Turk J Phys Med Rehab 2023;69(3):261-265
DOI: 10.5606/tftrd.2023.12933
Available online at www.turkishjournalpmr.com

Invited Review

Upper limb prosthetic prescription

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Received: April 18, 2023 **Accepted:** April 24, 2023 **Published online:** May 26, 2023

ABSTRACT

One of the most important parameters of prosthesis rehabilitation is to determine the most suitable prosthesis in patients with upper extremity amputation. When deciding on the prosthesis, the clinical features of the amputee should be highly matched with the predicted prosthesis. Prescribing the most suitable prosthesis and minimizing the mismatch can be possible with a detailed prosthetic evaluation.

Keywords: Amputation, prostheses, rehabilitation.

Although upper extremity amputations (UEAs) are much less common than lower extremity amputations, they cause more functional, social, and emotional loss. Among patients with UEAs, the proportion of young individuals is high. Thus, UEAs mostly affect people of productive age, which might lead to a significant economic burden.[1] Traumatic causes such as traffic accidents, work accidents, or electric shocks are the top causes of UEA. In addition, peripheral vascular diseases and malignancy can also cause UEA. In the pediatric group, limb loss may be seen due to congenital deficiency.

While the rate of gait recovery with the help of prosthesis is high, the rate of fulfillment of the functions of the upper extremity, particularly of the hands and fingers, is much lower since the hand and fingers have unique anatomic and functional features. Deciding on the prosthesis suitable for the characteristics of the amputee is not a simple process. However, return-to-work rates can be as high as 80% with a proper prosthesis.[2] The clinical features of the UEA patient should be evaluated in detail and the basic features of currently available prosthetic systems should be known to prescribe the ideal prosthesis.

PROSTHETIC ISSUES

One of the important steps in prescribing upper limb prosthesis is the amputation specific history. The age of the patient, the time elapsed after amputation, etiology, accompanying comorbidities, the type of previous prosthesis, the characteristics of the environment, activities of daily living, profession, hobbies, and social security should be questioned.[3] Prostheses recommended for pediatric, geriatric, or productive age are different. For geriatric patients, cosmetic or mechanical prostheses that do not cause mental fatigue and are easy to put on and take off can be selected. Lightweight prostheses that allow a tripod grip can be chosen for holding pencils in pediatric patients. It should be kept in mind that the level of amputation may vary in individuals with vascular amputation, such as diabetes mellitus

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Cite this article as:
Demir D. Upper limb prosthetic prescription. Turk J Phys Med Rehab 2023;69(3):261-265. doi: 10.5606/tftrd.2023.12933.

patients.[4] Prosthetic use might be affected by outdoor environmental conditions, such as humidity, dust, wind, and magnetic field. Personal needs, preferences, previous prosthetic experience, and functional needs should be determined, and the predicted prosthesis should be compatible with these features.[5]

PHYSICAL EXAMINATION

After a detailed history, amputation level, length, shape, and size of the stump, scarring, edema/swelling, joint range of motion, contracture, isometric stump muscle contraction, isotonic muscle strength in proximal muscles, phantom sensation, pain (phantom or stump), and cognitive and emotional status should be evaluated.

One of the most important parameters in deciding the upper limb prosthesis is the stump length and the level of amputation.[6] If supination and pronation are preserved in transradial amputations, a prosthesis capable of finger flexion and extension may be sufficient. Four-channel control may be difficult in patients with small muscle volume. For transradial amputees with short stumps, a two-channel prosthesis may be more appropriate instead of a four channels. If there is limitation of elbow extension or if suspension cannot be provided due to short stump, the socket can be planned with limited elbow extension. The lateral joint can be used to prevent body asymmetry in elbow disarticulation. Elbow flexion-extension is needed in addition to hand, finger, and wrist functions in patients with transhumeral amputations. In these cases, elbow joint control can be achieved mechanically or electrically.

Skin condition, scarring, and presence of grafts may affect the number of electrodes to be used. It is important to provide the maximum possible range of motion before deciding on the prosthesis. Phantom pain or sensation may be intensely felt by patients in the early postamputation period, particularly in the first month. However, these conditions are expected to affect the patient less after prosthetic fitting.

Before deciding on the prosthesis and before taking a socket measurement, pathologies such as neuroma or infection that may cause stump pain should be detected and treated. The amputee must have a certain cognitive level to use the prosthesis safely and functionally. Passive or mechanical prosthesis, which is easier to use, will be more appropriate for individuals with cognitive impairment.

