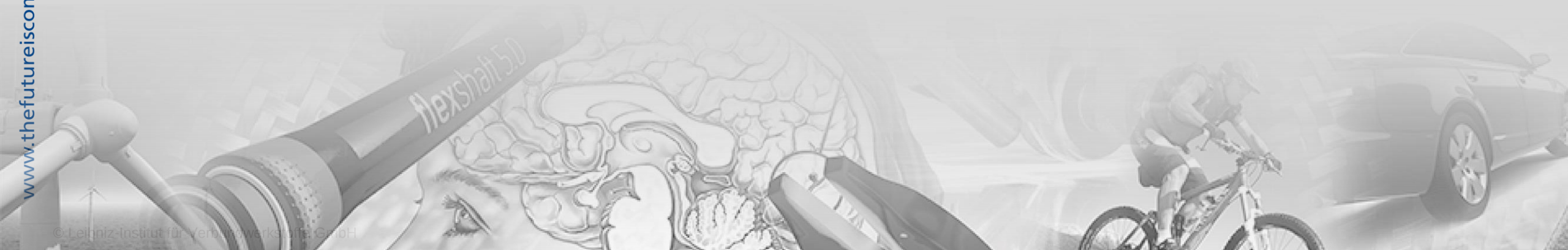
3DPrint2Fiber – Fiber reinforced ankle foot orthosis

Ulrich Blass

Leibniz-Institut für Verbundwerkstoffe



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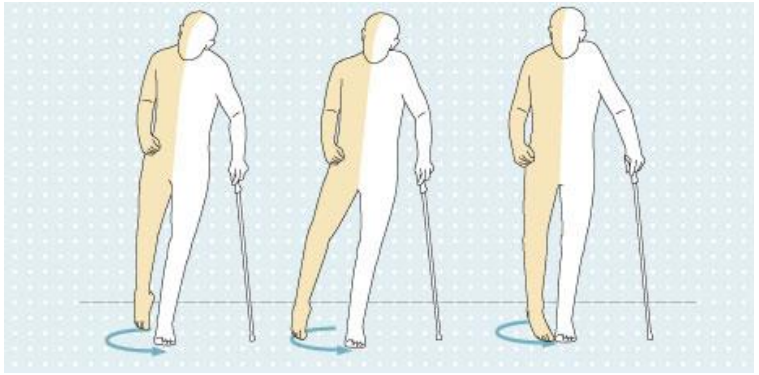
Motivation

Prosthesis

Orthosis

https://www.spineandlasercenter.com/drop-foot/



Stroke Guide: A concept for the Orthotic Treatment of the Lower Extremity following a Cerebral Vascular Accident

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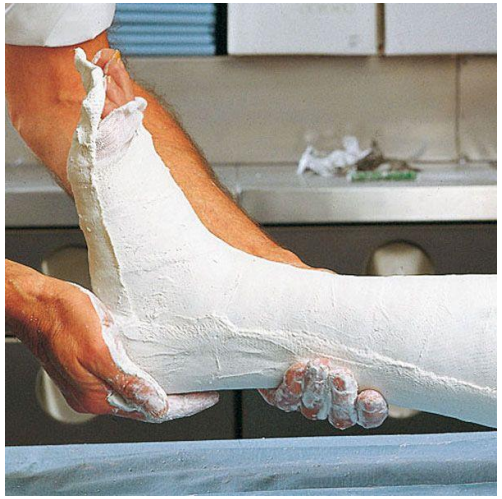
State of the art

current production process of orthoses



- production is based on a **blaster cast**
- **manually** laminated and cured in an autoclave
- process is expensive and **time consuming**
- just a **little post-processing** possible

project goal

- ✓ **fast** and cheap **production process**
- ✓ **individual** adaptable
- ✓ easy adaptation **on-site**
- ✓ **lightweight** design
  → improvement of the wear comfort

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Process chain

1. Scan

2. Design

3. CAD Model

4. 3D Print

5. Fiber Reinforcement

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Requirements

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Requirements

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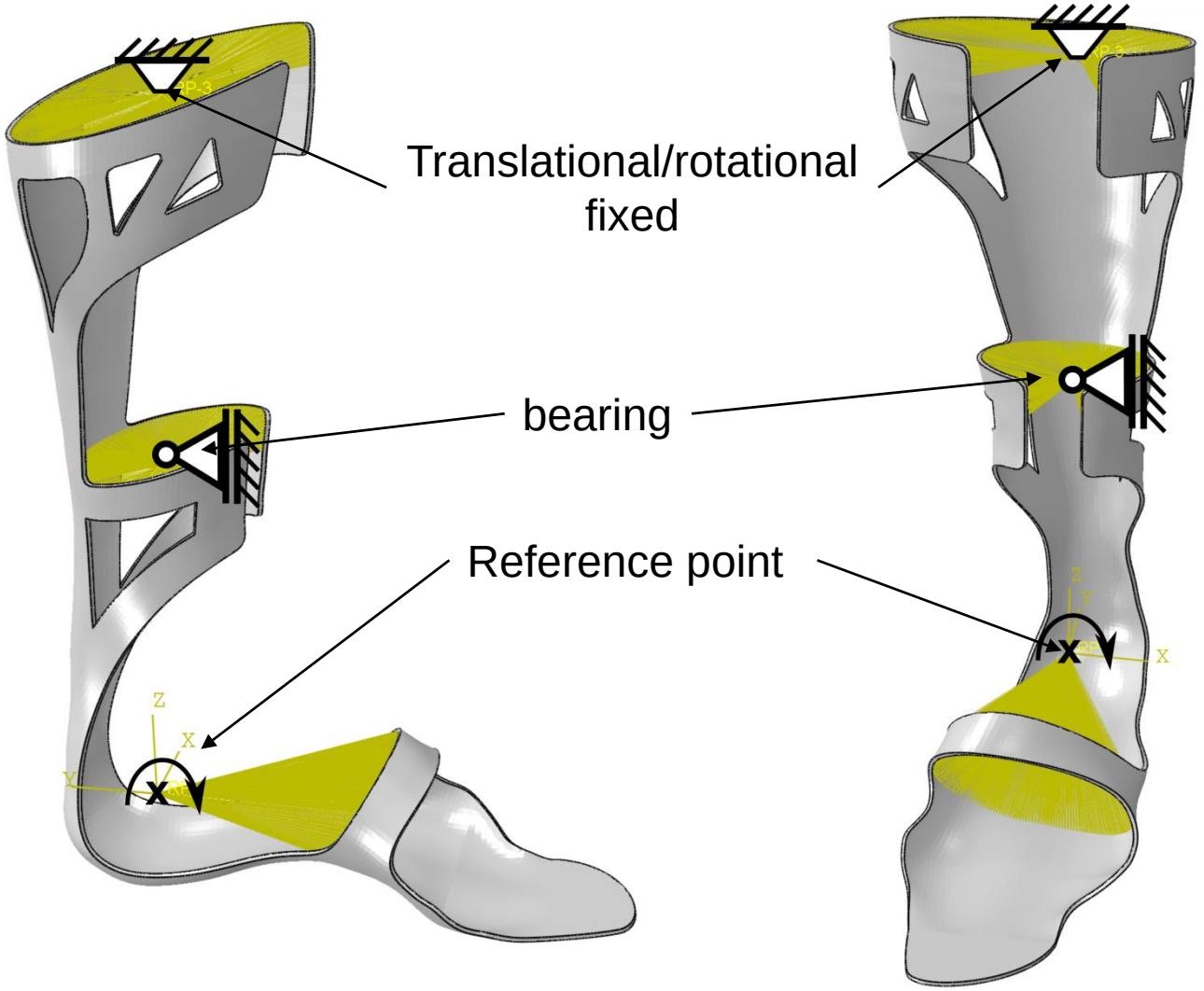
Finite element model



