

## Orthotic and Prosthetic Devices

### Prostheses

A prosthesis (also called a prosthetic limb, artificial limb, or limb replacement) is an artificially made substitute for a limb lost through a congenital defect (present at birth), accident, illness, or wartime injury. A type of prosthesis called a cosmesis is designed to be purely cosmetic and has little or no function; artificial hands often fall into this category. Other prostheses are highly functional and have little or no cosmetic disguise; artificial legs, designed to be covered by pants (trousers), are sometimes little more than metal rods and wires. In theory, any part of the body—from ear or nose to finger or toe—could be replaced by prosthesis.

### Artificial Limb and hand

In practice, there are four common types of prosthetic limb, which replace either a partial or complete loss of an arm or leg:

- Below the knee (transtibial): A replacement lower leg attached to an intact upper leg.
- Above the knee (transfemoral): A complete replacement leg.
- Below the elbow (transradial): A replacement forearm.
- Above the elbow (transhumeral): A complete replacement arm.

Prosthesis consists of a number of different parts. There's the prosthetic limb itself, the socket (the joint between the prosthetic limb and the patient's body), the attachment mechanism, and the control system.



Below Knee

Above knee

Foot



### General prosthetic design characteristics

**Custom Designed Prostheses:** Prostheses are custom made from an anatomical positive model of an individual's residual limb and in accordance with anatomical measurements of the sound limb.

**Pre-Fabricated Prostheses:** Prostheses are not pre-made in general anatomical sizes except for a temporary residual limb interface utilized in the design for a preparatory prosthesis.

**General prosthetic structural design characteristics**

**Endoskeletal Prostheses:** Prostheses with a soft exterior covering and designed with an internal supporting structural system or components.

**Exoskeletal Prostheses:** Prostheses with a hard exterior covering and designed with rigid reinforced external supporting structural system or shell.

An **orthosis** (plural: *orthoses*) is "an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system". An orthosis may be used to:

- Control, guide, limit and/or immobilize an extremities, joint or body segment for a particular reason
- To restrict movement in a given direction
- To assist movement generally
- To reduce weight bearing forces for a particular purpose
- To aid rehabilitation from fractures after the removal of a cast
- To otherwise correct the shape and/or function of the body, to provide easier movement capability or reduce pain

Examples:

**Cervical orthosis** - one that encircles the neck and supports the chin, used in the treatment of injuries of the cervical spine.

**Dynamic orthosis** - a support or protective apparatus for the hand or other body part which also aids in initiating, performing, and reacting to motion.

**Halo orthosis** - a cervical orthosis consisting of a stiff halo attached to the upper skull and to a rigid jacket on the chest, providing maximal rigidity.

**General prosthetic design characteristics**

**Custom Designed Orthoses:** Orthoses which are custom made and designed from an anatomical positive model, specific anatomical measurements and/or contour drawings of the affected limb, torso or spine for the purpose of providing support and/or control of complex neuromuscular and/or musculoskeletal disorders.

**Custom Fitted Orthoses:** Orthoses which are pre-made in specific anatomical sizes and are modified and custom fitted to the affected limb or spine to control moderate or complex neuromuscular and/or musculoskeletal disorders.

**Pre-Fabricated Orthoses:** Orthoses which are pre-made in generic anatomical sizes and shapes i.e.; small, medium and large, and are fitted to the affected limb or spine to control mild neuromuscular and/or musculoskeletal disorders or for the purpose of evaluating the need for a custom designed orthosis.

**Intelligent prosthetics**

People without one or more limbs use artificial extensions that replace their missing body parts. These extensions use a combination of mechanical devices and human muscles to move and act as a supplement limb. Nowadays modern technology offers not only creation of lifelike limbs, but also introduces intuitive control of arm and leg prostheses. Intelligent prosthetics will use human nerve system and brain interfacing to increase precision and comfort of movements. Eg.,

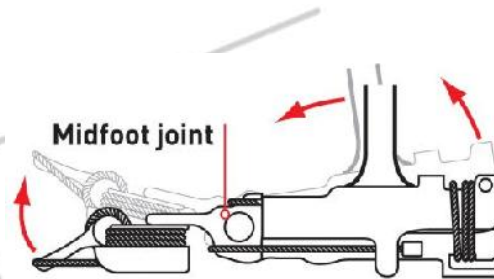
- (A) **Immaculate** is a lightweight prosthetic arm (less than 60% of the weight of original arm). It is stylish, sleek and made from advanced materials, with a possibility to integrate additional

devices (an ipod, for instance). Immaculate has a ball joint, which provides total freedom of movements – 360 degree in every joint.