Figure 1. Cosmetic hand prosthesis.

UPPER LIMB PROSTHETICS

It is necessary to know the currently available prostheses to decide on the most suitable prosthesis for the patient. In general, prosthesis types are divided into four: passive, mechanical, electrical, and hybrid prostheses.

1. Passive (cosmetic) prostheses

The main purpose of these prostheses is to cosmetically complete the missing part. Since the aim is cosmetic, it is tried to imitate the human hand as much as possible (Figure 1). It has no functional features other than light touching or providing minimal support. No movement is observed at the terminal end. They do not have a harness-cable system and are lightweight. It can be preferred in individuals who do not want or cannot use other types of prosthesis, particularly in the elderly, and in pediatric cases under the age of three who have not yet started using prosthesis. Despite low function, it may increase social participation.[7]

2. Body-powered prostheses

Activation in mechanical prostheses is achieved by transmission of muscle power to artificial joints. In other words, elbow and finger movements are provided by the harness cable system (Figure 2). The force generated in the trunk, shoulder girdle and upper extremity is transferred to the harness system and from the harness system to the hand or elbow. With various maneuvers, the harness cable is stretched to produce flexion in the fingers or elbow and extension by loosening the cable. Commonly used maneuvers are intact-side scapular abduction or amputated-side shoulder flexion. One of the notable problems in the use of cable control systems is to provide precision grasp. In addition, they can increase the load on the shoulder and periscapular muscles.[8]

Figure 2. Body-powered prosthesis.

There are mechanical prosthetic hand types that are voluntarily closed (finger flexion) or opened (finger extension). There are three subtypes of the mechanical elbow joint: free joint, manual locking joint, and extension-controlled joint. In the free joint type, elbow flexion-extension occurs as the cable is stretched or released, and there is no locking mechanism in the joint. In the manual locking type, flexion and extension are provided as in the free joint. The elbow can be locked at the desired angle when the locking mechanism is activated with the contact hand. When the locking mechanism is deactivated, then the elbow joint is released. In the extension-controlled elbow joint, elbow flexion and extension are provided as in the free joint. When the desired angle is reached, the elbow is locked with shoulder or arm extension. The same movement is repeated to release the elbow joint.

3. Electrically powered prostheses

a. Myoelectric prostheses

The electrical activity created by the muscles is sensed by the electrodes. Then this electrical activity is amplified and sent to the motor; thus, the targeted function is created. Myoelectric prostheses have the ability to perform finger flexion-extension, wrist supination-pronation, and elbow flexion-extension according to the number of channels. Electrodes that detect the electrical activity created by the muscle can be applied in pairs, if possible, or individually. Myoboy test device (Ottobock SE & Co. KGaA, Duderstadt, Germany) is frequently used to determine the appropriate electrode location (Figure 3). With this device, the most appropriate electrode area, where the patient can control the stump isometric muscle contraction most comfortably and easily, is determined for both the flexor and extensor sides. Electrodes are placed in the detected area in the temporary socket. Occupational therapy training begins with computer-

Figure 3. Electrical signal detection device.

aided programs to increase the patient's isometric contraction compliance and ability. After adequate control is achieved, the electrodes are placed in the permanent socket. Occupational therapy continues to increase upper extremity and hand functionality after the prosthetic fitting is completed.

EMG channel

Two-channel myoelectric prostheses are capable of finger flexion (hand closing) and extension (hand opening). Flexion and extension occur in the first three fingers while the fourth and fifth fingers passively accompany the other finger movements. Finger flexion occurs when the electrode in the flexor side is stimulated with the isometric contraction of stump flexor muscles. Similarly, finger extension is generated with stump extensor muscle stimulation.

In four-channel prostheses, besides finger flexion and extension, wrist supination and pronation can also be performed with the help of a rotator unit. For wrist supination and pronation, it is necessary to create either a long-term contraction or a mode change. After a mode change is achieved with both flexor and extensor contraction, stimulation of the same electrodes will reveal wrist supination or pronation instead of finger flexion and extension.