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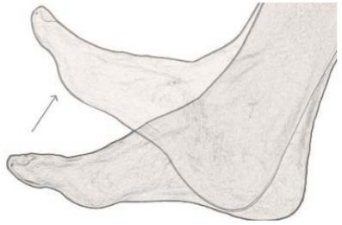
Load cases

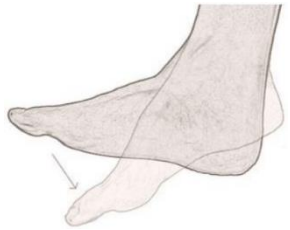
dorsiflexion
15°



abduction
10°

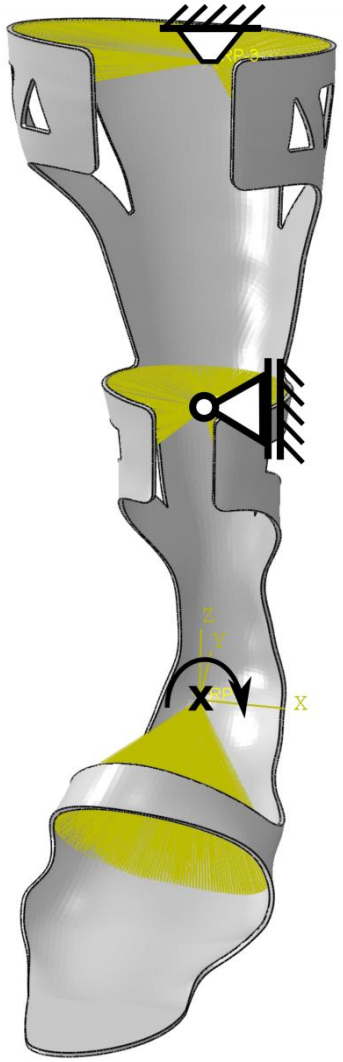
eversion
10°

plantarflexion
20°



adduction
10°

inversion
10°



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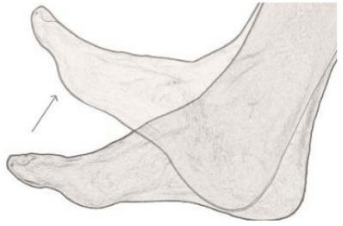
Load cases

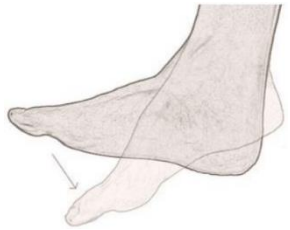
dorsiflexion
15°



abduction
10°

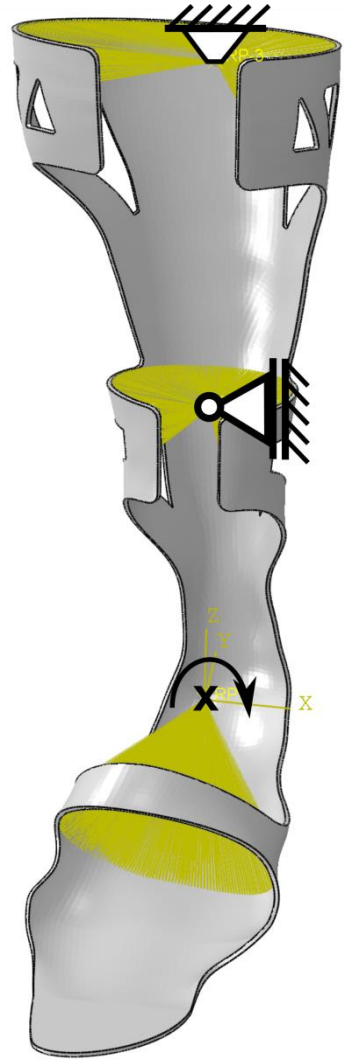
eversion
10°

plantarflexion
20°



adduction
10°

inversion
10°



Conditions:

1. strain < elongation at break of ud-tape (1,34%)
2. stress < strength of PA 12 (50 MPa)

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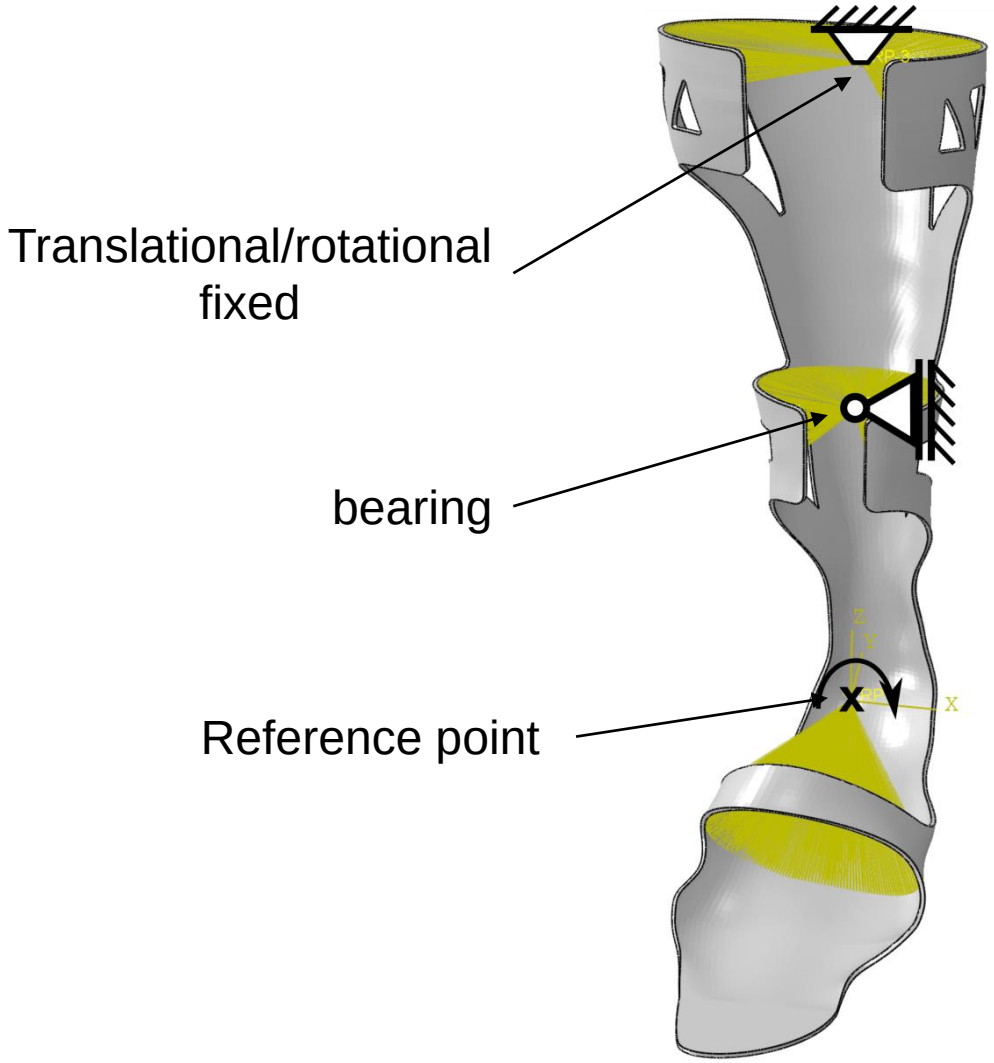
Master foot



