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Biomechanics of transfemoral amputations

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Quality for life

Reliable knee functionality

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Transfemoral amputees

Variables

- ➔ **Residual limb motor system**
- ➔ **Component features (knee and foot)**
- ➔ **Prosthetic alignment**

Prosthetic alignment

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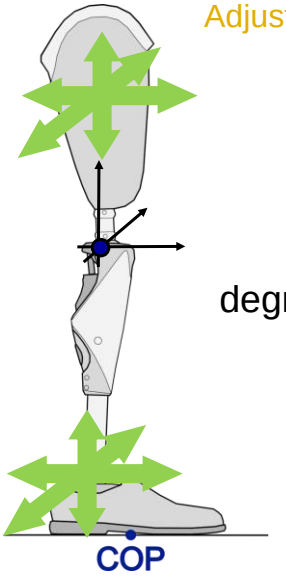
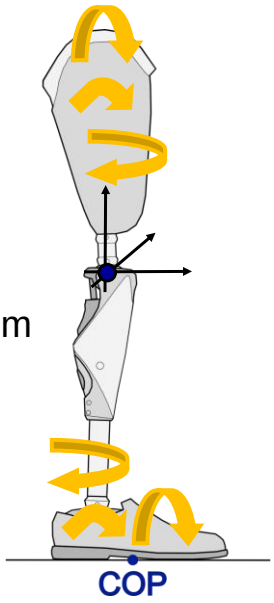
Adjustment options



12
degrees of freedom



Prosthetic alignment: example

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Static alignment: posture

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Residual limb motor system

Hip joint

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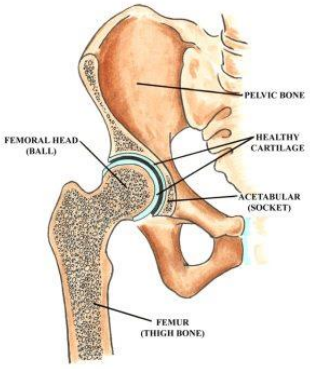
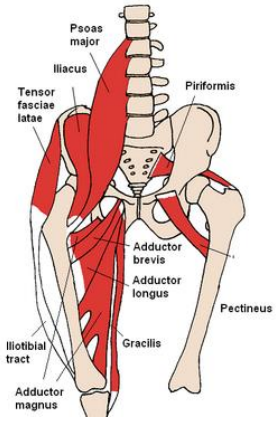
Anatomy



Ball-and-socket joint



Muscular guidance

Biomechanics of the residual limb

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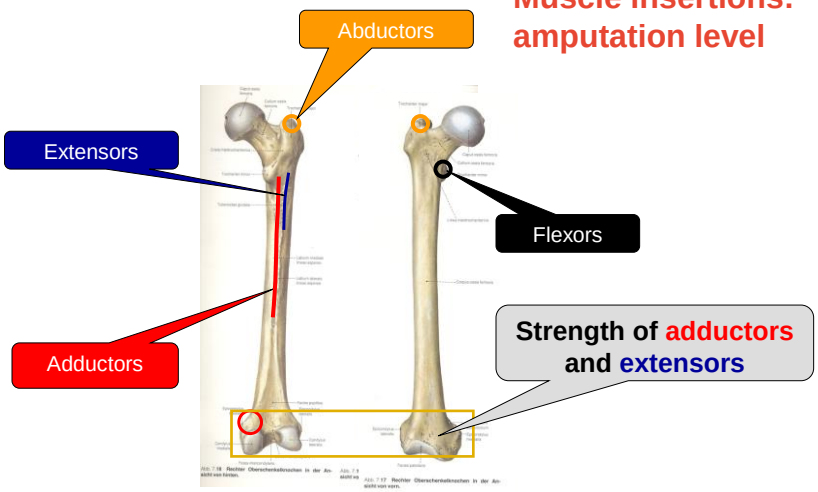
Muscle insertions: amputation level



Blumentritt et al. MOT 6/2009

Biomechanics of the residual limb

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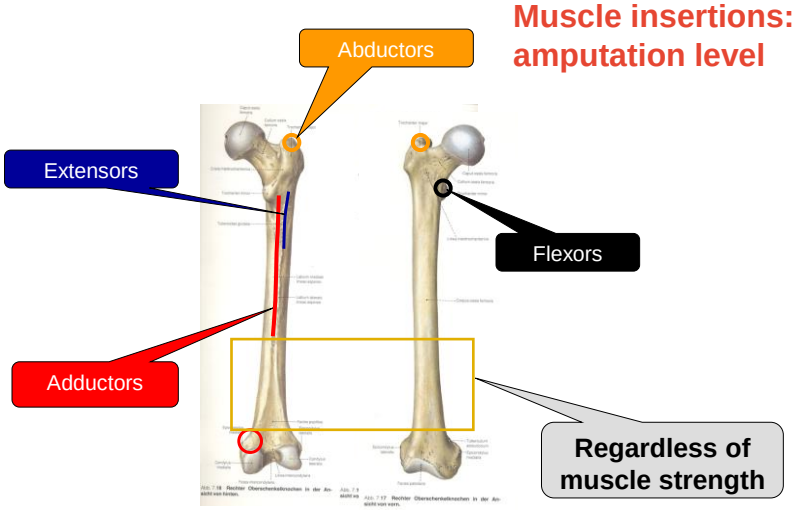
Muscle insertions: amputation level



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Biomechanics of the residual limb

