Lower Limb Prosthetics

PRESENTING BY :

YOOSEF GHADIRI

ORTHOTIST & PROSTHESIST

PROSTHETIC FITTING AND TRAINING

- Functional needs
- Interest and motivation
- Assessment of ambulatory potentiel

Not all the individuals with an amputation are candidates for prostheses

- Negative prognostic factors associated with a poor outcome in returning the individual with an amputation to functional ambulation include:
- delay in wound healing
- presence of joint contractures
- dementia or cognitive disorders
- medical comorbidities
- higher levels of limb amputation (transfemoral)
- Age has inconsistently been identified as a predictor of prosthetic success, implying that except in advanced age (>80 to 85 years)

An individual with an amputation should have reasonable:

- cardiovascular reserve
- adequate wound healing
- good soft tissue coverage
- range of motion,
- muscle strength
- motor control,
- Learning ability

Examples of poor candidates for functional prosthetic fitting

- individual with a dysvascular LE amputation with an open or poorly healed incision
- a transfemoral amputation with a 30-degree flexion contracture at the hip,
- transradial amputation with a flail elbow and shoulder
- individuals with a bilateral, short, transfemoral amputation over the age of 45 years are considered unlikely candidates for full-length prosthetic fitting

Other additional problems

- medical problems such as severe coronary artery disease,
- pulmonary disease, severe polyneuropathy, or multiple joint arthritis
- May result in an individual with an amputation who could be fitted with a prosthesis but who may not be a functional prosthetic user
- Patients in whom prognosis is poor
- life expectancy is short
- disease that results in significant fluctuations in body weight are not good candidates

Rigid dressing

- introduced on a wide scale in the 1970
- it was used to implement immediate postoperative prosthesis (IPOP) (a rigid dressing with a pylon and foot)
- A means to speed rehabilitation for individuals with LE amputation

Rigid dressing

- Problems with wound healing and residual limb trauma from poorly
- fabricated devices and a lack of experienced teams to manage this approach
- to early postoperative care led to abandoning their use in the individual with a dysvascular amputation

Prognosis of IPOP in Traumatics

- Immediate fitting in the younger patient with traumatic amputation has been more successful and is a reasonable method of treatment
- Immediate and early postoperative prostheses are, in effect, an RRD with a pylon and foot attached.
- This device is used to achieve limited partial to full weight bearing, reduce edema, and accomplish initial gait training
- Because the fit of these devices is always suboptimal compared to a custom-molded socket, they are not recommended for extended use

concern over wound healing

- dominates clinical care in the postoperative period, prosthetic fitting is delayed until the residual limb has healed adequately to allow unrestricted weight bearing

Providing a prosthesis is typically performed in two stages:

- a preparatory prosthetic limb
- phase is followed by the provision of a definitive prosthesis
- The preparatory prosthesis is often of simple design, lower performance, and more adjustable to changes in residual limb volume than is the definitive limb
- It allows the individual with an amputation to gain skill and confidence in walking with prosthesis
- facilitates residual limb maturation
- affords the rehabilitation team the opportunity to better define the ultimate functional level of the individual

- The definitive prosthesis is provided when the residual limb shape has stabilized and the patient has reached a functional plateau with the preliminary prosthesis

Stump maturation

- volume of the residual limb has stabilized
- soft tissue atrophy has occurred
- the residual limb has been molded into a cylindrical shape that optimizes prosthetic fitting
- This can usually be determined when the individual with an amputation reports a plateau in the number of sock plies worn from day to day and by clinical exam that shows edema resolution
- Limb maturation, typically, takes about 4 months
- may extend substantially longer depending on the activity level, amount of prosthetic limb use, and coexisting medical disease

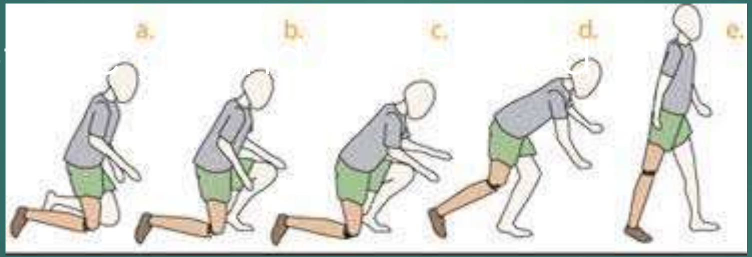
- In the case of young children, the prosthesis prescription must also meet any needs related to the development of age-appropriate motor milestones
- Although a two-stage approach (preparatory followed by definite limb) is commonly used
- Patients who are not candidates for functional prosthetic use may choose to have a cosmetic prosthesis that has an appearance similar to that of the opposite limb

GAIT TRAINING

- For the individual with a new amputation, it is best if the initial gait training occurs while the prosthesis is still capable of being adjusted to permit alignment or length changes that may become apparent during gait training
- Gait training often occurs on an outpatient basis
- may last from weeks to months
- The more proximal levels of amputation require lengthier gait training
- Gait training begins with weight shifting and balance activities while still in the parallel bars

- weight shifting and balance activities
- program of progressive ambulation begins in the parallel bars and progresses to the most independent level of ambulation possible with or without gait aids
- Transfers
- knee stability
- equal step lengths
- avoiding lateral trunk bending

Following mastery of ambulation on flat, level surfaces, techniques for managing:
uneven terrain
Stairs
Ramps
Curbs
falling and getting up o