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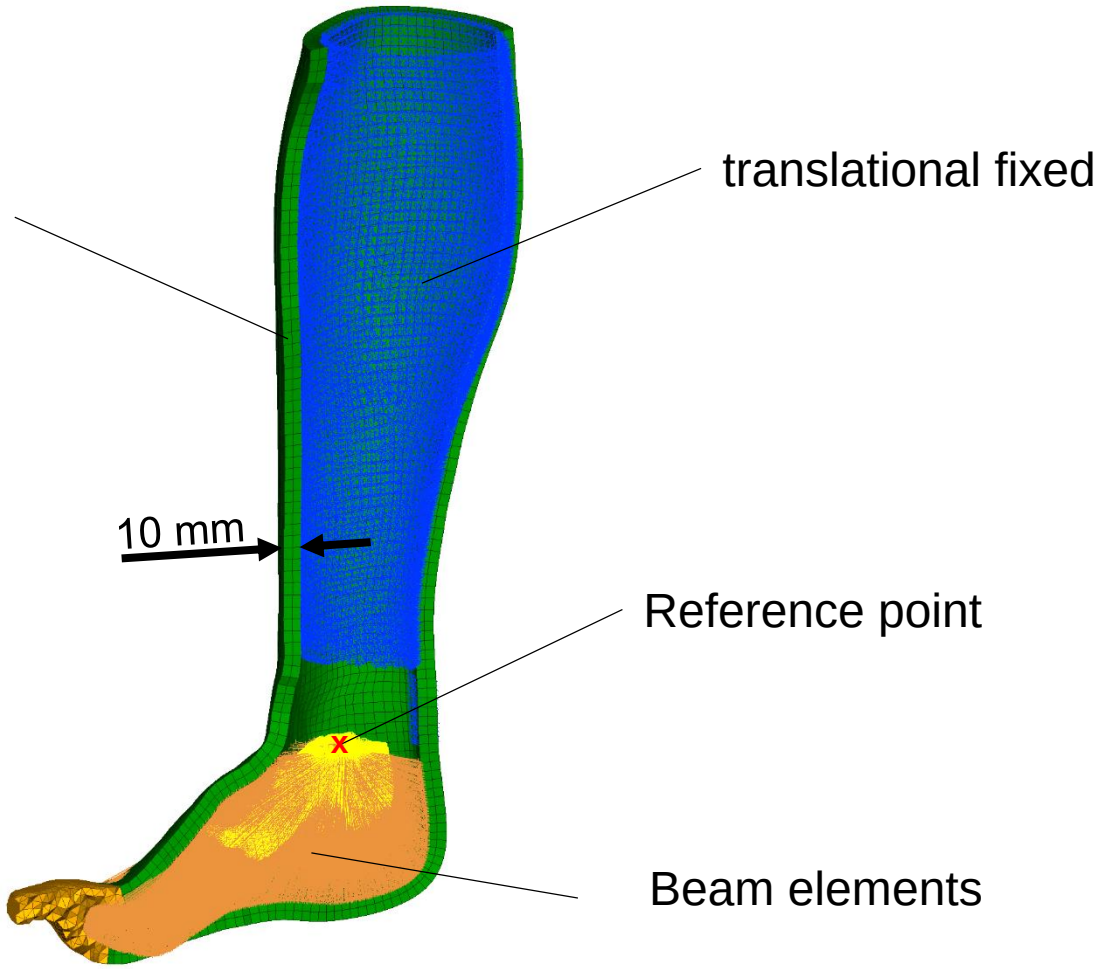
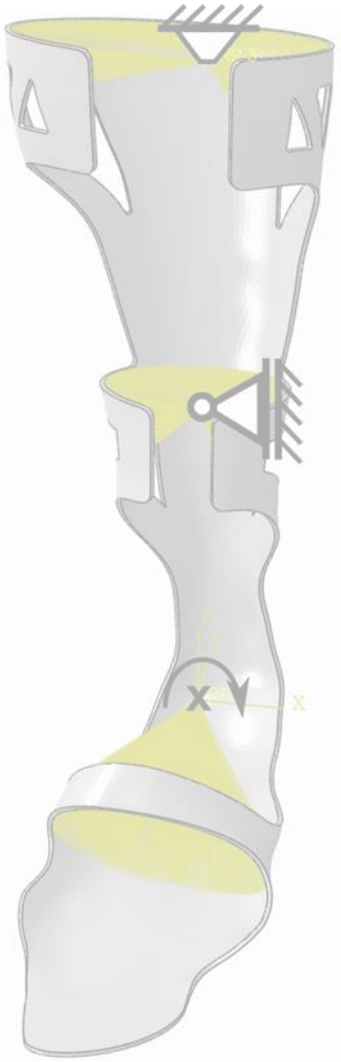
Master foot





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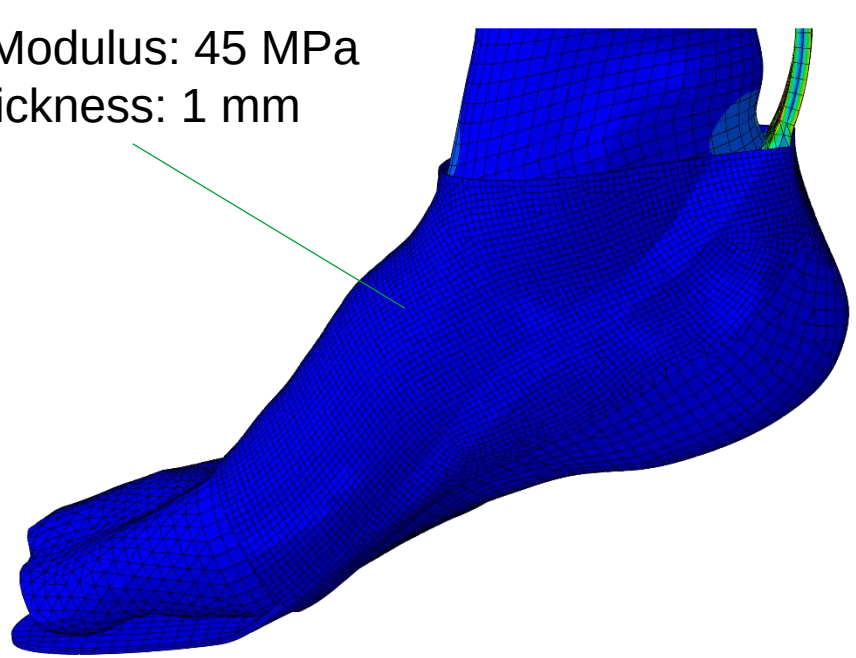
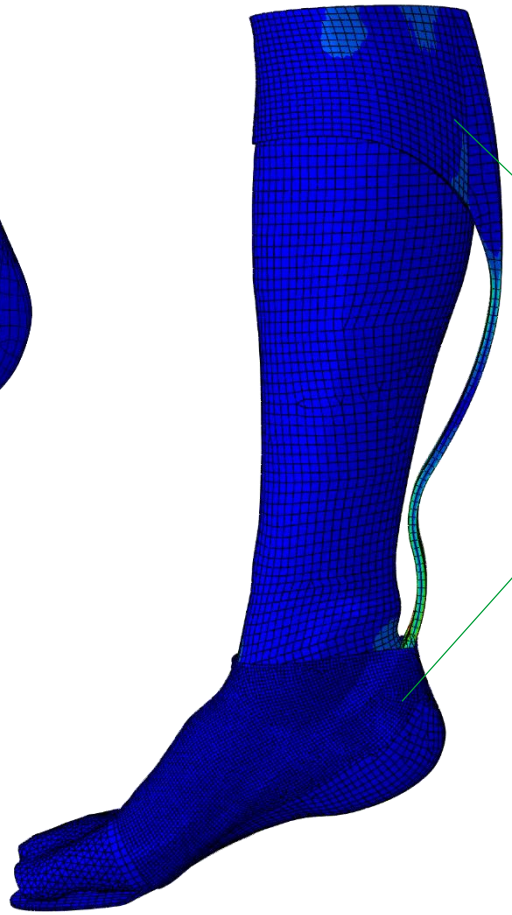
Digital shoe

