LECTURES 1-2: INTRODUCTION

LECTURES 3-4: Prosthetics for Upper-Extremity Amputation

3.1 Introduction

Prosthesis

- **A prosthesis is a device that is designed to replace, as much as possible, the function or appearance of a missing limb or body part.**
- **It is a device that is designed to support, supplement, or augment the function of an existing limb or body part.**

Prosthetic management of individuals with upper-extremity amputations presents all allied health professionals, including prosthetists, with a set of unique challenges. By its level, the person with upper-extremity amputation must cope with not only physical appearance changes but also the loss of some of the most complex movement patterns and functional activities of the human body.

In addition, limb deficiency in the upper extremity deprives the patient of an extensive and valuable system of tactile and proprioceptive inputs that previously provided “feedback” to guide and refine functional movement.

Many of these challenges have been addressed with new and emerging technologies. These new technologies have made it possible, in some circumstances, to successfully “fit” a patient with high-level amputation who previously would have little or no reasonable expectation to succeed with traditional technology and fitting techniques.

Advanced socket interface designs and material science have afforded prosthetists the ability to offer stronger, more stable platforms for all levels of amputation, while in most cases saving substantial amounts of weight.

Similarly, more innovative suspension strategies and interface mediums have increased the functional ranges of motion a patient can comfortably achieve. These advancements have had a profound and positive effect on the comfort, function, and compliance of both conventional body-powered and externally powered prostheses at all levels of amputation.

The most common reasons for an upper extremity amputation

- **Correction** of a congenital deformity or
- **Tumor** is commonly seen in individuals aged 0-15 years.
- **Trauma** is the most common reason for amputation in patients aged 15-45 years, with tumors being a distant second.
- Upper extremity amputations tend to be rare in patients who are older than 60 years, but they may be required secondary to tumor or medical disease.

Amputation levels

- **Transphalangeal amputation**
- **Transmetacarpal amputation**
- **Transcarpal amputation**
- **Wrist disarticulation**
- **Transradial amputation**
- **Elbow disarticulation**
- **Transhumeral amputation**
- **Shoulder disarticulation**
- **Interscapulothoracic disarticulation**

DIFFERENT TYPES OF PROSTHESES

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The continuum of prostheses ranges from mostly passive or cosmetic types on one end to primarily functional types on the other. The purpose of most prostheses falls somewhere in the middle. Cosmetic prostheses can look extremely natural, but they often are more difficult to keep clean, can be expensive, and usually sacrifice some function for increased cosmetic appearance.

Functional prostheses generally can be divided into the following 2 categories

- ***Body-powered prostheses*** - Cable controlled
- ***Externally powered prostheses*** - Electrically powered.
  - **Myo-electric prostheses**
  - **Switch-controlled prostheses**

Body-powered prostheses

- Body-powered prostheses (cables) usually are of moderate cost and weight. They are the most durable prostheses and have higher sensory feedback. However, a body-powered prosthesis is more often less cosmetically pleasing than a myoelectrically controlled type is, and it requires more gross limb movement.

