Lower Limb Orthoses to Enhance Ambulation

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OBJECTIVES

- Discuss the principles used in designing orthotic interventions for the lower extremity to restore mobility and function
- Identify orthotic components and relate their function and use to patient criteria
- Analyze the effect of orthoses on joint motion based on biomechanical needs during ambulation

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OBJECTIVES

- Identify indications for use of specific orthosis designs based on goals related to
  - functional ambulation,
  - protection,
  - and contractures

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Role of Orthoses in the Rehabilitation Process

- Provide safe and efficient ambulation to access surroundings
- Maximize function
- Reduce long term effects of skeletal mal-alignment

Patient Assessment

The assessment aids in determining the biomechanical forces necessary to provide:

- Stable skeletal alignment
- Stable base of support to facilitate safe ambulation
- Substitute for impaired muscle strength
- Control unwanted motion from spasticity

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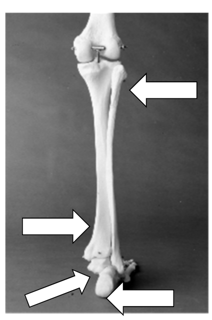
Biomechanical Principles

- Three-point force systems
- Ground reaction force force vectors
- Alignment
  - Tibial angle to floor
  - AFO/Footwear Combination (AFO-FC)

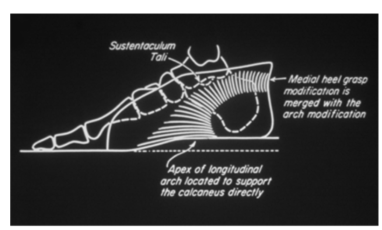
3-Point Force System Subtalar Eversion Control

- Corrective Forces
  - Proximal to medial malleolus
  - Sustentaculum tali
- Counteractive Forces
  - Proximal lateral calf
  - Distal lateral calcaneus



3-Point Force Systems

Sustentaculum tali modification



Courtesy of Martin Carlson, CPO

3-Point Force System
Subtalar Eversion Control

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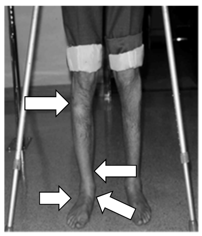

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Describe the 3-point force system used to control excessive plantarflexion in a thermoplastic AFO?

a. posterior calf, plantar surface of the foot at the MT head region, ankle strap
b. posterior calf, dorsum of the foot, anterior calf
c. anterior calf, posterior calcaneus, dorsum of the foot
d. proximal lateral calf, medial malleolus, lateral calcaneus

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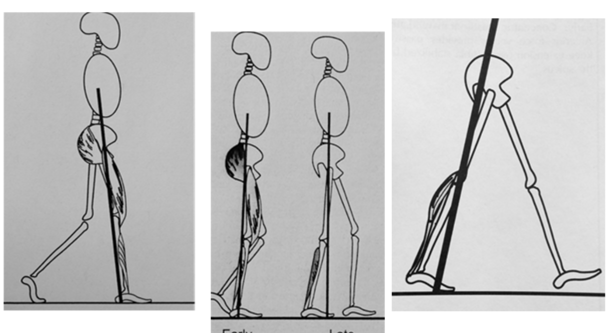
Ground Reaction Force Vectors



Perry, J. Gait Analysis, 2010

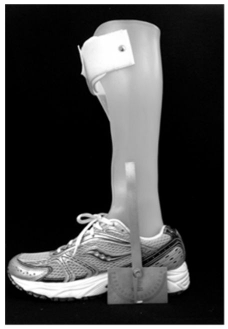
Tibial Angle to Floor

- Distal 1/3 of tibia/fibula to floor
- Considerations
  - Ankle joint ROM
  - Heel height of shoe

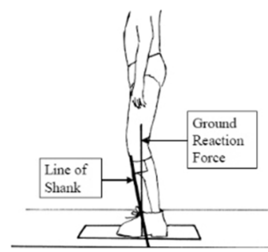
Tibial Angle to Floor

While wearing shoes

- Heel height
  - Differential from the ball of the foot to the heel
- Heel wedges may be used in the shoe to accommodate a plantarflexion contracture



