PROSTHESES IN UPPER LIMB TREATMENT: RECENT DEVELOPMENTS

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INTRODUCTION

A trauma or congenital pathology may seriously compromise the performance of upper limbs from an operative standpoint and informally, through sensitivity. These special aspects show how difficult it is to develop an artificial limb capable to reply important functions, such as for example: eating, independence in the bathroom.... and so on. In order to carry out a good treatment with orthopaedic devices, it is necessary to define specific and closely-aimed rehabilitation programs that are personalized and differentiated in relation to the case to be treated. First of all, it will be necessary to make specific psycho-physical evaluations regarding mobility, function, muscular potential (when applying myoelectric-controlled upper limb prostheses), motivations, learning capacity of the subject in question and anything else necessary in order to define the correct protocol to be adopted. (Special attention must be paid when treating children, which requires full involvement and conviction by the parents).

THE REHABILITATIVE PROSTHESIS PROGRAM

Treatment of a pathological subject, especially the first treatment, does not end simply by applying an orthopaedic device. Application must be associated with correct pre- and post- prosthesis rehabilitative training.

An adequate personalized prosthesis program consists of three stages:

- **pre-prosthetic**, psycho-physical preparation for prosthetization;
- **prosthetic,** building and testing the prosthesis;
- **post-prosthetic**, prosthetic re-education and rehabilitation.

I shall deliberately avoid going into detail on these three phases, but will only outline a few major concepts.

A prosthesis program requires teamwork involving a number of different professional figures. The possibility of obtaining good results in applying of the orthopaedics device begins with excellent surgery treatment; the doctor will think still to the orthopedic device that will be applied later.

The ***pre-prosthetic stage*** has two main objectives:

- to prepare the subject psychologically to receive the prosthesis;
- to set up, through specific exercises, a preparatory kinetotherapy aimed at maintaining and/or restoring joint movements and muscular trophism.

Frequent use is also made of electrical stimulation which improves the muscular contraction capacity. The pre-prosthetic stage is different in relation to the pathology, the type of prosthesis that will be applied, and some other aspects to be identified in each case.

The treatment will also be aimed at teaching the patient to re-acquire the major body motor schemes, in the case of traumatic pathologies, or re-acquiring major bodily schemes for congenital pathologies.

The ***prosthetic stage:***

The main purpose of an orthopaedic device is to restore, even partially, the functions lost or which have never existed. In truth, for upper limbs, the first aspect in the beginning is to recover to a "whole body". Cosmetics may contribute, especially in the early stages of treatment, to a greater degree of acceptance, and thus more cooperation in applying and using the device. The loss or deficit of one or more limbs not only leads to functional limitations, thus shifting the centre of gravity of the body, but may also lead to automatic postures and compensation strategies that easily induce further complications, especially at the expense of the vertebral column. The weight of the prosthesis may, in serious monolateral congenital pathologies, regarding the shoulder level, aid in regaining balance and realigning of the rachis.

PROSTHESES TYPES

Upper arm prostheses may be divided into cosmetic prostheses and functional prostheses. The main purpose of cosmetic prostheses is to obtain a good cosmetic effect, but they have no intrinsic functional value. They play a mainly psycho-social role though they may actually play important roles indirectly as a contralateral grip element, improving the static-dynamic equilibrium and symmetry (important for clothing). Functional prostheses may be divided into body-energy and extra-energy prostheses. The most commonly applied body energy prostheses take advantage of associations of special movements by the contralateral shoulder, the stump and the neck, the activation system consists of harnesses holding the shoulder in place.

Electromechanical prostheses operating on extrabody energy are those that have, without a doubt, offered the best performance in recent years. To operate, these may use the electrical potential that a muscle is able to generate against an isometric contraction, and which special receiving electrodes can detect; these prostheses are known as myoelectric. In other cases, special pressure microswitches may be applied, activated by small movements, in this case, we speak of "electronic"

prostheses. Recently, Dr. Childress of the University of Chicago has proposed a direct muscular control for extrabody energy prostheses, using a muscular channel created according to the "Sauerbruch technique" to control the prehensile part.

