Functional outcome following the implantation of the modal/bipolar radial head endoprosthesis. Preliminary results

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Radial head fractures constitute 33% of all elbow fractures. In cases of unreconstructible fractures, the resection of the head was advocated. Radial head arthroplasty is an alternative way of the treatment. As the implantation could end up with complications, thus new and better designs are constantly looked for. One of such designs is modal/bipolar radial head endoprosthesis. The aim of this paper is to assess the functional outcome following the implantation of this endoprosthesis using movement analysis system. Seven patients participated in the study: 5 after implantation of endoprosthesis and 2 after surgical reconstruction of the radial head. The upper extremity movements with EMG were assessed during gait and pronation/supination movements with and without the external load. The functional abilities of patients with radial head endoprosthesis do not differ from those of the patients after the elbow reconstruction. This allows the patients normal, daily activity, with no restrictions and pain.

Key words: elbow reconstruction surgery, radial head endoprosthesis, movement analysis, functional outcome

1. Introduction

Radial head fractures constitute 33% of all elbow fractures. In cases of unreconstructible radial head fractures, the resection of the head was advocated. This treatment can cause many complications (i.e. stiffness, instability, chronic pain, lack of strength, degenerative changes in elbow and wrist) [1]. Thus radial head arthroplasty is an alternative way of the treatment of these complicated fractures which should minimize the prevalence of complications. The surgical goal is to establish a congruous and stable elbow joint which will allow the active range of motion [2].

Elbow flexion–extension and pronation–supination movements are indispensable for patients' daily activi-ties. The shape of the endoprosthesis should therefore allow for the normal movement of the ulna during elbow motion. If this condition is not fulfilled the high stress at the bone-stem appears, which could cause the aseptic loosening of the endoprosthesis. A cadaveric study revealed that a mean axial rotation of at least 3.2° should be allowed [3].

The implantation of the radial head endoprosthesis could also end up with complications, such as the loss of elbow flexion and pain. In some cases, these complications lead to the removal of the endoprosthesis [4]. Therefore much effort is dedicated to the design of new endoprostheses which allow for better functional outcome and reduction of the complication rate. One of such designs is modal/bipolar radial head endoprosthesis. The new design was based on anatomical studies of 17 cadaveric radial heads [5]. This new

prosthesis consists of two parts: a stem and a head. A ball-socket joint between them allows the head to rotate and tilt. Due to an asymmetrical shape of the head the remaining bones act in synergism with the endoprosthesis, and the 3 degrees of freedom given by the ball-socket joint allow the automatic positioning of the head against the humerus and ulna. These features reduce the risk of the loosening and damage of the prosthesis [6].

Upper extremity function is usually assessed clinically using various types of scoring systems. Unhappily, they have all the shortcomings of the subjective assessments. The comparison of five scoring systems of the elbow in the same group of 69 patients revealed lack of agreement between them [7]. To minimize such errors Research Committee of the American Shoulder and Elbow Surgeons developed a standardised form for the elbow assessment. It contains two parts: the first filled by the patient, and the second filled by the surgeon. They evaluate pain, function (patient's part), mobility, stability, strength and physical findings (surgeon's part). Responses to the series of questions are scored on a 4-point ordinal scale [8]. The society recommended assessing the functional outcome of the surgical procedures of the elbow based on this scale [9].

Recently more objective methods are under development. Marker-based systems can be used to assess the movements of the upper extremity. Despite the errors in marker placements and skin movement artefacts the reliability of the measurements of this type is high. The errors depend on the type and range the movement chosen for the assessment and on the chosen location of the markers on the upper extremity. The maximum error from all sources does not exceed 32 mm at the worst combination of the marker set/type of movement, the minimum error is 3 mm [10].

The aim of the present paper was to assess the functional outcome following the implantation of the new modal/bipolar radial head endoprosthesis using movement analysis system, together with the EMG recordings of the chosen upper extremity muscles.

2. Materials and methods

2.1. Patients

In the study, 7 subjects participated. They were all adults under the age of 40, who due to an accident were the victims of severe elbow fractures with radial head destruction. They were in good health and good physical condition. Prior to the accident all subjects were of very good health and did not have any functional limitations, all were physically active. Two subjects were the victims of the work accidents, all the other of the sport accidents. After the surgery and rehabilitation they resumed their normal activities. The time span between the accident and time of the study varied from 2 to 5 years.

In five cases (1 female, 4 males), the destruction of the radial head was so great that the reconstruction was impossible (Massion type III fractures). After the resection of the radial head the modal/bipolar endoprosthesis (RHE) was implanted. In the remaining two cases (2 males), despite the severe destruction, the reconstruction of the radial head was possible using the metal palates.

All patients with degenerative illnesses, with the history of previous accidents, neurological conditions, which may influence the motion abilities, were excluded from the study.

2.2. Methods

All patients underwent two types of functional tests, in which both movement data and dynamic EMG data were recorded. In the first one, the movements of upper extremities were recorded during gait. In the second one, patients were pronating and supinating the wrists while the elbows were flexed at 90°. Patients were sitting during this test being carried out under two conditions: without external load and with each hand loaded with 1 kg. All recordings were done bilaterally and the non-affected upper extremity was the reference for the affected one.

