DEFINITION & GENERAL PRINCIPLE OF PROSTHESIS

BME-UOT

5TH LEVEL

BIOMECHANICS, BIOMEDICAL INSTRUMENTS

Definition :

A prosthesis is an artificial replacement for any or all parts of the lower or upper extremities.

It is a device that is designed to replace, as much as possible, the function or appearance of a missing limb or body part.

Purpose

A prosthesis is used to provide an individual who has an amputated limb with the opportunity to perform functional tasks, particularly ambulation (walking) which may not be possible without the limb.

The type of prosthesis is determined by the extent of an amputation.

Most Common Causes of Limb Amputations

1. Trauma

2. Cancer/tumors

3. Vascular complications of diseases

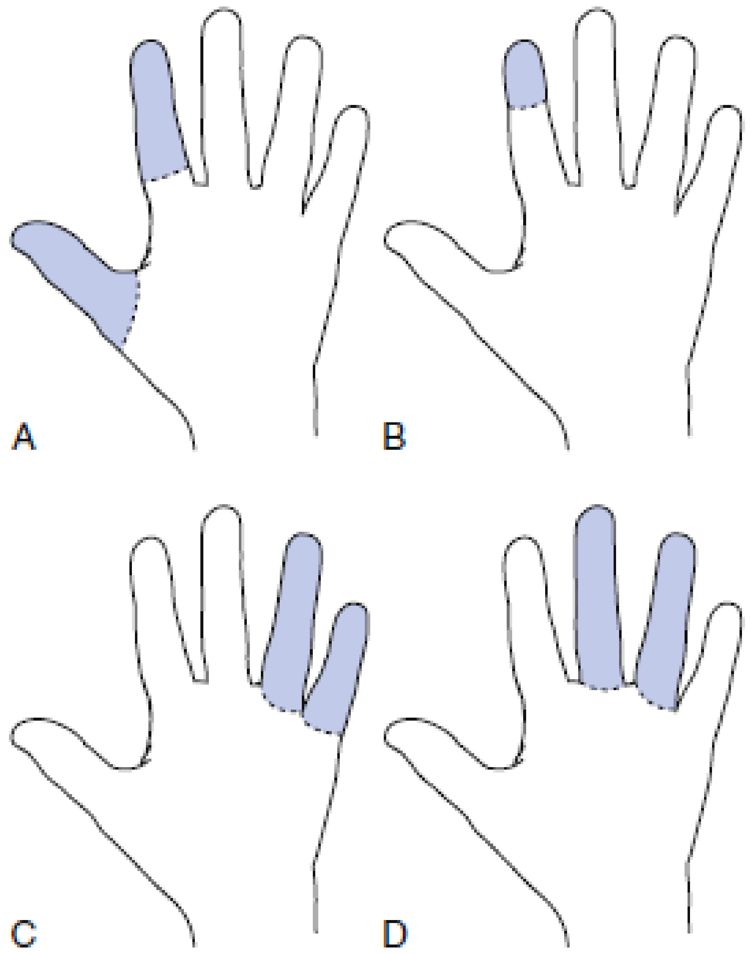


FIGURE 12-2 Types of hand amputations. (A) Radial. (B) Fing
(C) Ulnar. (D) Central.