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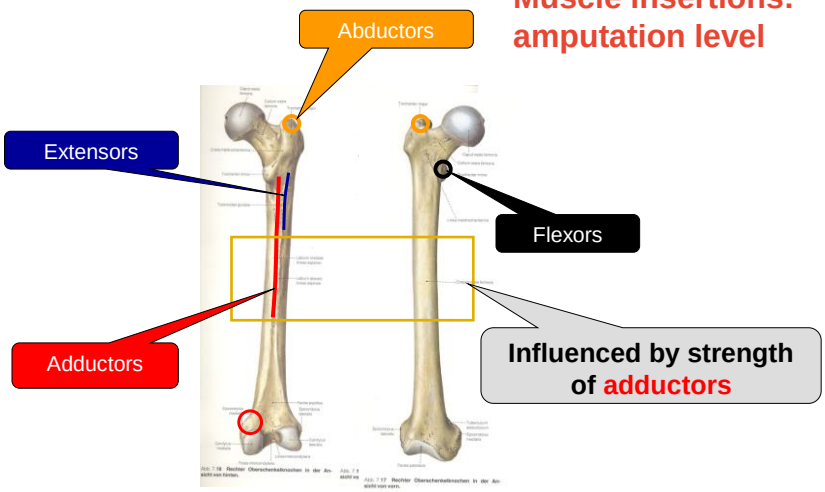
Muscle insertions: amputation level



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Biomechanics of the residual limb

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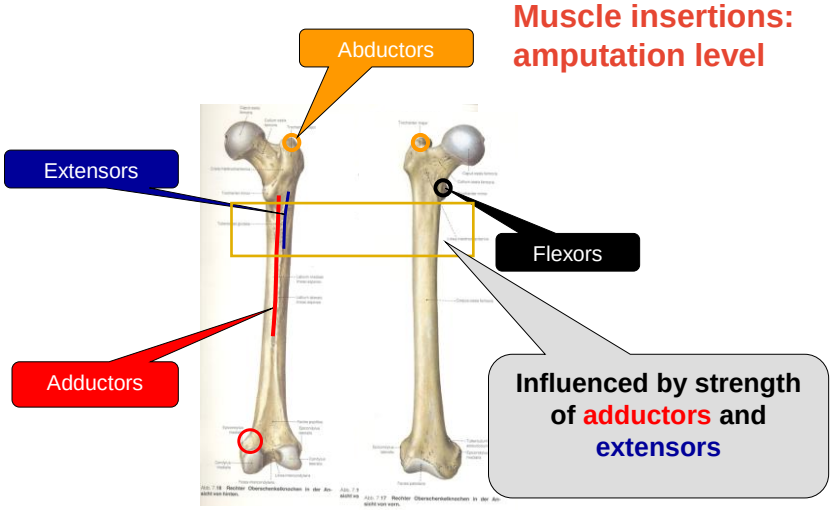
Muscle insertions: amputation level



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Biomechanics of the residual limb

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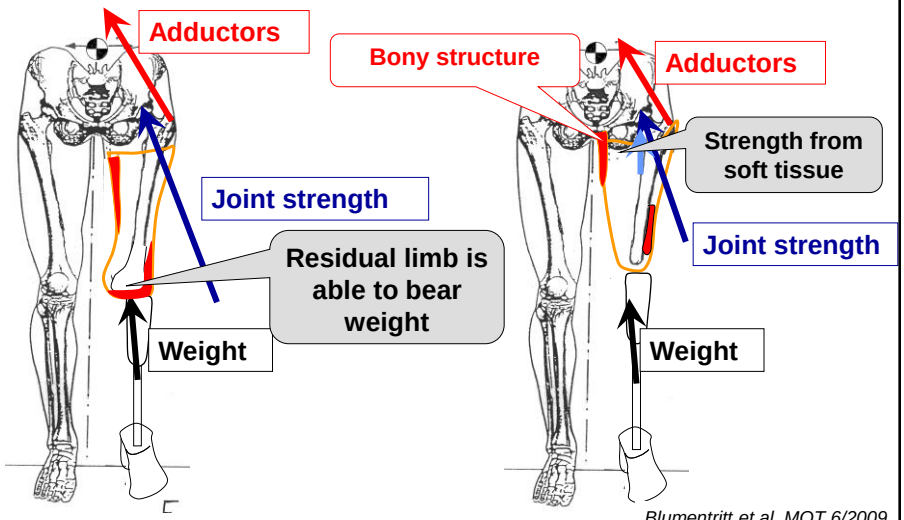
Transmission of forces



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Biomechanics of the residual limb

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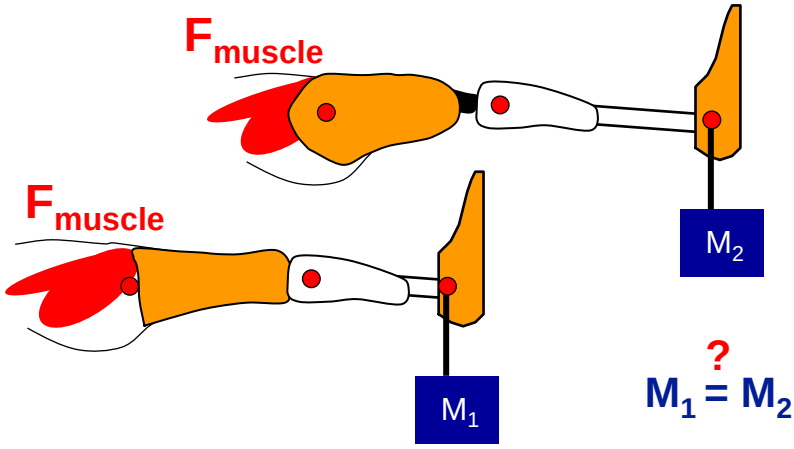
External forces
Load lever



$M_1 \overset{?}{=} M_2$

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Biomechanics of the residual limb

