methods include: pressure mapping systems; photographs and ink or carbon paper imprinting systems.

Extrapolation System Foot Orthotic (ESFO).

An ESFO is made directly from an Extrapolated Volumetric Foot Model (EVFM). The EVFM is modified as per the prescription with:

• medial and/or lateral arch fill,
• lateral column expansion,
• heel expansion, and
• intrinsic forefoot and/or rearfoot corrections.

The entire dorsal surface of said custom device matches the surface of the modified, or corrected, EVFM.

Library System Foot Orthotic (LSFO)

An in shoe device that is made from a library of pre-manufactured shells, pre-manufactured corrected positive molds or pre-determined digital shape files (from which shells or molds are milled.) The foot orthotic shape is chosen by matching a library shape with either an AVFM or EVFM.

Key Point

If the goal is to capture the forefoot to rearfoot relationship of a foot a STJN anatomical volumetric foot model should be captured.

Arch Pain-Top and Bottom
The plantar fascia will resist the foot bending during *heel rise*.

Common locations of osteoarthritis in the foot

Manual foot treatment for OA

Key point

Arch pain can respond to both orthotic therapy or manual therapy
An extremely flatfoot occurring on one side is common in women over 50 with pre-existing diabetes, hypertension and obesity.

If the single leg tiptoe standing sign is painful it is suggestive of Adult Acquired Flatfoot.
If the patient can perform the single leg tiptoe on the affected side but forefoot abduction as well as valgus translation of the heel persists this is suggestive of spring ligament insufficiency.

The spring ligament complex creates a talar acetabulum that restrains multi-planar talar motion by functioning as an articular sling.

The superficial deltoid ligaments form a concavity around the head of the talus and insert into the entire length of the spring ligament.

1 Spring ligament
2 Ant. Tibiotalar
3 Tibionavicular
4 Tibiocalcaneal
5 Ant. Tibiofibular
The posterior tibialis muscle has the greatest influence on rearfoot motion during *heel rise*.

The tibialis posterior tendon also helps to support the spring ligament as well attaches to approx. 9 points on the midfoot arch bones.

The tibialis posterior muscle becomes over used with time.

Extremely flat feet require orthotics that stabilize the arch using a deep heel cup and medial flange.

There must be a balance in pull between the flexor and extensor tendons to prevent a hammer toe.

Hammer toes develop during terminal stance to help stabilize the forefoot.
Ankle sprains cause damage to the lateral structures of the foot.

Modified Romberg's Test to Assess Proprioception

Eyes open

Eyes Closed

Initiated after swelling has reduced.

Time how long the patient can stand on one leg in both situations before going off balance.

Key Point

Proprioception exercises and lateral arch fill foot orthotics can help prevent lateral rollover.

Heel spur syndrome/plantar fasciitis

Heel spur forms where plantar fascia joins onto heel bone.

Heel spur syndrome can be caused by damage to fascia, ligament and muscle pulling away from bone, or nerve and fat pad trauma.

The plantar fascia will resist the foot bending during heel rise.

The plantar fascia resists foot bending during heel rise in terminal stance.
The pain of bunions

Types of Bunion Surgeries

The bunion deformity develops during terminal stance

Key Point

A rotated big toe can lead to an ingrown nail over time

Key Point

Ingrown Nail
Flexible orthoses with lateral stabilization are indicated for high arched feet.
Low dye taping helps to stabilize the foot and if successful is a good indicator for orthotic use.

What really happens when we injured our feet

Timing is everything

The foot contacts the ground for about 3/4 of a second (750 mille-seconds) sometimes less time, sometimes more time.
Each area on the bottom of the foot will be in contact with ground for only a short period of time.

The speed of walking determines the duration of contact time on the bottom of the foot.

Increased speed equals greater stride length decreased speed equals shorter stride length.

Increased speed of walking can produce greater forces underneath the foot.

Damage to the foot depends on the magnitude of the force and how often it is being applied to the foot.

**Stress vs. Strain**

**Stress** = Force (load) / Cross sectional area (internal reaction)

**Strain** = Change in dimensions of a material (Deformation) / Original dimension of material (External reaction)

Change in size or shape of an externally applied force

No standard unit of measurement
Tensile strain

Compression strain

Shearing strain

Bending strain

End supported

Bending measured by radius of curvature.

Cantilever Loaded Beam Femur

Torsion strain

- This develops when a rod or shaft is loaded so that it tends to twist around its long axis.
- Load applied perpendicular to the rod.
- Change in radius of rod.
- Compression, tension, and shearing strain occur.
- Spiral fracture of long bone occurs from torsion.
### Stress Strain Curve

- **Elastic Region**: Will return to original length and slope.
- **Plastic Region**: Permanent deformation occurs.
- **Yield Point**: Transition between elastic and plastic regions.
- **Failure Point**: Material fails.

### Time and Stress

#### MECHANICAL FATIGUE
- Can change based on rest between cycles or repetition.
- Applies to rehabilitation and training.

#### Creep
- Strain increases over-time as material is kept at a constant stress.

#### Stress Relaxation
- Take material to a constant length (e.g., 10 cm to 11 cm).
- Less stress over time is needed to take the material to a specific strain.

### Time and Stress

#### Mid-tarsal joint
- Calf muscles: Tibialis posterior m.
- Body weight: 1st toe joint
- If the foot is unstable, tissue damage will occur due to repetitive strain.

### Key Point

The foot undergoes the bending strain during the propulsive phase.
- If the foot is unstable, tissue damage will occur due to repetitive strain.

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The patient satisfaction can be maximized with a well-informed staff being able to confidently answer basic podiatric biomechanics and foot orthotic terminology questions.