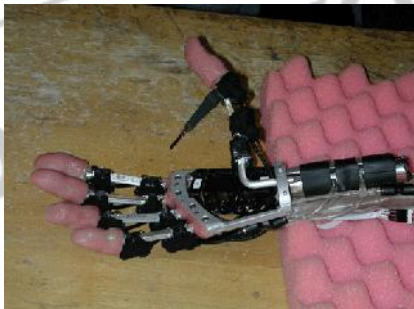
- (B) **Tensegrity foot** is designed to mimic the action of a real foot in order to allow for more natural and stable movements. It bends and adjusts to the surface underneath it.
- (C) **Fluidhand** is a soft prosthetic hand, which is more natural than conventional artificial hands. Its user is able to fully wrap around and grip objects, and at the same time sense the strength of the grip.
- (D) **i-LIMB Hand** is a prosthesis with separately powered fingers. It offers a more intuitive control system of a limb. It is guided by electrical signals from the patient muscles, which are then read by electrodes sitting on the surface of the patient skin. Research shows that it is easy to use and adapt within minutes.



Immaculate



Tensegrity foot



Fluidhand



i-LIMB

### Externally powered and controlled orthotics and prosthetics

Externally powered prostheses use electrical power to provide function. The electrical power is applied via motors located in the terminal device (hand or hook), wrist, and elbow. The grip force of the hand can be in excess of 100 N. Command signals are generated by using switches or different kinds. For applications that are more complex, both the command signals are used for different operations (eg., control of several degrees of freedom).

Hybrid prosthesis utilizes a body-powered elbow and a myoelectrically controlled terminal device-hook or hand. Most important ability provided to the patient is to simultaneously control elbow flexion and extension while opening or closing the electric hand/hook or while rotating the wrist. The other prosthetic options generally require the wearer to control one function at a time (flex the elbow, lock the elbow, open or close the terminal device). The hybrid prosthesis weights less and is less expensive than an similar prosthesis with an electrically powered elbow and hand. An example is the Ergo arm from Otto Bock that uses the new elbow system that can be unlocked or locked in any position, even under loads up to 250N. A slight pull on the cable lowers the forearm gradually. Releasing the cable immediately locks the elbow in that position. For normal locking or unlocking, the cable has to be pulled stronger. The elbow is designed to support myoelectric hand. When the prosthetic arm is extended, the system stores the energy to facilitate flexion. The arm swings smoothly while walking. Subject-adjustable counterbalance makes the arm fell lighter, even with an electric wrist and terminal device.

## **FES System**

Functional Electrical Stimulation (FES) can help in regaining functional movements in numerous paralyzed humans. FES activates innervated but paralyzed muscles, by using an electronic stimulator to deliver trains of pulses to neuromuscular structures. The basic phenomenon of the stimulation is a contraction of muscle due to the controlled delivery of electric charge to neuromuscular structures.

FES systems can restore (1) goal-oriented (hand and arm) movements, and (2) cyclic (walking and standing) movements.

FES for restoration of standing and walking:

This system is only suitable for stroke patients and a limited group of incomplete spinal cord injury patients. The FES in these humans is used to activate a single muscle group. The stimulation is applied to ankle dorsiflexors so the “foot-drop” can be eliminated. A commercial system has been designed by Stein and colleagues, which integrates a single-channel stimulator and a tilt sensor; thus, eliminating a foot switch which was proved for easily generating false triggering and malfunctioning. Single and dual channel correcting foot-drop is now a regular clinical treatment in some rehabilitation institutions.

A multichannel system with a minimum of four channels of FES is required for ambulation of a patient with a complete motor lesion of lower extremities and preserved balance and upper body motor control. Appropriate bilateral stimulation of the quadriceps muscles locks the knees during standing. Stimulating the common peroneal nerve on the ipsilateral side, while switching off the quadriceps stimulation on that side, produces a flexion of the leg. This flexion, combined with adequate movement of the upper body and use of the upper extremities for support, allows ground clearance and is considered the swing phase of the gait cycle. Hand or foot switches can provide the flexion–extension alternation needed for a slow forward or backward progression. Sufficient arm strength must be available to provide balance in parallel bars (clinical application), and with a rolling walker or crutches (daily use of FES).

A multichannel totally implanted FES system was proposed and tested in a few subjects. This system uses a 16-channel implantable stimulator attached to the epineurium electrodes. Femoral and gluteal nerves were stimulated for hip and knee extension. The so-called “round-about” stimulation was applied in which four electrodes were located around the nerve and stimulated intermittently. This stimulation method reduces muscle fatigue.

