

# *Designing & manufacturing light weight full contact orthosis*

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Light weight full contact orthosis what is the benefit ?



**noppe**  
orthopedietechniek  
Maakt deel uit van **oim**  
orthopedie

**oim**  
orthopedie



It can be quite complex !!!



# Physical examination

Before we produce the orthosis, we must understand the problem

- ✓ Gait analysis, MRI. X-ray
- ✓ Physical condition (limitations in hand function)
- ✓ Mobility of the Hip, knee and ankle joint (contracture)
- ✓ Muscle strength (weakness) of the hip and leg
- ✓ Muscle length
- ✓ Bone abnormalities
- ✓ Misalignments of the leg, insufficiency ligaments (correct or accept)
- ✓ Leg length differences
- ✓ Abnormalities in the pelvis and spine

# Physical examination

The outcome of the physical examination, and the wishes of the Client is crucial for the type of orthosis

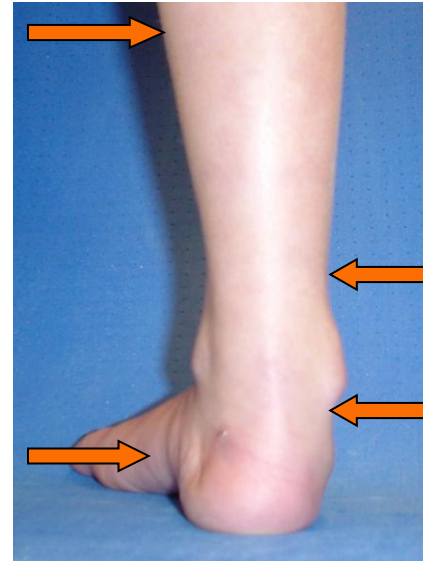
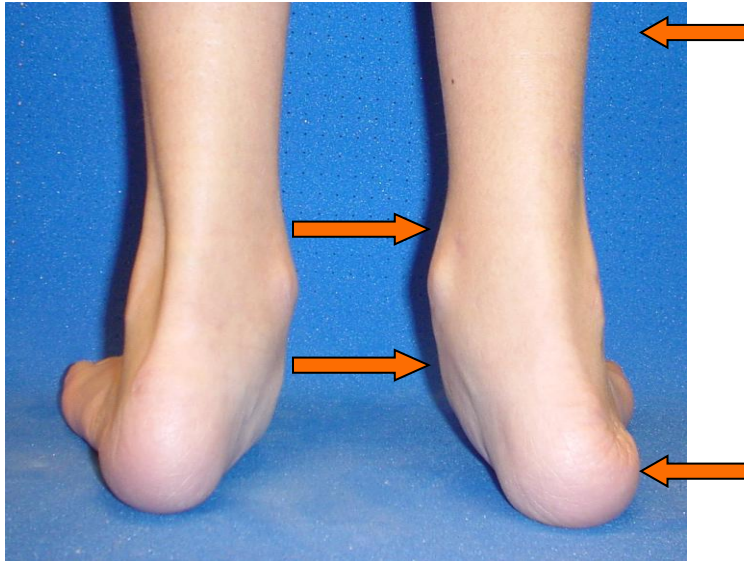
- ✓ Type orthosis ?
- ✓ Type of knee and ankle joints ?
- ✓ Type of material
- ✓ Acceptation correction, stabilization ?
- ✓ Placement of the shells ?
- ✓ Allow or limit joint rotation ?
- ✓ Support of the pelvis ?

# Correction and stabilization using GRF and 3PP

The Orthotist has three operating principles to determine the type of orthosis

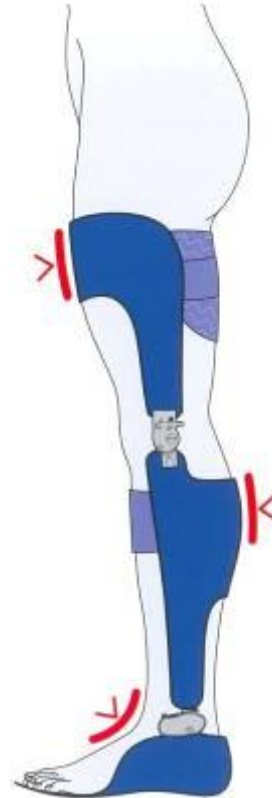
- ✓ Biomechanical principle 3PP (three-point pressure principle)
- ✓ GRF (Ground Reaction Forces)
- ✓ Limitation or allow joint rotation