Prosthesis prescribed according to level of amputation

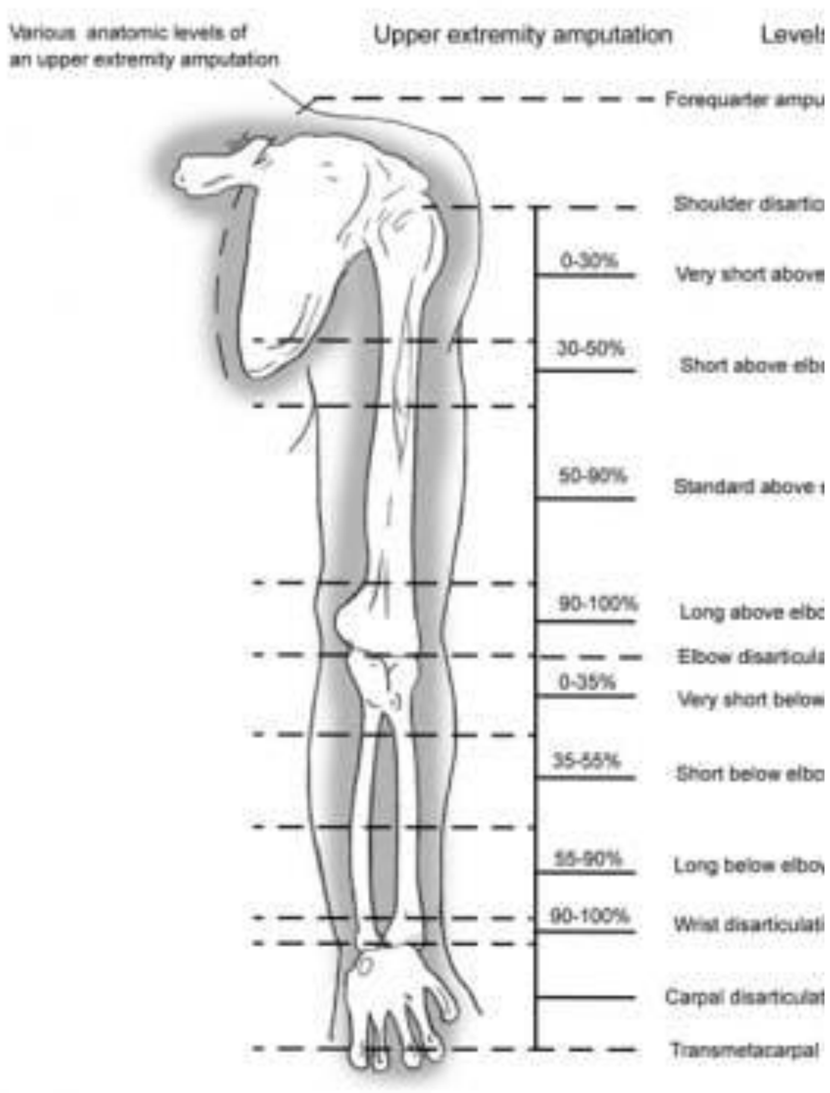
A)Radial amputations involve the thumb and index finger

B)Fingertip amputation is the most common type of amputation.

Thumb amputation, partial or complete, results in loss of palmer grip and tip-to-tip pinch.

C)Ulnar amputations involve digits IV and V, and hook grasp is lost.

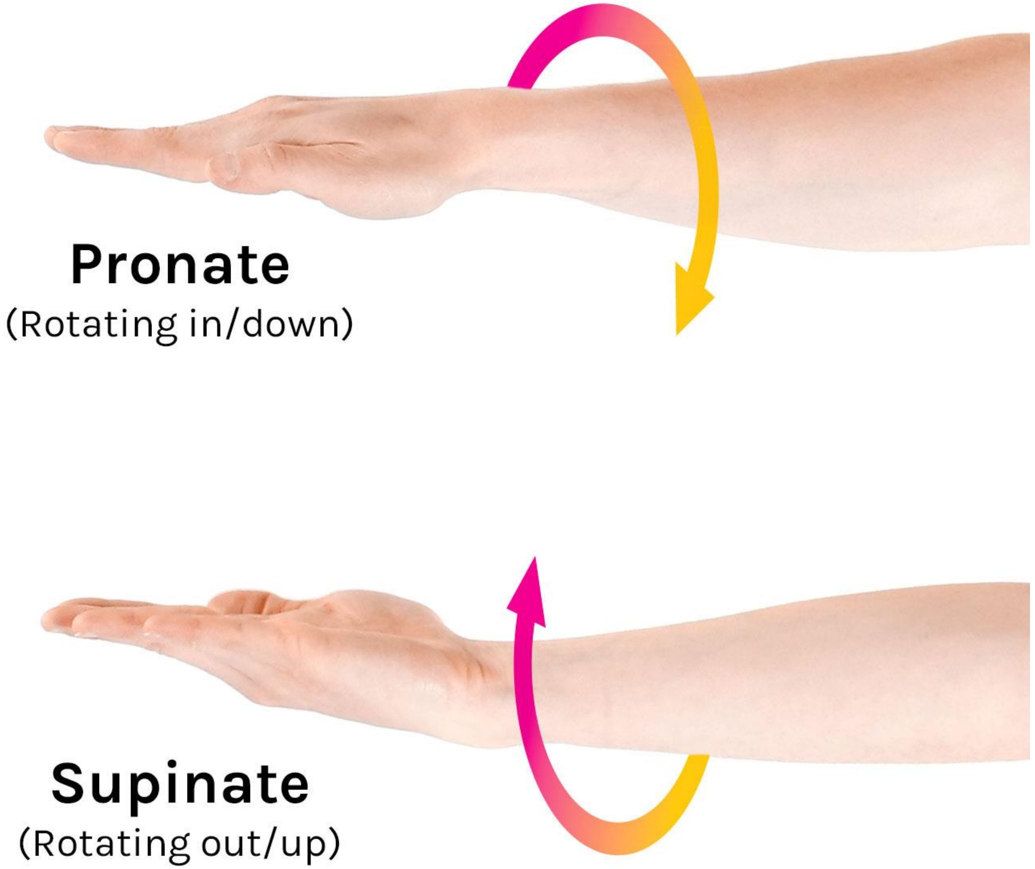
D)Central amputation involves digits III and IV



