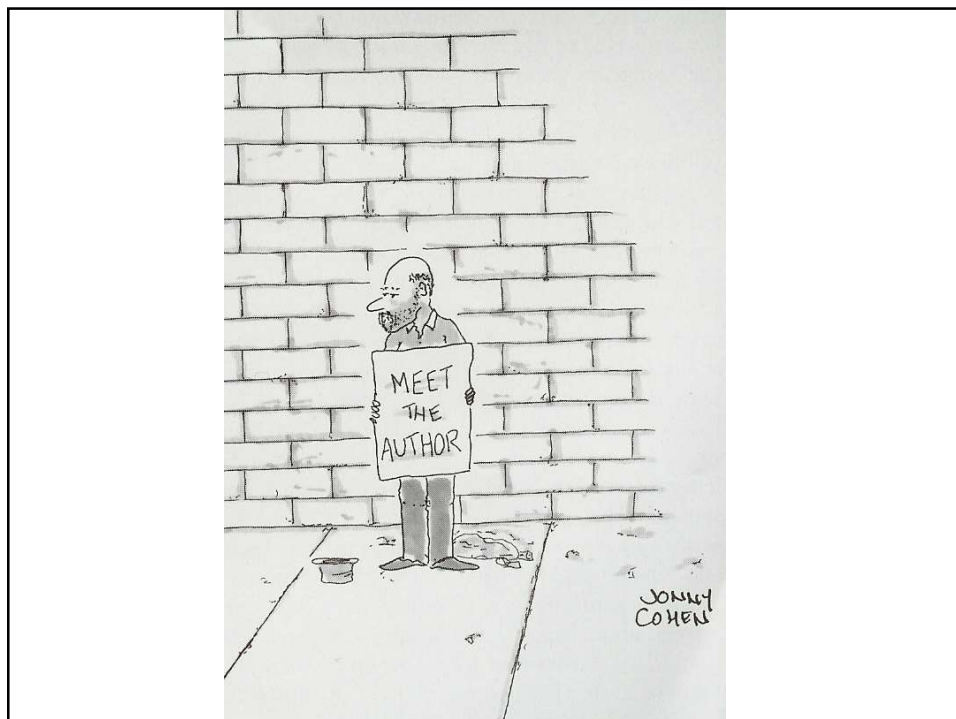


LOWER-LIMB PROSTHETIC BIOMECHANICS

Joan E. Edelstein, PT, MA, FISPO
Special Lecturer, Columbia University

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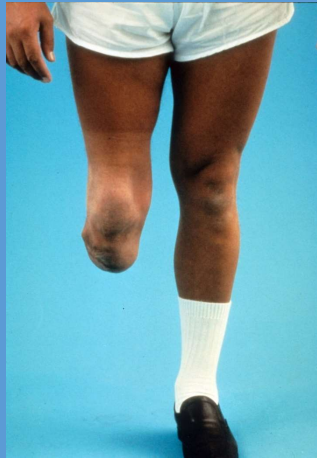


TRANSTIBIAL PROSTHESES

GOALS

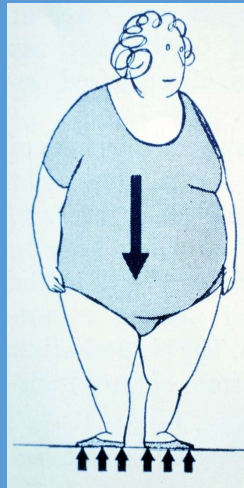
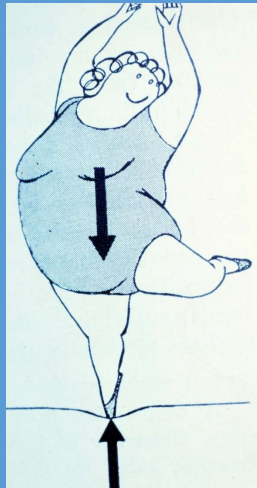
- **Comfort**
 - Pressure distribution
 - Socket shape
 - Prosthetic alignment
- **Function**
 - Stability
 - Appropriate ease of knee flexion
 - Alignment

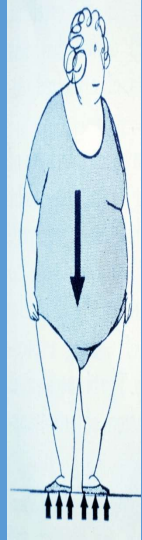
SOCKET DESIGN DEPENDS ON
PHYSICAL EXAMINATION



- Length
- Shape
- Scar
- Skin
- Range of motion
- Strength
- Comfort

DECREASE PRESSURE





Reduce Force
(&/or Increase Area) to
Reduce Pressure

TOTAL CONTACT



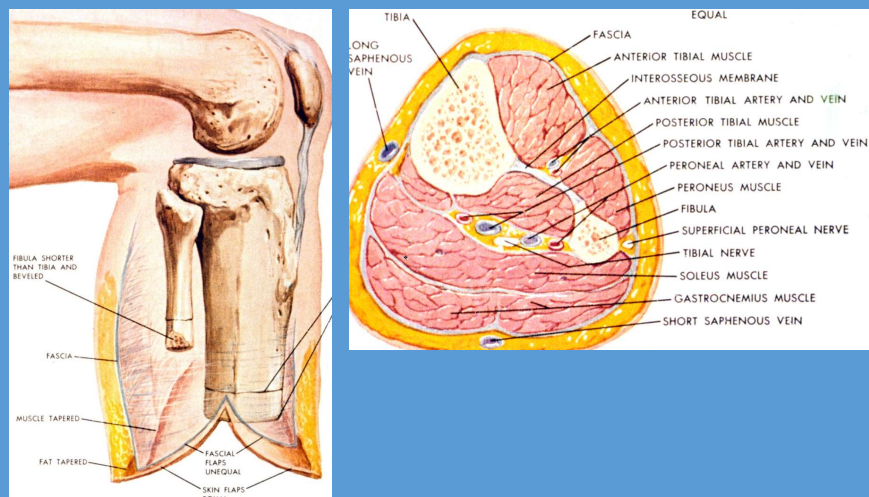
- Variable amount of load taken by all areas of amputation limb
- Usually peripheral (not end) bearing
- More area & leverage
- Tactile sensation
- Venous return