Moving from a walker to less cumbersome gait aids can be achieved for most individuals with an LE amputation
higher functioning individuals with an amputation, prosthetic training should include instruction and practice in driving, recreation, and vocational pursuits

Developing the optimal benefit from a prosthesis must take into account the specific mechanical attributes of the components used

For example

using a dynamic response (i.e., energystoring) prosthetic foot requires loading the prosthetic toe during mid-stance and late stance to capture energy for push-off assistance or to activate a prosthetic knee to initiate the swing phase

Wearing tolerance for the prosthesis must be gradually increased

wear the prosthesis only for 15 to 20 minutes, removing it to check the condition of the skin

- As tolerance to weight bearing increases, the length of wearing time is gradually increased
- Several weeks may be required before the individual with an amputation is able to wear the prosthesis full time
- Taking the prosthesis to home for independency and residual limb skin checks are assured

Lower Extremity PROSTHETIC FOLLOW-UP

- During the initial 6 to 18 months, most individuals with an amputation will experience continued loss of residual limb volume, resulting in a prosthetic socket that will be too large
- During this period, return visits should occur frequently enough to ensure that this loss of residual limb volume is being compensated for by the use of additional limb socks or by appropriate modifications of the prosthetic socket
- It is usual for an individual with a new amputation to require replacement of the prosthetic socket during this time because of the significant loss of soft tissue volume

- yearly visits to the amputee clinic are appropriate
- Once the residual limb has stabilized, the average life expectancy for an LE prosthesis before replacement should be 3 to 5 years

Lower Limb prosthetic prescription

- Stability
- Mobility
- Durability
- cosmesis
- cost

Comfort

is the most critical aspect and depends on:

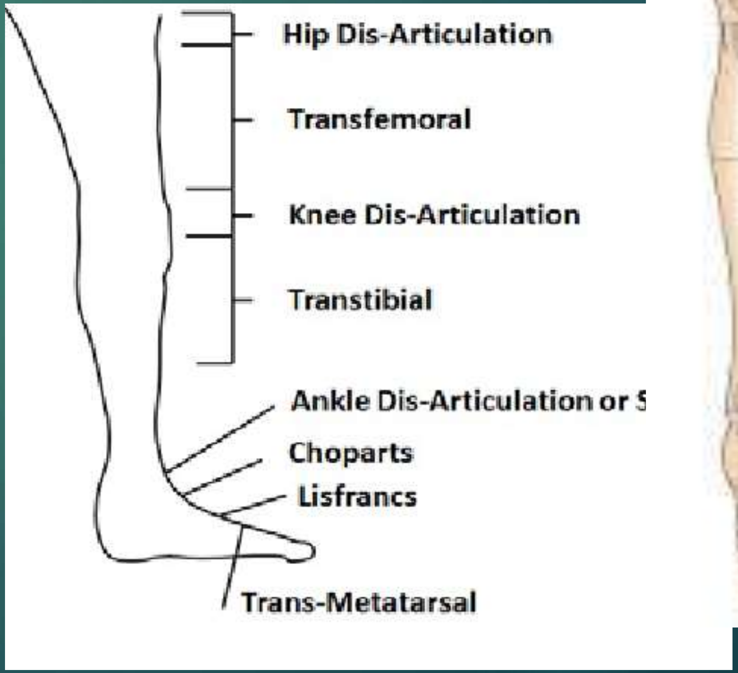
- achieving an appropriate distribution of forces between the residual limb and the socket
- A poorly fitting or uncomfortable socket will limit the mobility and often lead to rejection of the prosthesis

cosmetic

- Lastly, cosmetic concerns are considered
- Cosmesis is influenced by personal preferences and psychosocial dynamics but is usually satisfactorily achieved using contoured foam and a nylon or rubber skin tone cover.
- Some individuals with an amputation prefer not to have their prosthesis
because of the possible interference with prosthetic component

Prostheses by Level of Amputation

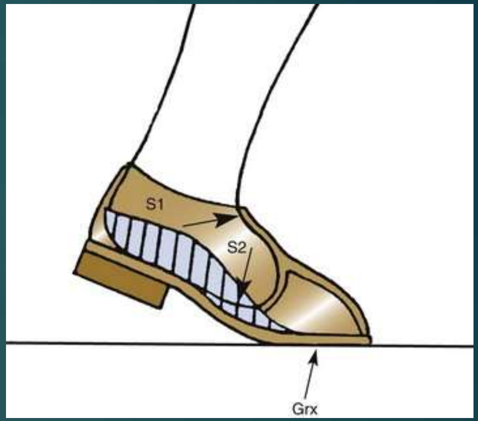
- Partial Foot Amputation
- Syme Amputation
- Transtibial Amputation
- Knee Disarticulation
- Transfemoral Amputation
- Hip Disarticulation/Hemipelvectomy
- Hemicorporectomy