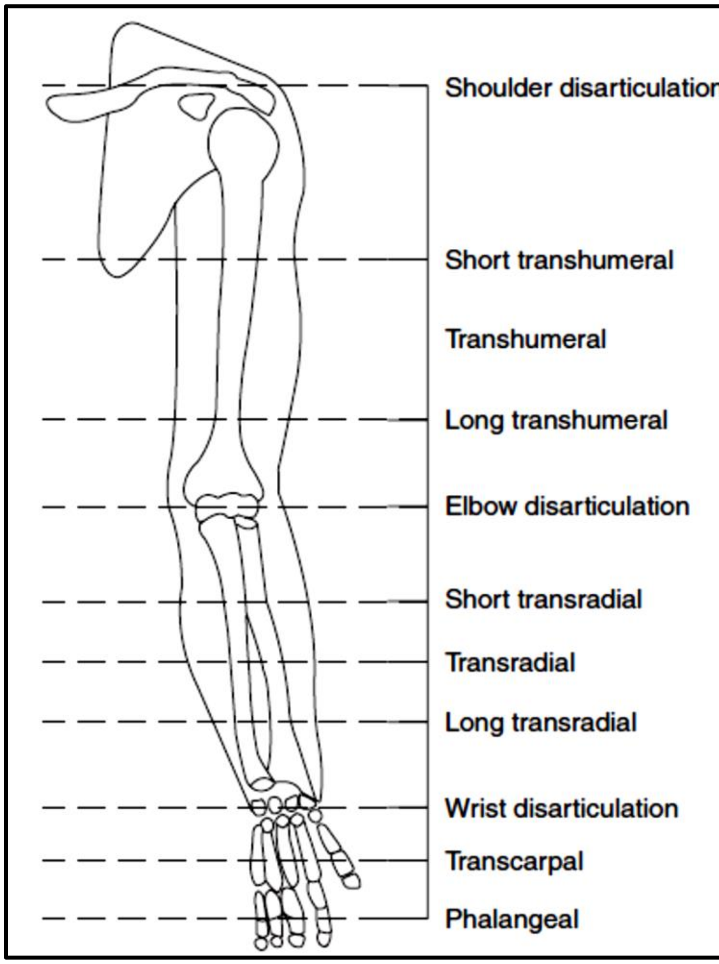
3.2 Length of the Residual Limb

- Amputations to the upper extremity can be classified or named by the limb segments affected (Figure 1). The most distal are at the finger, partial hand, or trans carpal levels.
- Amputations that separate the carpal bones from the radius and ulna are referred to as wrist disarticulations.
- Amputations that occur within the substance of the radius and ulna are classified as trans-radial amputations.
- When the humerus is preserved but the radius and ulna are removed, the

amputation is referred to as an elbow disarticulation.

- Those that leave more than 30% of humeral length are designated as transhumeral
- In clinical prosthetic and rehabilitation practices, trans-radial and trans-humeral amputations account for nearly 80% of all upper extremity amputations.

Figure (1): Classification of upper-extremity amputation and residual limbs.



For patients with partial hand amputations, the range of motion (ROM) of any remaining digits and the condition of the structural bones of the hand has a profound effect on the selection of possible prosthetic options.

For those with transverse amputations of the forearm, the length of the residual limb affects the amount of functional elbow flexion and forearm pronation and supination that will be retained independent of prosthetic intervention.

When the residual forearm is extremely short, all transverse motion is essentially lost, and it is difficult to gain any active functional forearm rotation for prosthetic use (Figure 2).