VERRUCUOUS HYPERPLASIA

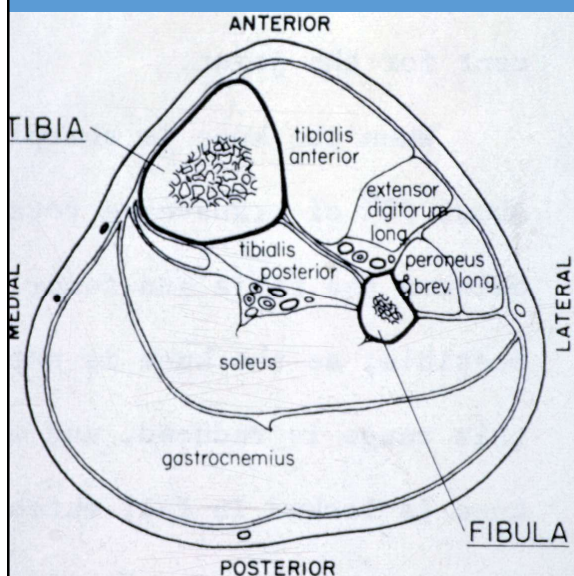


Lack of
distal contact
permits
venous pooling

TISSUE TEXTURE



PRESSURE TOLERANT TISSUES

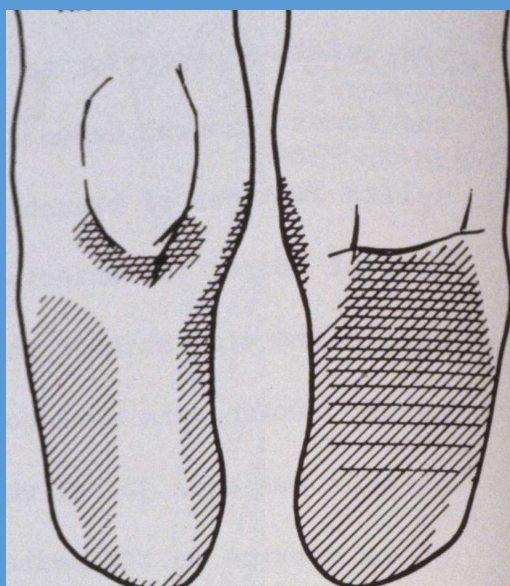


Anterior & lateral compartments contribute tolerant tissue

Posterior pressure tolerant tissue

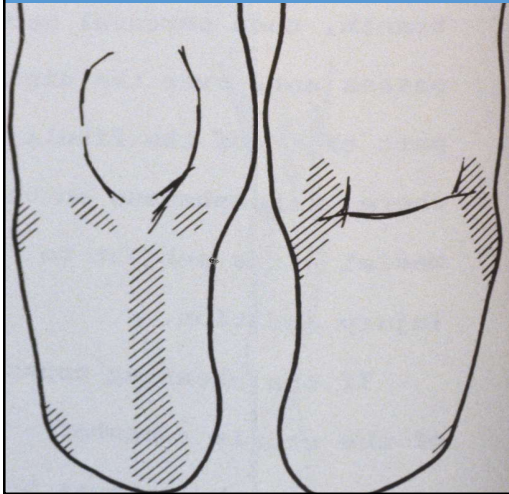
Socket build up (convexity)

PRESSURE TOLERANT TISSUES



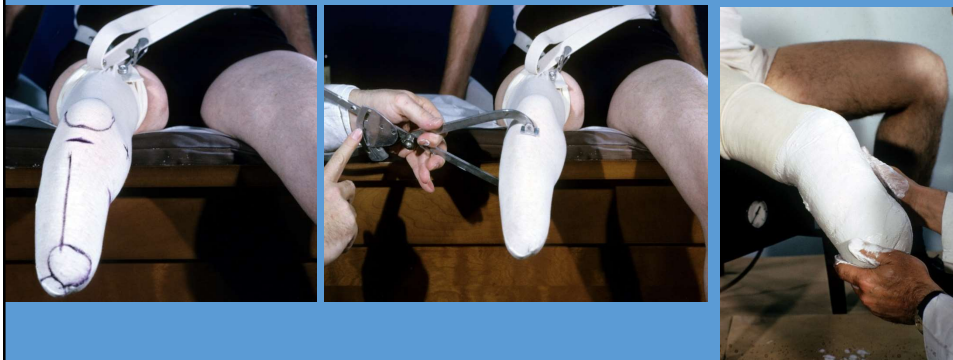
- Triceps surae belly
- Patellar ligament (tendon)
- Pes anserinus (medial tibial flare)
- Lateral compartment

PRESSURE SENSITIVE TISSUES



- Tibial crest
- Tibial condyles
- Distal tibia
- Fibular head
- Distal fibula
- Hamstring tendons
- Socket relief (concavity)

SOCKET FABRICATION



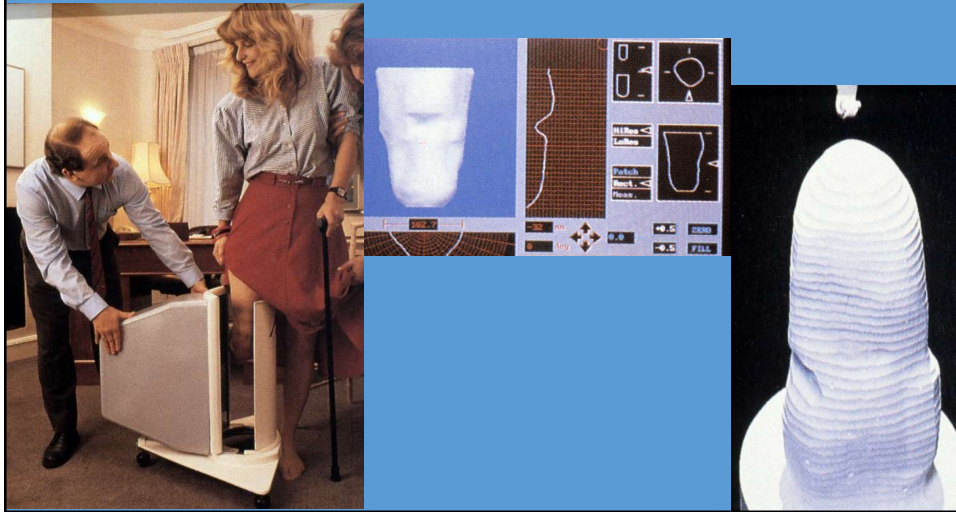
SOCKET

- Pressure **tolerant**: build-up
Concavity on model
Convexity within socket
- Pressure **sensitive**: relief
Convexity on model
Concavity within socket