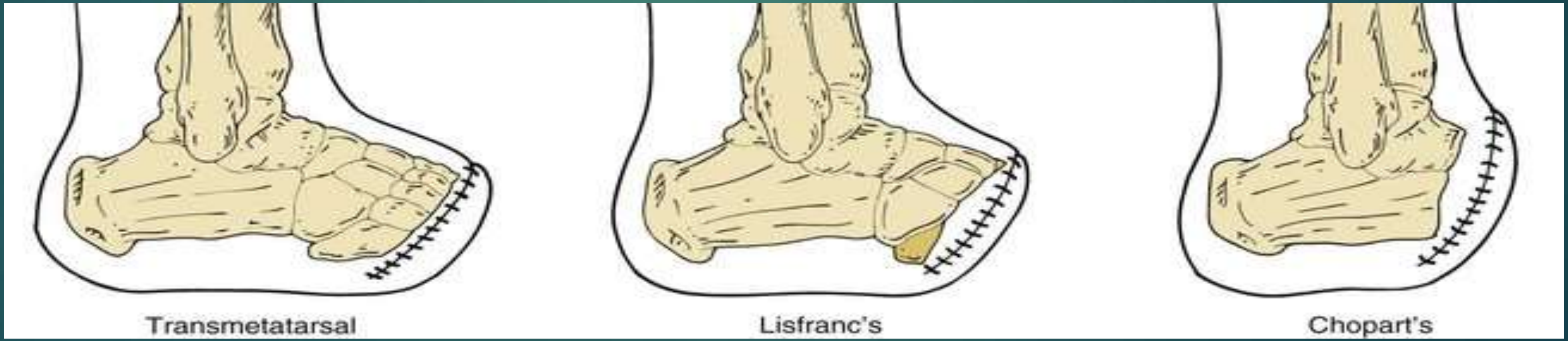
Partial Foot Amputation

- Toe amputations, ray resections, and transmetatarsal amputations require minimal prosthetic/orthotic intervention.
- At the more distal foot amputation levels and for the less active individual with a transmetatarsal amputation, accommodative shoes with custom insoles, arch supports, and toe fillers are usually adequate
- More active individuals with a transmetatarsal amputation may benefit from orthotic modifications that better substitute for the lost anterior foot lever arm

- Options include the addition of
- carbon fiber
- spring steel sole shanks,
- rocker soles,
- short ankle foot orthosis



- Partial foot amputations at the tarsal-metatarsal and transtarsal levels (e.g., Lisfranc, Chopart) are relatively uncommon and have historically been associated with equinovarus contracture of the hind foot, increasing the likelihood of skin breakdown over the plantar surface of the foot.



Prosthetic/orthotic devices for the individual with a proximal partial foot amputation

- need to supply medial-lateral stabilization of the hind foot and substitute for the lost forefoot lever

A major advantage of all partial foot amputations is the ability to be fully end bearing, allowing ambulation without any devices

Syme Amputation

- Similar to the hind foot amputation, the modified Syme (tibiotarsal disarticulation) amputation is capable of full weight end bearing.
- The heel flap is anchored to the distal end of the tibia and fibula, and following healing, allows short distance ambulation without a prosthesis
- leg length discrepancy
- Over time, posterior migration of the distal heel pad occurs in some individuals with a Syme amputation leading to problems with skin breakdown and difficulty in prosthetic fitting

- bulbous distal end of the residual limb has the advantage of enabling the use of self-suspending prosthetic designs
- it also contributes to the major disadvantage of the Syme amputation—poor cosmesis due to the bulkiness of the prosthesis around the ankle joint

- The most common prosthetic style uses a total contact socket with a removable medial window
- The distal removable medial window allows the distal bulbous portion of the residual to slip easily into the socket, which is then held in place by closing and securing the window with Velcro straps

- The major disadvantages to this prosthesis style are the poor cosmesis and the reduced strength of the socket due to the window
- A second option uses a fixed posterior opening socket
- This type of prosthesis is used for a very bulbous residual limb
- This prosthesis is prone to breakage at the ankle joint and is not recommended for heavy duty users

Low-profile feet are needed for Syme prosthesis due to the limited space available beneath the socket

Acceptable foot options range from the rigid keel SACH feet through multiaxial and dynamic response feet

Transtibial Amputation

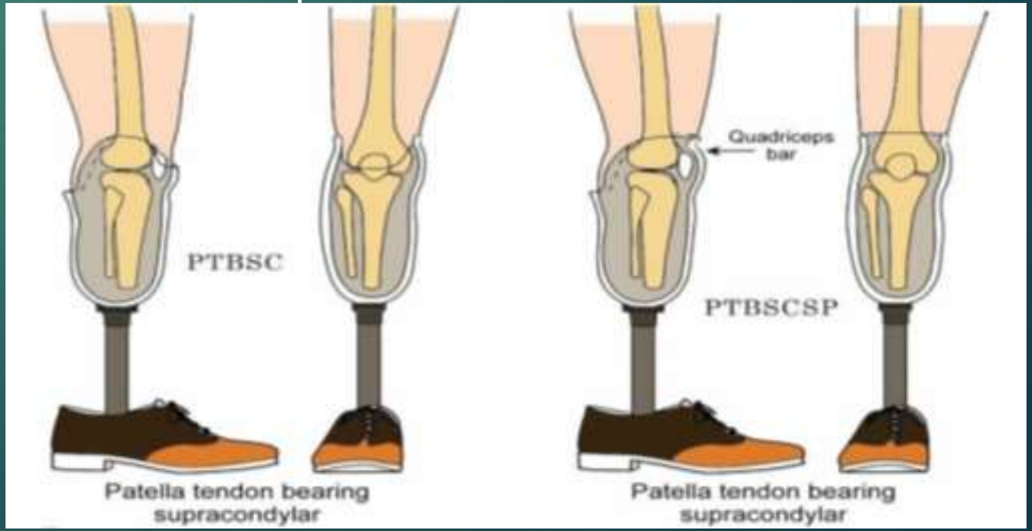
- Transtibial amputations are the most common amputation level seen in general practice
- Initially, the socket and liner system that will optimize comfort and skin protection is determined
- Next, the suspension system is chosen and finally pylon and foot/ankle components are selected.