Myoelectrically-controlled functional prostheses can actively reproduce the following functions:

- opening and closing the hand;
- prono-supination at wrist level;
- flexing and extending of the elbow.

The most popular functional electromechanical artificial hand at the moment has a pincer grip between the thumb and welded index-middle finger, with joints at the metacarpus phalanxes. The functionality and cosmetics are more than acceptable. The hand may be interchanged with a manipulator developed specifically for work activities. Around two years ago, Otto Bock placed a new children's hand on the market with a special type of grip. In brief, we may summarize as follows:

HAND	NATURAL	BODY E	EXTRABODY E.		MANIPULATOR
			adult	child	
GRIP STRENGTH (N)	150	30-40	100	40	320
MAX.APERTURE (mm)	190	45	100	47	400
WEIGHT (g)		290	440	190	440

Active prono-supination with body energy, possible only if there are long forearm stumps or with extrabody energy, makes it possible to rotate the hand clockwise and counter-clockwise. This is of fundamental importance for the bilateral patient, as it makes it possible to compensate for the lack of flexion-extension at the wrist level.

The elbow joint may be extrabody or body energy; in the latter instance, it is possible to make so-called hybrid prostheses whose main purpose is to reduce the weight. Then the hybrid prostheses will be made: body energy on the elbow joint and extrabody energy on the hand and/or prono-supination.

The socket is the most important part of the prosthesis, as it must be made according to a personalized anatomical configuration, for perfect symbiosis between the stump and the socket and the amputee-prosthesis. A good socket can permit a complete control of the prosthesis.

The technique used for building a quality socket requires taking a negative and positive plaster cast. This is the only way that you can create total contact between the stump and the taper. A test socket is often created, especially for fairly complex prosthesis such as extrabody energy ones.

The choice of components making up a prosthesis depends on a number of factors: mono- or bilateral amputation; learning ability of the disabled person; level of amputation; motivation, etc. Indicatively speaking, we can state that:

- subject with monolateral pathology: in this case, the remaining limb becomes dominant, and the prosthesis may be considered mainly an aid to the remaining limb, and should be built so as to ensure the greatest possible aid to the functions of the latter. In any case, it plays an important role that restores a balancing bodily completion, and offers the possibility of having a complete range of action.

- bilateral subject: in this case, the prostheses becomes an element necessary in order to perform the most elementary functions, and its importance increases the closer the level of the missing limb.

It may be said that treatment should be carried out as soon as possible, always preferring a functional device over a purely cosmetic one. Electronic-myoelectrically controlled electromechanical prostheses are the maximum expression of function for a functional upper limb prosthesis.

The ***post-prosthetic stage***, as soon as the prosthesis/orthesis is given on trial, continues the information function and begins educating as to its correct use, beginning from how it is worn, to how it is to be used. The entire medical-technical staff participates in this extremely important stage, but the main participants are: the therapist, the orthopaedic technician, and the family members.

The rehabilitation therapist must create a friendly, open relationship with the patient, in order to obtain maximum collaboration towards achieving results. Keep in mind that the first prosthesis-rehabilitation treatment is of fundamental importance, also because some wrong attitudes or habits are difficult to climinate once acquired. It is of fundamental importance to teach the patient how to wear the orthopaedic device correctly, how to move correctly, how to grip correctly. In particular, gesture analysis studied and personalized in relation to the type of pathology and the type of device applied is of primary importance. More explicitly, the patient is taught through specific compensatory movements. How to move the device correctly in order to carry out a particular operation.