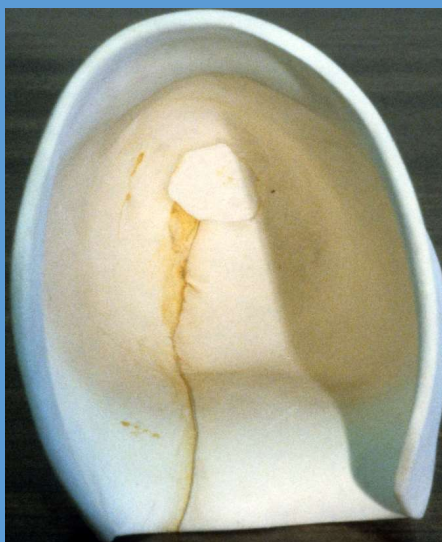
BUILD UPS & RELIEFS



CAD CAM (Computer-aided Design, Computer-aided Manufacture) SOCKET

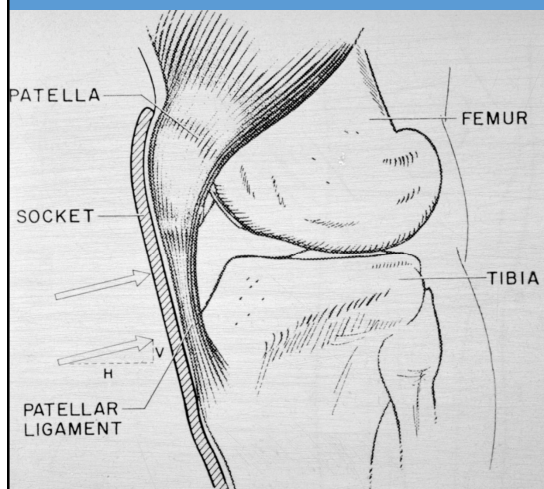


SOCKET INTERIOR



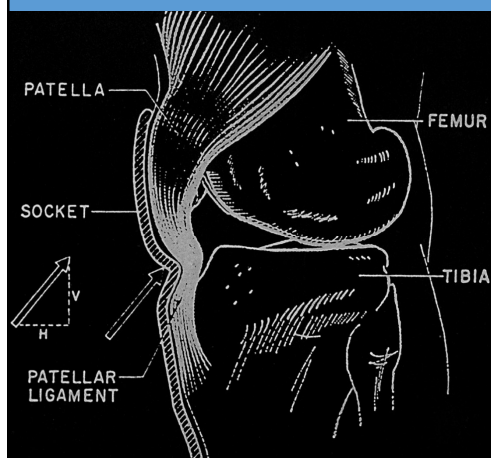
More triangular
than amputation
limb exterior

SOCKET CONTOURS



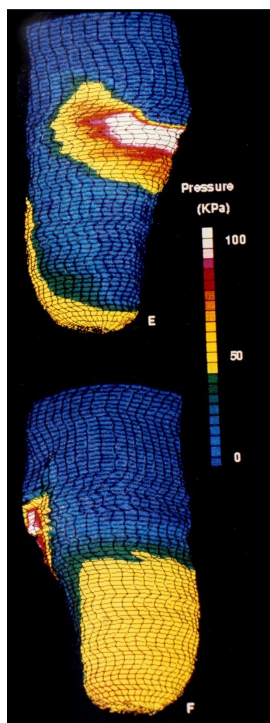
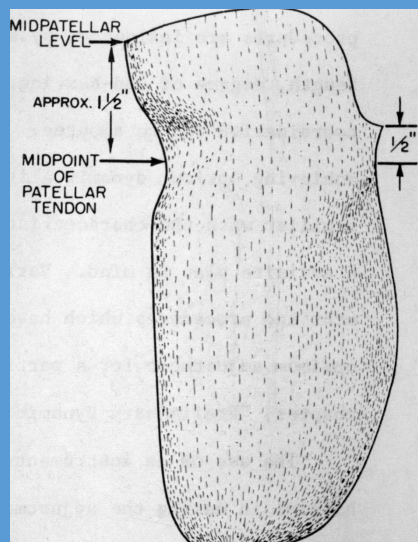
- Steep anterior wall
- **High force** needed to prevent amputation limb from slipping

PTB SOCKET CONTOURS



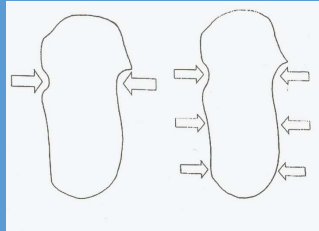
- Patellar bulge indentation reduces force needed to prevent amputation limb from slipping = PTB socket
- Deeper bar = **less load** on other tissues
BUT
may be uncomfortable

PTB SOCKET CONTOURS

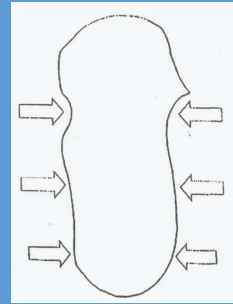


LOADING AREAS

SOCKET COMPARISON



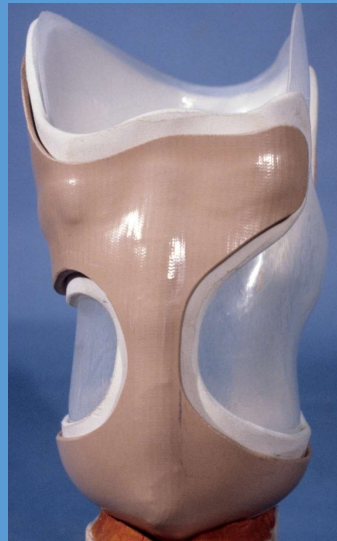
Bearing
PTB



Total Surface

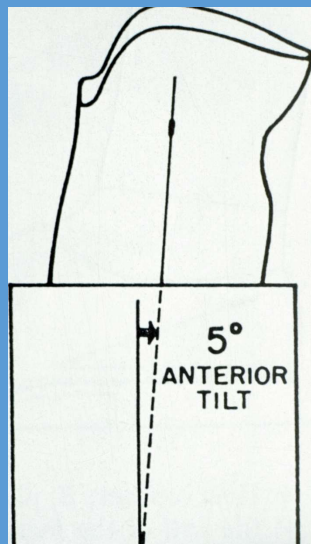
SOCKET COMPARISON

- All are total contact
- **Patella tendon bearing: PTB:**
 - Major loading on patellar **ligament**
 - Medium to short, bony
 - Past wearer
 - High posterior trim line may limit sitting
- **Total Surface Bearing:**
 - Less prominent patellar bulge
 - All lengths, adherent scar
 - Distal pin suspension
 - Needs expensive liner