Orthoses with „shoe“

E-Modulus: 45 MPa
Thickness: 1 mm





General contact:
μ = 0.2

<u>Plantarflexion</u>:
Foot loses contact with orthoses
→ Tie constraint

<u>Dorsiflexion</u>:
Orthoses penetrates foot

➡ Digital shoe

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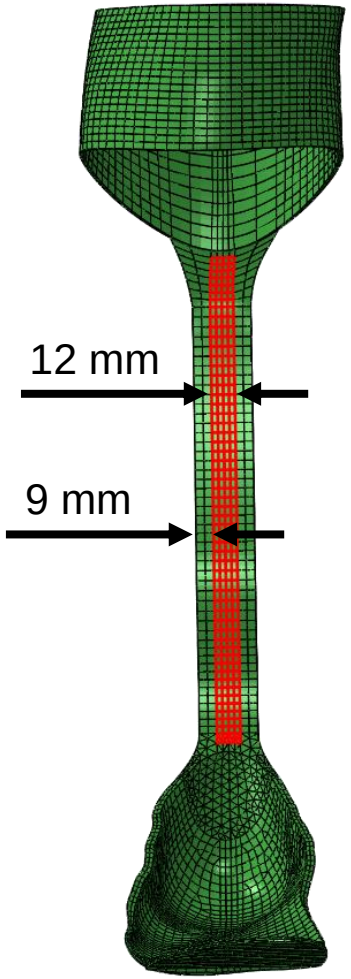
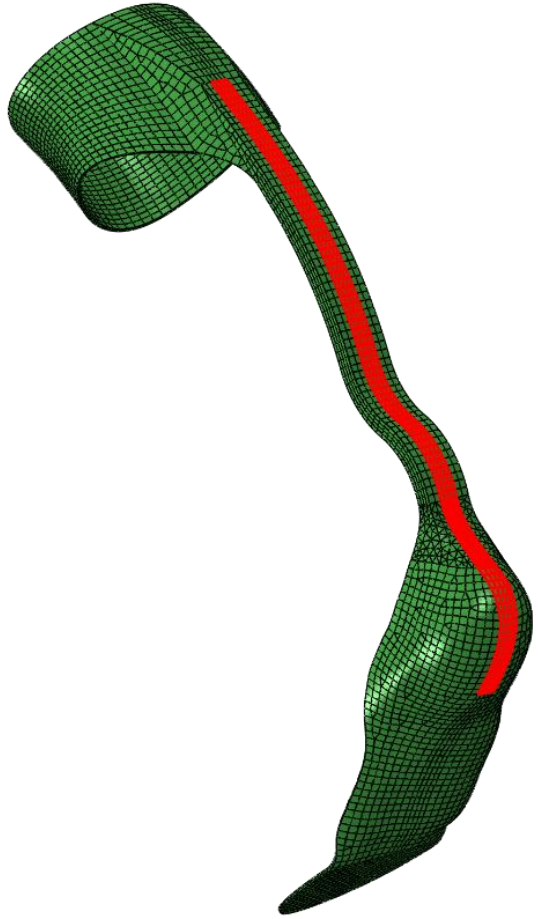
Basic AFO design

UD-Tape on the inside



UD-Tape on the outside



Requirements

- Easy to reinforce: Only straight tape laying path
- Light weight design: not more material than needed
- High stiffness and strength: thickness of spring adjustable
- Wearable under clothes: fits closely to lower leg

Material: PA 12
- E-Modulus = 1400 MPa
- Poisson´s ratio = 0.4

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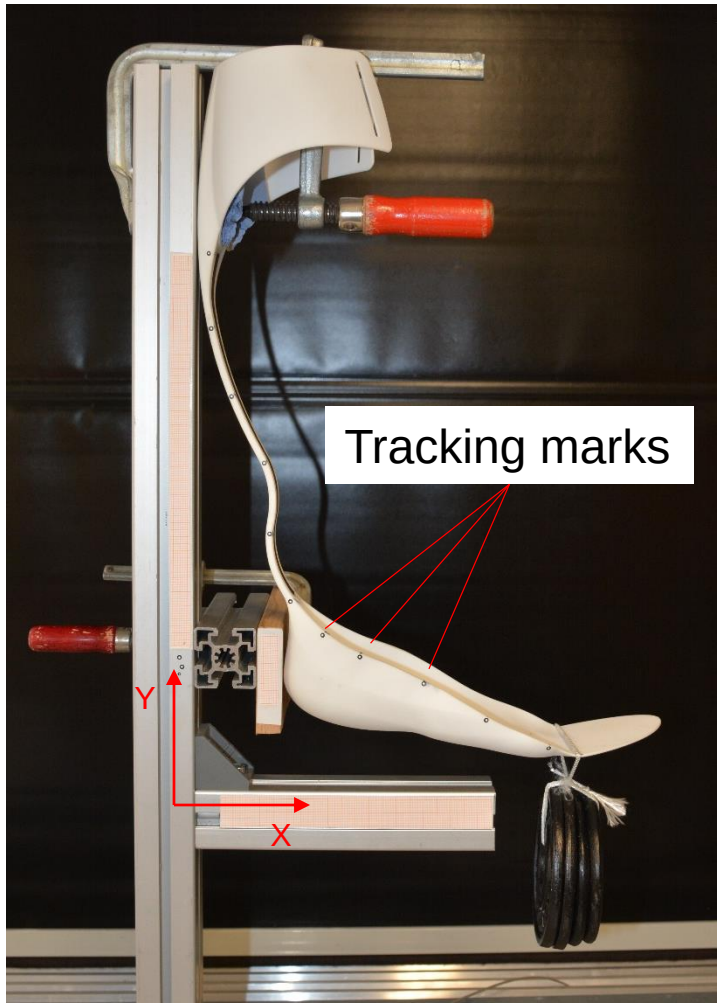
FE model validation