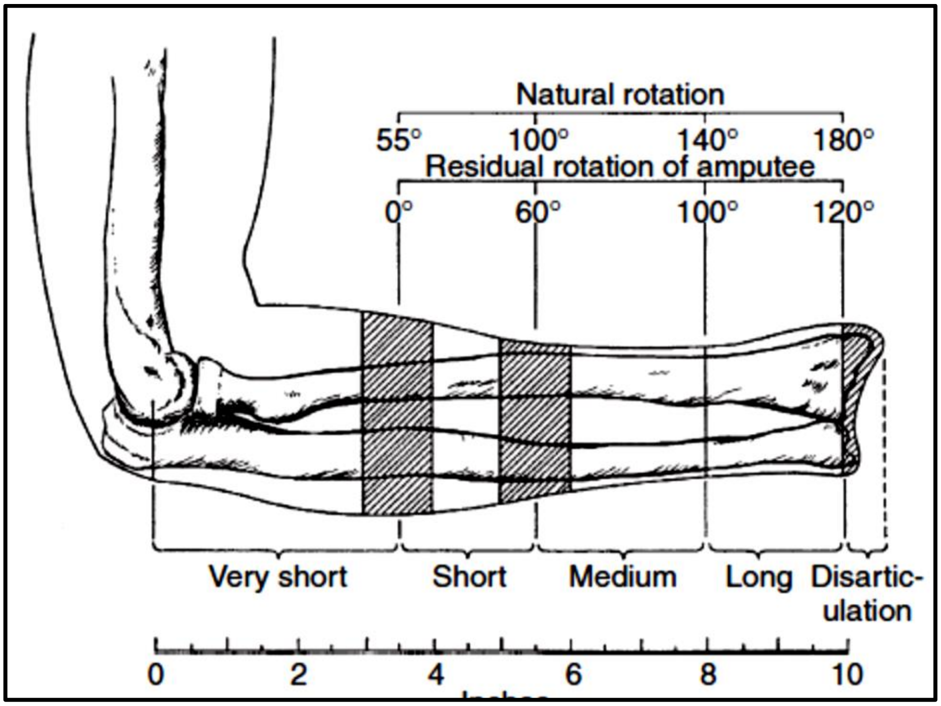


Figure (2): Potential for pronation and supination of transradial residual limbs of differing lengths.

Amputations at the level of the elbow (elbow disarticulation) derive little functional benefit from the added length because the length of the limb limits options for cosmetic and functional placement of elbow units within the prosthesis, without substantially improving functional leverage.

3.3 Upper Extremity Prosthetic Component

Prosthetic components can be thought of as a means to replace lost functional capacity associated with the anatomical loss of limb segments.

An elbow mechanism is used to replace the humeral-ulnar articulation; a shoulder mechanism is placed proximally to provide humeral orientation in space at the shoulder disarticulation and scapulothoracic amputation levels.

Rotators can be placed in the forearm of the prosthesis to substitute for pronation and supination or above the elbow unit to substitute for internal and external rotation of the shoulder as well.

3.3.1 Partial Hand, Trans carpal, and Wrist Disarticulation

Until recently, patients with digit, partial hand, or trans carpal amputations were often offered passive (nonfunctioning) cosmetic prostheses (restorations). Depending on the characteristics of the residual limb, a functional prehensile post might have been fabricated to regain some grasp and release capability of the affected limb. Recent advances in technology and microprocessors have made externally powered options more readily available (Figure 3).

These advances permit electric control despite the extremely distal amputation site. Consideration must be given preoperatively to any remaining functional digits. The status of sensation and mobility of these digits should not be understated.

The wrist disarticulation residual limb provides a long and functional lever for prosthetic use. In that case, the prosthetist can use a positive suspension strategy over these prominences to keep the prosthesis and stable suspended on the residual limb, making harnesses unnecessary.