Six-channel myoelectric prostheses are used in patients with transhumeral amputation. Finger flexion-extension and wrist supination-pronation features are the same as described in four-channel prostheses. In addition, elbow flexion and extension are created by the same electrode stimulation. Appropriate electrode locations are determined on the biceps and triceps muscles (Figure 4). Mode change is required to be able to switch between the joints (elbow-wrist-finger). Mode change can be achieved in different ways, such as synchronized stimulation of both electrodes or pressing the button. When mode change is achieved, the selected joint will be active for electrode stimulation.

b. Bionic hand

The basic mechanism of a bionic hand is similar to the myoelectric prosthesis. The most important difference is that there are separate motors placed at each finger. Thus, many different grip positions can be obtained. In addition, a better grasp of the object is possible with a bionic hand. The most common grips that the patient wants to use are determined by the therapist and matched to the bionic hand via a computer/tablet. There are various methods to switch from one grip to the other. It is possible to switch between different types of grips by the button on the prosthetic hand, stimulating both electrode sides at the same time, and extending the arm forward or to the side. It is also possible to use bionic hand prostheses as four or six channels by adding wrist rotator or elbow joint units.

The most important disadvantages of electrically controlled prostheses are that they are heavy, require maintenance, and have a high cost.[9,10] Although it provides an increase in upper extremity functions, difficulties in transition between joints or between grips, lack of combined movement, mental fatigue, and being easily affected by stump volume changes are limitations of use.

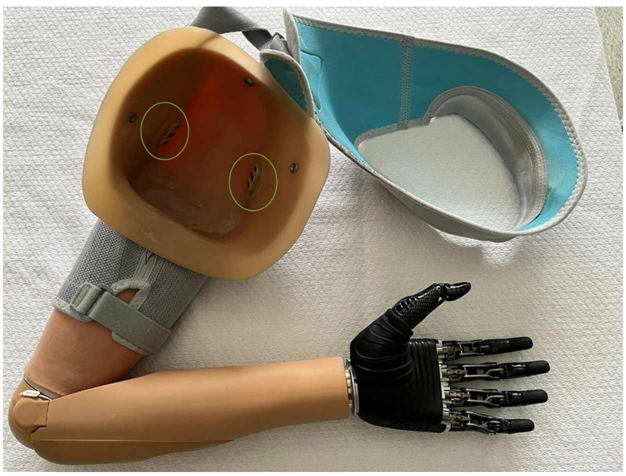

Figure 4. Electrode location in six-channel prosthesis.

4. Hybrid prostheses

Hybrid prostheses have both mechanical and electrical control. They are frequently used in patients with transhumeral amputations. While the finger flexion-extension and wrist supination-pronation is electrically activated, the elbow joint is controlled via the harness-cable system. With these systems, the disadvantage of six-channel prostheses while the transition between joints might be reduced.

ADVANCE IN UPPER LIMP PROSTHETICS

Targeted muscle reinnervation

In high-level amputees, residual muscle tissue may be insufficient to reveal the desired function. In targeted muscle reinnervation, intact peripheral nerves in the residual limb are implanted in the chest and back muscles. It is aimed to reveal hand, finger, wrist, and elbow movements by stimulating the chest and back muscles after reinnervation.[11]

Multiple electrodes

Recently, multielectrode systems have improved to remove the disadvantage of two-electrode systems used in electrically controlled prostheses. A cuff with an increased number of electrodes is used in the Myoplus system. During the training, the electrical activity of the stump during different grips is detected by the multielectrode system and matched to the prosthetic hand unit. When the patient creates an electrical activation on the stump, this activation is revealed with whichever grip is matched with the prosthetic hand. Similarly, eight pairs of electrodes are used in the Coapt system. These electrodes can be placed on the desired residual muscle. With residual muscle activation, finger flexion-extension, wrist supination-pronation, or elbow flexion-extension can be elicited.

PEDIATRIC CASES

In congenital extremity loss, passive prostheses can be started at the age of two to four months in suitable patients. In a study comparing the period before and after 30 months of age in terms of myoelectric prosthesis, it was observed that the skill development was rapid in the early prosthesis group but had a higher percentage of prosthesis rejection.[12] In general, four years of age is recommended for electrically controlled prosthesis to become regular users.

Another critical issue in pediatric cases is the ongoing physical growth and development. Socket fit might be revised in a six-month period. Additional socks should be an option to increase suspension and comfort. If the prosthetic hand has become too small for the patient, it may need to be replaced with a bigger one.

In conclusion, matching the patient's characteristics with the features of prosthesis is the most prominent issue in upper limb prosthetic prescribing. With all these parameters, the experience and foresight of the patient and the prosthesis team and, if possible, the demo application of the possible prostheses should be considered.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

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