NG

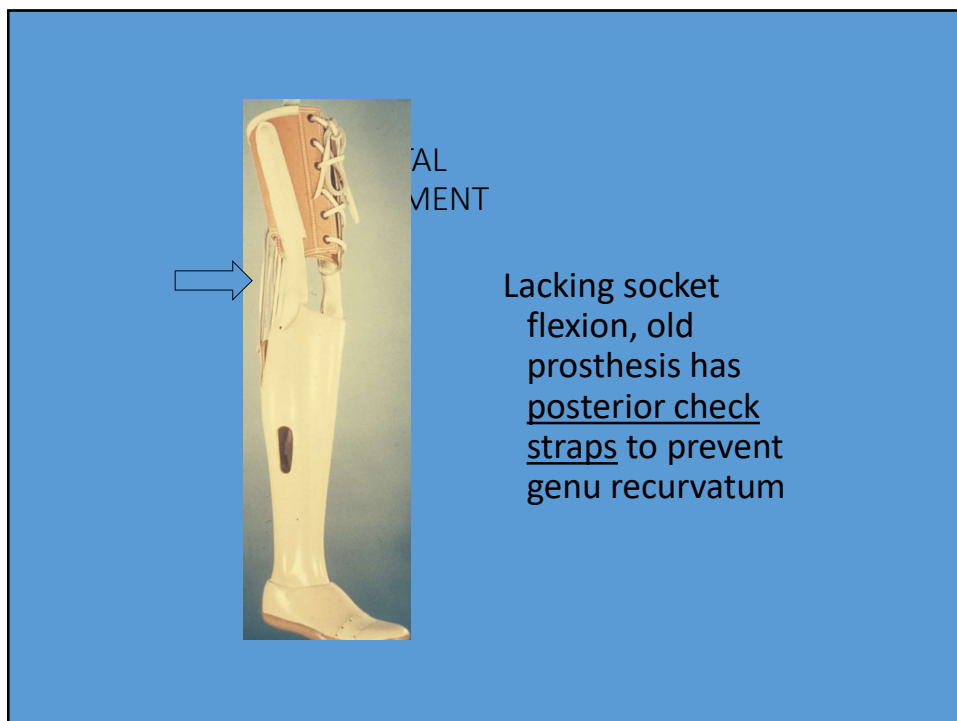
Medial relief is lower



AL
MENT

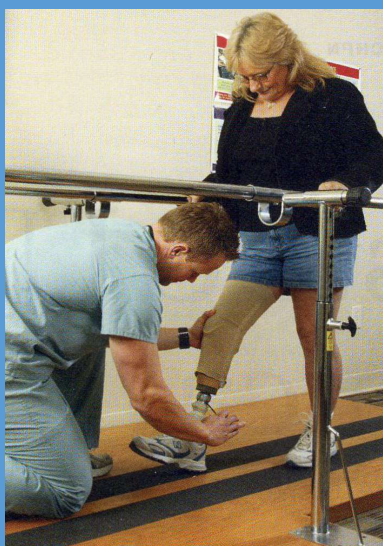
Socket flexion:

- Reduces risk of slippage
- Facilitates quadriceps
- Aids early stance
- Prevents genu recurvatum
- Increases load on patellar ligament

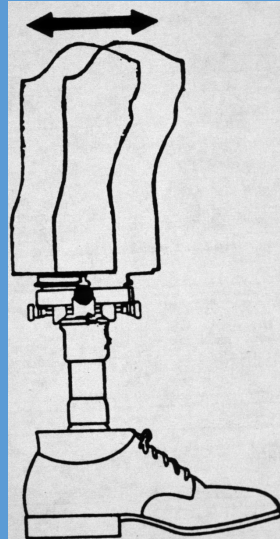




- Adjustable leg
- Static alignment: patient stands
- Dynamic alignment: patient walks



IST
S



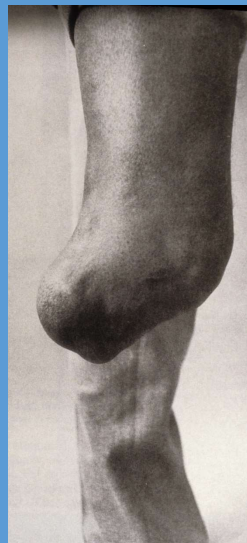
SAGITTAL PLANE MOVEMENT

- Socket **anterior**:
knee easier to
flex
- Socket **posterior**:
knee more
stable
- Foot moved in
opposite
direction

SAGITTAL PLANE

To increase ease of flexing knee:

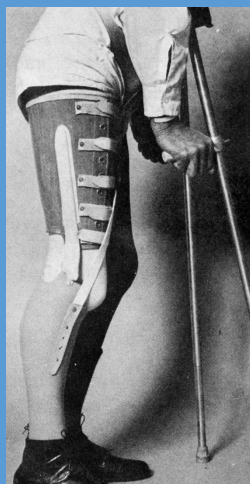
- Socket shifted anterior to foot
- Socket flexed
- Heel cushion firm
- Shoe heel high

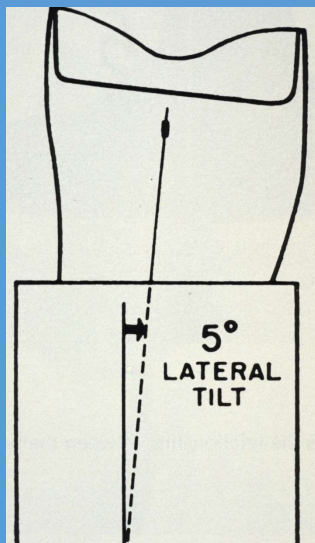


ION
TRACTURE

Standard alignment
would make knee
unstable

FLEXION CONTRACTURE





L
MENT

Lateral tilt reduces
load on fibular
head



FRONTAL
ALIGNMENT

Moving foot inward =
foot inset =
socket lateral slide

- Reduces pressure on head of fibula
- Narrow walking base
- Reduces lateral trunk bending

- Socket lateral slide = foot inset
- Reduces load on fibular head
- Narrow walking base

- Prefer foot inset
- Pressures at Proximomedial & Distolateral aspects
- ←---Inset
- Outset --->

IDEAL ALIGNMENT

- A-P: Socket over middle 1/3 of foot
- M-L: Proximomedial pressure + narrow base



**THE
END**

TRANSFEMORAL BIOMECHANICS

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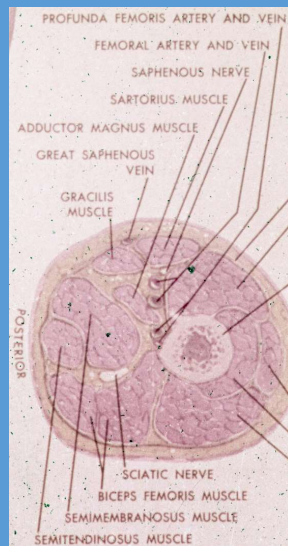
TRANSFEMORAL BIOMECHANICS

- Socket
 - *Quadrilateral
 - *Ischial containment
- Alignment
 - *Sagittal plane
 - *Frontal plane

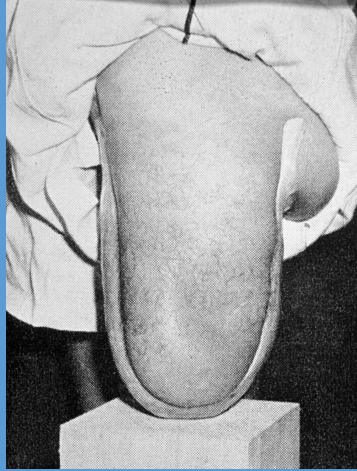
SOCKET:
AMPUTATION LIMB FACTORS



- Length
- Shape
- Scar
- Skin
- Range of motion
- Strength
- Comfort

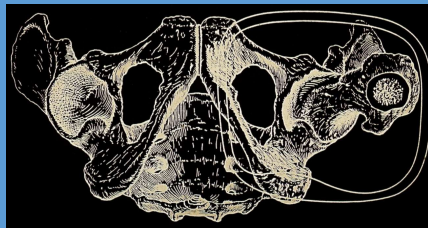


TOTAL CONTACT SOCKET



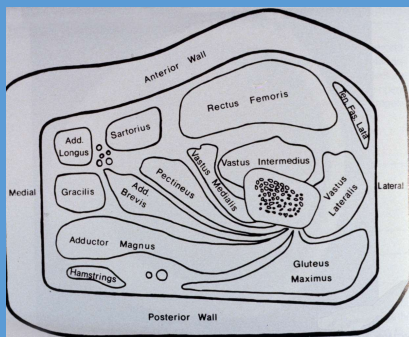
Load taken
distally reduces
load taken
proximally

