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BIONIC HAND EXOPROSTHESIS EQUIPPED WITH SENSORY INTERFACE: TECHNICAL INNOVATIONS AND FUNCTIONAL RESULTS

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The amputation of a thoracic limb is challenging for a patient's life, both personally and professionaly. Our objective is to develop a bionic hand exoprosthesis, equipped with a sensory interface designed to collect mioelectric stimuli (EMG) from the surface of the amputation stump. We intend to modify the classical forearm amputation technique, allowing us to perfect an elaborate bionic hand exoprosthesis, equipped with a higher number of sensors; this will be accomplished by suturing the muscle groups in the adequate positions in order to obtain clear and distinct mioelectric signals. A more distinct and natural command of the exoprosthesis' movements will be allowed, and also a greater number of motory functions. During the training a software application will be used, in order to collect and interpret EMG signals and display them as movement of a virtual hand in a simulated reality, allowing assistment, through visual bio-feedback, in an efficient training, and developement of the necessary abilities in order to control the prosthesis. Through this study we intend to elaborate a revised method of intra-operatoy preparation of the amputation stump, that, together with a phisical and virtual training, will allow the artificial hand to be more accesible for patients.

Key words: forearm amputation, mioprosthesis, virtual environment.

INTRODUCTION

Wether in a traumatic, tumoral, infectious or vascular disease context, losing a limb through amputation, be it thoracic or pelvic, causes great difficulties in a patient's life, affecting both his personal and his professional life. Still, the greatest impact comes from losing the thoracic limb, often leading to a severe loss in life quality for the patient, irespective of gender, age or social status.

Although in the last 60 years prosthesis have known a notewothy developement, both in performance as well as in variability, their cost remains prohibitive for most patients. Also, the status of the amputation stump may constitute a difficulty, as current surgical techniques may not always permit an efficient detection of well differentiated mioelectrical signals from the epidermis, necessary for a well functioning modern exoprosthesis.

Under these conditions, our main objective is to develop a bionic hand and forearm exoprosthesis, designed to detect mioelectric stimuli from the surface of an amputation stump, sustained by a modification to the classical forearm amputation technique, in order to facilitate the process of stimuli detection, esssential to a functioning exoprosthesis. We also aim to develop a program of training for the patients equipped with the prosthesis, using the virtual reality as an working environment, aided by visual and acoustic bio-feedback techniques. Last, we aim at reducing the effective production cost of the hand exoprosthesis, thus facilitating greater access for the patients.

Our hypothesis is that the hand bionic exoprosthesis with sensory interface (the artificial hand), is a viable alternative in Romania following a forearm amputation, using a specially modified surgical technique.

MATERIALS AND METHODS

In order to reach our research objectives and verify the hypothesis, we intend to modify the classical forearm amputation technique, allowing us to develope an elaborate bionic hand exoprosthesis model, equipped with a greater number of sensors for receiving mioelectric signals.

In order to achieve this, the Orthopaedics – Traumathology Clinic in the Universitary Emergency Central Military Hospital in Bucharest has the infrastructure necessary in order to perform surgical forearm amputations or amputation stump revisions (correspondingly equipped operationg theatres, acces to medical personell and patients). In our study, we will be addressing patients 20 to 70 years old, without significant associated pathology, both genders included. Criteria for exclusion are: patients outside the age group, with significant associated pathology, or patients with bilateral forearm amputation.

Also, the Politechnical University in Bucharest has the facilities and qualifies personell necessary for the completion of the prototipe exoprosthesis, including up-to-date EMG machines, specifical hardware and software for creating the virtual interface, and a complex training laboratory for using the artificial hand.

The surgical procedure will be performed by suturing the muscle groups in the forearm in adequate positions in order to obtain clear and distinct mioelectic signals. This method can also be applied to forearm stump revision surgery. (Figs. 1–3).