The patella tendon-bearing (PTB) total contact socket

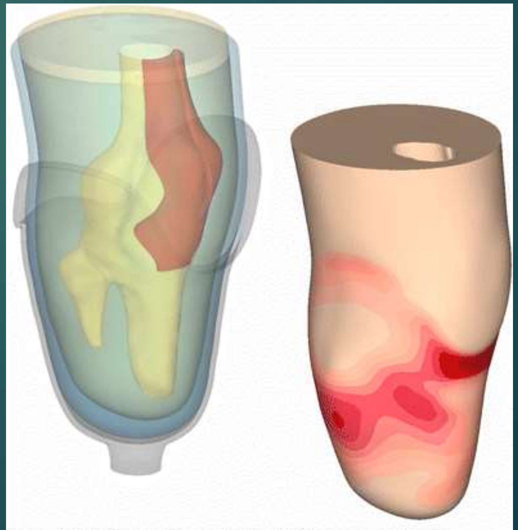
- has been the internationally accepted standard transtibial socket since the 1960s
- PTB total contact socket is fabricated from a cast or scan of the residual limb
- which is modified to specific weight-bearing (SWB) regions that are pressure tolerant and correspondingly modified to decrease pressure over bony prominences such as the tibia crest, fibula, and distal portion of the tibia

Variations of PTB

- The PTB supracondylar (PTBSC) socket: has high medial and lateral sidewalls that extend above and over the femoral condyles, providing enhanced mediolateral stability and self-suspension of the prosthesis
- The PTBsupracondylar/suprapatellar (PTBSCSP) socket: further extends the PTBSC socket concept by also extending the anterior aspect of the socket so that the patellar is encompassed within the socket.



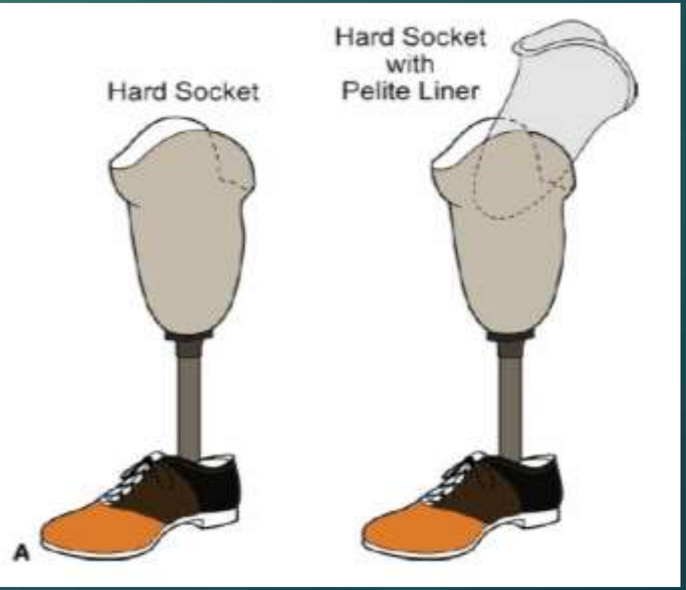
- The PTBSCSP gives additional stiffness to the mediolateral walls and applies force proximal to the patella during stance to provide sensory feedback to limit genu recurvatum
- Both the PTBSC and PTBSCSP are primarily used in individuals with short residual limbs to improve varus/valgus control and to provide greater surface area for weight distribution



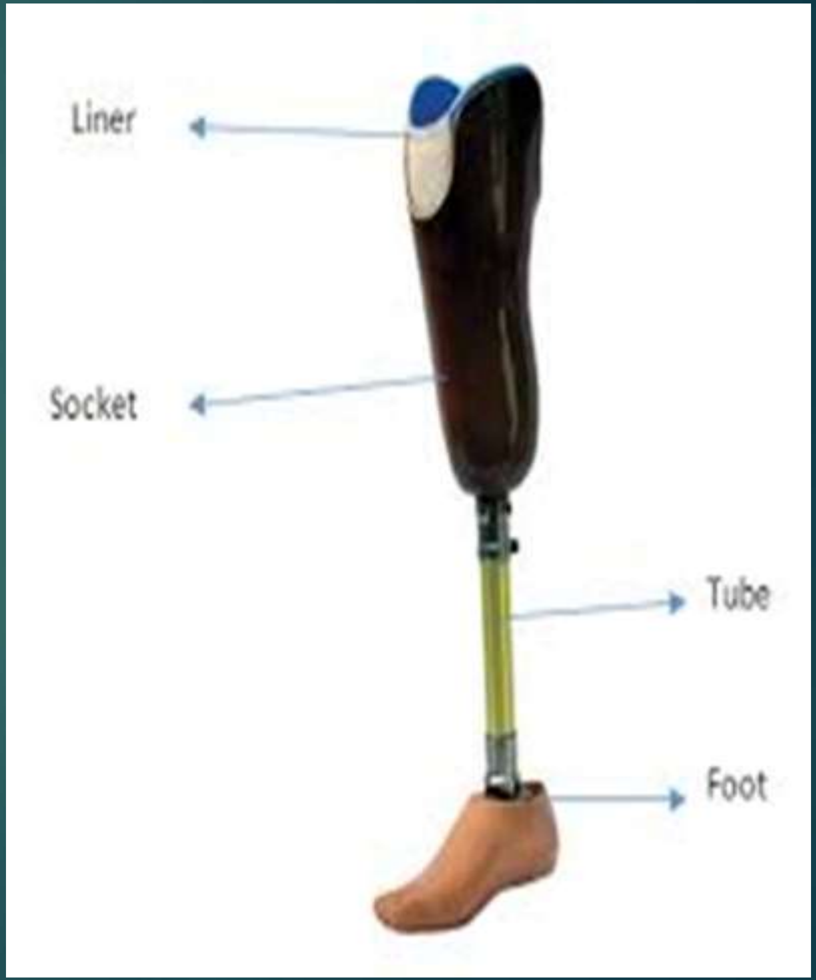
Residual limb finite element model. Left: model components. Right: interface pressures during stance phase.