QUADRILATERAL SOCKET



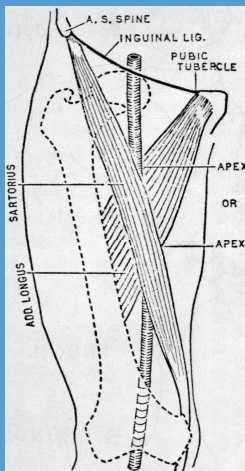
- Major loading on ischial tuberosity
- Trochanter relief

QUADRILATERAL SOCKET

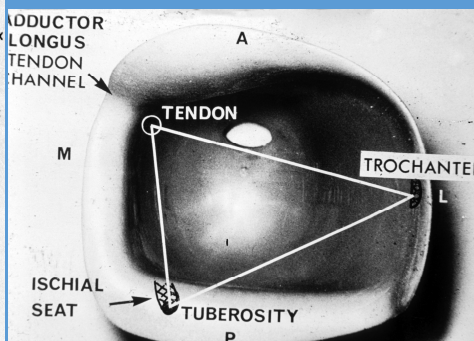


- Anteromedial: adductor relief
- Posteromedial: hamstring relief
- Anterolateral: rectus femoris channel
- Posterolateral: gluteus maximus channel

QUADRILATERAL SOCKET



Scarpa's Bulge

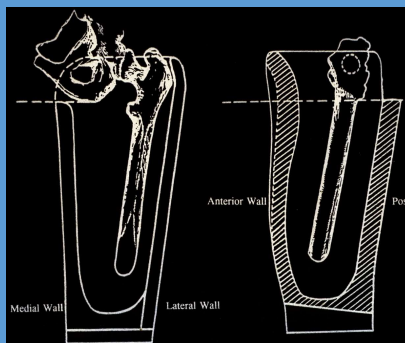


QUADRILATERAL SOCKET



Walls:
Anterior &
lateral:
2-3 inches
higher

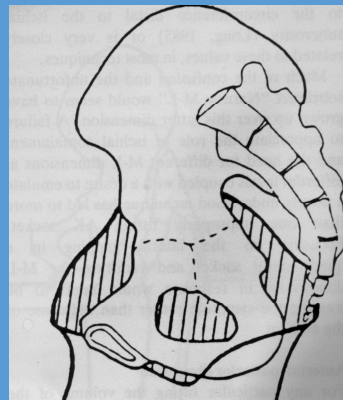
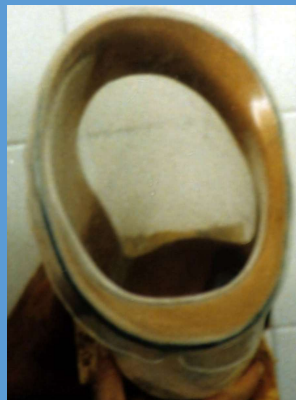
QUADRILATERAL SOCKET



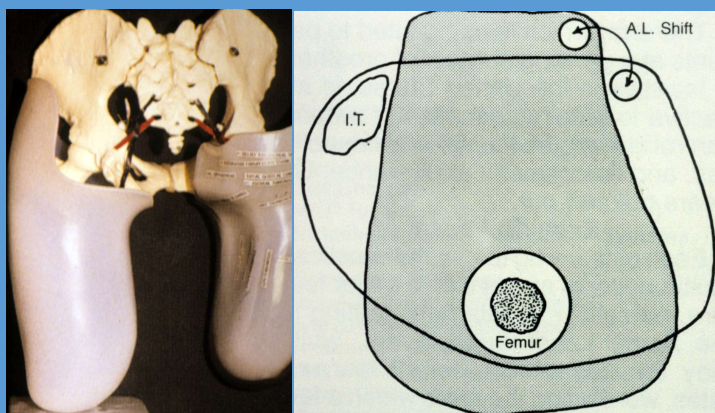


MODIFYING
MODEL
to create posterior
brim for
quadrilateral socket

ISCHIAL CONTAINMENT SOCKET
"Pelvic Lock"



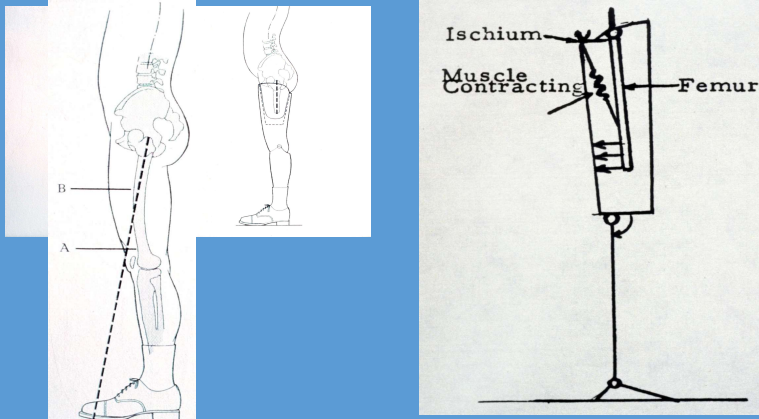
QUADRILATERAL (Gray) vs. ISCHIAL CONTAINMENT SOCKET (White)



SOCKET WALLS

	QUADRILATERAL	ISCHIAL CONTAINMENT
Posterior	Low	High
Anterior	High	Low
Medial	Low	High
Lateral	High	High

SAGITTAL ALIGNMENT



5 degrees initial flexion

SAGITTAL ALIGNMENT

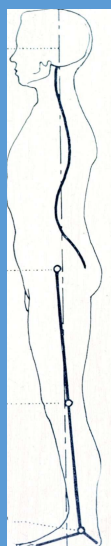
5 degrees initial flexion

- Reduces lordosis
- Facilitates gluteus maximus to stabilize knee during early stance
- For quadrilateral socket: also seats ischium



L
ENT

- Socket on wood block onto adjustable leg
- Knee bolt can be located forward or backward



