THE PRINCIPLES OF BUILDING OF MULTIFUNCTIONAL ARTIFICIAL HANDS FOR THE BIOELECTRICALLY CONTROLLED PROSTHESES

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Summary

On the basis of the analysis of the results of studying the main biomechanical laws of grasp of a natural hand, the most significant principal propositions are established for development of multifunctional hands for the bioelectric prostheses. Tested on the invalids two models of multifunctional hands which satisfy the requirements of biomechanical principles provide us the possibility of carrying out most of the different types of grasp.

The complication of the problem of building a multifunctional hand lies in the fact that the reproduction of the different functions of a grasp by a natural hand in a rather wide range must be combined with the possibilities of modern engineering and science not exceeding a reasonable level of costs.

In connection with this a careful selection was required from a great variety of possibilities represented by a human hand, i.e. those principal and the most significant peculiarities which should be foreseen in the construction of an artificial hand.

Three main types of grasp are known to exist; an end-grasp, a fist grasp, and a lateral one.

As a result of investigations of different types of grasp, the plots have been made which define the angle changes between articulations of fingers while carrying out the fist-grasp. These plots show three phases in this type of a grasp. The first phase is defined by the movement in all the joints. At the second phase a sharp deceleration of the thumb's movement takes place that is revealed in inhibiting or complete ceasing of the movement at the metacarpo-phalangeal joint and especially at interphalangeal joints of the thumb. As regards the articulations of the 2nd - 5th fingers their movement increases sharply at the 2nd phase. During this phase a group of the 2nd - 5th fingers forms a fist grasp. When forming this type of a grasp a rather complete synergy of movements is found at all the joints of the 2nd and 3rd fingers. At the 3rd phase completion of a fist grasp takes place: i.e. the

movements are decelerated shaprly at the joints of the 2nd - 5th fingers; simultaneously, in the first half of the 3rd phase, the movement at the interphalangeal or metacarpo-phalangeal joints of the 1st finger is resumed or is accelerated. During this phase the locking of grasp is carried out, requiring an increase of muscle tension. Comparison of a fist-grasp with an end grasp shows inequality of a kinematic connection between the 1st and the 2nd - 5th fingers when fulfilling the main types of grasp.

Other biomechanical investigations showed that a lateral grasp, made possible by the presence of the 2nd degree of freedom at the carpometacarpal joint of the thumb, presents the greates conveniences for gripping some objects and tools (for example, flat objects, located, and carried anywhere in the horizontal plane), especially if these objects or tools are necessary to be held with considerable force for a long time.

The hand of a prosthesis intended for the main functions, together with reproduction of all of the principal types of grasp (end, fist and lateral) and provision for adaptation of the fingers about a grasped object, must reproduce a number of combined functions, such as when some part of the hand is maintaining the object, and one or two fingers are manipulating it.

As regards to the hand of a prosthesis intended for auxiliary functions, it may be limited by the functions of a grasp, i.e. of an end, a fist, or a lateral one.

The results of the analysis enabled us to establish the following four principles, on the basis of which the multifunctional hands are being worked out:

1. With the purpose of accomplishing different types of grasp, the movements of the 1st finger (thumb) must be independent (to some extent) of the movement of the 2nd - 5th fingers, and accordingly a permanent simple kinematic connection between them must not be used.
2. There must be possible changing of geometry of the movements of the 1st finger by providing in the hand the carpometacarpal joint (or the hinge) of the 1st finger with two or three degrees of freedom.
3. It appears possible to proceed from complete adequacy of the movements of the phalanges of the 2nd - 3rd fingers at the grasp by the tips and during the 1st phase of a fist grasp. This allows a simple geometry of the move-

ment of the phalanges of the 2nd - 3rd fingers.

4. To improve the contact of the fingers with a grasped object (i.e. for provision of an adaptation the fingers to the form of objects), to improve grasping by the tips, and to increase the possibility of fulfilling some combined functions (when some part of the fingers is keeping the object, and the others - are manipulating with it), the movements of the 4th and the 5th fingers must be, to some extent, independent of the movement of the 2nd - 3rd fingers.

In accordance with the abovesaid a classification of the possible methods has been worked out for a practical realization of indicated principles of multifunctional hand construction.

The examples of realization of some of these methods, are the multifunctional hands worked put in TsNIIPP with one drive and two drives. The multifunctional hands permit grasping of small objects by the tips of fingers when simultaneous complete flexing of the 4th - 5th fingers (that is especially comfortable when writing) are used, to fulfill a fist grasp of objects having different forms. In addition these hands provide comfortable carrying of a bag, a briefcase and other similar objects, and enable us to realize as well a lateral grasp and a fist-lateral type of grasp. The force of grasp exceeds 5 kilograms without additional maintainence of the grasp, and 8 kilograms with additional maintainence. The time of grasp does not exceed a second.

Conclusion

The experience of working out the multifunctional hands and their tests on the invalids (as regards especially the last model with one drive) has proved the possibility of the development of artificial hands, satisfying rather high biomechanical demands. They are rather simple in design and are designed for mass production.