- The liner functions as the primary interface between the residual limb and the remainder of the prosthesis
- In this role, it must complement socket fit to ensure optimal pressure distribution while also eliminating harmful shear forces and providing a favorable moisture, heat, and chemical environment that prevents skin breakdown.

- PTB total contact sockets can be fit as hard sockets that do not use a liner or more commonly use a liner made from closed cell foam such as Pe-Lite for improved comfort
- Using PTB total contact sockets and pelite liners are often an advantage in the preparatory prosthesis because of the relative ease with which the liner can be modified to accommodate changes in residual limb volume

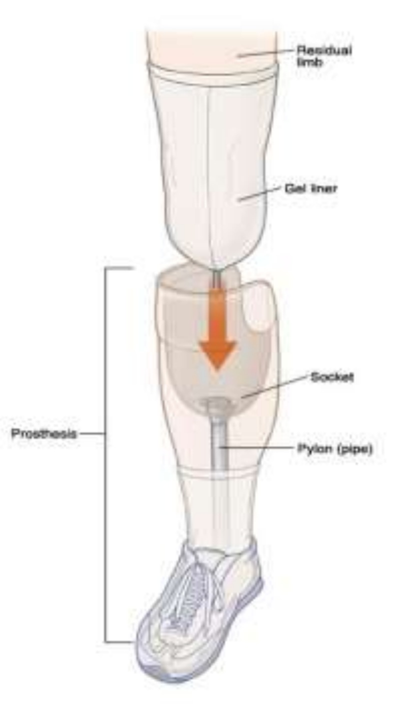


- The prescription for an LE prosthesis should include the Medicare “K” code, diagnosis including
- level of amputation and underlying medical conditions,
- type of prosthesis
- socket type,
- liner, suspension method
- Foot
- knee and hip systems(as required by amputation level), diagnostic or check socket, and supplies.



- Roll-on silicone or elastomeric gel liners are another option that can be used with a PTB total contact socket but are generally recommended for use with TSB socket designs
- Gel liners are thought to enhance comfort and reduce shear, making them the initial choice for residual limbs with scarring or skin grafts that compromise skin integrity
- Gel liners result in more sweating and are generally less tolerated in warm climates than other liners.
- Contraindications to the use of gel liners are residual limbs with open wounds, poor hygiene, or a history of contact dermatitis

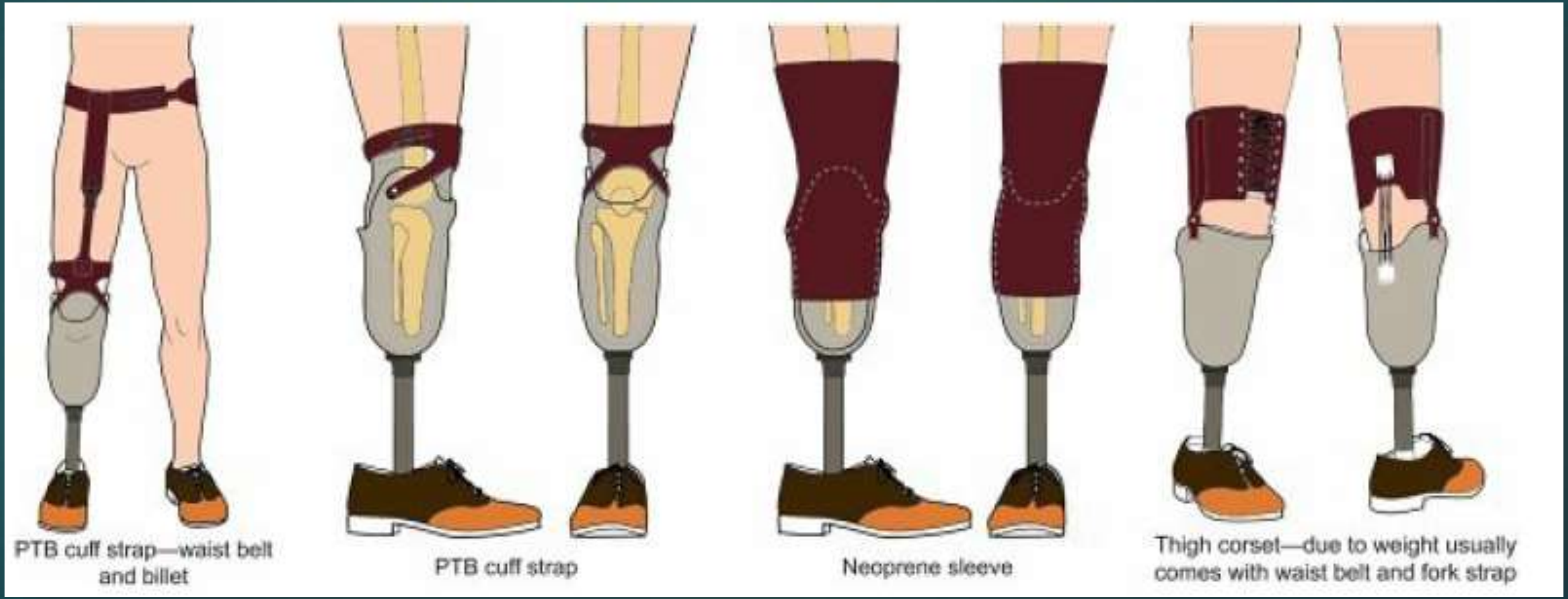
- The suspension system for the transtibial prosthesis must securely attach the limb during activities, minimize pistoning, and be comfortable when sitting