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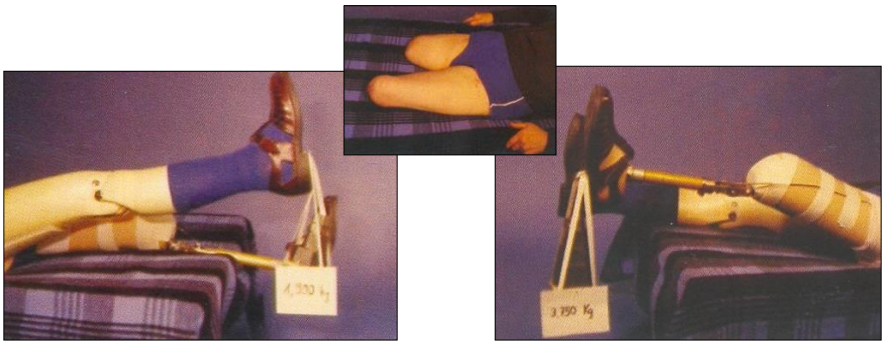
External forces
Load lever



1.900 kg

3.750 kg

Baumgartner R: MOT 5/2006

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Statics
- Standing -

Lower extremities statics

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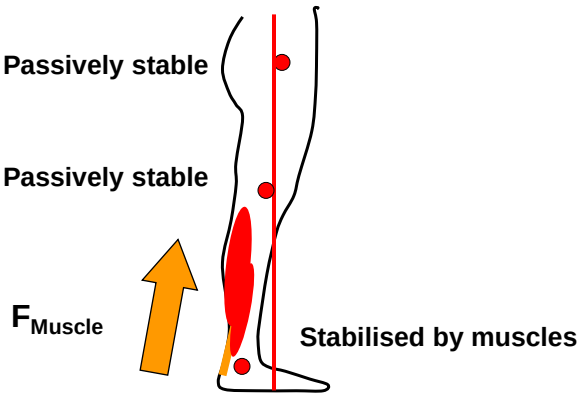
Muscle activity



Transfemoral amputee standing

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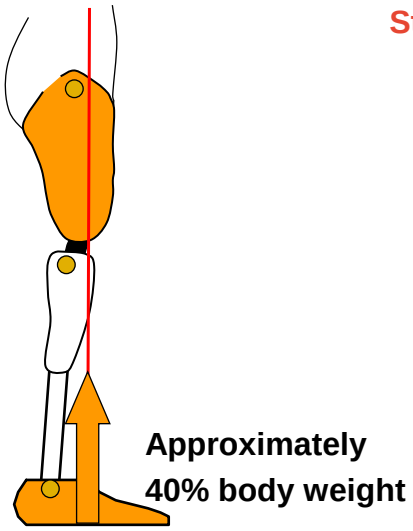
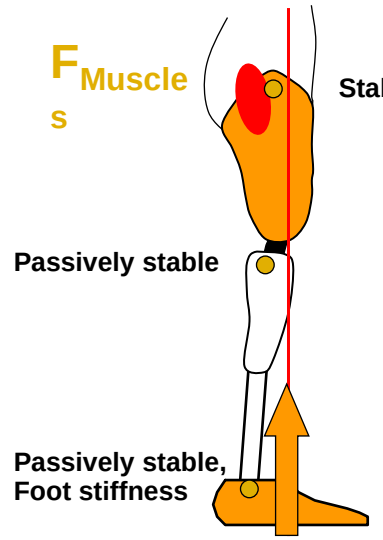
Statics



Transfemoral amputee standing

ottobock.

Statics



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Walking

Biomechanics of the residual limb

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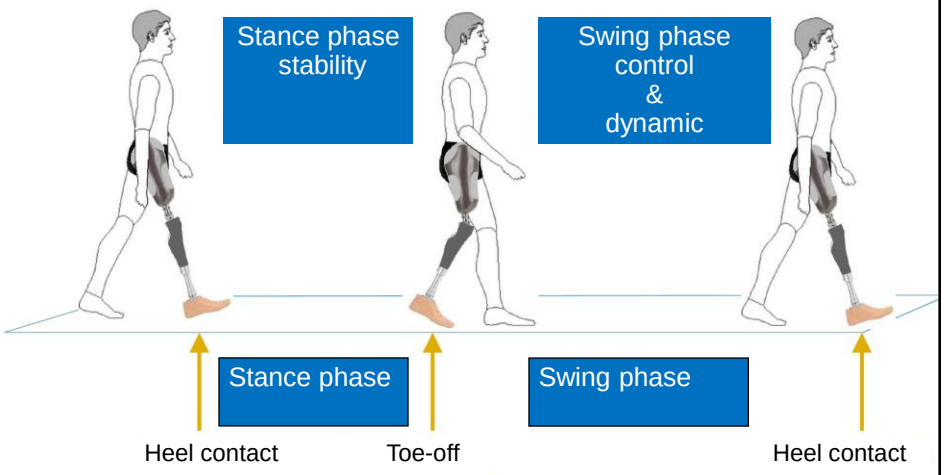
Gait cycle phases