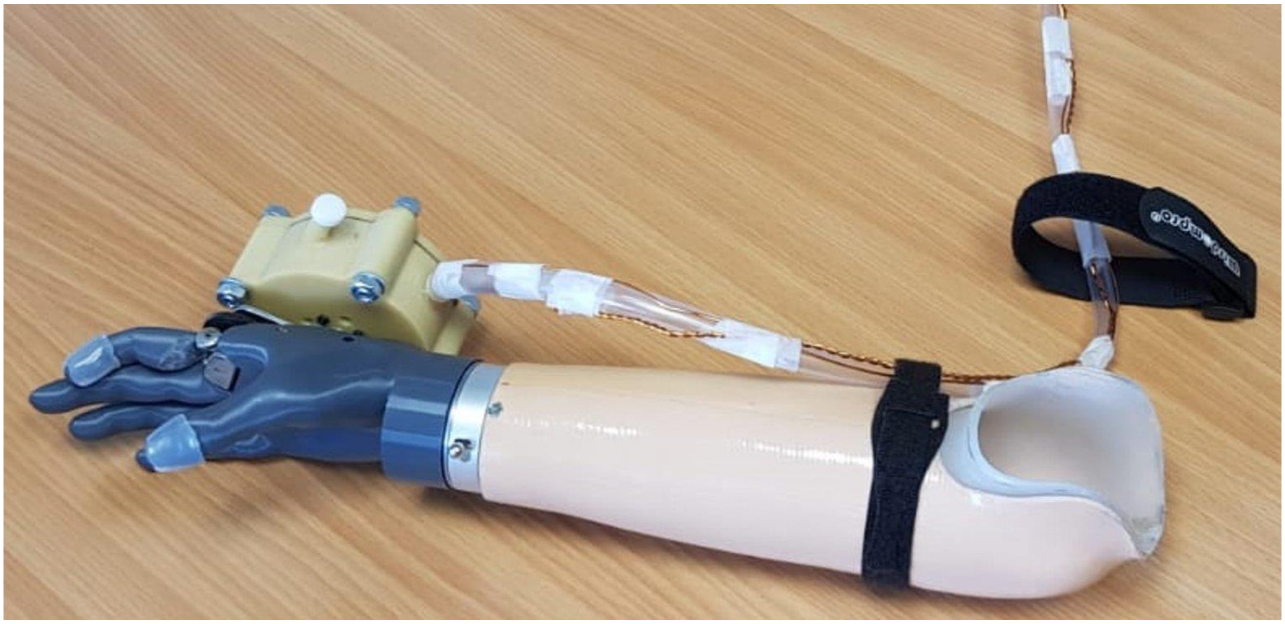


Figure (3): Example of an externally powered prosthetic hand used for individuals with a partial hand amputation or wrist disarticulation.

The disadvantage of wrist disarticulation, however, is the limitation in the room to fit a wrist and hand unit into a cosmetically acceptable prosthesis. In such cases, a more proximal amputation would allow for a full complement of prosthetic options.

3.3.2 Trans radial and Trans humeral Considerations

For most adult trans-radial prostheses, nearly 8 inches of space is necessary beyond the distal residual limb for the prosthetic wrist rotator and hand. Similarly, at the transhumeral level, approximately 6 inches of space must be present beyond the distal residual limb to accommodate a mechanical elbow mechanism within the prosthesis.

For patients with a short residual humerus, a conventional (body-powered) prosthetic system may not be realistic, and even an externally powered prosthesis may be difficult or problematic to fit, suspend, and control. When the residual humerus is short, it may be necessary to treat a transhumeral amputation functionally as a shoulder disarticulation (Figure 4).