AFO-Footwear Combination



Courtesy of Elaine Owen

- Shank vertical angle
  - Line of shank is along anterior tibial crest in relationship to vertical
  - Measurement taken with shoe
  - Evaluate overall postural alignment

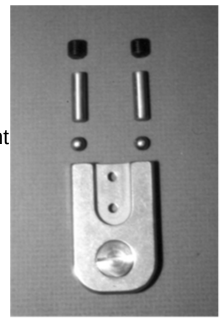
Anatomy of an AFO

- Stirrup
- Soleplate
- Sidebar/ Upright
- Calf band
- Pretibial shell

Anatomy of a Thermoplastic AFO

- Foot plate
  - Length
- Trim lines
  - Rigidity through position of trim lines at ankle region

Ankle Joint Controls

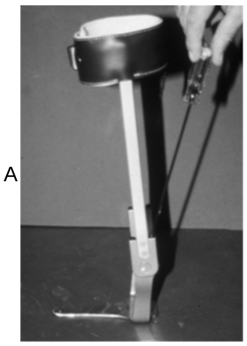


Double Adjustable / Dual Channel ankle joint

- Plantarflexion stop
  - Pin placed in the posterior channel
- Dorsiflexion stop
  - Pin placed in the anterior channel

Plantarflexion Stop

- Tilts the tibia anterior and positions the ankle joint in dorsiflexion
- Function
  - Provide clearance during swing phase
  - Produce a knee flexion moment at loading response



Dorsiflexion Weakness

AFO with a Plantarflexion (PF) Stop

- Provides stability in the sagittal plane by controlling ankle PF during swing phase
- Relationship between
  - adequate clearance during swing phase
  - knee flexion stability during loading response

Dorsiflexion Stop

- Limits dorsiflexion or tibial advancement
- Function
  - Create a knee extension moment midstance through terminal stance

Plantarflexion Weakness

AFO with a Dorsiflexion Stop

- Provides stability in the sagittal plane by controlling tibial advancement during midstance and terminal stance
- Relationship between
  - adequate clearance during swing phase
  - knee stability during stance phase

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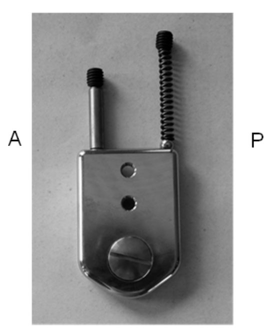
An ankle-foot orthosis with a plantarflexion stop positioned in dorsiflexion will induce a/an

a. decreased knee flexion moment.
b. increased knee extension moment.
c. increased knee flexion moment.
d. increased hip extension moment.

Ankle Joint Controls



Double Adjustable / Dual Channel

- Spring placed in the posterior channel to allow controlled PF at loading response
- Pin placed in the anterior channel for a DF stop

Ankle Joint Controls

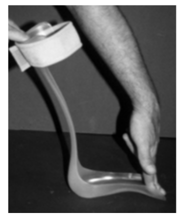
Ankle joint with a spring in the posterior channel

- allows PF ROM at loading response
- provides increased knee stability at loading response by decreasing the knee flexion moment

Ankle Joint Controls


Dorsiflexion Assist


Posterior Leaf Spring AFO



Functions:

- allow controlled plantarflexion at loading response and

- dorsiflexion ROM during late midstance and terminal stance

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Posterior Leaf Spring AFO

Indications:

- Dorsiflexion weakness
- Minimal need for stability of subtalar and midtarsal joints

Biomechanical goal:

- Limit unwanted plantarflexion ROM during swing phase

Carbon AFO Designs

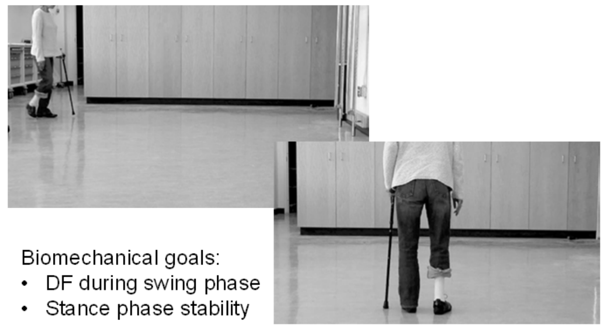

- Varied designs
  – Similar to Posterior Leaf spring
  – Rigid limiting dorsiflexion and plantarflexion
  – Prefabricated

Ankle Foot Orthoses


Custom fabricated
- Polypropylene
- Laminated
- Carbon
- Hybrid



Case Scenario-Hx of Polio



Biomechanical goals:
- DF during swing phase
- Stance phase stability

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Case Scenario-Hx of Polio

Clinical Considerations:
- Knee strength
- Activity level, function
- Leg length discrepancy
- PF contracture

Case Scenario-Polio



Custom fabricated carbon AFO
- Rigidity/flexibility
  - Ankle
  - Metatarsal heads

Lower Limb Orthoses Categories based on Purpose

- Ambulation
  - To improve mobility and independence
- Protection
  - Protect or prevent further deformity
- Contractures
  - Reduce or prevent limitation of range of motion

Lower Limb Orthoses For Ambulation

- Accommodative Foot Orthoses
  - Accommodate alignment and deformities
  - Lower durometer materials

Lower Limb Orthoses For Ambulation

- Biomechanical Foot Orthoses
  - Coronal plane alignment control
  - Subtalar and midtarsal joint control

Lower Limb Orthoses For Ambulation

UCBL FO

- (UC Biomechanics Lab Foot Orthosis)
- Indications:
  - Midtarsal pronation/supination, forefoot abduction/adduction
- Biomechanical goals:
  - Control of midtarsal and transtarsal joints

AFO Function
Clearance during Swing Phase

- Indications
  - Inadequate DF strength
- Design Options
  - DF assist
  - PF stop

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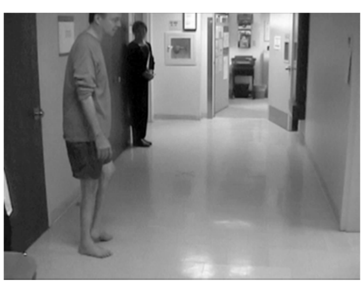
Dorsiflexion Weakness

- Clinical Observations
  - Absent heel strike if weakness <3/5
  - Adequate clearance during swing, foot slap at LR with 3/5
  - Clearance of the foot reduced during swing phase
  - Compensation with a steppage gait pattern
  - Instability of the subtalar joint

Case Scenario-CMT



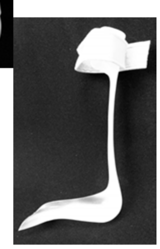
MMT:

- Weak DF, PF
- Good knee and hip

Biomechanical goals:

- Clearance during swing phase
- Subtalar joint control

Dorsiflexion Assist AFO



- Clinical Considerations:
  - DF ROM of the ankle joint since the design allows DF ROM midstance to terminal stance
  - Allows PF ROM at loading response
  - Stability of the subtalar, midtarsal, and transtarsal joints

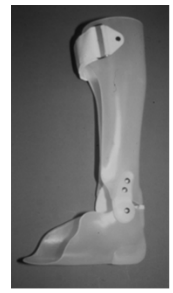
Articulated Plastic AFO
Plantarflexion Stop

- Indications:
  - Dorsiflexion weakness
  - Sagittal, coronal and transverse plane control
- Biomechanical goals:
  - Clearance of the foot during swing phase
  - Stability of the subtalar, midtarsal joints
  - Allow DF/tibial advancement

Articulated Plastic AFO
Plantarflexion Stop

Clinical Considerations

- Produces a knee flexion moment at loading response dependent on tibial angle to floor or shank vertical angle
- Trade off between clearance of the foot during swing and knee stability during stance phase