We have deliberately emphasized these aspects regarding a correct and complete treatment aimed at applying prostheses because in order to make "comparisons" or discuss the results achieved it is obviously necessary for the device to have been tested for a sufficient period (even over a year in some cases), in order to make objective evaluations throughout the day of the following:

- wearability
- functionality and performance
- reliability
- cosmetics

Body energy upper limb prostheses are more simple in construction, leading to lower weight, greater reliability and less maintenance. It is obvious that functionality is frequently lower to that of extrabody energy prostheses. This type of technological solution plays a role of primary importance especially for those treating disabled persons who do not have access to electrical energy, and thus the only possible choice is this type of prosthesis (for amputations, in this regard we recall Krunemberg-type operations, or forceps adaptation of the forearm).

Body energy prostheses still play an important role, also thanks to important new experiences that Dr. Leblanc and Dr. Sumida are having with the development of innovative hooks. Frequently, it is possible to replace the hook with an artificial hand, so as to achieve excellent gripping functions and an acceptable cosmetic appearance at certain times. It should be kept in mind that in some countries, such as the United States, Germany, etc., function prevails over cosmetics: the exact opposite occurs in countries such as Italy, Spain, etc., where the cosmetic appearance plays an extremely important role on the ulilitation of the prosthesis.

From a functional standpoint, body energy prostheses offer acceptable results beginning with amputations at the metacarpus phalanx level to the transomeral stump (middle third). Closer to this level, especially in bilateral cases, obvious functional limitations intervene that require the application of extrabody energy prostheses. Myoelectric-electronically controlled extrabody energy prostheses can be applied beginning with wrist disarticulation all the way the shoulder, as long as the electromyographic potential present may be used to control the prosthesis. These prostheses offer the greatest functionality obtainable today in terms of strength and field of grip, and require no harnesses for operation: their disadvantages are: heavier weight, noisiness, need to be installed in a specialized center, the limited number of individually controllable and reproducible electromechanical functions, the need to have a source of electric energy to recharge the NiCd batteries, the need to plan for maintenance at regular intervals.

A study carried out in 1989 by Sandra Gold Millestein at the Downsview Center in Ontario revealed that the degree of acceptance of extrabody energy prostheses was more than 83% versus 68% for body energy prostheses. Through computerized movement analysis systems, studies have been made concerning how a forearm amputee moves toward and grasps an object with different types of prostheses.

SOME RESULTS

I present a video-tape regarding a few amputation people with different prostheses and a few paralysis of the bracial plexus people with ortheses.

FUTURE ORIENTATIONS

To speak of recent developments in upper limb treatment means, in part, dealing with current research under way:

- the anthropomorphic artificial hand: within the EEC research program known as TIDE MARCUS, several prototypes have been developed of multiple-jointed hands, at the level of the phalanxes of the index and middle fingers, capable of gripping extremely well with the thumb. The fingertips are sensitized with strength, slip and position sensors. The hand is controlled proportionally, passing through an EMG microprocessor. Thanks to certain choices to optimize weight and function, it has been possible to limit weights to below 550g against the 460g of the normal electromechanical hand, to contain the electrical absorption of the system within values approximately 15% greater than current ones, achieving better performance in terms of grip capacity while introducing sensorial and position aspects. A very difficult aspect is to find a solution for the cosmetic aspect.

- developments on prosthesis control through the neuroelectric signal. Currently, some neural connectors have been developed, through which it has been possible to read the neuroelectric signal on laboratory animals.

CONCLUSION

To conclude this presentation, we would like to emphasize that:

- for correct treatment, it is first of all necessary to develop a complete rehabilitative prosthesis program, to include the three stages: pre-prosthetic, prosthetic and post-prosthetic.

- the best artificial limb will always be much lower in terms of function and cosmetics than a healthy limb, but what is important is to accept it, learning how to take the best advantage of it in order to achieve the greatest autonomy and social and job independence;

In any case, the objective is always clearly defined: "To achieve the greatest possible recovery in terms of function and appearance in relation to the pathological status."