Standard Levels of Upper-Limb Amputation

1. Trans phalangeal
2. Trans metacarpal
3. Trans carpal
4. Wrist disarticulation
5. Trans radial (below elbow) amputation
6. Elbow disarticulation
7. Trans humeral (above elbow) amputation
8. Shoulder disarticulation
9. Forequarter amputation

1. عبر السلامية
2. عبر المشط
3. ترانسكاربوس
4. تفكك المعصم
5. البتر عبر الشعاعي (تحت الكوع)
6. تفكك الكوع
7. البتر عبر العضدي (فوق الكوع)
8. تفكك الكتف
9. بتر الربع الأمامي



Trans phalangeal amputation

amputation through distal interphalangeal joint /proximal interphalangeal joint or metacarpophalangeal joint

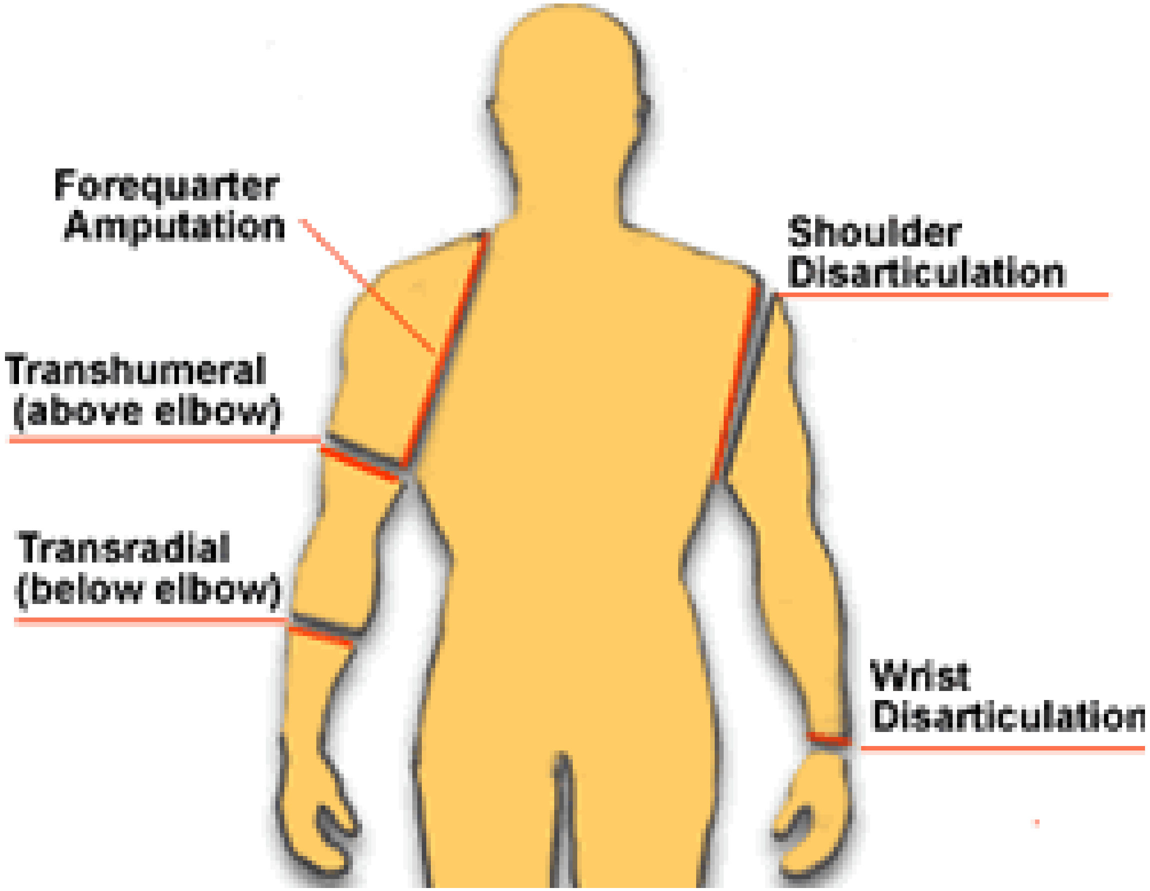
Trans radial amputation: amputation through radius and ulna.devided into three level :

1. Long: residual limb length of 55–90%
2. Short: residual limb length of 35–55%

3 Very short: residual limb length of less than 35%

The long below-elbow residual limb retains 60–120° degrees of supination and pronation and the short below-elbow residual limb retains less than 60° supination and pronation with prosthesis. A very *short transradial* amputation is results in difficult prosthetic suspension and the additional loss of full range of motion (ROM) at the elbow

The long forearm residual limb is preferred for optimal prosthetic restoration goal.