Biomechanics of the residual limb

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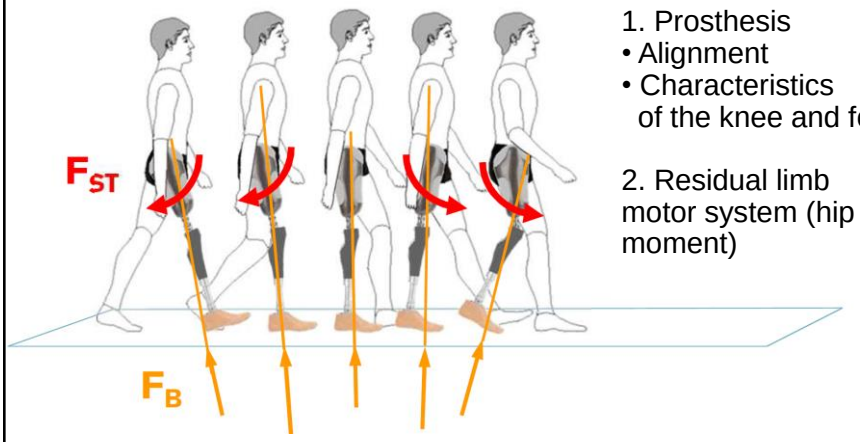
Stance phase stability



1. Prosthesis
   - Alignment
   - Characteristics of the knee and foot

2. Residual limb motor system (hip moment)

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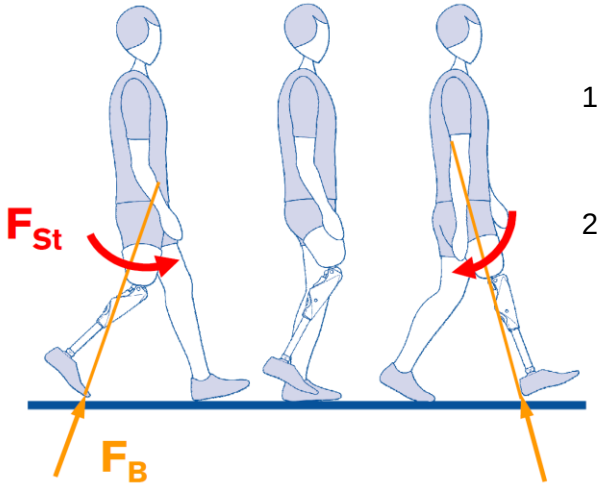
Swing phase control



1. Residual limb motor system (hip moment)
2. Swing phase control

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Alignment of transfemoral prostheses

Transfemoral prosthesis alignment

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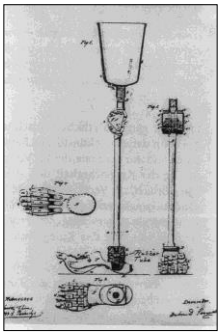
History

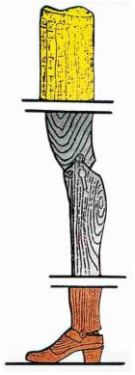
Pare 1586



Parmelee 1863

First "endoskeletal prosthesis"

1919: Otto Bock starts his company



Concept

Transfemoral prosthesis alignment

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History

Up to 1920	Not very systematic
1919	Plumb alignment, contralateral anatomy (Schede, Görlach)

➔ Alignment according to anatomy is unsuccessful

1928	Plumb alignment, load stool (Görlach)
1934	Alignment by balancing (Franke)

➔ Frontal alignment good, sagittal unsuccessful

1969	Pyramid system, modular prosthesis (Glabiszewski, Näder)

➔ Dynamic alignment becomes possible, high level of variability

1997	LASAR Posture, load line (Blumentritt)

Transfemoral prosthesis alignment

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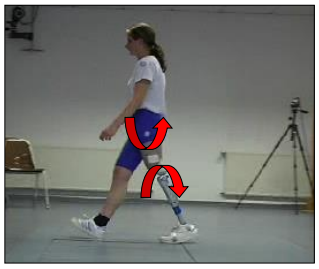
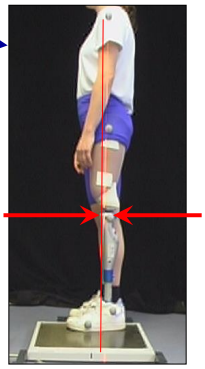
Study process

Assembly

3. Subjective assessment



1. Gait analysis



2. Statics/standing

Transfemoral prosthesis alignment

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Socket flexion

➔ **Experience with fittings with 3 - 5 degree flexion angle**

➔ **with hip flexion contracture?**

Transfemoral prosthesis alignment

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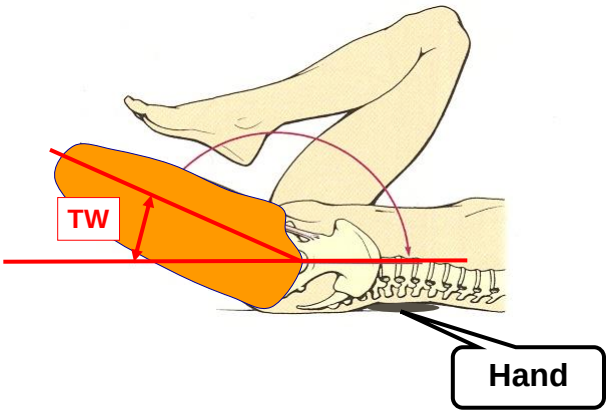
Thomas test



Transfemoral prosthesis alignment

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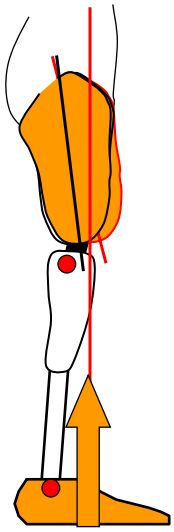
Socket flexion



➔ **Experience with fittings with 3 - 5 degree angles**

➔ **In the case of extension deficit in the hip joint, flex contracture angle (Thomas step) TW plus 5-10 degrees, depending on expected step length**