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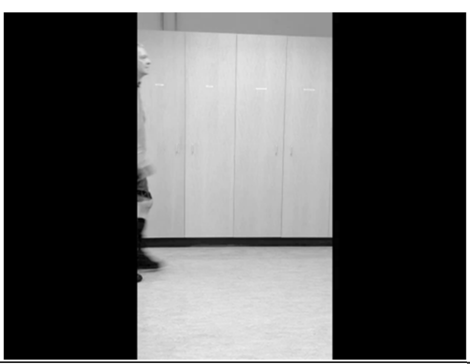
Case Scenario-CMT



Solid Ankle AFO

- Biomechanical goals:
  - Clearance of the foot during swing phase
  - Control of dorsiflexion/tibial advancement
  - Provide stability of the subtalar and midtarsal joints

Solid Ankle AFO

- Indications:
  - Combined dorsiflexion and plantarflexion weakness
  - Sagittal, coronal and transverse plane control

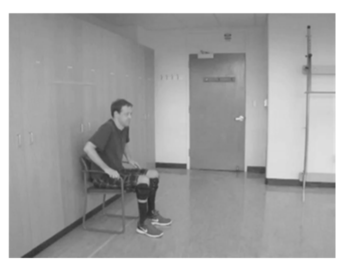
Solid Ankle AFO

- Clinical Considerations
  - Fair quadriceps strength to control destabilizing knee flexion moment at loading response (LR)
  - Shoe modifications to reduce knee flexion moment at LR
    - Bevel heel
    - Cushion heel
    - Rocker sole

Carbon AFOs

- Custom Fabricated
  - Determine PF/DF resistance
  - Footplate length/flexibility

Case Scenario
Spinal Muscular Atrophy



MMT:
- No DF or PF strength

Biomechanical goals:
- Clearance of foot during swing phase
- Substitute for PF during stance phase
- Tri-planar control

Plastic Ground Reaction AFO

- Design Characteristics
  - Solid ankle with pretibial shell
  - Tibial angle 90 degrees to floor with shoes
  - Shank vertical angle with shoes
  - Extended footplate
- Indications:
  - Quadriceps weakness (3-/5)
  - Plantarflexion weakness

Plastic Ground Reaction AFO

Biomechanical goals:

- Provide knee extension moment midstance through terminal stance

Considerations:

- Creates a knee flexion moment at loading response

Articulated Ground Reaction AFO

- Spring in the posterior channel
- Stop in the anterior channel
- Reduces knee flexion moment at loading response

Articulated Ground Reaction AFO

- Indications:
  - Weak plantarflexors
  - Weak quadriceps
  - Weak hip extensors
- Biomechanical goals:
  - Provide a knee extension moment midstance through terminal stance
  - With a spring in the posterior channel, decrease the knee flexion moment at LR

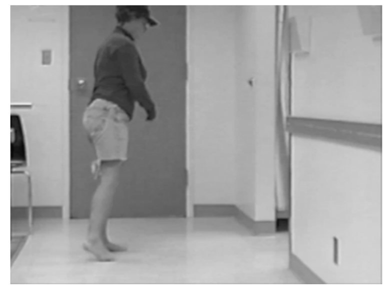
Case Scenario Stroke

Biomechanical goals:

- Prevent mal-alignment and deformities
- Substitute for muscle weakness/motor control
  - Ankle joint
  - Subtalar joint
  - Forefoot
  - Knee
  - Hip

Case Scenario-Stroke

- Affect sagittal plane control at the knee by ankle position and control
  - Hyperextension
  - Flexion



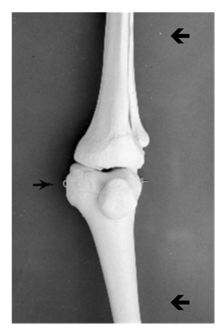
Knee Ankle Foot Orthosis

- Indicated for control at the knee
  - Valgum
  - Varum
  - Recurvatum
  - Quadriceps weakness