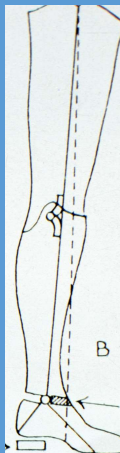
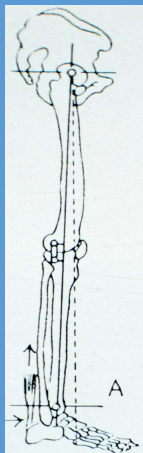
ITTAL
GNMENT

Normally, weight line passes:

- Posterior to hip.
Anatomic hip is stable
- Anterior to knee.
Anatomic knee is stable
- Anterior to ankle.
Triceps surae needed for standing

SAGITTAL ALIGNMENT

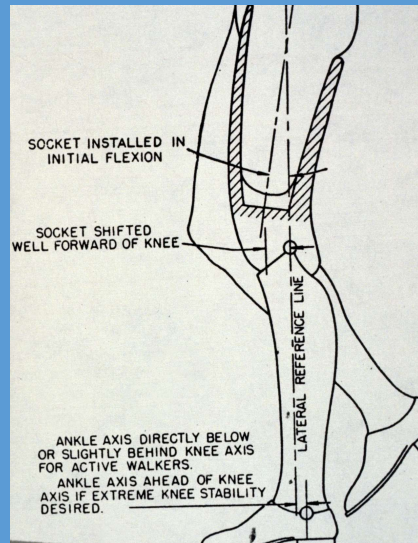
Weight line usually anterior to knee



SAGITTAL ALIGNMENT

Knee axis relative to trochanter/ankle line:

- Posterior: Stable,
for feeble patient
- On line = "trigger": Athlete
- Anterior: Stance control
knee unit



T
ITY

- Socket flexed
- Socket anterior to knee
- Ankle anterior to knee

SAGITTAL ALIGNMENT

To maximize stability:

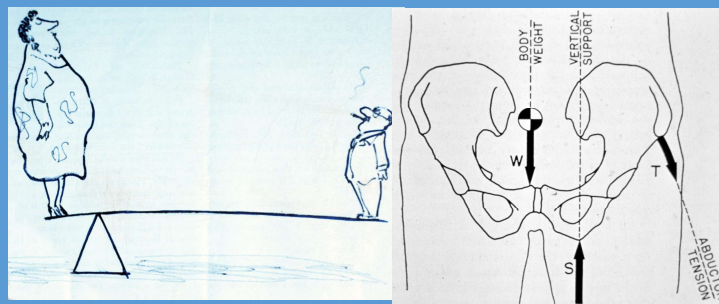
- Socket flexion
- Knee axis posterior to socket
- Ankle anterior to socket
- Soft heel cushion
- Soft shoe heel
- Low shoe heel

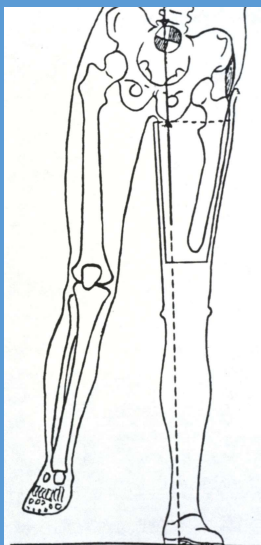
SAGITTAL ALIGNMENT

Other means of increasing stability:

- Polycentric knee unit
- Manually locked knee unit
- Stance control knee unit
- Cane

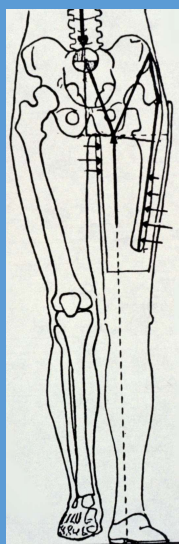
FRONTAL ALIGNMENT





MENT

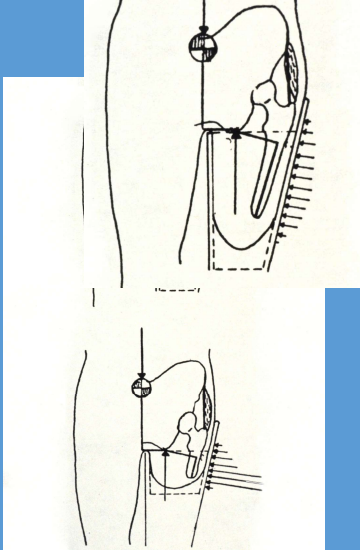
Lateral trunk bending compensates for lack of femoral stabilization



TAL
JMENT

Adduct lateral socket wall in attempt to stabilize femur

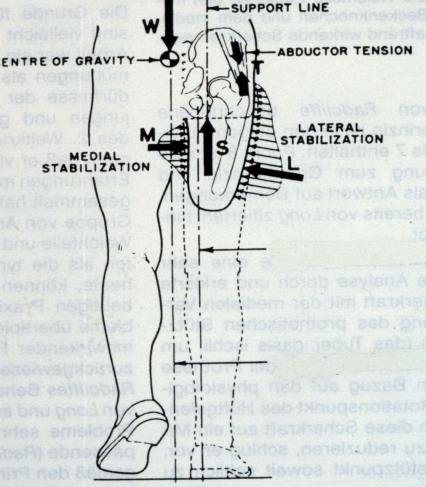
Force couple:
High medial wall +
Distal lateral wall



NT

Longer amputation limb provides more area for medially directed stabilizing force, thus more comfortable

FRONTAL ALIGNMENT



W

SUPPORT LINE

ABDUCTOR TENSION

CENTRE OF GRAVITY

MEDIAL STABILIZATION

S

L

LATERAL STABILIZATION

FRONTAL ALIGNMENT

- Lateral socket wall adduction
- High medial wall
- Ischial containment:
 - *Higher medial wall: “pelvic lock”
 - *Narrower mediolateral dimension
- Outset foot



NT

Foot outset
increases frontal
stability,
BUT
Increases lateral
trunk bending

FRONTAL ALIGNMENT

Other means of increasing stability:

- Pelvic band:
 has single-axis hip joint
- Cane
- Osseous integration

THE END

TRANSFEMORAL BIOMECHANICS

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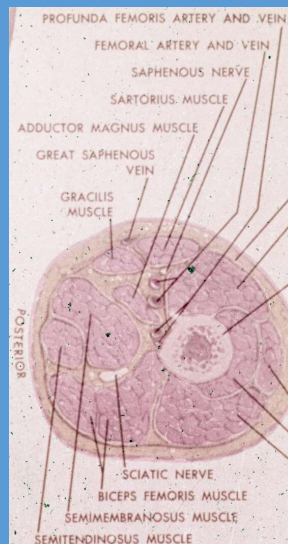
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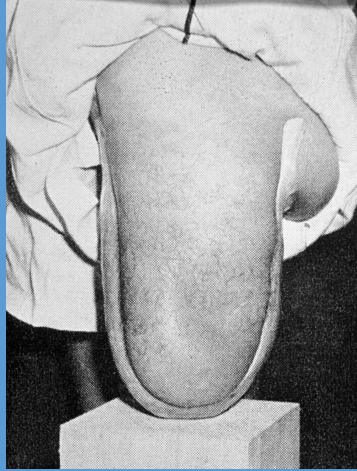
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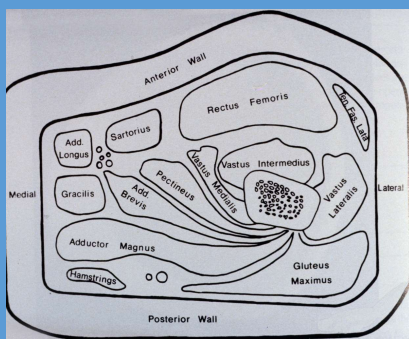
Load taken
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proximally