# Correction and stabilization using 3PP



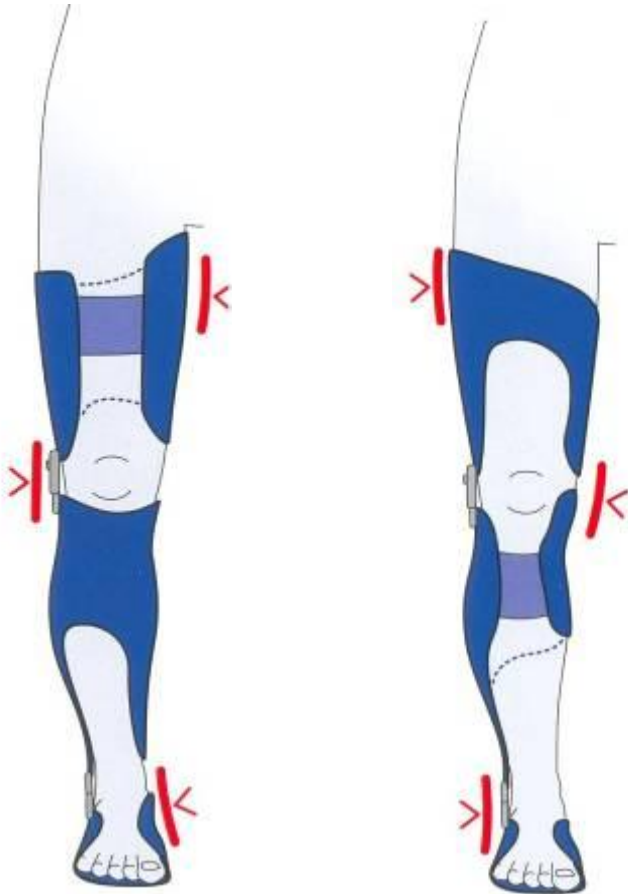
- 3PP Correction of the subtaculair ankle joint with valgus or varus deformity
- 3PP Correction of the forefoot abduction or adduction

# Correction and stabilization using 3PP



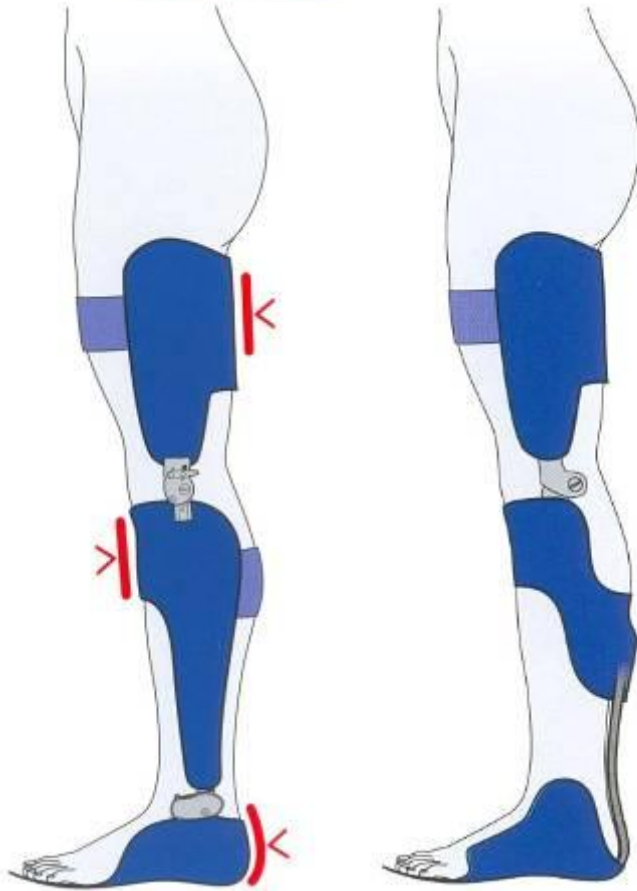
Three point pressure correction of knee-hyperextension

# Correction and stabilization using 3PP



Three point pressure correction of knee genu valgum or varum

# Correction and stabilization using 3PP



Knee Ankle Foot Orthosis (KAFO)  
for quadriceps weakness

# Correction and stabilization using GRF

## Application of ground reaction forces to correct the gait pattern

- ✓ Ground reaction force is called pressure force
- ✓ Action- and reaction forces perpendicular to the contact area
- ✓ Ground reaction are facing each other along the same working line