Residual limb biomechanics

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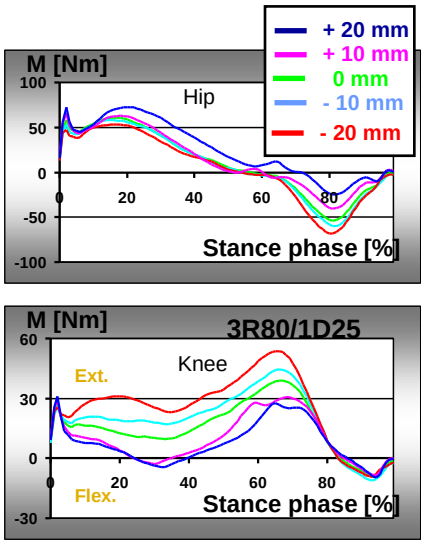

Sagittal knee position

Med Orth Tech 118(1998)51-61

Basis of alignment recommendations

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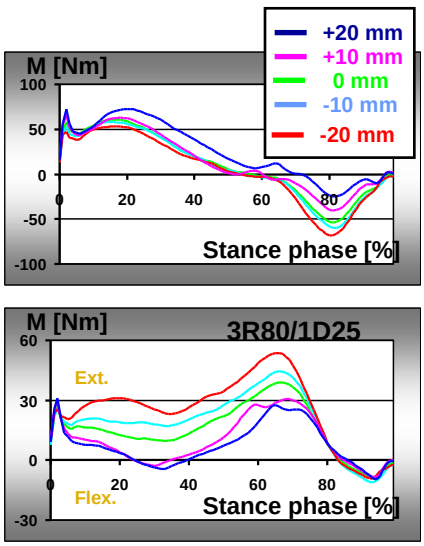

Sagittal knee position

Stance phase stability

With the hip moment necessary for walking, depending on walking speed

Initiation of the swing phase

Correlates to static alignment, regardless of walking speed, based on the patient's feeling

Med Orth Tech 118(1998)51-61

Prosthesis length

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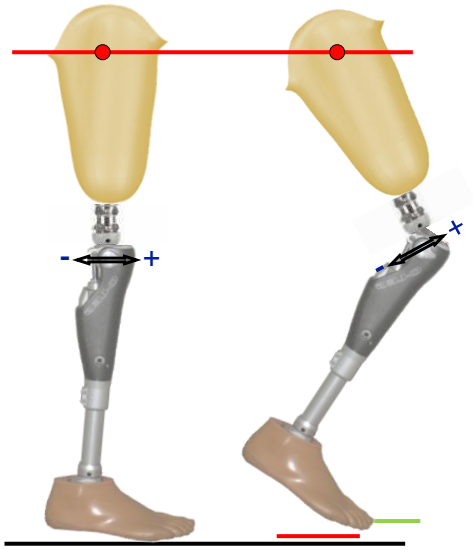

Ground clearance: effect of sagittal knee position

Monocentric joint

Knee position	Δh
- 2 cm	+ 1.5 cm
- 1 cm	+ 0.7 cm
Normal	0 cm
+ 1 cm	- 0.7 cm
+ 2 cm	- 1.3 cm

Transfemoral prosthesis alignment

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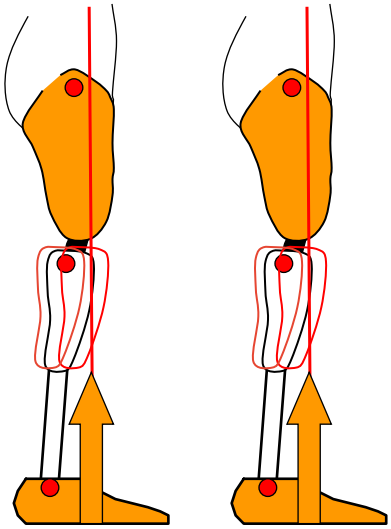

Sagittal knee position

Optimum

- Stance phase stability
- Initiation of the swing phase

➔ **Depends on knee mechanism**

Transfemoral prosthesis alignment

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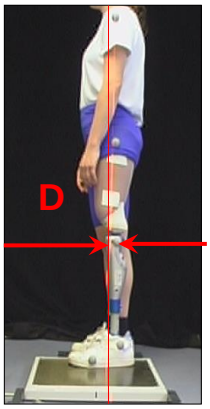
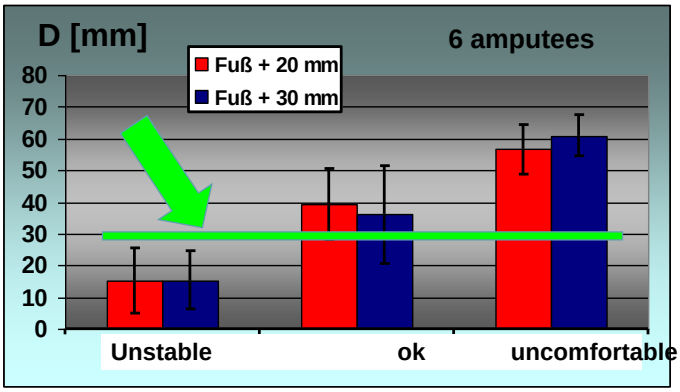
Plantar flexion





Transfemoral prosthesis alignment

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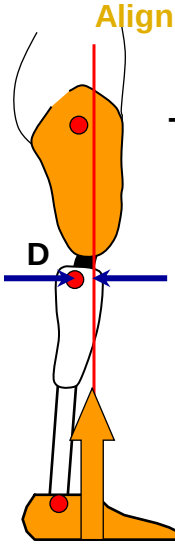
Alignment recommendations



-1...+3 cm

Distance depends on knee mechanism

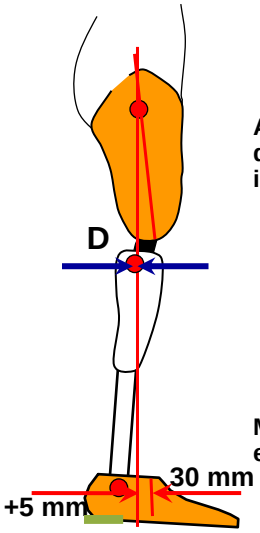
4...6 cm

Alignment recommendations

ottobock.