The tran shumeral amputation

can be performed at 3 levels

1. Standard transhumeral: Residual limb length of 50–90%

2. Short transhumeral: Residual limb length of 30–50%

3. Humeral neck: Residual limb length of less than 30%

Glenohumeral motions are preserved and uninhibited by the prosthetic socket with standard transhumeral amputation

With *short transhumeral amputation* results in loss of glenohumeral motion because of the inhibition of the prosthetic socket that encompasses the acromion.

The glenohumeral motions of flexion, extension, and abduction are lost with humeral neck level amputation, *shoulder disarticulation,* and *forequarter amputation*.

Lower limb amputation level

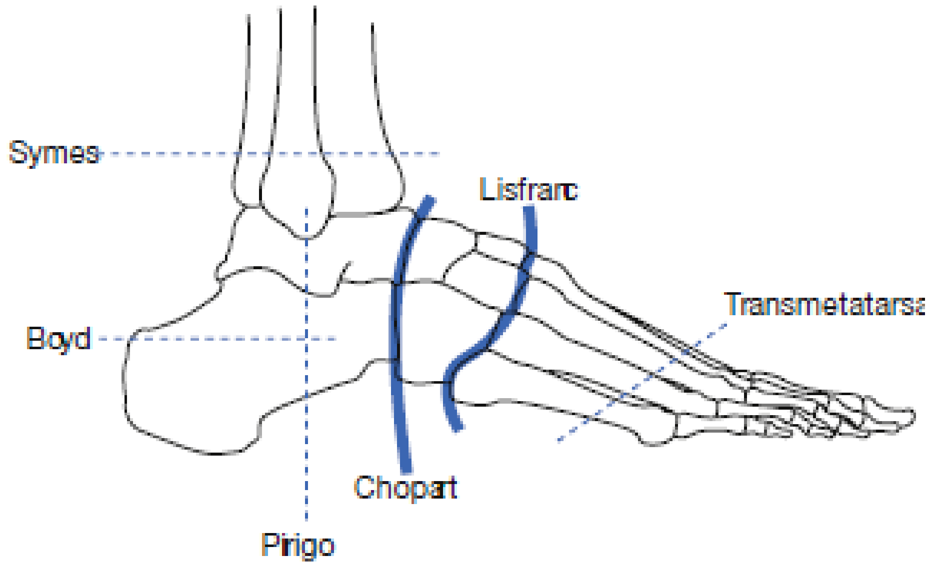
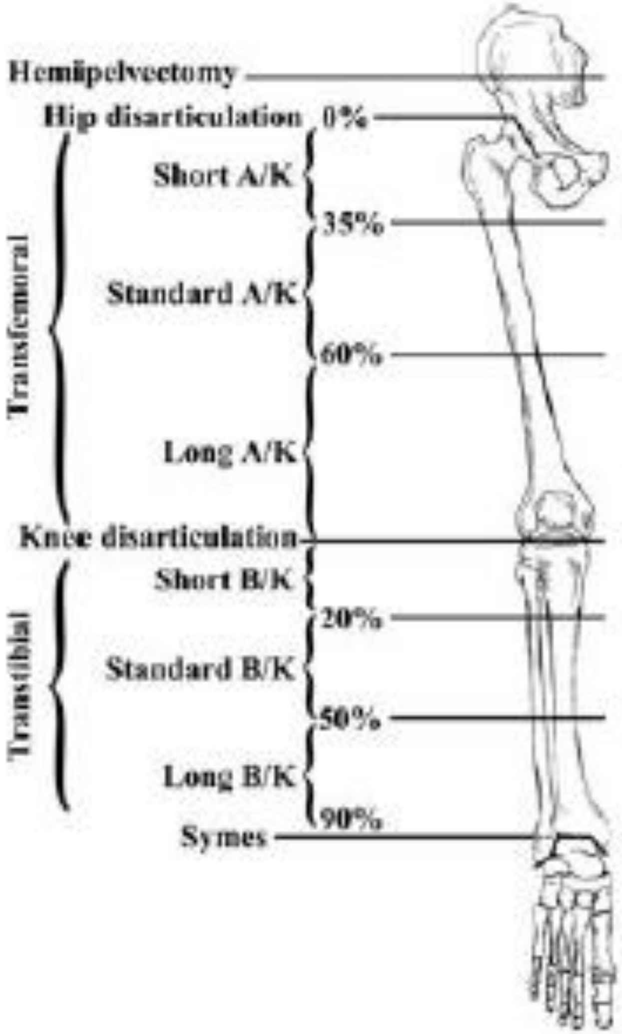


FIGURE 13-9 Levels of partial foot amputations.