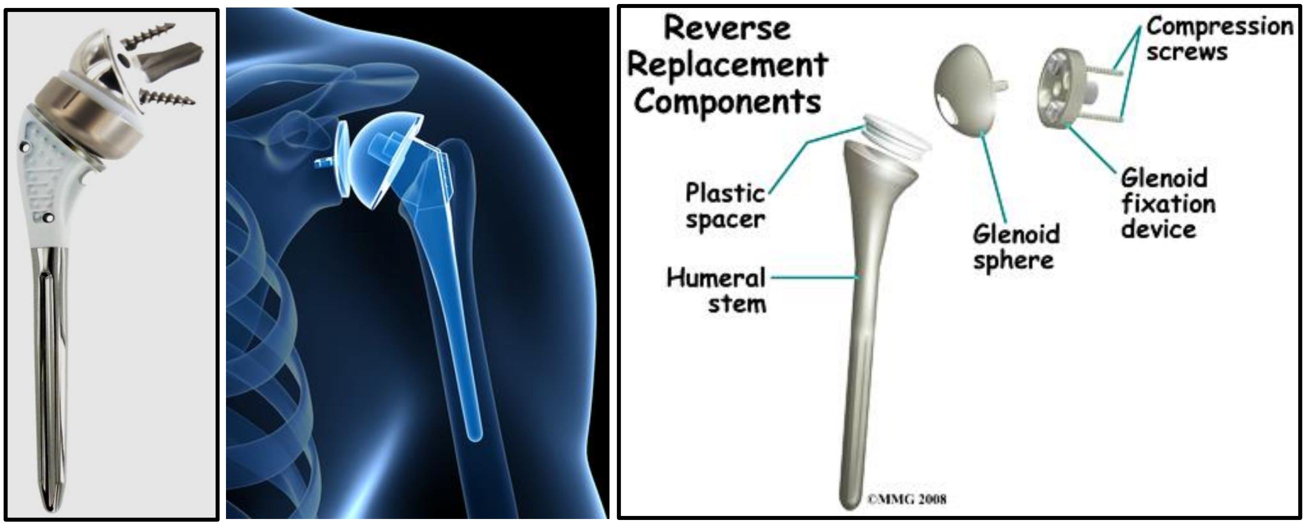
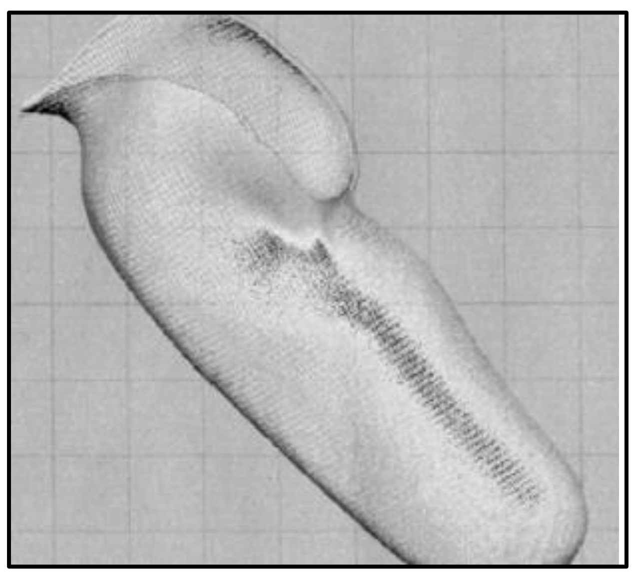


Figure (4): Example of a prosthetic shoulder joint used in individuals with a shoulder disarticulation or extremely short transhumeral residual limb.

Model acquisition and data collection are also possible using computer-aided design. This technology is particularly valuable to quantify and document volume and shape changes, enhancing fit and function for optimal clinical outcomes (Figure 5).

Figure (5): A computer-assisted design model of a transradial prosthetic socket. Note the aggressive anatomical contouring of the socket and the anteroposterior force system (between the anterior cubital fossa and olecranon) that will be used to suspend the the socket on the residual limb.



TYPICAL COMPONENTS OF AN UPPER EXTREMITY, BODY-POWERED PROSTHESIS

- A typical example of a transradial (below-elbow) prosthesis includes a voluntary opening split hook; a friction wrist; a double-walled, plastic-laminate socket; a flexible elbow hinge; a single–control-cable system; a triceps cuff; and a figure-8 harness.
- A transhumeral (above-elbow) prosthesis is similar but includes an internal-locking elbow with a turntable for the missing anatomic elbow, uses a dual–control-cable system instead of a single-control cable, and does not require a triceps cuff.
- All conventional body-powered, upper extremity prostheses have the following components:

All conventional body-powered, upper extremity prostheses have the following components

- Socket
- Suspension
- Control-cable system
- Terminal device
- Components for any interposing joints as needed according to the level of amputation

Socket

- The socket of an upper extremity prosthesis typically has a dual-wall design fabricated from lightweight plastic or graphite composite materials. In this design, a rigid inner socket is fabricated to fit the patient's residual limb and the second, outer wall is added, designed to be the same length and contour as the opposite, sound limb. Comfort and function are directly tied to the fit of the inner socket. An alternative approach parallels the rigid frame, flexible liner approach sometimes used in lower extremity socket fabrication. The inner socket is fabricated from flexible plastic materials to provide appropriate contact and fit. Surrounding the flexible liner, a rigid frame is utilized for structural support and for attaching the necessary cables and joints as needed. The windows in the outer socket allow movement, permit relief over bony prominences, and enhance comfort.