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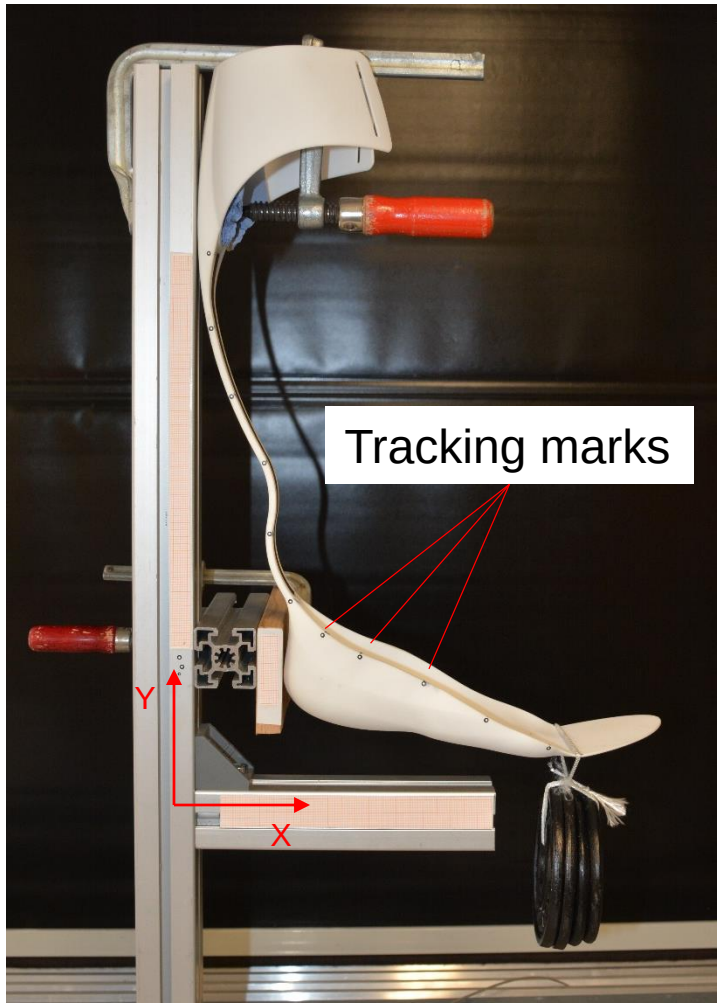
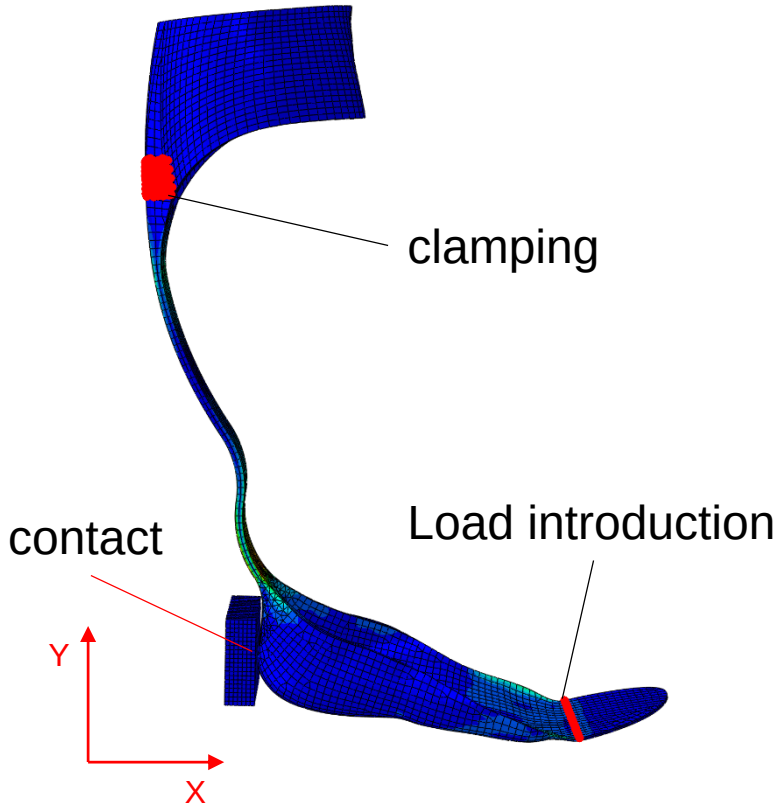
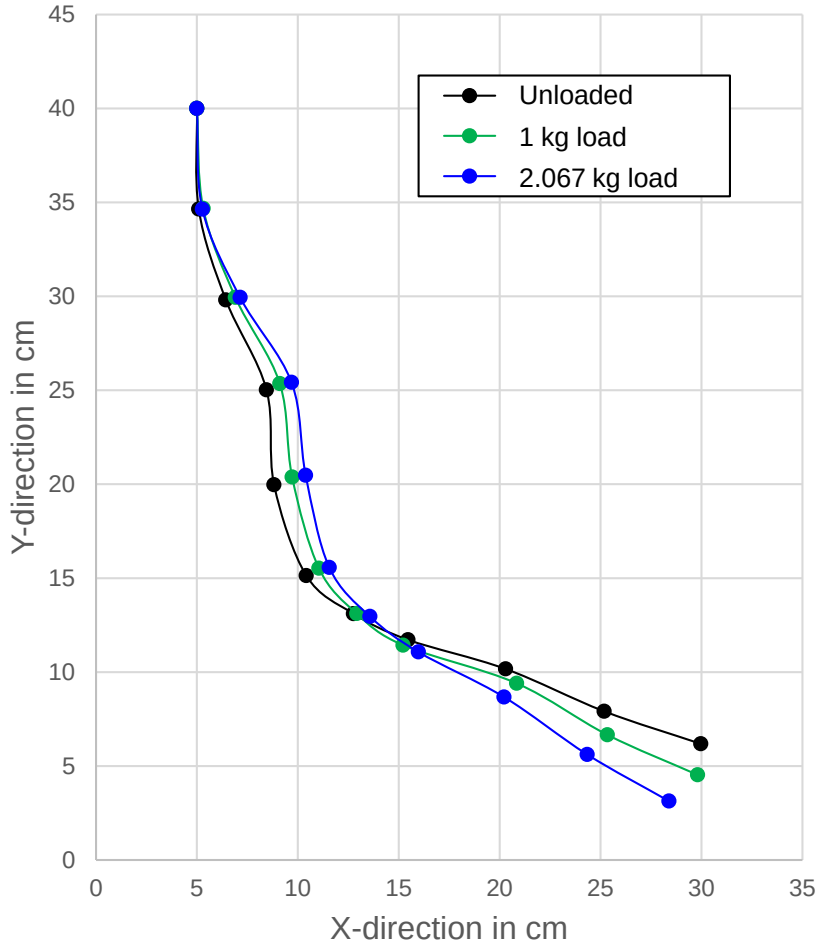
FE model validation