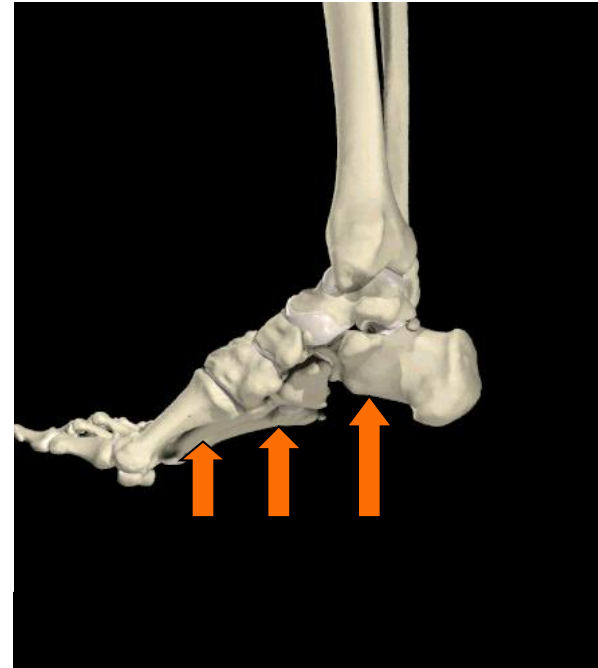
How can these ground reaction forces useful, during standing and walking ?



# Correction and stabilization using GRF



Correction of pes varus adductus

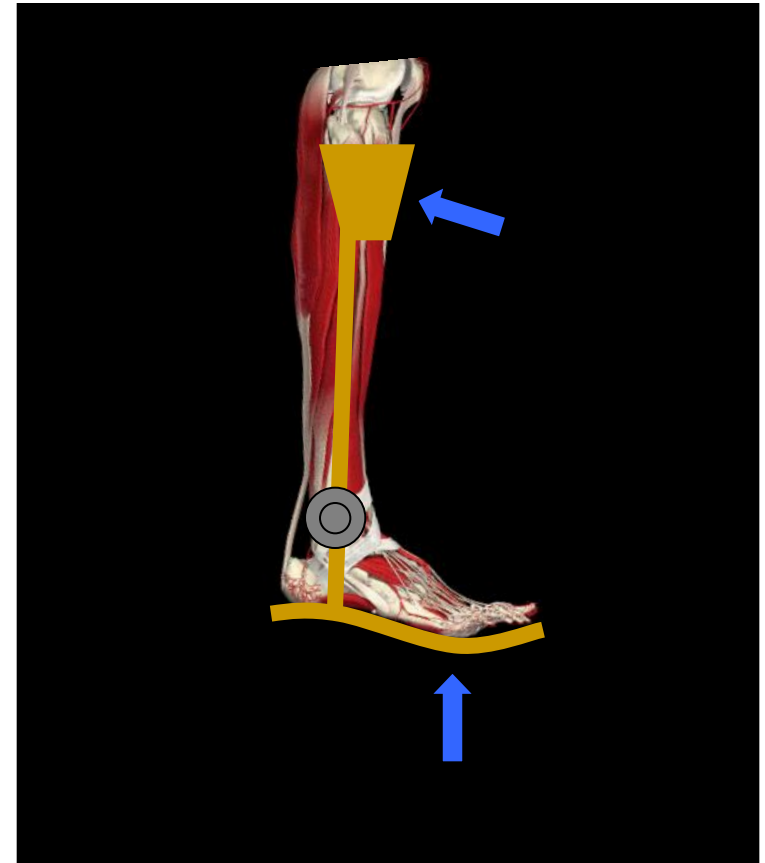


Correction of pes plano valgus

Ground reaction forces can be used to correct misalignments and deformations

# Correction and stabilization using GRF

- ✓ Limitation of dorsiflexion, stabilizes the knee to extension
- ✓ This effect is also created by the ground reaction forces



# Correction and stabilization using GRF

- ✓ Reduction of the axial load on the leg, through the mutual support of the pelvis
- ✓ Stabilizing the hip joint (weakness hip extensors and hip abductor muscle)



GRF

# Fitting and alignments

## AFO for calf muscle weakness

### Ankle Foot Orthosis for calf muscle weakness

Aim: Restore rocker of the foot during mid-stance and terminal stance

#### Essentials AFO design:

- Dorsiflexion stop ankle joint
- Anterior shell if possible
- Foot plate rigid with flexible forefoot (to enable forefoot rocker)

#### Attention!

Pes plano valgus deformity may be forced in mid-stance and terminal stance by shortness of the MTS.