All the parts of the prosthesis fit together for comfort and function. Drawing showing the prosthesis, socket, and pylon, as well as the residual limb, and gel liner.

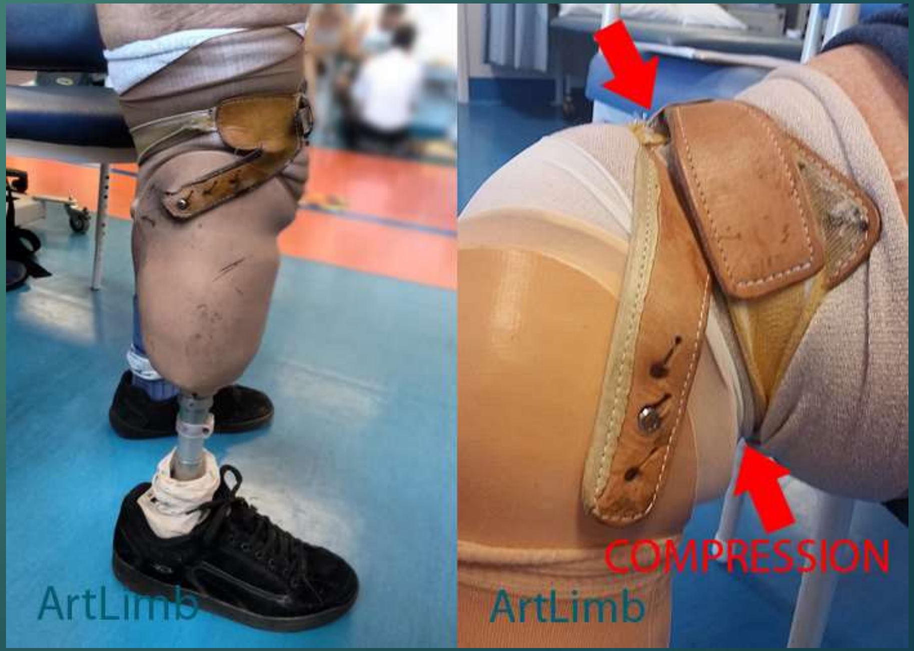
Suspension systems

- can be grouped into categories that include straps, sleeves, gel liners with locking mechanisms, and suction



supracondylar cuff strap

- Several variants exist, all of which consist of a multipart strap that attaches to the sidewalls of the socket and encircles the distal thigh using the normal anatomic flare of the supracondylar portion of the femur to maintain suspension.



Thigh corset and side joints

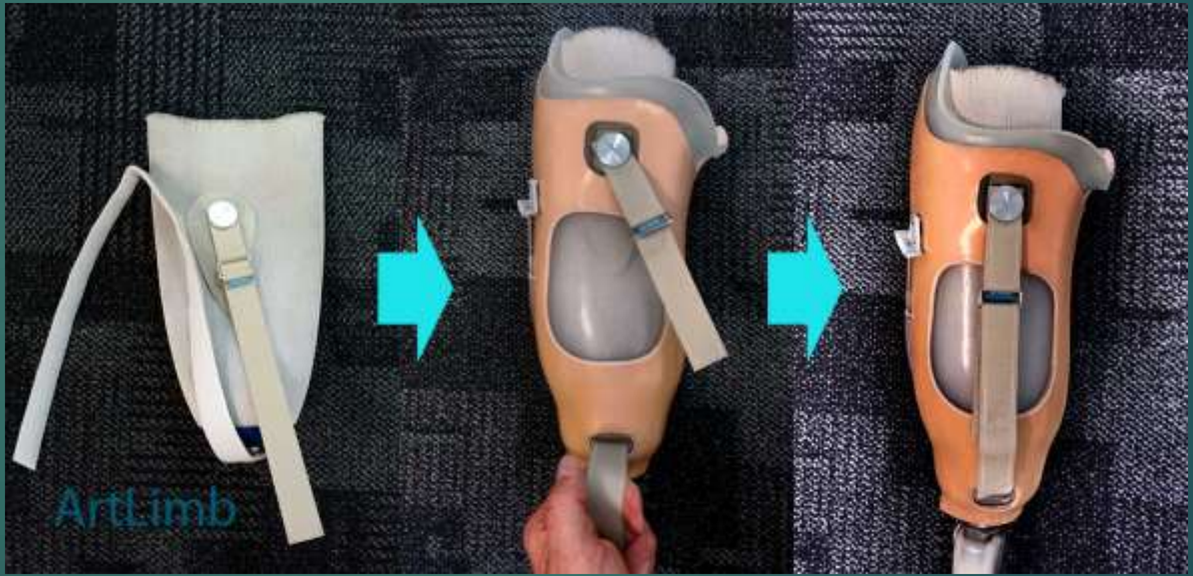
- Thigh corset and side joints attached to the socket are a more rigid suspension option
- The weight and bulk of the resulting limb makes it a poor initial choice for a contemporary prosthetic limb;
- individuals with an amputation who may benefit from this type of limb are those with a short transtibial amputation who require maximal medial-lateral stability for outdoor or work activities
- This type of limb may also be preferred when coexisting ligamentous instability of the knee is present or to partially offload a painful or weight-intolerant residual limb