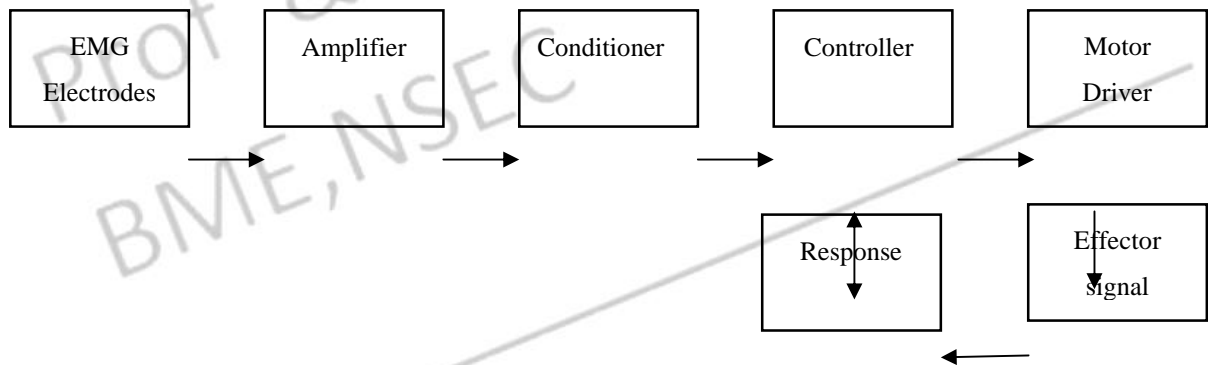
## **Hybrid Assistive Systems (HAS)**

This specific system approaches to integrating two assistive systems (FES and an external mechanical orthosis). These systems are called hybrid assistive systems (HAS) or hybrid orthotic systems (HOS). A few possibilities for HAS design have been suggested, which combine relatively simple rigid mechanical structures for passive stabilization of lower limbs during stance phase and FES systems. These systems combine the use of a reciprocating gait orthosis with multichannel stimulation, the use of an ankle–foot orthosis or an extended ankle–foot orthosis with a knee cage, or the use of a self-fitting modular orthosis. The following features can serve as criteria for a closer description of various HAS designs: (1) partial mechanical support, (2) parallel operation of the biological and mechanical system, and (3) sequential operation of the biological and the mechanical system. The partial mechanical support refers to the use of braces to assist FES only at specific events within a walking cycle.

## Myoelectric Hand and Arm Prosthetics

One of the most advanced techniques used in the upper limb prosthesis implementation is the myoelectric prosthesis, also known as the “Myoelectric Hand”. Here, the electromechanical joint activates the structure of the prosthesis which is activated by the amputee by means of the electromyographic signal (EMG) which is detected by the electrode (skin response). The entire structure is run on batteries and processed through a programmable central circuit. The main objective of the myoelectric hand is to device prosthesis for the upper limb amputees. The development of the myoelectric hand follows the following steps.

- Electrodes – to detect the EMG signal superficial ‘dry’ skin electrodes are designed. The signals received by the electrodes are further amplified by an instrumentation amplifier. The location of the electrode is very important for efficient signal detection. The electrodes should also avoid cross talk and other artifacts.
- Conditioner – This unit receives the output of the electrodes and transforms the electrical signal to a logical signal, indicating the presence of the signal.
- Controller – this unit monitors the presence and source of the EMG signal. Based on this information, it commands the monitor and direction of the motor driver. It also stops the action, if overflow of current.
- Motor driver – Determine the direction of the current in the motor winding.
- Power distribution – It receives the voltage power and thus, distributes the same to the entire system.
- Batteries – Provides power supply to the myoelectric hand.
- Mechanical Hand – The physics and the structure of the mechanical hand is very important for the construction of this prosthesis. The weight of the body determines the weight of the hand. Miscalculation may lead to failure and uncomfartability



## MARCUS Intelligent Hand Prostheses

Manipulation/ Manipulative Automatic Reaction Control under user Supervision (MARCUS) is an advanced prosthetic hand that utilizes supervisory control and also involves the brain, correlation of



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Prosthesis is an artificial device designed to replace a missing part of the body or to make a part of the body work better. The missing part of the body may be lost through trauma, disease, or congenital conditions. Diseased or missing eyes, arms, hands, legs, or joints are commonly replaced by prosthetic devices. False teeth are known as dental prostheses. An artificial replacement of the jaw bone is called a maxillofacial prosthesis. The origin of prosthetics as a science is attributed to the 16th-century French surgeon Ambroise Paré. Later workers developed upper-extremity replacements, including metal hands made either in one piece or with movable parts.

**Limb Prostheses** include both upper and lower extremity prostheses.

**Upper extremity prostheses** are used at varying levels of amputation: shoulder disarticulation, transhumeral prosthesis, elbow disarticulation, transradial prosthesis, wrist disarticulation, full hand, partial hand, finger, partial finger.

**Lower extremity prostheses** provide replacements at varying levels of amputation. These include hip disarticulation, transfemoral prosthesis, knee disarticulation, transtibial prosthesis, symes, foot, partial foot, and toe. The two main subcategories of lower extremity prosthetic devices are trans-tibial (any amputation transecting the tibia bone or a congenital anomaly resulting in a tibial

deficiency) and trans-femoral (any amputation transecting the femur bone or a congenital anomaly resulting in a femoral deficiency).

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