# Fitting and alignments

## AFO for calf muscle weakness

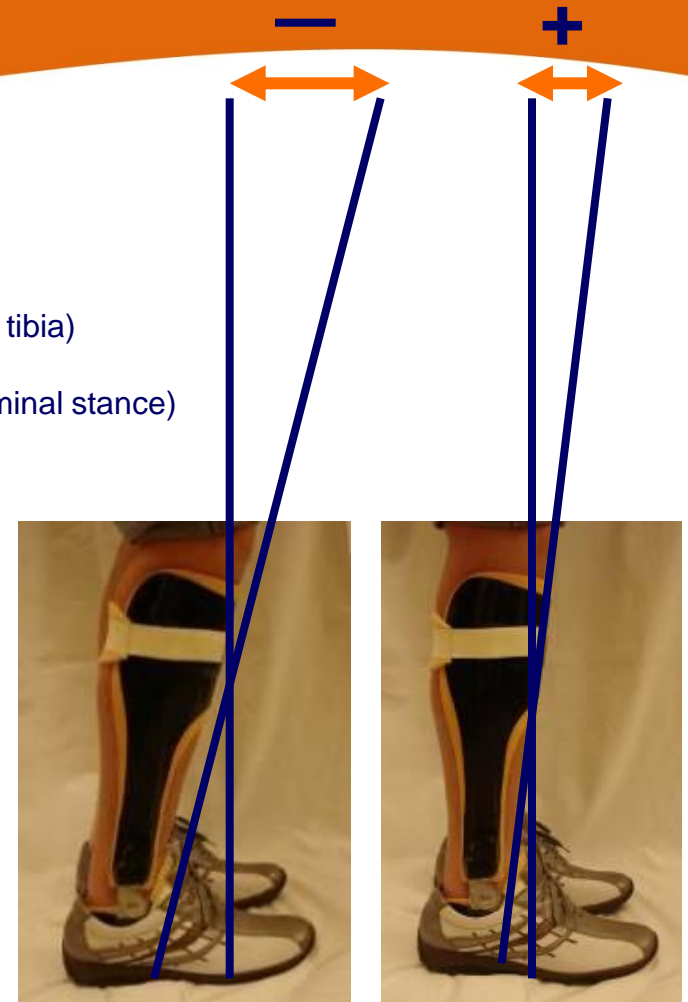
- ✓ Check the fitting of the test socket
- ✓ Check the alignment with the shoe into the sagittal plane (shaft vertical angle of the tibia)
- ✓ Check leg length difference ( compensate if necessary)
- ✓ Check the alignment in the frontal plane (genua varus/valgus)



# Fitting and alignments

## AFO for calf muscle weakness

- ✓ Check the shape of the carbon AFO (full contact)
- ✓ Check the alignment in combination with the shoe (shaft vertical angle of the tibia)
- ✓ Limitation of dorsiflexion (correction of the knee flexion in midstance and terminal stance)
- ✓ Check the foot in transversal plane (endorotation or exorotation)
- ✓ Check leg length difference (compensate if necessary)
- ✓ Fixation of AFO: Velcro straps, or circular in case of high deformity



# Fitting and alignments

## AFO for calf muscle weakness



# Fitting and alignments

## KAFO for quadriceps weakness

### Knee Ankle Foot Orthosis (KAFO) for quadriceps weakness

Aim: To stabilize the knee in loading response and early midstance

#### Essentials KAFO design:

- Anterior tibial shell if possible and posterior femoral shell (3PP)
- Locked or StanceControl (SC) joint depending on gait analysis and physical examination

#### Attention!

Add dorsiflexionstop ankle joint in case of calf weakness to stabilize in late midstance, or to enable unlocking of SC-KAFO (knee extension moment)

Hip extensor/abductor weakness include tuber support



# Fitting and alignments

## KAFO for quadriceps weakness

### Check plaster model with a test socket

- ✓ Check the fitting of the shape by a polypropylene test socket
- ✓ Check the positioning of the ankle and knee axis
- ✓ Check alignment in the saggital plane (flexion and extension of the knee)