During all tests the EMG signals were recorded from the following muscles: biceps brachii, triceps brachii, brachioradialis, deltoideus, and group of finger flexors. Thirteen retroreflective markers were placed on the upper extremity, defining seven rigid segments [11]. Markers were placed on C7, acromions, lateral elbow epicondyles, both sides of the wrist and on the hands at the bottom of the middle finger (figure 1). During the gait the Helen Hayes marker set was used to identify the phases of the gait cycle. Data were collected using VICON 460 six camera system. The EMG signals were collected using the Motion System Lab. The model of the upper extremities was developed using the Visual 3D software (see figure 2).

Additionally all patients underwent clinical examination (Lovett test for muscular strength, clinical

assessment of ROM of the upper extremity joints, with special emphasis on pronation/supination movement of the elbow). They were also asked whether they experienced any limitations or problems (e.g. pain) in daily activities, both at home and in work environment.
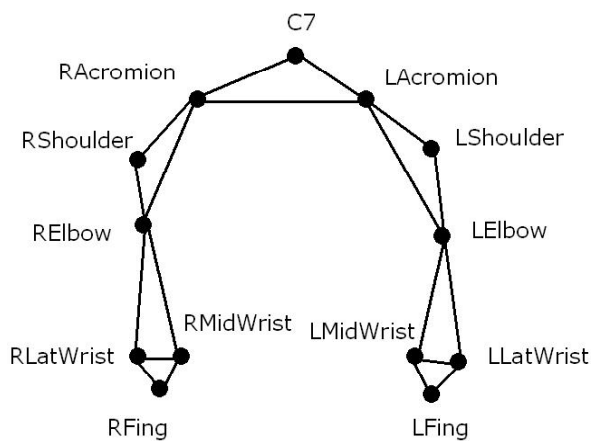

Fig. 1. Marker set used for the upper extremities

Fig. 2. Model of the upper extremities together with the local reference frames at the wrist, elbow and shoulder

X-ray examination of the affected elbow was also performed. The clinical results of the surgery were assessed using Mayo Elbow Performance Score, and in all the patients under examination the results proved to be excellent.

3. Results

3.1. Gait analysis

The data from the EMG and upper extremity movements were assessed in respect of the gait cycle (left upper extremity in left lower extremity gait cycle,
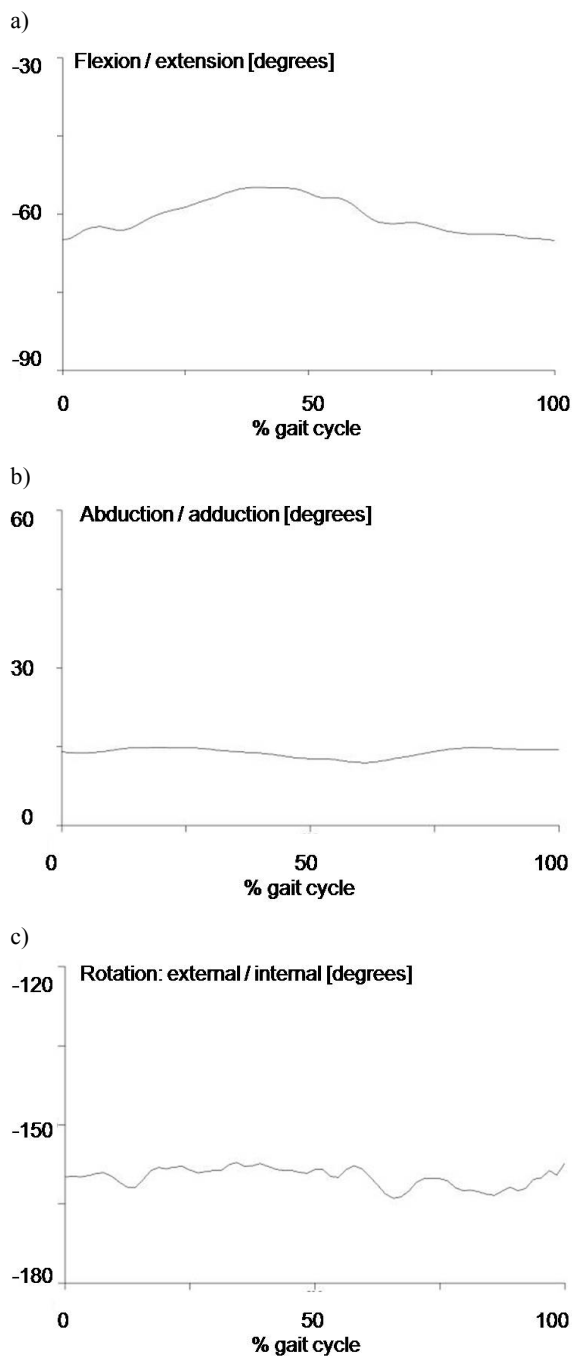