Sleeve suspension systems

- consist of rubber, neoprene, or elastic sleeves that are pulled up onto the distal thigh after donning the prosthesis
- Sleeves are a general purpose suspension system that is inexpensive and effective for individuals with an amputation across a wide spectrum of activity levels
- The primary disadvantages are related to excessive heat or sweating, the need for good grip strength to pull the sleeve up, and the occasional occurrence of contact dermatitis, especially with the use of neoprene-based sleeves

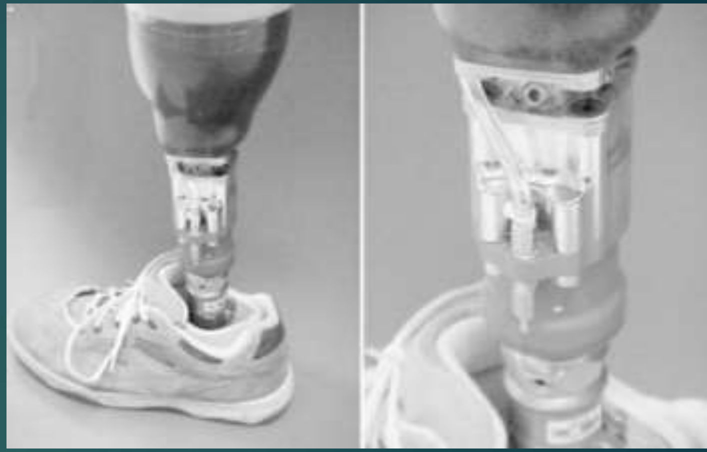
- Silicone and elastomeric gel liners are prosthetic sock-shaped sleeves made from a variety of silicone and urethane elastomeric compounds that are rolled onto the residual limb
- They function as both an interface and suspension method
- The suspension function requires either a metal pin attached to the distal end of the liner that inserts into a locking mechanism in the bottom of the socket or by a Velcro lanyard strap that passes through a slot in the socket and connects with its counterpart attached to the outside of the socket


ICEROSS • TRANSFEMORAL


ArtLimb

Suction Suspension

- By combining a one-way air valve ported to the bottom of the socket with an airtight sleeve, a partial vacuum is created within the socket effectively suspending the prosthesis during the swing phase
- The vacuum needed to hold the residual limb can be generated through a pistoning action of the residual limb within the socket or by a vacuum pump built into the prosthetic shank or foot that is activated at heel strike or by an electric-operated vacuum pump attached to the socket
- These later options are known as vacuumassisted socket suspension (VASS)



- Most contemporary prostheses are endoskeletal in design
- Using an endoskeletal pylon allows alignment changes after prosthetic fabrication and enables the use of additional components that can absorb forces or allow motion between the socket and the remainder of residual limb
- Commonly used components include transverse rotators that reduce axial torques and vertical shock absorbers that cushion impact loading and may reduce oxygen consumption

Transfemoral Amputation

- Because liner and suspension options are closely linked at the transfemoral level, they are discussed together

Socket Designs for Transfemoral Level

- quadrilateral socket
- ischial containment socket (ICS):

Sabolich ICS

Northwestern ICS

M.A.S. (Marlo Anatomical Socket)

- The newest transfemoral socket designs use a strut frame with a flexible inner socket and adjustable straps, allowing the patient some control of the socket fit

- During the last decade, a wide variety of prosthetic knee joints have been designed, fabricated, and made commercially available. A recent survey cataloged over 200 knee units, ranging from the simple single axis knee joints to the completely computerized knee units

FIGURE 56-11. Some of the computerized knees available. **Left to right** is the C-leg, Compact knee, Rheo Knee, Smart Adaptive knee, and the Plie knee. (Courtesy of Otto Bock, Ossur, Endolite and Freedom Innovations. See

Modern joints

The prosthesis for a hemipelvectomy resembles that for the hip disarticulation except in the interior configuration of the socket

In the hemipelvectomy, most of the weight is borne by the soft tissues on the amputated side, with some of the weight being borne by the sacrum, the rib cage, and the opposite ischial tuberosity