Suspension

- The suspension system must hold the prosthesis securely to the residual limb, as well as accommodate and distribute the forces associated with the weight of the prosthesis and any superimposed lifting loads. Suspension systems can be classified as follows:
- **Harnessed-based systems.**
- **Self-suspending sockets.**
- **Suction sockets.**

Harnessed-based systems

- ***Harnessed-based systems*** and their variants are the most commonly used systems. For the figure-8 strap, a harness loops around the axilla on the sound side. This anchors the harness and provides the counterforce for suspension and control-cable forces. On the prosthetic side, the anterior (superior) strap carries the major suspending forces to the prosthesis by attaching directly to the socket in a transhumeral prosthesis or indirectly to a transradial socket through an intermediate Y-strap and triceps cuff. The posterior (inferior) strap on the prosthetic side attaches to the control cable. For heavier lifting or as an alternative to the figure-8 harness, a shoulder saddle with a chest-strap suspension can be used with a transradial prosthesis. A chest strap alone is sometimes used to suspend a transhumeral prosthesis. The figure-9 harness is an alternative for a patient with a long transradial amputation or a wrist disarticulation, in order to provide the control harness provides minimal suspension and requires a self-suspending socket, it is more comfortable than a figure-8 harness. Self-suspending and suction sockets are capable of providing adequate prosthetic suspension without the use of a harness. However, either design can also be used with a harness suspension to provide for a more secure suspension of the prosthesis.

Self-suspending sockets

- ***Self-suspending sockets*** are largely limited to wrist or elbow disarticulations and to transradial amputations. This socket design is most commonly utilized with an externally powered, myoelectrically controlled transradial prosthesis. An example of this type is the Munster socket. Proper fit of this socket precludes full elbow extension.

Suction suspension

***Suction suspension* is similar to lower extremity options.** These sockets use an external, elastic suspension sleeve; a one-way air valve; or roll-on gel suspension liner with a pin-locking mechanism. Upper limb suction sockets (unlike nonsuction sockets) require a total contact socket design and ideally a residual limb with no skin invagination, scarring, and stable volume to avoid skin problems, such as a choke syndrome. Suction socket designs are most commonly used for the patient with a transhumeral amputation.

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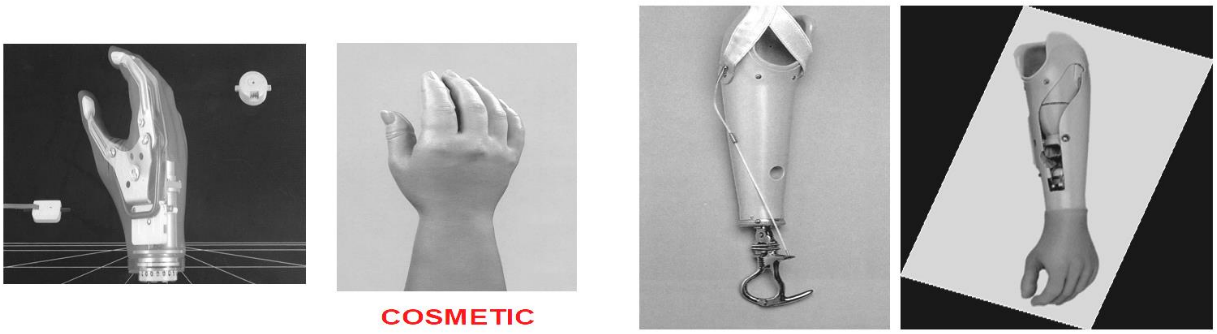
WRIST, ELBOW, SHOULDER, AND FOREQUARTER UNITS



COSMETIC

FUNCTIONAL CABLE-ACTIVATED TERMINAL

MYOELECTRICALLY CONTROLLED