Knee Ankle Foot Orthosis

Genu valgum 3-point force system

- Corrective force
  - Medial femoral condyle
- Counteractive forces
  - Lateral proximal thigh
  - Lateral distal calf



Knee Ankle Foot Orthosis

Recurvatum control

- 3-point force system
- Plantarflexion stop

Knee Ankle Foot Orthosis

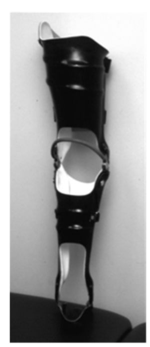
- Indicated for use with less than 3-/5 Quadriceps strength OR bilateral weakness

Bilateral KAFO’s

- Locked knee joints
- Ankles locked in dorsiflexion
- Weight line maintained posterior to hip joint to provide stability at the hips

Knee Ankle Foot Orthoses Components

- Ankle joints
- AFO section
- Thigh section
- Infrapatellar and suprapatellar straps
- Knee Joints



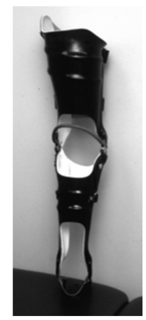
Knee Joints

- Bail Lock
- Drop Lock
- Offset Free Knee

Knee Joint Components

Bail Lock

- Easier to unlock when moving from standing to sitting
- Consider use with
  - bilateral KAFOs
  - decreased hand function



Knee Joint Components

- Drop Lock/Ring Lock
  - Good hand function required to operate
  - Freely falls into locked position when fully extended

Knee Joint Components

Offset Knee Joint

- Provides increased knee stability during stance phase
- Mechanical knee axis aligned posterior to anatomical knee joint axis

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Knee Joint Components

- Offset knee joint optimal function
  - Approximately 10 degrees plantarflexion ROM at loading response
  - Incorporate a dorsiflexion stop at the ankle joint

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Quadriceps Weakness

- Clinical Observation
  - Mild to moderate weakness
    - Eliminate knee flexion by maintaining knee extension at initial contact
  - More severe weakness
    - Forward trunk leaning
    - genu recurvatum

Quadriceps Weakness

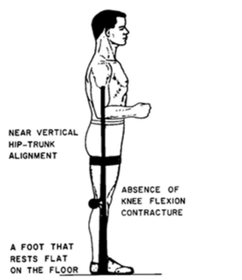
- Cauda Equina Injury
- No intervention for many years

Quadriceps Weakness
Offset Free Knee KAFO

- Dorsiflexion stop
- Plantarflexion stop
  - Posterior spring
- Degree of recurvatum determined for stability
- 3-pt. Force system

Offset Knee Joint KAFO Indications

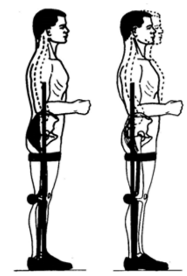
- Unilateral involvement
- Vertical hip-trunk alignment
- Absence of contractures
  - Knee and hip
- Plantargrade foot
- Quadriceps weakness
- Hip strength 2/5 or >
- Joint proprioception



Lister, MJ, Principles LE Bracing, 1967

Quadriceps Weakness Offset Knee Joint KAFO Option

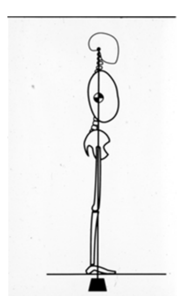
- Center of mass in relationship to mechanical knee joint axis
  - Hip extensor strength most effective



Lister, MJ, Principles LE Bracing, 1967

Quadriceps Weakness

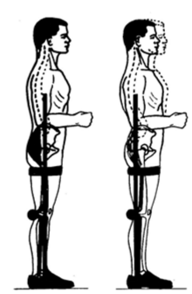
- Quadriceps strength
  - at least 3-/5 or 3/5
- Center of mass must be maintained anterior to knee joint axis
  - ground reaction force vector for knee stability