Partial toe	Excision of any part of 1 or more toes
Toe disarticulation	Disarticulation at the MTP joint
Partial foot/ray resection	Resection of a portion of up to 3 metatarsals and digits
Transmetatarsal amputation (TMA)	Amputation through the midsection of all metatarsals
Lisfranc	Amputation at the tarso-metatarsal junction
Chopart	Midtarsal amputation—only talus and calcaneus remain
Syme's	Ankle disarticulation with attachment of heel pad to distal end of tibia; may include removal of malleoli and distal tibial/fibular flares



Long BKA (transtibial)	> 50% of tibial length
Standard BKA	20–50% of tibial length
Short BKA (transtibial)	< 20% of tibial length
Knee disarticulation	Amputation through the knee joint, femur intact
Long AKA (transfemoral)	> 60% of femoral length
AK (transfemoral)	35–60% of femoral length
Short AKA (transfemoral)	< 35% of femoral length
Hip disarticulation	Amputation through hip joint, pelvis intact
Hemipelvectomy	Resection of lower half of the pelvis
Hemicorporectomy	Amputation of both lower limbs and pelvis below L4, 5 level

Upper Limb Prostheses

Four categories of upper limb prosthetic systems:

- *Passive system : is primarily cosmetic but also functions a stabilizer. A passive system is fabricated if the patient does not have enough strength or movement to control a prosthesis or wears a prosthesis only for cosmoses.*
- *Body-powered system : prosthesis uses the patient's own residual limb or body strength and ROM to control the prosthesis. This includes powering the basic functions of terminal device opening and closing by elbow and shoulder joint mobilization.*
- *Externally powered system : uses an outside power source such as a battery to operate the prosthesis.*
- *Hybrid system: uses the patient's own muscle strength and joint movement, as well as an external supply for power. An example of a hybrid system is one in which there is a body powered elbow joint but an externally powered terminal device.*