QUADRILATERAL SOCKET



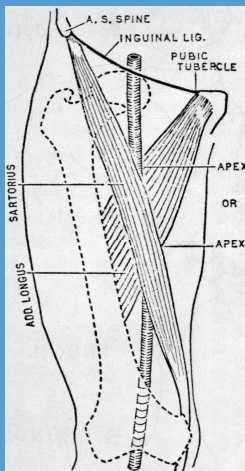
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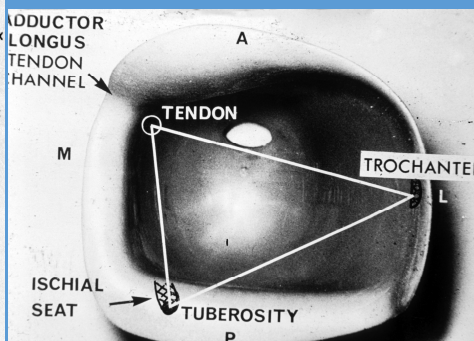


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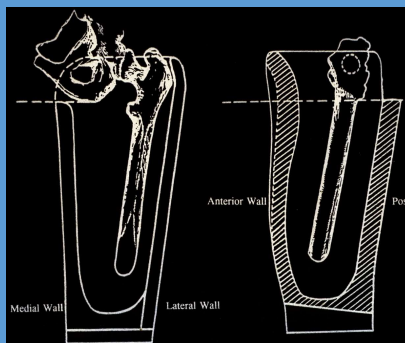


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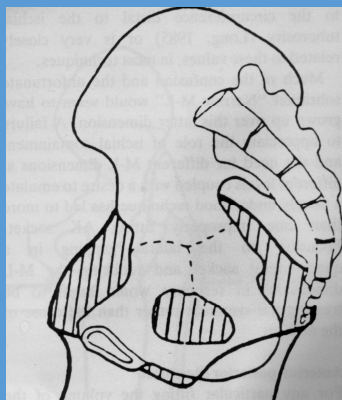
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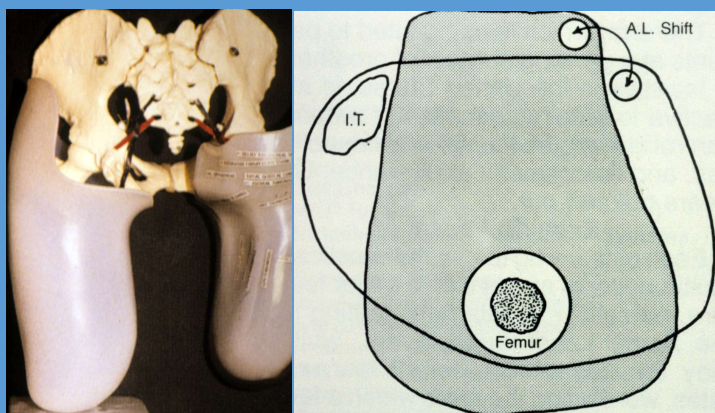


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MODEL
to create posterior
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ISCHIAL CONTAINMENT SOCKET
"Pelvic Lock"



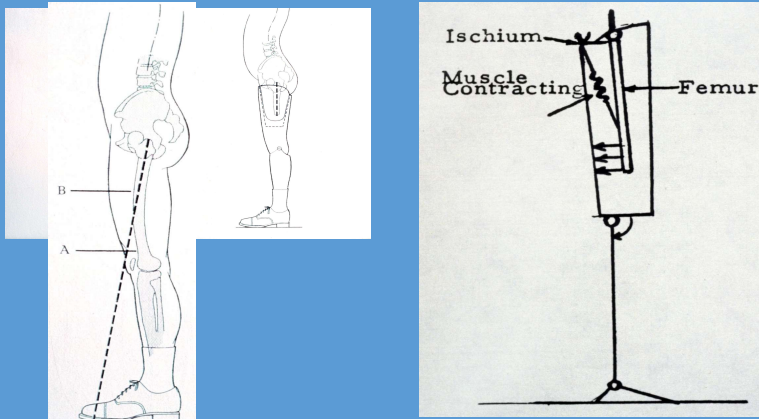
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SAGITTAL ALIGNMENT



5 degrees initial flexion

SAGITTAL ALIGNMENT

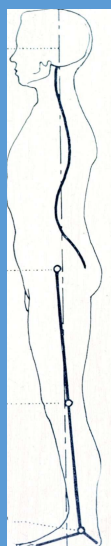
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L
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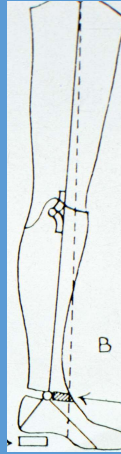
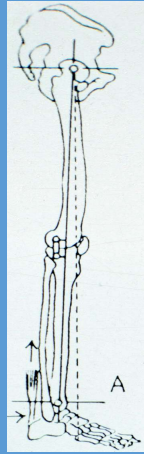
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Triceps surae needed for standing

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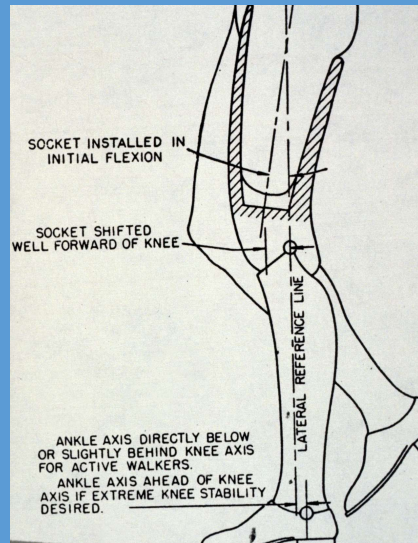
Weight line usually anterior to knee



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for feeble patient
- On line = "trigger": Athlete
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knee unit



T
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- Socket anterior to knee
- Ankle anterior to knee