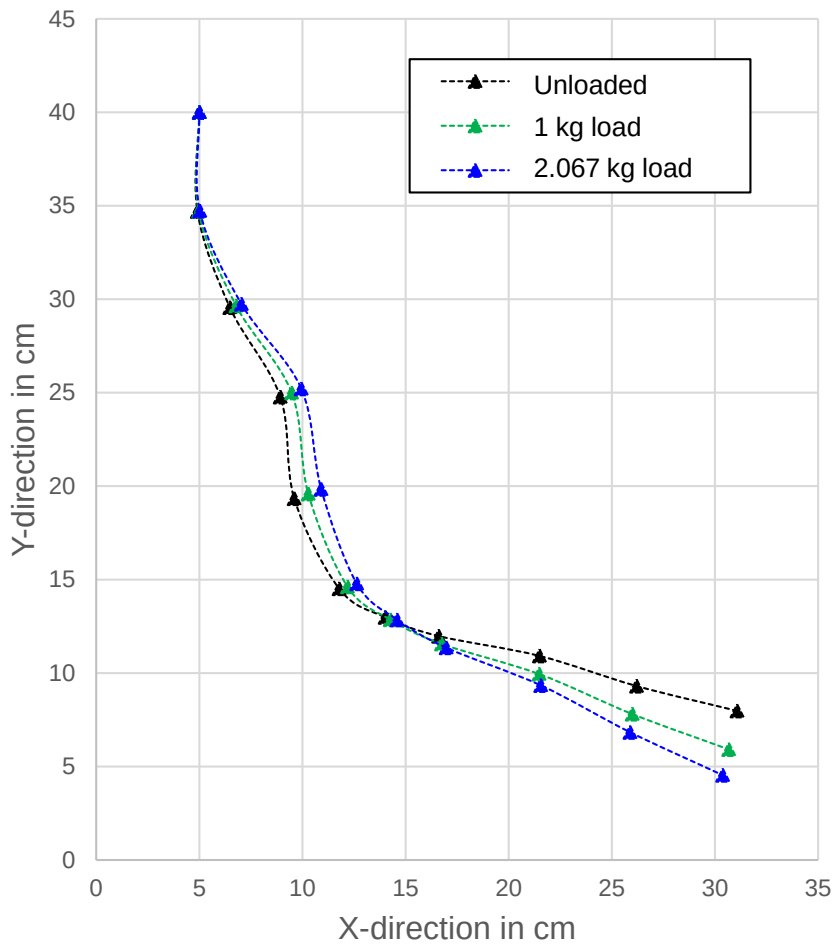


FE model validation

Experimental results



Simulation results



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Process chain

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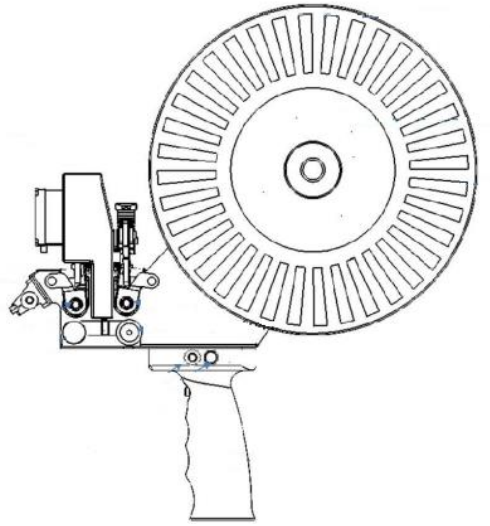
Hand held tape-laying device

Tape laying process

- Adjustable process temperature
- Adjustable process velocity
- Feed back about contact pressure



Operability

- Usable without special training
- Usable on site
- Easy to use without time-consuming preparation

Economy

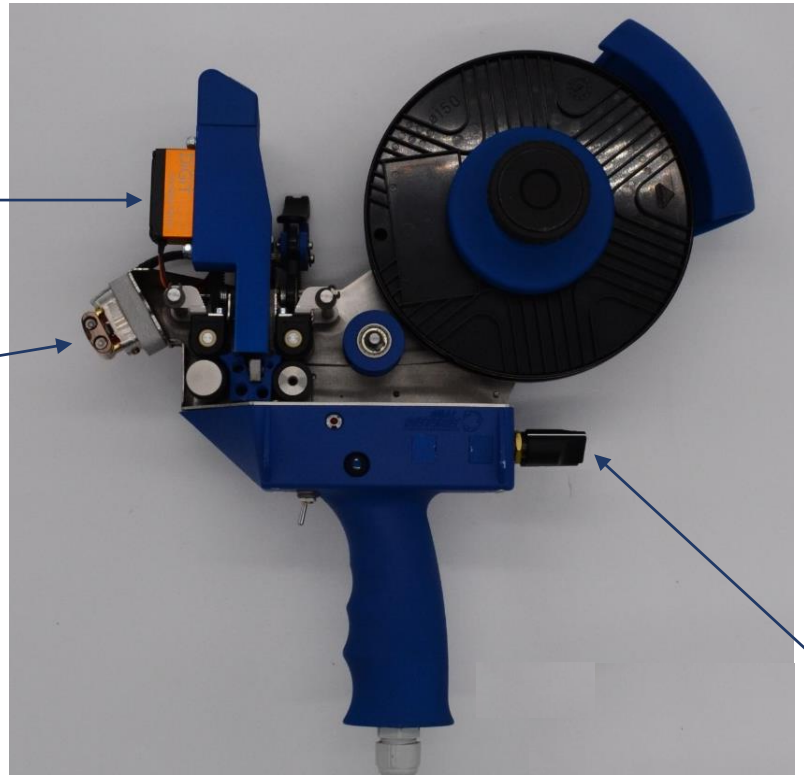
- Low acquisition and process cost

Hand held tape laying device

LCD display:
target / current temperature

Controller
cartridge heaters

Cartridge heaters



Controller for process
temperature

- Controlling of the process temperature by cartridge heaters

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Hand held tape laying device

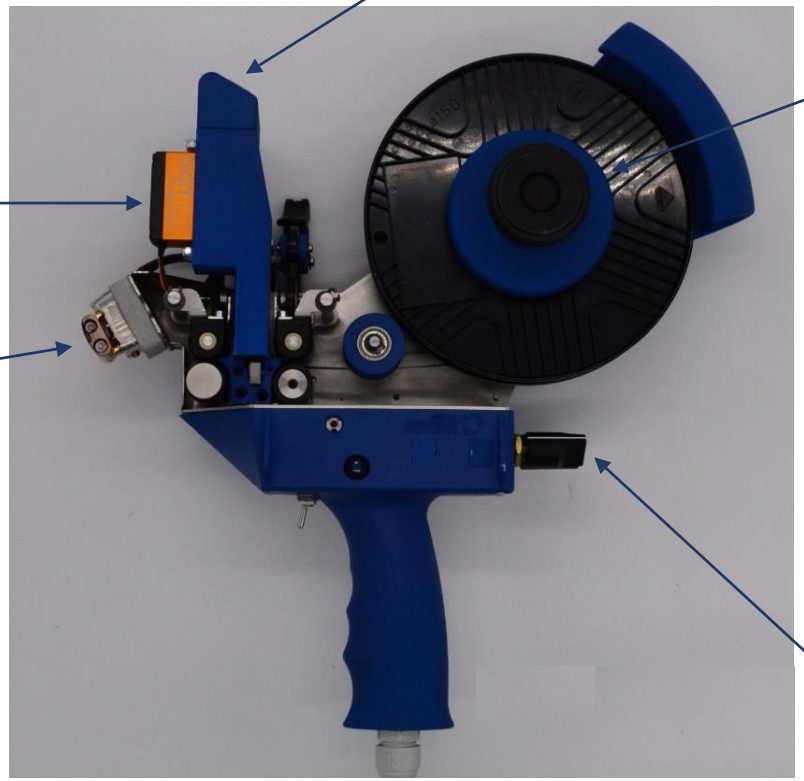
LCD display:
target / current temperature
target velocity

Current velocity

Velocity sensor

Controller
cartridge heaters

Cartridge heaters



Controller for process
temperature and velocity

- Controlling of the process temperature by cartridge heaters
- Controlling of the process velocity by rotation of the tape spool

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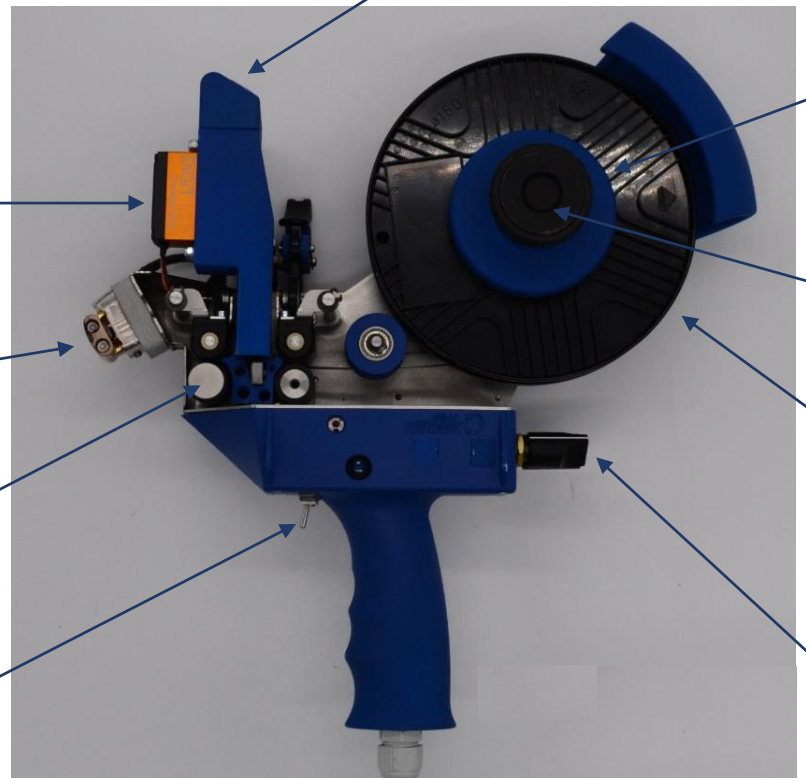
Hand held tape laying device