### Weight bearing standing with the socket!!

- ✓ Check the position of the tuber support, comfortable or not?
- ✓ Check correction and/or stabilization
- ✓ Check the shape and the fitting comfort ability
- ✓ Cut the test socket and check by flexion and extension for frictions

# Fitting and alignments

## KAFO for quadriceps weakness

### Check plaster model with a test socket

- ✓ Position of the ankle and knee joint tubes in the plaster negative
- ✓ Remove plaster for stabilization (think of the full contact principles and 3PP)
- ✓ Compensate bony structures (pressure problems)



# Fitting and alignments

## KAFO for quadriceps weakness

Check fitting and alignments of the pre-preg KAFO



# Fitting and alignments

## KAFO for quadriceps weakness



# Fitting and alignments

## KAFO for quadriceps weakness

### Check fitting and alignments of the pre-preg KAFO

- ✓ Check the range of motion of the knee joint
- ✓ Check the fitting of the KAFO (no pressure problems)
- ✓ Check trim lines, remove material if possible (weight and cosmetic)
- ✓ Mark the position of the Velcro straps
- ✓ Check leg length, if necessary supplement underneath the foot plate
- ✓ Check position of tuber support (height and comfort during sitting, standing, walking)
- ✓ Check the alignment and fitting during sitting, standing and walking

# Essentials of manufacturing carbon AFO and KAFO

- ✓ Full contact principles for stabilization (not too much space between leg and orthosis)
- ✓ Restrict mobility in the orthotic joints (increasing deformation)
- ✓ Bony deformities: no correction but acceptance!
- ✓ Correct external rotation of the foot to 5 degrees maximal in case of calf muscle weakness for foot rocker
- ✓ Always use a test socket (remolding after manufacturing is not possible)
- ✓ Manufacturing a tuber bar, make it small (comfortable by sitting and walking)
- ✓ Positioning knee joint and ankle joint is crucial, can not be corrected
- ✓ Apply long lever arms in case of knee valgus or varus deformities
- ✓ Increase strength by applying additional layers of carbon in case of higher external forces in varus and valgus deformities

# Manufacturing carbon AFO & KAFO

## What is Pre-Preg material?



### Advantage:

- ✓ Good mechanical properties
- ✓ Orthoses produce subtle
- ✓ Less weight
- ✓ Processes involved in building composite easier to control
- ✓ Ferrous and non ferrous alloys hybrids easy to handle
- ✓ Carbon composite easy to build

### Disadvantages:

- ✓ Labor intensive (Expensive)
- ✓ Non-deformable after hardening (if not optimal fit → new orthosis)
- ✓ Proper working conditions necessary during the production
- ✓ Investments in equipment

# Manufacturing carbon AFO

1. Compensate soft lining with cork lay up
2. Check position ankle joints on the plaster model
3. Position of carbon and kevlar fibers
4. Integration of the ankle joints into the carbon fibers
5. Stiffness of the footplate (resistance) of the third rocker



# Manufacturing carbon KAFO

- ✓ Integration of the knee joints into the carbon fibers
- ✓ Integration of the titanium bars into the carbon fibers
- ✓ Using multidirectional and unidirectional carbon fibers
- ✓ Using kevlar fibers
- ✓ Integration of the tuber bar
- ✓ Locking system of the knee joint
- ✓ Integration of leather materials in combination with the carbon fibers



# Overview ankle joints

Foot lifter spring,  
free or limited to  
dorsal flexion.

Otto Bock



Free or limited  
movement, not  
adjustable.

Otto Bock



Foot lifter spring,  
adjustable dorsal  
flexion stop.

Fior&Gentz



Adjustable plantair  
and dorsal flexion  
stop.