Components of prosthesis

1. Socket
2. Body of prosthesis
3. Harness /suspension system
4. Control system
5. Terminal device

Socket

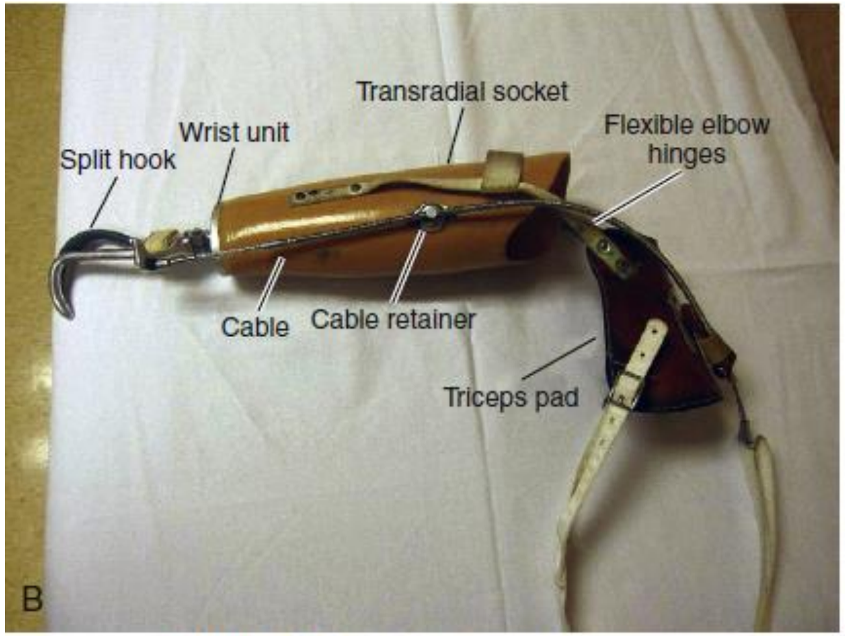


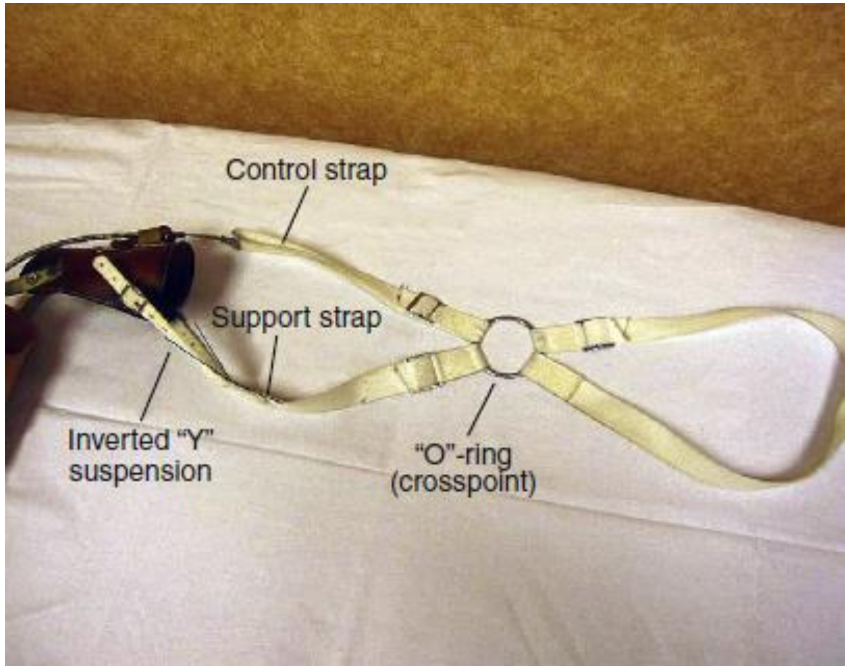
FIGURE 12-7 (**A** and **B**) Transradial prosthesis.

The socket is that part of the prosthesis into which the stump is inserted .There must be an intimate & comfortable fit between the socket & stump.

The socket of upper extremity prosthesis has a double wall framework made of resin, light weight plastic or composite material.

Inner wall conforms to the stump and outer wall provides length and contour to forearm replacement

The wrist unit is attached onto the distal end of forearm piece



Harness

The harness is attached directly to the socket. Its function is to:

1. provide stable support of prosthesis
2. To provide attachment for control cables
3. To help controlling terminal device and/or the elbow unit through control cables.example:

Figure-of-eight harness

Power:

Body-powered prostheses:

Cable controlled

Externally powered prostheses:

Electrically powered Myoelectric prostheses

Switch-controlled prostheses

Body-powered prostheses

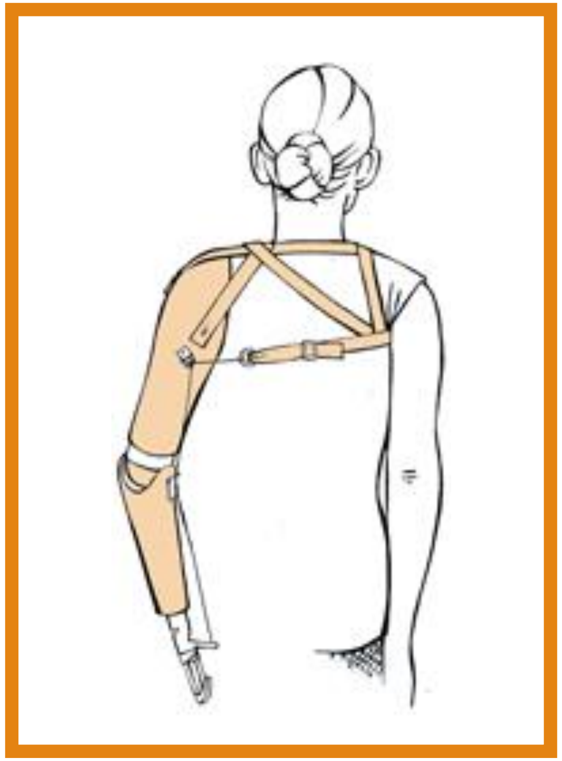
Body powered prostheses use forces generated by body movements transmitted through cables to operate joints and terminal devices.

Forward flexing the shoulder to provide tension on the control cable(Bowden cable) of the prosthesis resulting in opening the terminal device. Relaxing the shoulder forward flexion results in return of the terminal device to the static closed position.

Body-powered prostheses are more durable and are less expensive and lighter than myoelectric prostheses