LCD display:
target / current temperature
target velocity



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- Controlling of the process temperature by cartridge heaters
- Controlling of the process velocity by rotation of the tape spool
- Easy to use by easy solutions

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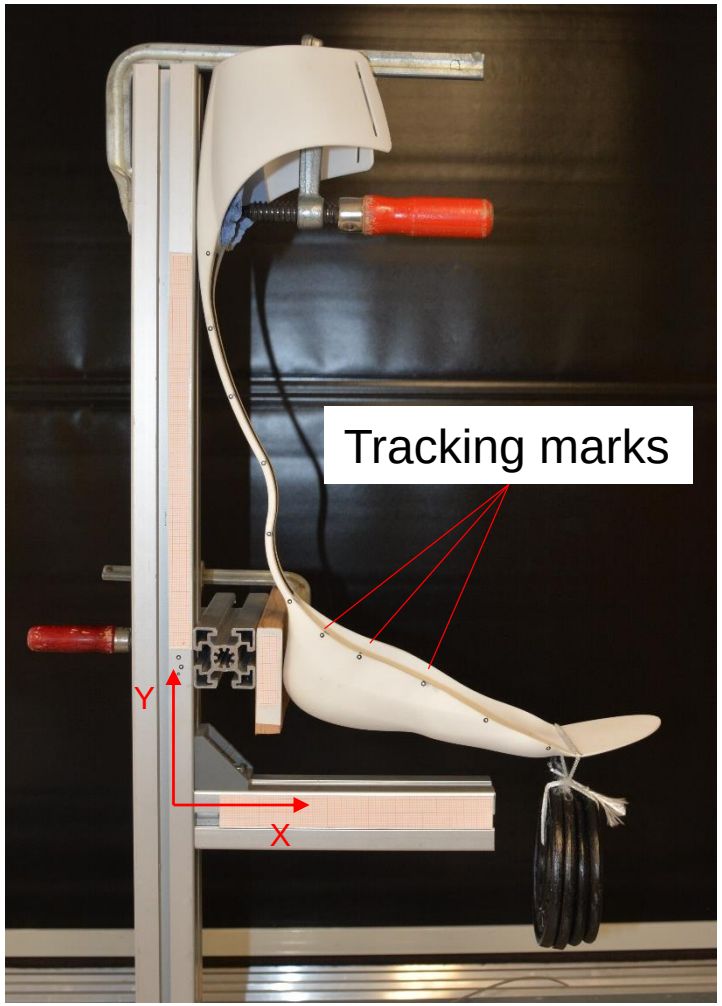
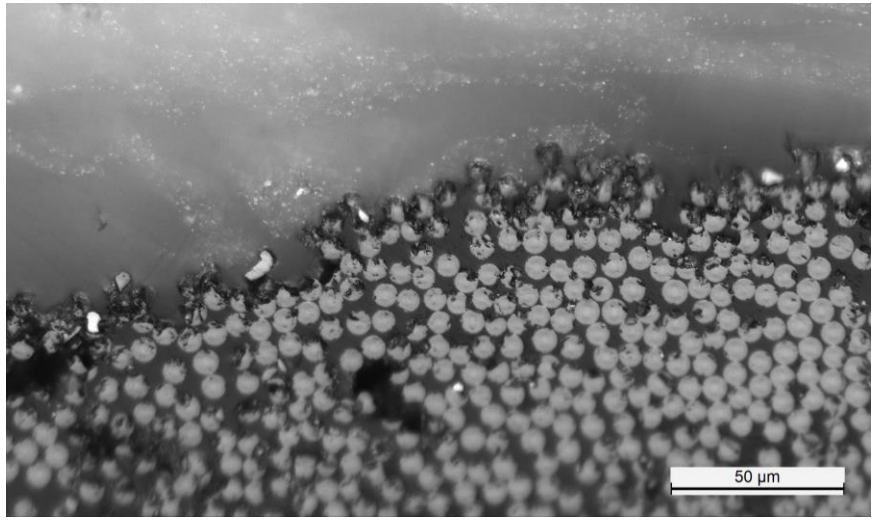
Reinforced AFO



Fiber tape:

- Matrix material: PA 12
- Fiber material: Carbon fiber
- Thickness: 0.6 mm
- E-Modulus: 83.000 MPa
- Tensile Strength: 992 MPa



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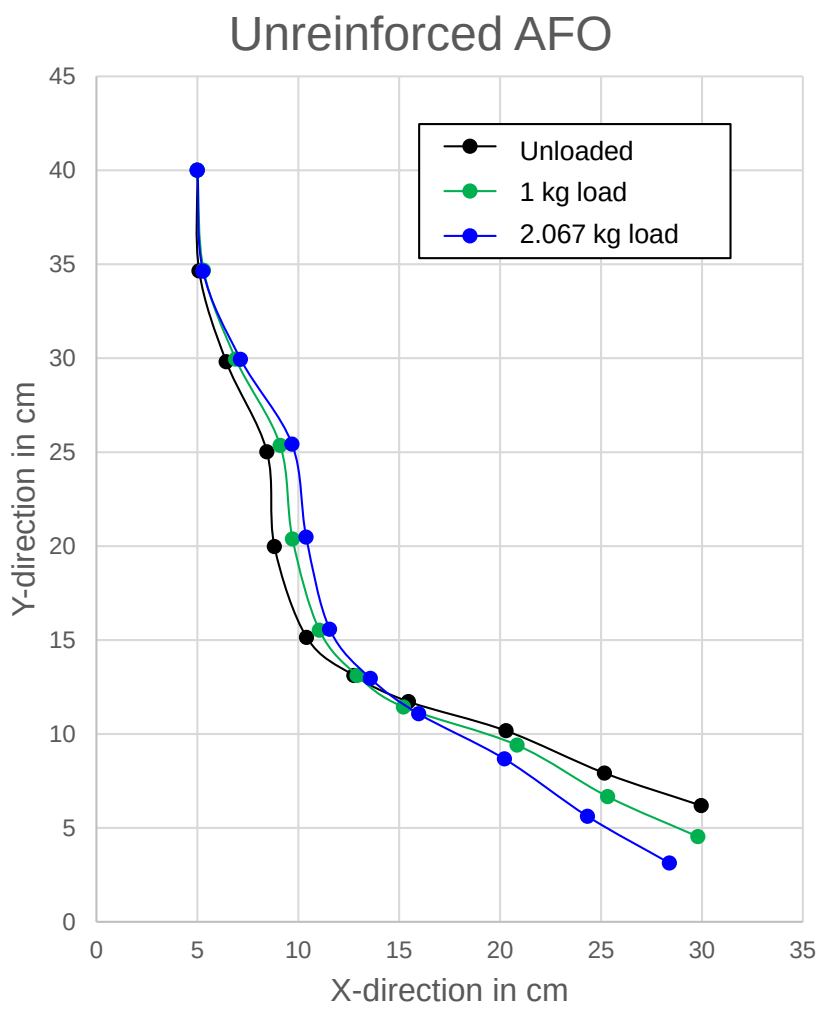
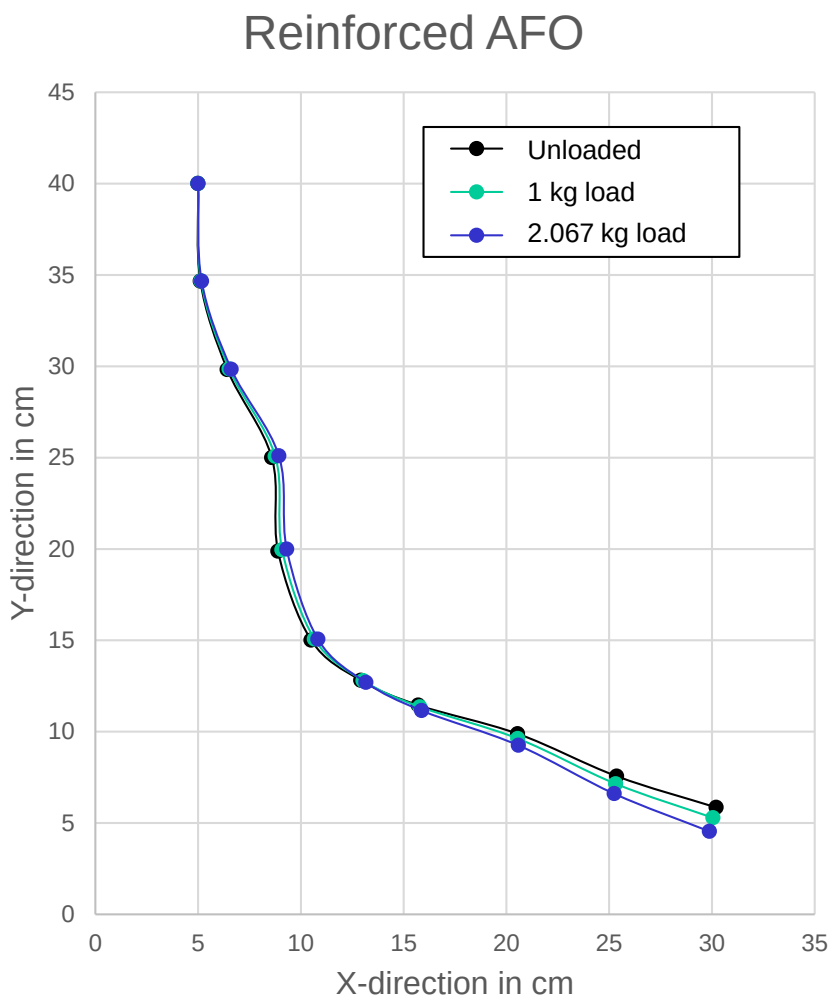
Reinforced AFO