Basic alignment

Knee joint	D
3R40/41	15 mm
3R15/49	10 mm
3R90/92	10 mm
3R95	15 mm
3R60	0 mm
3R20/36	0 mm
3R106	0 mm
3R80	0 mm
C-Leg	+5 mm



Approx. 4° flexion, depending on individual situation

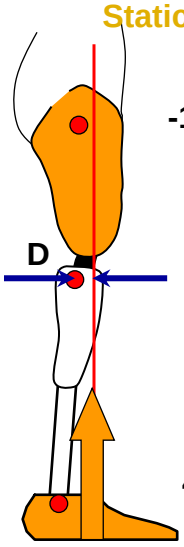
Middle of foot 30 mm anterior, effective heel height + 5 mm

Alignment recommendations

ottobock.

Statics with LASAR Posture

Knee joint	D
3R40/41	45 mm
3R15/49	40 mm
3R90/92	40 mm
3R95	45 mm
3R60	10* mm
3R20/36	35 mm
3R106	35 mm
3R80	35 mm
C-Leg	30 mm



-1...+3 cm

4...6 cm

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Alignment Instructions

TF Prostheses

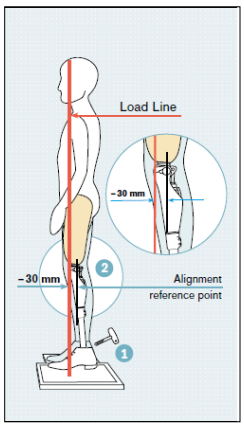
Academy

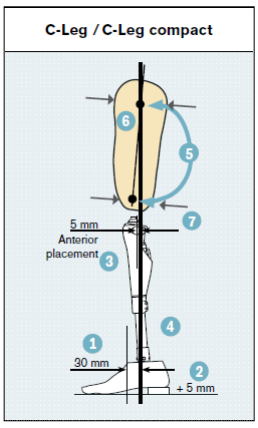
Frederik Thiede, OTM (CPO)

Quality for life

Process of Prosthetic Alignment TF

1. Introduction



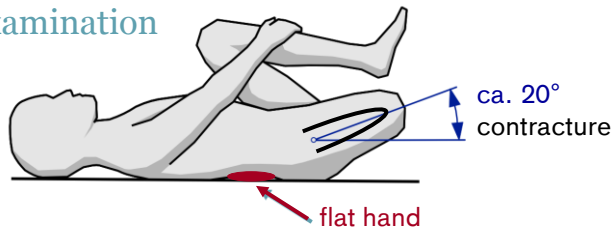


- Systematic prosthetic alignment is essential for correct posture
- Based on Otto Bock instructions for basic alignment

1. PROS.A. Assembly used for basic alignment
2. L.A.S.A.R. Posture used for static alignment
3. Dynamic otimisation
   - Socketflexion
   - Ad/Ab-duction of Socket
   - Rotation of Foot/Knee

Process of Prosthetic Alignment TF

2. Clinical examination



"Thomas test"

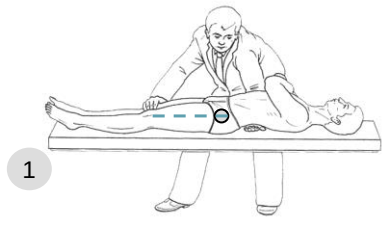
Evaluation of ability to extend leg at hip joint Procedure

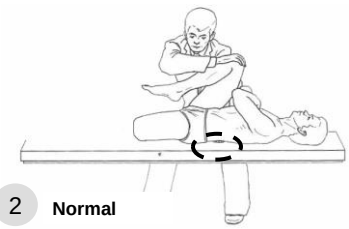
- Supine position
- Bend the healthy leg until there is no more lumbar lordosis (check this by placing hand between lumbar spine and examination table)
- In this position, the pelvis is secured in its normal position
- Pelvis tilts forward by approximately 12°
- This causes lumbar lordosis
- Possible to compensate for increased hip flexion contracture by intensifying lumbar lordosis
- Patient merely appears to be adopting normal posture

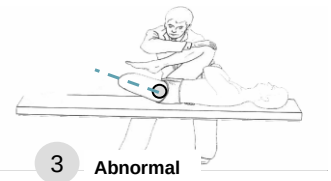
Process of Prosthetic Alignment TF

2. Clinical examination

"Thomas test"





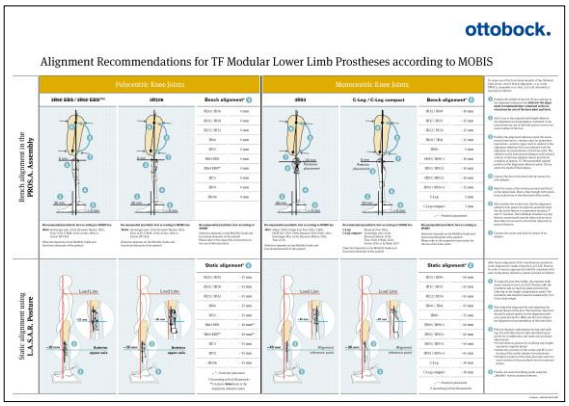


Source: K. Buckup: klinische Teste, Thieme Verlag

Process of Prosthetic Alignment TF

3. Basic Alignment

Alignment Recommendations for TF Modular Lower Limb Prostheses according to MOBIS