Fior&Gentz



# Overview knee joints

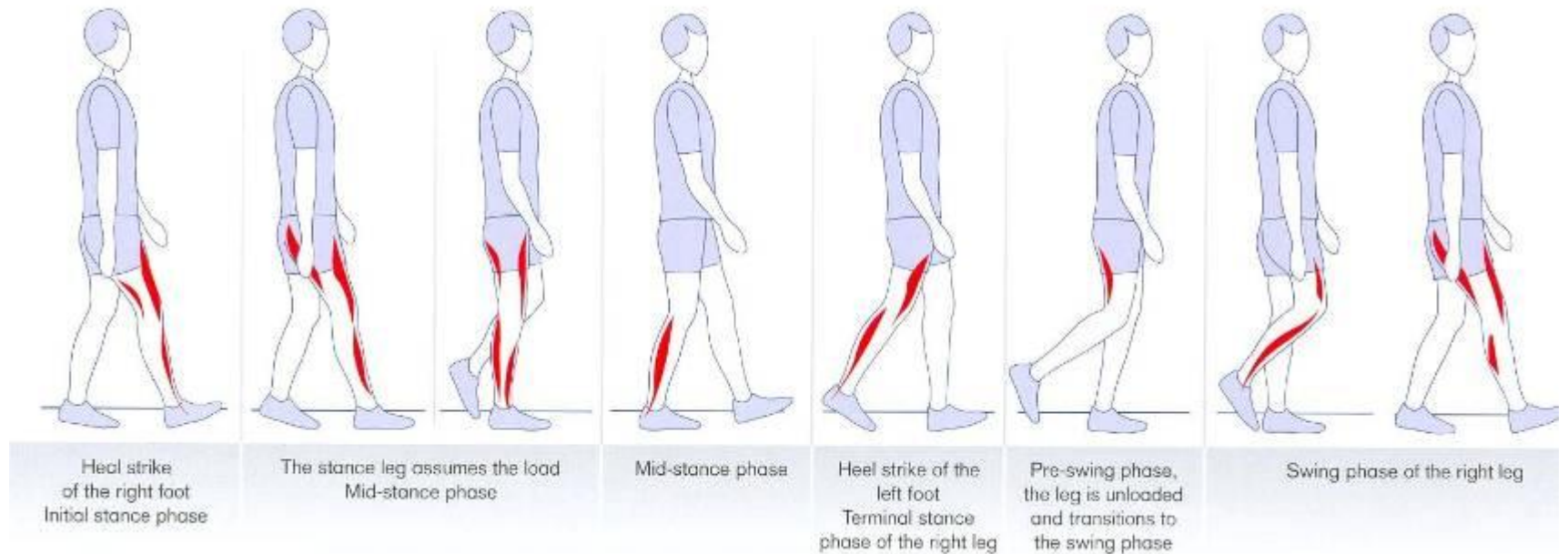
## Operating principle stance phase controlled knee joints

### Why stance phase controlled knee joints ?

- ✓ Block only if stand on it.
- ✓ Leg can bend in the swing phase.
  
- Cost less energy.
- Less compensation
- Nicer

# Overview knee joints

## Operating principle stance phase controlled knee joints



Locking

Unlocking

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Maakt deel uit van **aim**  
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# Overview stance phase controlled knee joints



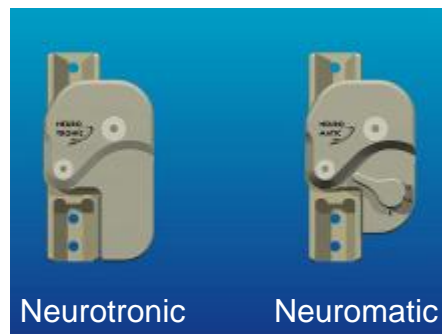
UTX -  
Ambroise



Free Walk –  
Otto Bock



E-MAG active –  
Otto Bock



Neurotronic      Neuromatic  
Fior en Gentz



SPL –  
Basko HealthCare



Sensor Walk  
Electronic –  
Otto Bock USA

# Overview Orthoses, AFOs and KAFOs

Uni lateral knee KAFO with Neuromatic hinges →

Foot lifter spring with adjustable dorsal flexion →

Indications:

- ✓ Quadriceps weakness
- ✓ Weakness of the foot lifter

Contra indications:

- ✓ No movement (or limited) of the ankle joint
- ✓ Incomplete knee extension
- ✓ Active plantair flexors of the foot