Perry J, Gait Analysis, 1992

Offset Knee Joint KAFO Stability

- Center of mass maintained anterior to the mechanical knee joint axis
  - mechanical knee joint moves into extension
  - hip extensor strength necesary



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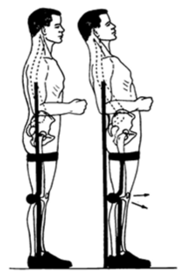
Offset Knee Joint KAFO Instability

- If the Center of mass passes posterior to mechanical knee joint axis, the mechanical knee joint flexes

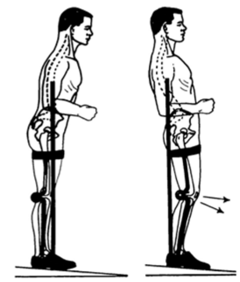


Lister, MJ, Principles LE Bracing, 1967

Offset Knee Joint KAFO Instability on Inclines

Weak hip extensors or trunk extension

- Center of mass falls posterior to mechanical knee joint axis
- Knee flexion instability



Lister, MJ, Principles LE Bracing, 1967

Offset Knee Joint KAFO Instability

- Uneven ground
  - Elevation under heel of shoe

Lister, MJ, Principles LE Bracing, 1967

KAFO with Offset Knee Joints

- Advantages
  - Ease in rising from a chair
  - Ease in walking due to lack of knee locked in extension
- Disadvantages
  - Uneven ground instability
  - Difficulty in going down inclines
  - Cognitive demand

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What muscle group is assessed to determine if an individual with quadricpes weakness would be able to successfully utilize a unilateral KAFO with an offset knee joint?

a. ankle dorsiflexors
b. hip flexors
c. abdominals
d. hip extensors

Quadriceps Weakness AFO Option

- Hip extensor strength 3/5
  - Pre-tibial shell, DF stop
- Knee extensor strength 3-/5
  - Pre-tibial shell, DF stop
  - Spring in posterior channel DAAJ

Quadriceps Weakness AFO with DF stop

- DF stop limits ankle dorsiflexion
  - midstance to terminal stance

AFO with DF stop PF stop/spring

- Controlled PF ROM
  - spring in posterior channel
  - decreases knee flexion moment at loading response

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A patient with fair minus quadriceps strength wearing a ground reaction ankle-foot orthosis will have knee extension facilitated from midstance to terminal stance by utilization of a

a. plantarflexion stop
b. dorsiflexion assist
c. dorsiflexion stop
d. plantarflexion resist

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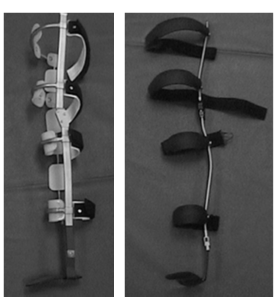
Stance Control KAFOs

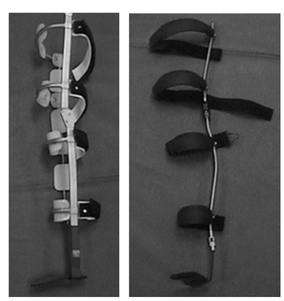
- Method of activation
  - Ankle, gait
- Many recommend use with 3/5 hip extensors
- <10-15 degrees genu valgum
- Knee flexion contractures <10 degrees
- Achieve knee extension at terminal stance
- Unilateral
- Varied weight limits

Stance Controlled Knee Joints



- Ability to flex knee during swing phase
- Stabilization with a locked knee during stance phase
- Limited designs have stabilization of knee with flexion

Stance Controlled Knee Joints



Tubular upright houses cables
- Full extension locks the joint
- Unlocks at terminal stance with
  - 5-10 degrees DF ROM
  - Knee extension

Recommendations
- 3/5 hip extensors
- <5 degrees knee flexion contracture

Stance Controlled Knee Joints

- Ankle joint with dorsiflexion ROM to unlock knee joint
- Full extension locks knee at terminal stance