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Process of Prosthetic Alignment TF

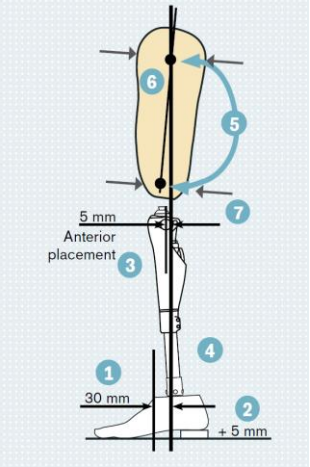
3. Basic Alignment

743A200 PROS.A. Assembly

1. Mounting plate for adapter inserts
2. Mounting frame for basic alignment of leg prostheses
3. Socket adapter height support
4. Adjustment of socket adapter height support
5. Innovative socket quick-clamping fixture
6. Knee brackets for adapter inserts
7. Knee joint adapter height support
8. Foot support with angular adjustment
9. Heel plate for height adjustment
10. Scale for adjusting knee-floor measurement and the trochanter-floor measurement

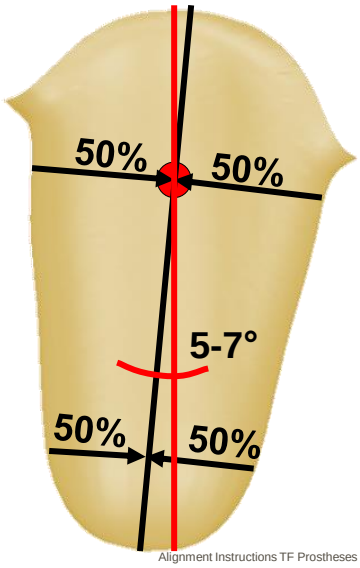
Process of Prosthetic Alignment TF

3. Basic Alignment

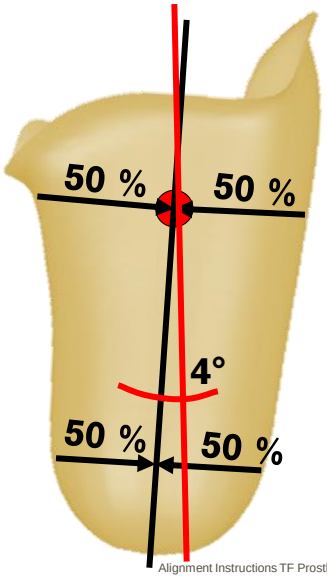


1. Position the middle of the food 30 mm anterior to the alignment reference line.
2. Add 5 mm to the effective heel hight and set the correct outward rotation (4-6°).
3. Position the alignment reference point in relation to the alignment reference line in accordance with the alignment recommendation of the knee joint. Pay attention to the knee ground distance (20 mm above the medial tibea plateau) and outward rotation (5°).
4. Connect the foot to the knee joint by means of a tube adapter.
5. Mark the socket reference point/line.
6. Position the socket such that the alignment reference line passes through the reference point. Set the socket flexion (TW +4°) and take the ishial tuberosity to ground clearance in account.
7. Connect the socket and the knee joint by means of an adapter.

Process of Prosthetic Alignment TF



Process of Prosthetic Alignment TF



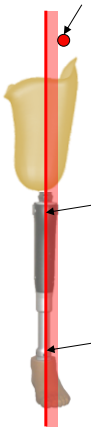
Process of Prosthetic Alignment TF

Alingment-Line

socketadduction without contraction

Process of Prosthetic Alignment TF

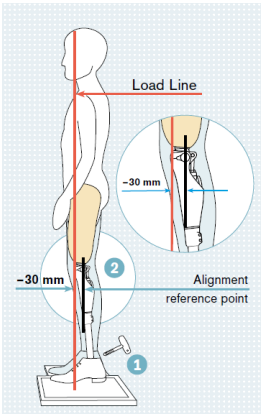
4. Static Alignment



Spina iliaca anterior superior ca. 0-2cm lateral

Mid to lateral of the knee

Mid to lateral of ankle adapter

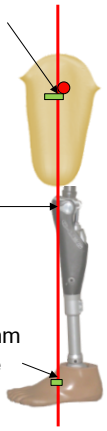


Trochanter major ca. -1 to 3 cm posterior

Depending on kneejoint

For example C-Leg 30 mm

50 mm +/- 10mm in front of ankle adapter



Process of Prosthetic Alignment TF

4. Static Alignment

Fitting with patient - Static alignment with the L.A.S.A.R. posture: frontal

Measuring the load line (on prosthesis side)

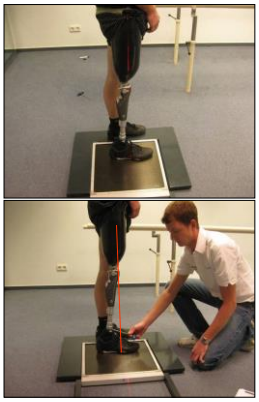
- Prosthetic side should be on measuring device
- Other leg should be on height compensation plate
- Goal should be load of >40% on prosthetic side
- Course of load line for ischial containment socket
  - Lateral socket region

Adjustment

- If necessary, move the knee joint position mediolaterally

Process of Prosthetic Alignment TF

4. Static Alignment



Fitting with patient – Static alignment with the L.A.S.A.R. Posture: sagittal

Measuring the load line

- Prosthetic side should be on measuring device
- Other leg should be on height compensation plate
- Goal should be load of >40% on prosthetic side