# Overview Orthoses, AFOs and KAFOs

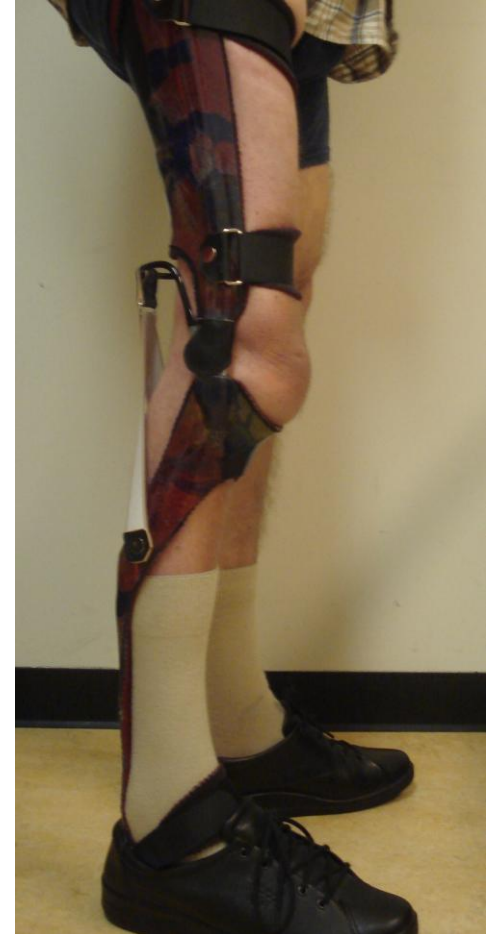
KAFO with locked knee joint and hinge leaf spring →  
Posterior shell above the knee and an anterior shell  
below the knee →

Indications:

- ✓ Quadriceps weakness
- ✓ Foot lifters weakness
- ✓ Arthrodesis of the ankle joint

Contra indications:

- ✓ Weakness of the calf muscle
- ✓ Knee flexion contracture greater than 15 degrees
- ✓ Varus or valgus instability of the knee
- ✓ Hyperextension of the knee



# Overview Orthoses, AFOs and KAFOs

KAFO with stance control Neuromatic knee joint. Ankle joint with foot lifter spring, adjustable dorsiflexion →

Circular leather sleeve for thigh and sandal for the foot.  
Pelvis support by tuber bar →

## Indications:

- ✓ Varus or valgus deformity of the knee
- ✓ Hyperextension of the knee
- ✓ Calf muscles weakness
- ✓ Hamstring weakness
- ✓ Leather sandal indicated in severe deformation of the foot
- ✓ Leather support for soft tissue proximal



# Overview Orthoses, AFOs and KAFOs

KAFO with stance control knee joint SPL (Swing Phase Lock). Joints unilateral →

Ankle joint with foot lifter spring, dorsalflexion adjustable. Anterior shells →

## Indications:

- ✓ Quadriceps weakness
- ✓ Weakness of the foot lifter

## Contra indications:

- ✓ No movement (or limited) of the ankle
- ✓ Incomplete knee extension
- ✓ Knee flexion contracture greater than 15 degrees
- ✓ Varus or Valgus instability of the knee
- ✓ Hyperextension of the knee



# Overview Orthoses, AFOs and KAFOs

AFO posterior shell with carbon leaf spring →

Indication:

✓ Foot lifter weakness

Contra indication:

✓ Hyperextension of the knee (more than 5 degrees)



# Overview Orthoses, AFOs and KAFOs

AFO anterior shell. Ankle joints dorsalflexion stop and foot lifters spring →

## Indications:

- ✓ Foot lifter weakness
- ✓ Calf muscle weakness (correction of the knee to extension midstance and terminal stance)

## Contra indications:

- ✓ Hyperextension of the knee (more than 5 degrees)
- ✓ Contractures of the ankle joint (dorsal flexion).



# Overview Orthoses, AFOs and KAFOs

AFO rigid, posterior pre-preg circular leather →

Indications:

- ✓ Foot lifter weakness
- ✓ Calf muscle weakness
- ✓ Prevents plantairflexion and dorsiflexion
- ✓ Controls hyperextension in the knee (GRF)
- ✓ Leather sandal used in case of an unstable midfoot
- ✓ Compensate for leg length difference



# *Designing & manufacturing light weight full contact orthosis*

Light weight full contact orthosis what is the benefit ?

- ✓ Less energy consumption during walking
- ✓ Full contact principles, more stability.
- ✓ Mechanical properties give the possibility to produce subtle
- ✓ Cosmetic benefits

# Conclusion

- ✓ Best results are achieved when Rehabilitation Doctors, Clients Orthopedic Technicians, and Physical Therapists work closely together in a team.
- ✓ Orthosis which are made of carbon composites and made according full contact principle, have advantages (strong light. subtle, stable) as compared to the conventional orthosis.
- ✓ Manufacturing of carbon orthoses should be centered to ensure high quality of devices (expertise center). Orthosis to be manufactured with a proper fit and function. is much knowledge about this group of customers requires



Maakt deel uit van 