(1) biscapular protraction

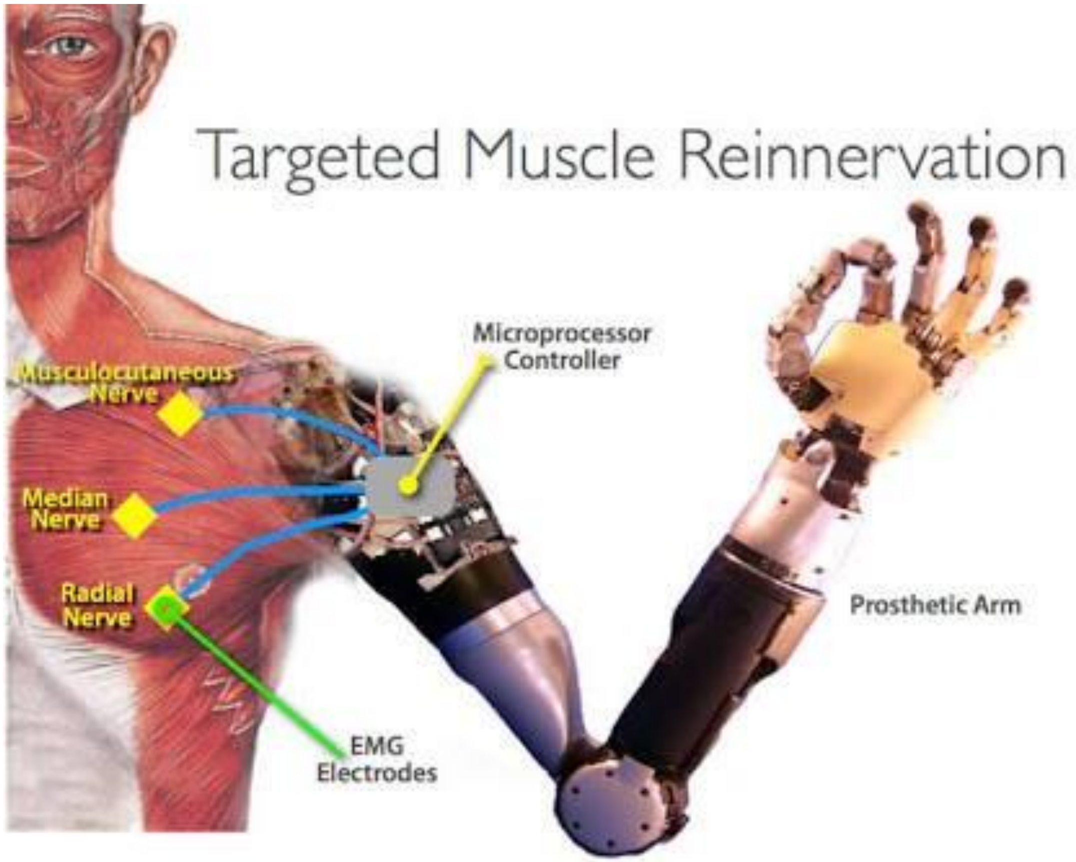
(2) shoulder flexion (and elbow extension = in cases of transradial amputation) are used to control terminal device.



Examples

Shoulder depression, extension, internal rotation, & abduction operate the elbow lock in trans humeral amputation.

Externally powered prostheses



Switch-controlled, externally powered prostheses use small switches to operate the electric motors. These switches typically are enclosed inside the socket or incorporated into the suspension harness of the prosthesis

Externally powered prostheses use muscle contractions or manual switches to activate the prosthesis. Electrical activity from selected residual muscles are detected by surface electrodes to control electric motors

A *myoelectrically controlled* prosthesis uses muscle contractions as a signal to activate the prosthesis. It functions by using surface electrodes to detect electrical activity from selected residual limb muscles to control electric motors.

Terminal Devices and Wrist Units

The terminal device is connected to forearm socket by wrist unit. prosthetic wrist allows passive pronation and supination.

Terminal devices are divided into two categories:

(1) Passive terminal device

(2) Active terminal device

(1)Passive terminal devices :

Designed primarily for function and those that provide cosmoses. Example: baby mitt frequently used on an infant’s first prosthesis to facilitate crawling & ball-handling terminal devices used by older children and adults for ball sports

مصممة في المقام الأول للوظيفة وتلك التي توفر الكون. مثال: قفاز الأطفال يستخدم بشكل متكرر في الطرف الاصطناعي الأول للرضيع لتسهيل الزحف والتعامل مع الأجهزة الطرفية التي يستخدمها الأطفال الأكبر سنا والبالغون في رياضات الكرة

Active terminal devices :

Two main categories

(1)*Hooks* including *prehensors* (which are devices that have a thumb-like component and a finger component)

(2) *Artificial hands*

Both device groups can be operated with a cable or by external power

Cable-operated terminal devices (hooks or hands) can be a voluntary opening design (most commonly used) or a voluntary closing design.

With a *voluntary opening mechanism* the terminal device is closed at rest. The patient uses the control-cable motion to open the terminal device against the resistive force of rubber bands (hook) or internal springs or cables (hand). Relaxation of the proximal muscles allows the terminal device to close around the desired object.

With a *voluntary closing mechanism* the terminal device is open at rest. The patient uses the control-cable motion to close the terminal device, grasping the desired object.