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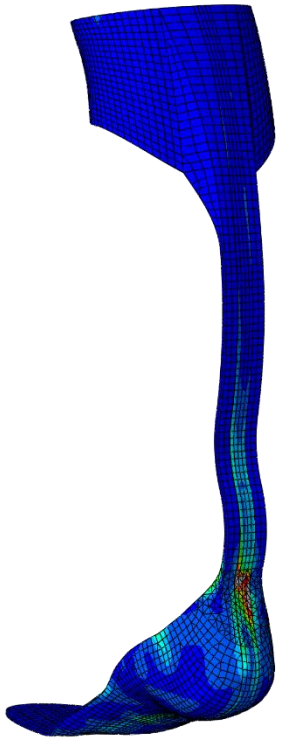
Reinforced AFO

Individualized Ankle Foot Orthoses

- Geometry is automatically adaptable to the anatomy of the patient
- Stiffness is adaptable to the intensity of paralysis
- Reinforcement of the AFO on site
- Improvement of the gait characteristic measured in a gait laboratory



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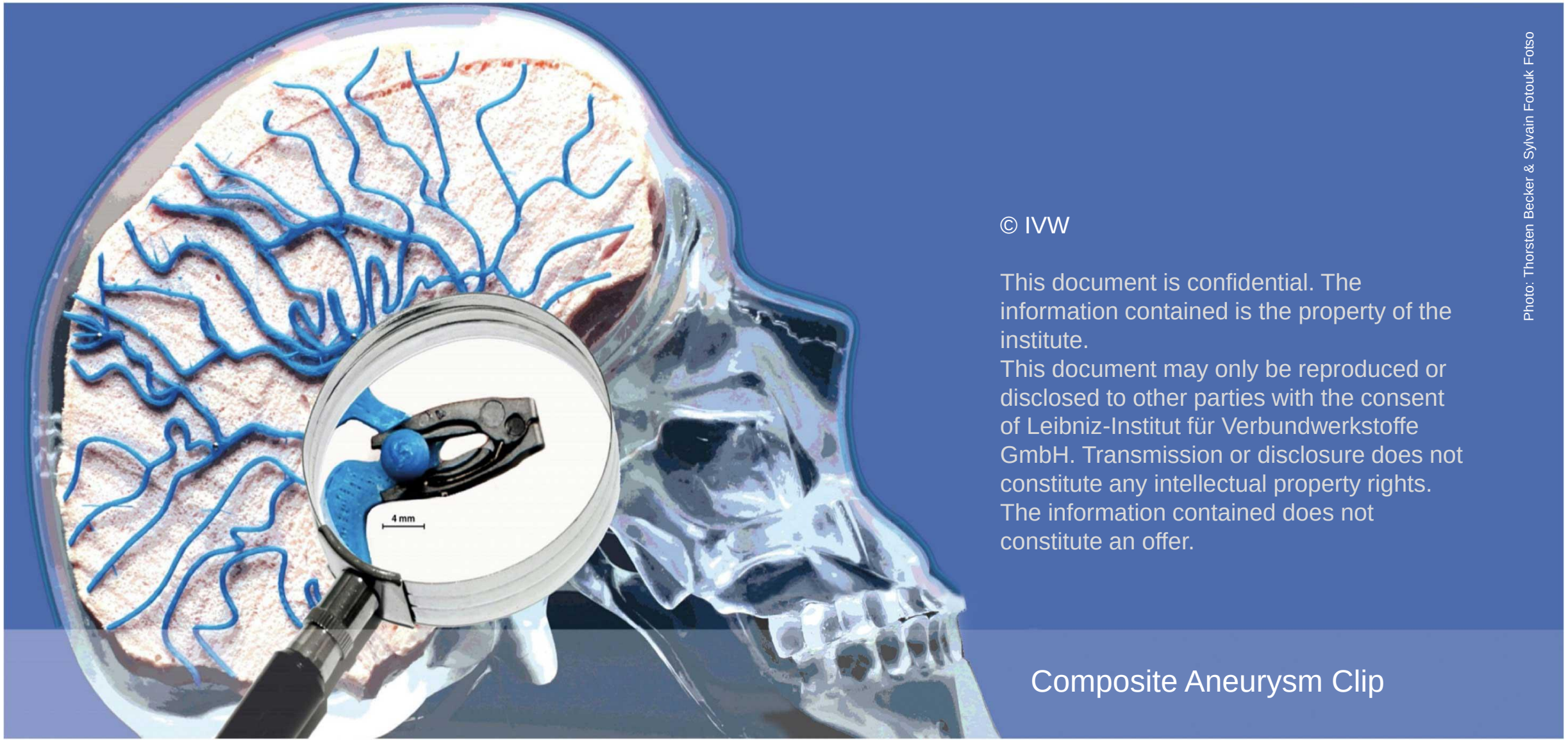

Photo: Thorsten Becker & Sylvain Fotouk Fotso

Composite Aneurysm Clip

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