BIOMECHANICAL ANALYSIS IN ARM PROSTHESES – OBJECTIFYING OF FUNCTIONAL ADVANTAGES OFFERED BY WRIST FLEXION

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ABSTRACT

By means of flexion wrists the functionality of prosthetic fittings for upper extremities can be improved significantly. Objects can be manipulated more favourably. Furthermore an optimized gripping position allows an improved body posture. Reaching objects or other dynamic processes are essential in amputee’s ADL’s. The path of motions influences the whole extremity in a physiological manner.

Biomechanical measuring results demonstrate the advantages in movement by individual hand positioning. Measurements were conducted by means of an optoelectronic camera system for recording motion kinematics (VICON 460, VICONPEAK Oxford, GB). The subjects were fitted with myoelectric arm prostheses and performed predefined motion tests. Position of flexion angle and hand rotation varied systematically. Depending on the posture of the hand the optimization of certain motion patterns could be proved. Repeating action is supported and can be performed more persistently. Some activities confirmed the significance of optimized interaction between wrist rotation and flexion.

INTRODUCTION

Benefits offered by arm prostheses are increased with each additional degree of freedom. A flexion wrist allows optimized gripping and manipulating of objects in different positions required in many daily situations. In a motion analysis lab it shall be visualized how the motion pattern of the whole arm is physiologically influenced.

MATERIALS AND METHODS

Subjects

Six subjects with below arm amputation or malformation were integrated in the tests. As prosthesis the flexion wrist MyoWrist Transcarpal 10V38 or the MyoWrist 2Act 10V40 was used in combination with a myoelectric prosthetic hand. These wrist joints permit locked flexion and extension of 0°, 20° and 40°. It was not allowed for the prosthetic device to cause additional unusual excess length of the system.

Instrumentation

The measurements were conducted by means of an optoelectronic camera system recording motion kinematics (VICON 460, VICONPEAK Oxford, GB). According to the VICON Upper Limb Model passive markers (in total 25) were placed on the upper part of the subjects’ body (figure 1) [1]. Based on the configuration of these markers the 3D angles of shoulder, elbow and wrist joint are calculated following the Euler convention. In addition the coordinates of the markers allow identification of important compensation movements of the upper body part using external software (MS EXCEL).
Measurement procedure

At first the single motion patterns were twice performed with the intact side followed by the same motion pattern with the prosthetic side. These movements were repeated six times. If the goals were not reached, only three motion cycles were recorded. In each test, the starting position was standing posture with hanging arm in neutral-0-position. The prosthetic hand was closed. The following motion patterns were performed at moderate speed without physical effort:

1. **Hand to the sternum**
The subject touches a defined point in the middle of the sternum. Afterwards the arm was moved back into initial position. This movement imitates activities in the middle of the body, e.g. buttoning of shirt or using of zipper.

2. **Hand to the contralateral spina iliaca anterior superior**
The subject touches the contralateral spina iliaca anterior superior. Afterwards the arm is moved back into initial position (see figure 1). This represents activities at the contralateral side, e.g. threading in of girdle or tucking the shirt into the trousers.

3. **Hand to the ipsilateral rear trouser pocket [2]**
The subject touches the ipsilateral rear trouser pocket. Afterwards the arm is moved back into initial position. This motion simulates activities at the rear body side, e.g. taking wallet, personal hygiene.

4. **Hand to the mouth**
The subject is standing in front of a table. The table board is level with the spina iliaca anterior superior. On a defined position a mug half filled with water is placed. The subject takes the mug and moves it to the mouth. After having drunk the mug is placed back to initial position. This movement imitates activities near the mouth, e.g. eating, drinking etc.

5. **Hand to the head**
For this test the subject is standing in front of a tripod. He moves the prosthesis to a defined place level with the head. Afterwards the arm is moved back into initial position. This motion pattern represents activities away from the body level with the head, e.g. driving a nail into the wall, taking objects from a rack or cupboard.

RESULTS

The results are explained using data from motion pattern 2. Figure 2 shows the typical structure of a shoulder angle. The dark graph illustrates anteversion of the intact arm when the marked position on the hip is reached (see figure 1). With a wrist flexion angle of 40° required abduction of the whole arm is significantly reduced compared to prostheses without wrist flexion. In the following figures the amplitudes of joint movements are demonstrated. Increased wrist flexion leads to reduced compensation movements in shoulder and elbow (see figure 3–5). Considering the results it is striking that in each joint and level the angles on the prosthetic side are higher than on the intact side. On the unaffected side, shoulder rotation, elbow flexion and wrist flexion are primarily used to reach the marked position (see figure 4–6). In anteversion and abduction an unfavourable lever for holding the arm is produced.
These movements are reduced on the intact side. The range of motion is restricted by the prosthesis causing compensation movements during abduction and anteversion primarily in the shoulder.

To reach the position on the contralateral side additional trunk rotation is required. In this case reduced trunk rotation with increasing flexion angle of the wrist is shown (see figure 7).
CONCLUSION
Different motion patterns performed by different patients were analysed. Before starting the tests hand rotation was adjusted to a position most favourable for the patient. It could be observed that some patients pronated in contrast to other patients that preferred supination although the motion pattern was identical. This can be attributed to different orientations of the sockets. Major compensation movements are generated in the shoulder. However, higher abduction respectively anteversion causes unfavourable arm levers. Further compensation movements are produced by trunk rotation. The results of investigation suggest that flexion and extension of the wrist leads to reduced compensation movements. Combined with rotation compensation movements may be minimized additionally.

REFERENCES