Stance Controlled Knee Joints

- Create knee extension moment during terminal stance with
  - active muscle control of hip extensors, plantarflexors
  - passive orthotic control
    - DF stop
    - Longer footplate length
    - Rocker fulcrum moved distally on the shoe

Stance Controlled Knee Joints

Stance Phase Lock
- Pendulum
- Full extension unlocks knee for swing phase
- 3/5 hip extensors recommended

Stance Controlled KAFOs

- Trial orthoses are available from most companies

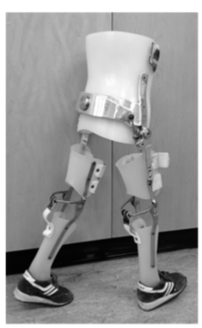
HKAFO

- Sagittal, coronal, and transverse plane control

Reciprocating Gait Orthosis

- Pelvic band and connected hip joints
- Hip flexion or trunk extension on one side facilitates hip flexion on the contralateral side
- Used in conjunction with KAFOs or AFOs

RGO



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Orthoses for Protection

- Goal:
  - Protect or prevent further deformity
    - Fracture bracing
    - Knee orthoses
    - Hip orthoses
    - CROW
    - PRAFO

Fracture Bracing

- General Principles
  - Protection/immobilization of the injured area through soft tissue compression
  - Mobilization of the patient once acute symptoms subside
    - ROM of adjacent joints
    - Muscle function
  - Graduated weight bearing

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Fracture Bracing

- Tibial diaphysis fractures
- Used post cast application (7-10 days)
- Orthosis will not address shortening
- Considerations
  - Apex anterior or posterior angulation
  - Tibial fx without fibular fx
  - Above tibial tubercle, distal tibial fx

Orthosis Design

- Prefabricated
- Thin, well conforming anterior section
  - 1/4” foam padding
- Foot section
  - Maintain heel in correct AP position
  - Maintain suspension
- Posterior calf flattened

Courtesy Wheaton Brace Co.

Ankle Foot Fracture Orthoses

- Immobilization of the affected area
- Rocker bottom to aid in smooth roll-over
- Circumferential Compression
- Post-operative rehabilitative orthosis
- Available in various styles with fixed and adjustable ankle ROM

Femoral Fracture Orthoses

- Distal 1/3, tibial plateau fx
- Provides for variable ROM at the hip and knee
- Free Motion at the ankle
- Circumferential compression
- Does not limit internal or external rotation at the hip

Hip, Knee, Ankle, Foot, Ankle Orthosis (HKAFO)

- Proximal Femoral Fractures
- Available prefabricated or custom to measurements
- Various joint selection available for hip and knee
- Limits internal and external rotation at the hip
- Circumferential compression

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Three Categories of Knee Orthoses

Prophylactic
- Attempt to prevent or reduce severity of knee ligament injuries

Rehabilitative
- Protect motion of injured knee or post-op

Functional
- Provide stability during activities

Knee Orthoses for OA

- Pre-fabricated and custom fabricated designs
- Uni-compartmental involvement

Hip Orthoses

Courtesy TLC Hip Abduction Brace

- Pre-fabricated designs
- Adjustable
- Use of heel cup extension if rotational control desired

CROW

- Charcot Restraint Orthotic Walker
- Goal:
  - Reduce pressure on specific areas of the plantarsurface of the foot
  - Rocker sole facilitates normal gait pattern

PRAFO

- Pressure Relief AFO
- Pre-fabricated
- Reimbursement guidelines
  - Not covered for addressing heel ulcers
  - Covered for plantarfasciitis, and contractures up to 45 degrees with 10 degrees PROM, active stretching program, interfering with functional abilities

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Objectives

- Discuss the principles used in designing orthotic interventions for the lower extremity to restore mobility
- Identify orthotic components and relate their function and use to patient criteria
- Analyze the effect of orthoses on joint motion based on biomechanical needs

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Objectives

- Identify indications for use of specific orthoses designs based on the categories of ambulation, protection, and contractures