LOWER LIMB PROSTHESIS

1.PREPARATORY (TEMPORARY) PROSTHESIS
2. DEFINITIVE (PERMANENT) PROSTHESIS

1.Preparatory (Temporary) Prosthesis

A preparatory (temporary) prosthesis is usually made prior to a definitive prosthesis. It helps in shrinking and shaping of the residual limb.

Allows for early prosthetic training (gait and functional training) and fine tuning of the prosthetic alignment as the amputee's gait progress

Usually used for 3 to 6 months of post surgery (until maximal stump shrinkage has been achieved).

Definitive (Permanent) Prosthesis:

When shaping and shrinking process has ended and residual limb volume has stabilized, a definitive or permanent prosthesis is made.

It can be applied after 3-9 months of postoperative.

Life span of 3-5 years.

Changes are needed when there is residual limb atrophy, weight gain or loss and excessive wear after prosthesis.

Lower limb prosthesis

Socket:

The socket is typically custom-made for the user. The socket is constructed using a cast of the residual limb. The residual limb shape can also be recorded via manual measurements or by digital measurements that track the outer shape of the limb. This shape is then used to create the socket interface.

In most sockets, the goal is to achieve total contact with the residual limb. Total contact does not necessarily imply equal pressure distribution.

Pressure-tolerant areas can receive higher pressures and pressure sensitive areas can receive lower pressures. Total contact helps decrease edema, increase proprioception and increase the overall weight-bearing surface

Lower limb prosthesis

The prosthetist notes the individual characteristic of stump & makes a cast of residual limb with plaster of paris & later the mould is filled with plaster of paris powder & positive mould is made

HDPE plastic is made soft by heating in hot air woven at 200 degree Celsius .Socket is constructed by moulding plastic directly over the positive model of residual limb.

Suspension:

Suspension is the method by which the prosthesis is held onto a person's residual limb.

Example:

Pelvic belt

Supracondylar calf

Body:

The prosthetic socket is connected to the remaining components in two ways:

(1) Exoskeletal construction

(2) Endoskeletal construction

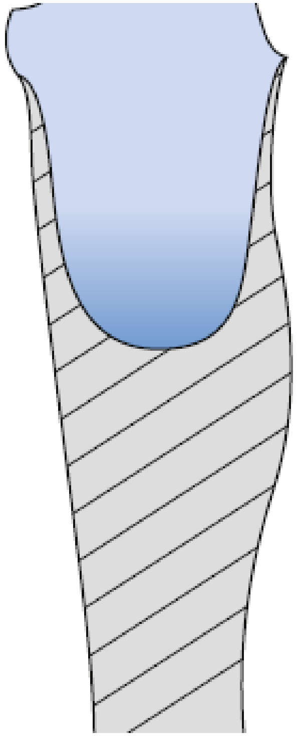
Endoskeletal construction

the socket connects to the remaining components through pipes called pylons. The modularity of these components allows for angular and linear changes in both the sagittal and coronal planes and makes it easy to adjust the height of the prosthesis if necessary.

An important benefit of this modularity includes the ability to use many different components (e.g., adapters and feet).

Endoskeletal systems are made of carbon fiber or titanium pylons or steel.

Exoskeletal construction



gains its structural strength from outer laminated shell through which the weight of the body transmitted.

This shell is made of resin or HDPE over a filler material of wood or foam and whole prosthesis shaped to provide a cosmetic appearance of amputed limb.

The opposite surviving leg is taken for reference for shape length and skin colour

Prosthetic feet

prosthetic feet are made out of many different materials including wood, plastic, foam, and carbon fiber. Example:

(1)SACH (solid ankle cushion-heel)

(2)Jaipur foot

Solid-Ankle Cushion-Heel Feet

The SACH feet, introduced in 1956 by Foort and Radcliffe

SACH feet have solid ankles in that there is no articulation within the foot. They attach to the distal aspect of the shank (endoskeletal pylon-ankle adapter or ankle block) in a way that permits no motion.

Motion in all planes is arrested. No plantar flexion, dorsiflexion, inversion, eversion or transverse plane motion is allowed during gait

It has to be used only with shoes since shape of toes are not discernible

Jaipur foot

It was developed at SMS medical college, Jaipur by prof PK Sethi and team.

The elasticity of rubber provides enough dorsiflexion to permit amputee to squat,transevrese rotation of foot on the leg to facilate walking and cross legged sitting and sufficient range of inversion & eversion to allow the foot to adapt itself while walking on uneven surface.

The foot and ankle assembly is made of uncured rubber material. Exterior is made of water proof material.

It enables barefoot walking

Prosthetic knee Joint

The knee joint is aligned in the prosthesis in extension .The best knee mechanism in one that offers adequate stability in stance phase

If the knee mechanism does not fully extend before heel contact it buckles causing the prosthetic knee to flex suddenly when weight is applied

Thank you