Adjustment

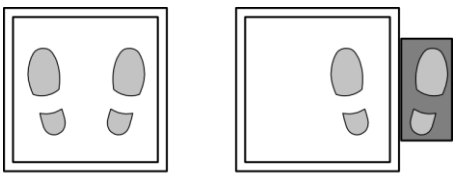
- Change plantar flexion/dorsal extension until
- the load line corresponds with the alignment recommendations for the knee joint

Process of Prosthetic Alignment TF

4. Static Alignment

L.A.S.A.R. posture

- The LASAR posture provides a way to check whether significant compensation motions exist
- Knee safety with both feet determine (- -> Heavy Line) and only the prosthetic foot (> load line)
- If the deviation is <+/-10 mm = OK (only small compensation)



Measurement with both feet

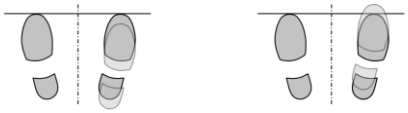
Measurement with prosthetic foot

Process of Prosthetic Alignment TF

4. Static Alignment

Check the socket flexion angle

- **The patient is in the upright position facing forward**
  - The patient lifts and loaded both sides as mutually
  - As a result, the stump goes into the most comfortable position



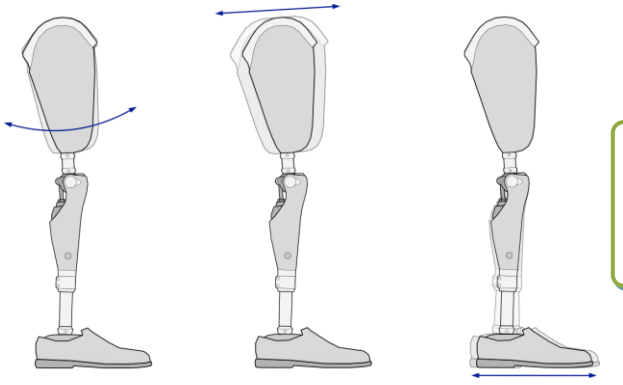
The prosthetic foot is moved backward -> socket flexion angle may be too much

The prosthetic foot is moved forward -> socket flexion angle may be too less

Process of Prosthetic Alignment TF

4. Static Alignment

additional options



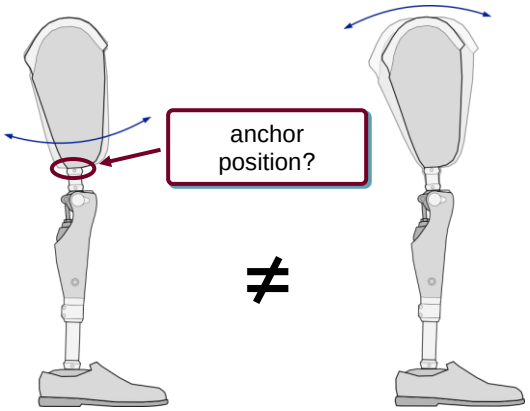
Socketflexion Socketposition Footposition

Changes always documented (so that they, if necessary, can be undone!)

Process of Prosthetic Alignment TF

4. Static Alignment

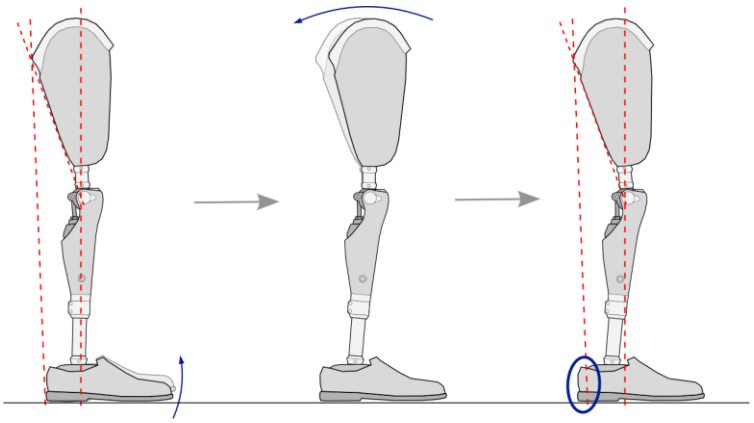
socketflexion vs. „sockettilt“



Process of Prosthetic Alignment TF

4. Static Alignment

Foot shifting



Process of Prosthetic Alignment TF

5. Dynamic Alignment Optimisation

- Check rotation of foot and knee
  - Wrong rotations in the knee joint can be observed during swingphase, ocuures rotation in the stancephase this is mostly caused by the socket fit. The prosthetic foot is designed for 5-7° outward rotation and not for a gait like: „Charlie Chaplin“
- Observe the A**b**duktion & A**d**duktion of the components
- Take heel and forefoot leverarm in account (eventualy shift the foot)
- Also check the length of the prosthesis: raises / lowers the center of mass during stancephase.

Process of Prosthetic Alignment TF

5. Dynamic Alignment Optimisation

Dynamic Alignment Video 1

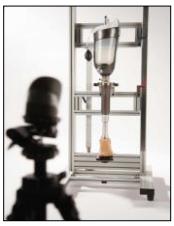
Dynamic Alignment Video 2

Dynamic Alignment Video 3

Dynamic Alignment Video 4

Process of Prosthetic Alignment TF

6. Verification and Documentation



The alignment of a modular leg prosthesis system in reference to the alignment reference line using the PROS.A. Assembly can be verified using an external laser (e.g., 743L5 crosshair laser or 743L20=230 LaserLine).

The three-dimensional alignment of the modular leg prosthesis with the PROS.A. Assembly is measurable and reproducible.

Alignment data can be documented and used for follow up fittings.

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