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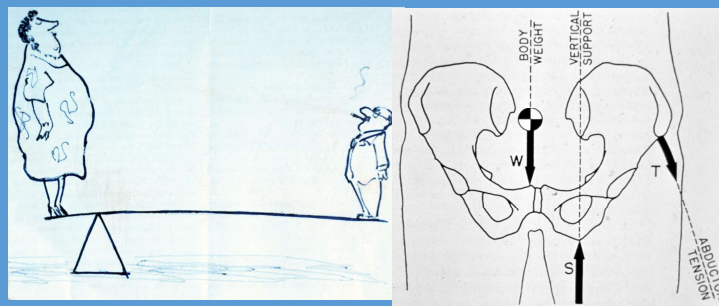
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- Knee axis posterior to socket
- Ankle anterior to socket
- Soft heel cushion
- Soft shoe heel
- Low shoe heel

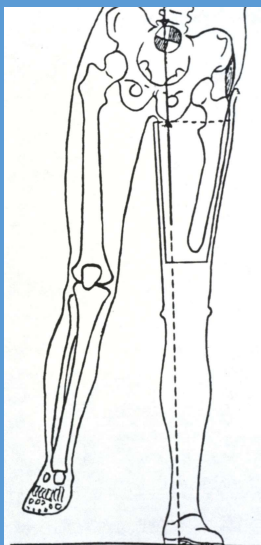
SAGITTAL ALIGNMENT

Other means of increasing stability:

- Polycentric knee unit
- Manually locked knee unit
- Stance control knee unit
- Cane

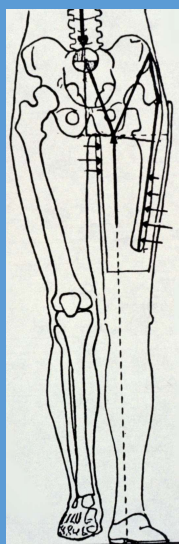
FRONTAL ALIGNMENT





MENT

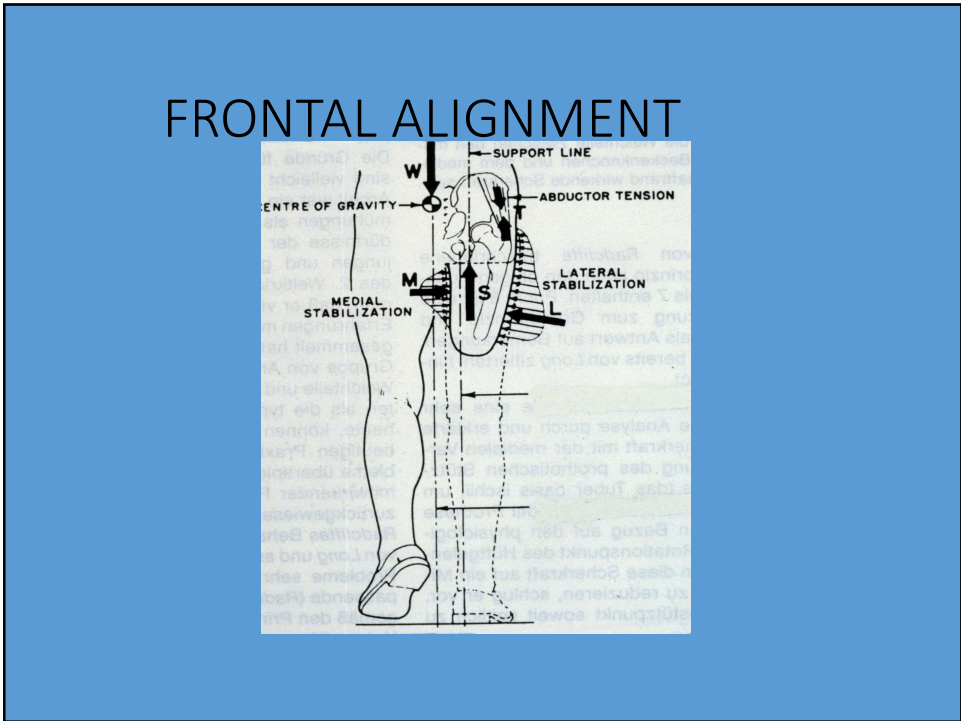
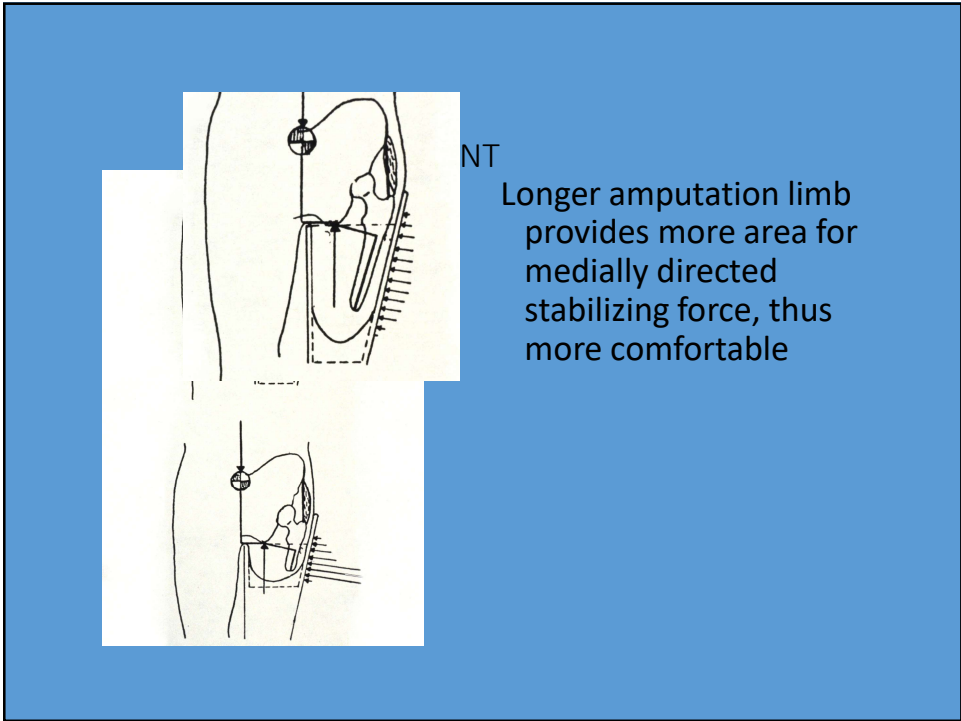
Lateral trunk bending compensates for lack of femoral stabilization



TAL
JMENT

Adduct lateral socket wall in attempt to stabilize femur

Force couple:
High medial wall +
Distal lateral wall



FRONTAL ALIGNMENT

- Lateral socket wall adduction
- High medial wall
- Ischial containment:
 - *Higher medial wall: “pelvic lock”
 - *Narrower mediolateral dimension
- Outset foot



NT

Foot outset
increases frontal
stability,
BUT
Increases lateral
trunk bending

FRONTAL ALIGNMENT

Other means of increasing stability:

- Pelvic band:
 has single-axis hip joint
- Cane
- Osseous integration

**QUESTIONS?
COMMENTS?**