Prosthetic Feet

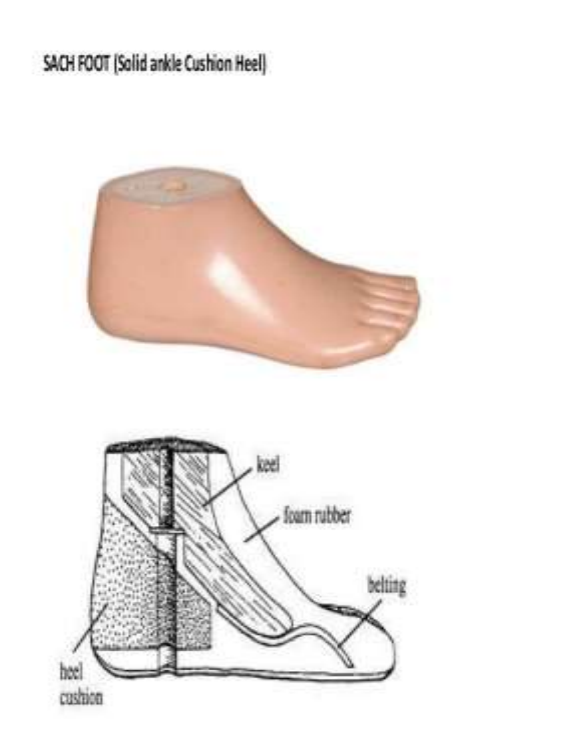
- Prostheses for amputations at or proximal to the ankle require the use of a prosthetic foot.

Hard to choose specific foot

- wide range of foot designs
- marketing-driven claims of performance
- limited availability of objective data comparing the relative biomechanical and functional advantages of different feet

Prosthetic Feet

- selection of a prosthetic foot is largely empirically in clinical setting
- conceptual goal of matching the functional characteristics of the foot to the expected activity needs of the individual
- Within this approach, it is useful to group feet by their major functional feature(s) as belonging to rigid keel, flexible keel, single/multiaxial, or dynamic response (or energy-storing) categories.



relay on the prosthetist who typically has a better working understanding of the commercially available feet to select the specific manufacturer and foot within the desired functional class.

Occasionally, another characteristic of a foot such as an adjustable heel height, cosmesis, or being waterproof is the primary determinate in its selection



(SACH) foot

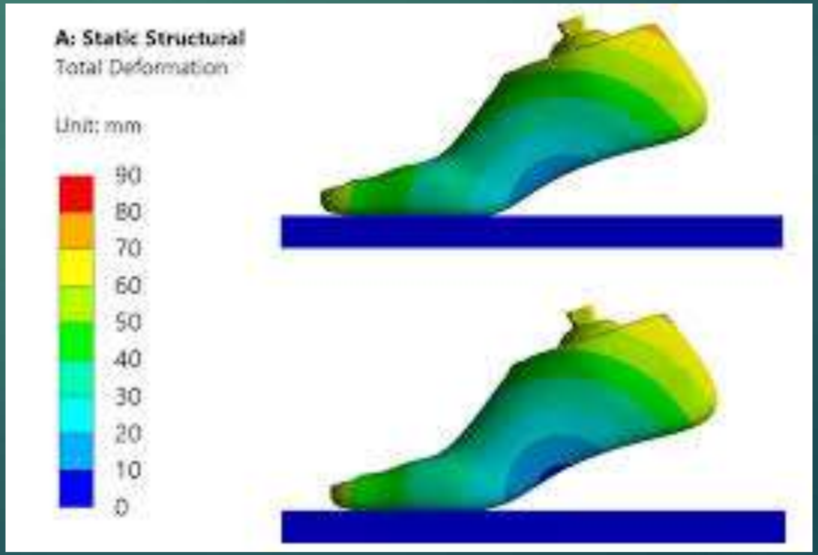
- Prosthetic feet from the solid ankle cushion
- the least expensive and most commonly prescribed prosthetic foot

- heel (SACH) and stationary attachment flexible endoskeletal (safe II flexible keel) foot

For a juvenile with an amputation, the SACH foot is often the most cost-effective foot due to the need for frequent foot changes because of rapid growth

The flexible keel foot

- The flexible keel foot is designed to mimic the motion of the forefoot rocker mechanism by replacing the rigid keel of the SACH foot with a flexible keel
- The keel bends with controlled stiffness as the foot moves from mid-stance through pre-swing



The stationary-ankle-flexible endoskeletal (SAFE) II foot

- commonly used flexible keel foot
- The flexible keel foot allows some inversion and eversion and gives a smoother rollover than a SACH foot, making it appropriate for general mobility needs in the individual with an amputation with a low to moderate activity level
- However, the more active individual with an amputation may perceive the flexible keel foot as being too soft, especially for fast walking or running activities

- Articulating prosthetic feet include both single axis and multiaxis designs
- The single axis foot allows controlled movement in the sagittal plane (plantar flexion and dorsiflexion), adjusted by using different durometer bumpers
- The primary advantage of the single axis foot is its ability to reduce knee-bending movements during limb loading, thus improving knee stability
- Disadvantages include a greater weight than many other feet and more maintenance to ensure correct function




- Prosthetic feet with integral hydraulic ankles can provide similar sagittal plane motion but with the advantages of easier and faster adjustments for plantar flexion and dorsiflexion resistance
- Multiaxial foot designs allow for varying degrees of controlled movement in the sagittal, coronal, and transverse planes (plantar/dorsiflexion, inversion/eversion, some degree of transverse rotation).
- Multiaxis feet can use mechanical joints to supply motion such as the Greissinger foot or the College Park TruStep foot
- but increasingly rely on the inherent flexibility of rubber and polymer materials to provide multiaxial motion