CLINICAL EVALUATION OF A MULTI-FUNCTIONAL SYSTEM WITH BIOELECTRICAL CONTROL

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The use of prostheses with the biolectrical control has already spread out from the Clinic of the Central Scientific Research Institute for Prosthetics and become usual practice in our country. Thirty two prosthetic/orthopaedic enterprises in our country make prostheses with bioelectrical control for patient with above- and below-elbow amputation.

We have investigated many amputees using prostheses with bioelectrical control and this has enabled us to gain some experience leading to appreciation of the methods of bioelectrical control, the mechanical design of prostheses and the manufacturing. The bioelectrical control is quite similar to the natural control of an intact arm. The natural function of contraction and relaxation is restored to the stump muscles what promotes the process of normalization of the tissue. The prostheses control by means of bioelectric potentials of the stump muscles is efficient at any position of the extremity. The fact that we have no need for compensating movements to control the prosthesis gives us the precision of action and preserves the function of the upper parts of the extremity. Therefore, the method of bioelectrical control is quite natural and functional. The main direction in promoting prostheses with the bioelectrical control is the improvement of the functional capabilities of the amputee. For this purpose externally controlled as well as passive degrees of freedom have to be introduced in the joint of the prosthesis. The mobility of the joint as well as the potentials of the stump muscles are used to produce control signals. The application of mobility of the extremity in controlling movements of the prosthesis joints is advisable if it corresponds to the character of these movements. As an example one may take the control of the wrist rotation in the case when below-elbow prosthesis is fitted using the pronation-supination movements of the stump. The movements of the upper joints of the extremity fitted with the prosthesis deprive the amputee of the possibility to use them in their typical functions. In addition, some other factors appear which hamper the control, for example, considerable energy loss when the control is performed by means of traction, an increase in compensatory movements, presence of so-called "dead" zones, etc.

This is why we carry on research work to prove the feasibility of the control of additional movements of the prostheses by means of bioelectrical signals of the stump muscles.

At present, the bioelectrical control system consisting of two pairs of movements is applied in the construction of protheses. The control may be performed by means of bioelectrical potentials of four or two stump muscles. In the first case there is possibility of exercising independent control of each movement, i.e. the possibility of performing two movements simultaneously. In the second case it is possible to carry out successive or combined exercise of two out of four controllable movements.

At the present level of technology, the facilities which enable four movements controlled by four muscles are cumbersome for the amputee as double control unit and power source are needed. That is why at this stage it is advisable to use the second method, that is, the successive control of two pairs of movements originating from two muscles. In this case the amputee is not burdened with the additional electrical components. The control of four movements originating from two stump muscles is exercised either by means of logical switching device, or by directing the biopotentials of different amplitudes to the control unit.

In the first case the switching device can be made with one or two fixed positions. The experience has proven that the switching device with two fixed positions is more comfortable for the amputee as it assures the arbitrary control of the prosthesis.

The clinical experience has shown that in the case of the amplitude control, the control of each of pairs of movements originating from each muscle taken separately, is the most convenient and can be easily mastered by an amputee. A movement which is especially undesirable in case of an arbitrary signal from the muscle, is avoided by biopotentials of the greater amplitude. In controlling movements of fingers, for example, the flexion is controlled by a small signal, while the extension is controlled by a great signal.

We have already gained some experience in designing prostheses using bioelectrical signals of two stump muscles for controlling the flexion and extension of fingers and wrist rotation for the above- and below-elbow amputation. The switching device as well as the control device based on different signal amplitudes are applied. The use of the switching device gives the best functional effect since the antagonist muscles exercise control of the opposite movements as is the case in normal situations. This kind of control, however, involves the loss of time necessary to switch the command at the moment when the amputee makes simultaneous contraction of two controlled muscles. The control of two movements is possible only in successive way.

The amplitude control allows saving the time and in some cases gives the possibility to exercise the control of two movements.

The experience we have in manufacturing prostheses shows that at present the best results are obtained when the control system with the switching device is used. By using the system with the amplitude control the amputee has to produce signal skilfully and quickly and to relax the muscle quickly, too. The amputee does not always succeed in this. The muscle which has not been relaxed completely will cause the prosthesis to operate the same way as in case of the signal of a small amplitude.

More clinical investigation is needed to be able to evaluate the advantages and shortcomings of the amplitude control.

We have fitted several amputees with both hand prostheses using bioelectrical signals of one stump to control both hands. The switching of signals was performed mechanically or by the switching device operated by simultaneous contraction of both control muscles. The investigations have shown that the mechanical switching of the signals makes impossible for the other hand to exercise its function if the first hand holds something. The amputee, however, widely uses the control of the second prosthesis for the subsidiary functions. The switching of the control signal from one prosthesis to the other one by the simultaneous contraction of the control muscles is very functional. The amputee easily exercises sequentional control of both hand prostheses and uses them according to the type of the work performed.

The amplitude control of two movements by one muscle is applied when the amputee does not succeed in performing the necessary activity of the second muscle, due to anatomical and physiological peculiarities of the stump.

The use of bioelectrical signals from one stump in controlling two prostheses demonstrates the feasibility of controlling a greater number of movements without any increase in the number of control muscles.

In regard to the functional improvements of the prosthesis and the possibility of using the multi-functional systems with bioelectrical control it is necessary to note a rise in the number of amputees using the prostheses with bioelectrical control.

At present we have succeeded in fitting women with above- and below-elbow amputations and children with congenital deformities of upper extremities of the type of above- and below-elbow stumps with prosthesis.

The investigations show that the character of the bioelectrical activity of control muscles of women and children is similar to one of men. The difficulties in the fitting are caused by the fact that women have bigger layer of the subcutaneous fat cellular tissue and children with congenital deformities of upper extremities have not the phantom sensation. This requires special training of the amputee. The type of the prosthesis control and the design peculiarities of its electrical part are the same as those for men. The type of the bioelectrical control of the multi-functional systems is the same too.

Thus the multifunctional control systems have been proved in practice. They improve the functional activity of the amputees through the control of additional movements. At the same time they may provide the prosthesis with the minimum necessary number of functions when a limited number of muscles is available for control.

The multi-functional control systems have great prospects for the functional improvements of the prostheses with bioelectrical control.