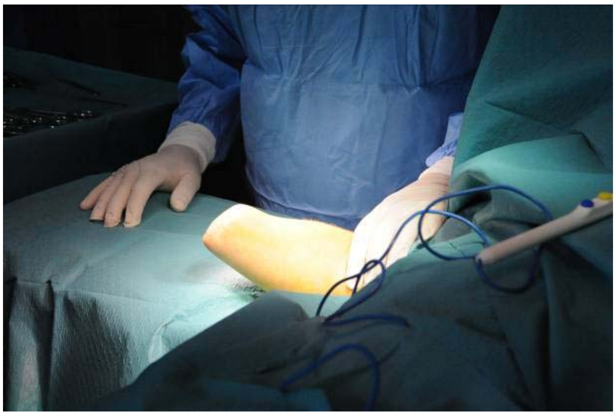

Figure 1. Preoperatory status of the amputation stump.

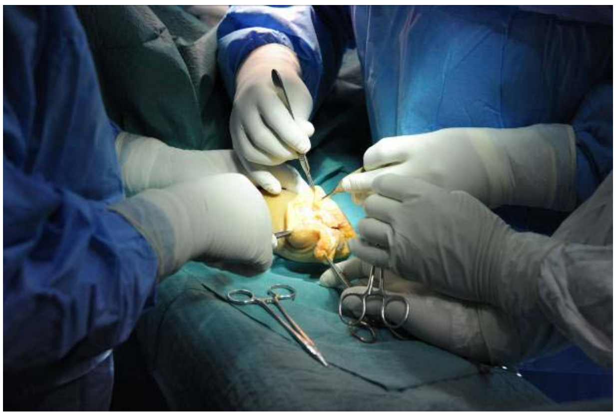

Figure 2. Intraoperatory aspect.

Figure 3. Postoperatory radiographic aspect of the amputation stump.

Another goal is to increase the muscular surface exposed to EMG measurements, by specific intraoperatory positioning techniques; also, we hope to reduce the electrical resistance of the anatomical layers betwwen the muscle mass and the EMG electrodes, applied to the surface of the amputation stump[1,2].

This will allow a distinct and more natural command of the prosthesis'movements, therefore permitting a greater number of motor functions to be used in the making of the artificial hand.

After the surgical procedure has taken place, and after a period of training, a personalized prototype prosthesis will be created for each patient. During the training period, all patients will practice isometric contractions of the remaining muscles in the affected forearm, in order to increase the patient's capacity for distinct control over each muscle.

Figure 4. Patient using a prototype of the bionic hand, in training.

For a more efficient training, we will be using a software application in order to acquire and interpret EMG signals, as well as representing them graphically in the form of a virtual hand's movements, in a simulated reality, both for the amputated forearm, as well as for the healthy one [3–6].

Figure 5. Patient using the bionic hand prototype.

This will permit a visual bio-feedback, assisting the patient in completing an efficient training and will allow him to develop the necessary skills for operating an artificial hand.

The interface with this virtual environment will be accomplished through a set of specially-designed gloves, used in virtual reality technology.

RESULTS AND DISCUSSIONS

After a predetermined period of using the prosthesis, we intend to evaluate the outcomes, through a questionaire regarding patient satisfaction, both those treated with the revised method, and those treated with the classical mioelectric prosthesis. We wish to evaluate and compare the results and benefits of using an artificial hand:

– an improved control of hand functions;

– a greater number of functions;

– a briefer response time to the motor command;

– an increase in patient satisfaction and quality of life.

Also, we aim for a decrease of production costs for the exoprosthesis, making it more readily available for patients.

Certain difficulties may arrise with the study, regarding the acquisition of EMG signals from the amputation stump; in this regard we are taking into consideration the modification of the type of electrodes used, or their sensitivity threshold. Also, specific surgical complications must be taken into consideration; these will be dealt with should they occure, according to their type.

CONCLUSIONS

We aim that, following our study, a more efficient method of intraoperatory preparation will be devised for the forearm amputation stump, and coupled with sustained training, both phisical and in a virtual environment, and a new exoprosthesis prototype, will make the artificial hand more available for patient use, thus notably improving their quality of life, both personally and professionally.

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