Fig. 3. Kinematics of the shoulder joint during one gait cycle – an example of the results of one patient

a)

Flexion / extension [degrees]

b)

Abduction / adduction [degrees]

c)

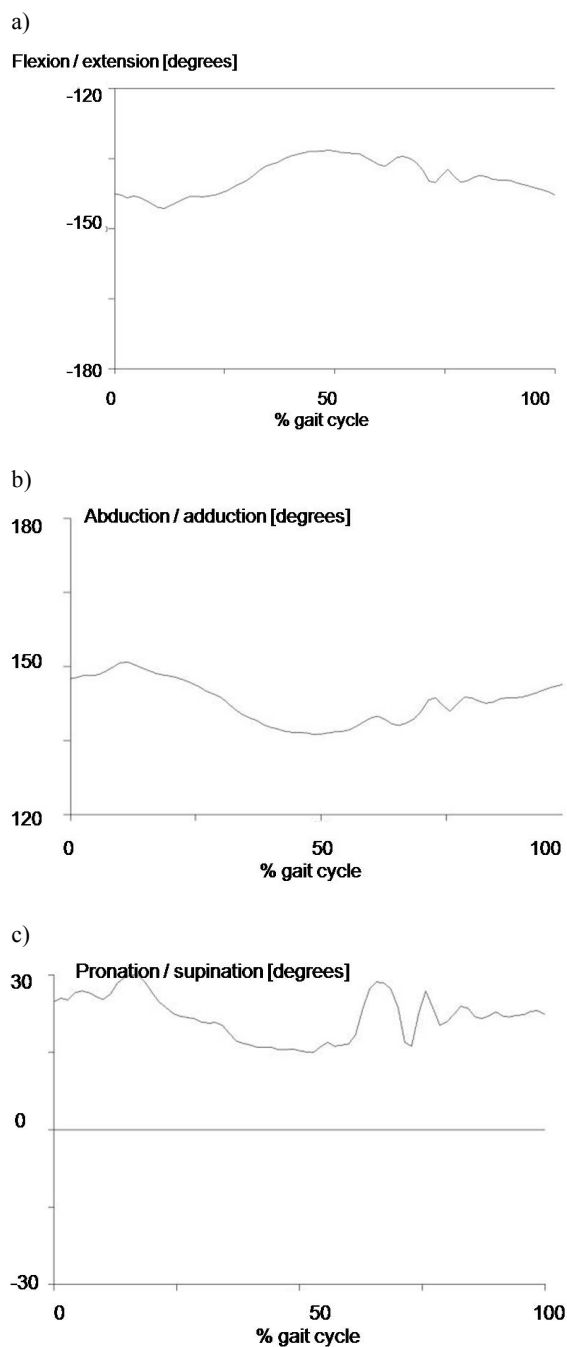Pronation / supination [degrees]

Fig. 4. Kinematics of the elbow joint during one gait cycle
– an example of the results of one patient

the same for the right side). In all patients, the movement of the shoulder, elbow and wrist joints were assessed in sagittal, frontal and transversal planes, and the results obtained from affected and non-affected sides were compared with each other.

In all patients, the kinematic curves representing the shoulder and elbow motions of both upper extremities were similar and do not differ in shape between the subjects. Figure 3 presents the motion of the shoulder joint kinematics in all three planes, while figure 4 shows the kinematics of the elbow joint. The differences between affected and non-affected sides were restricted to the range of motion (ROM).

In patients with radial head endoprosthesis, the same ROMs for both extremities were found in one patient, for 2 patients they were higher for the affected side, and for the remaining 2 – lower for the affected side. In one patient after surgical reconstruction, the ROM for the affected extremity was higher, in the second patient the non-affected extremity exhibited higher ROM.

The consistent pattern of the EMG was present for all the patients (figure 5): the only difference between the upper extremities was higher EMG of the deltoideus muscle in the limb with higher ROM of the joints.

3.2. Pronation/supination test

In this test, during its first part (without the external load), the range of movement of pronation/supination was narrower in the affected upper extremity than in unaffected one in all but one patient with RHE. The addition of external load (1 kg in each hand) reduced the range of movement in 3 patients on both sides (1 patient after reconstruction) and increased this range in 1 patient with RHE, in others no change was observed. In all the patients, the triceps activity was lower in the affected limb, in finger flexors was lower or symmetrical. The differences were noted in brachioradialis: its activity was lower in the affected limb in RHE patients and higher in patients after reconstruction. Opposite pattern was established in deltoideus. Figure 6 presents an example of the EMG recordings during pronation/supination movements without external load, and figure 7 – the same movements with external load in each hand. In the case of this patient, the left upper extremity underwent surgery (RHE implantation), the right one was healthy reference.

3.3. Clinical examination

During clinical examination no decrease of the muscular strength was found, and the ROM of all upper extremity joints were within the normal limits. Patients did not report any limitations nor problems. One patient (worker in a warehouse) complained that after the RHE surgery he could no longer carry heavy loads in the affected extremity (over 40 kg). There were no signs of the loosening of prostheses nor any other problems identified by the X-ray examination.
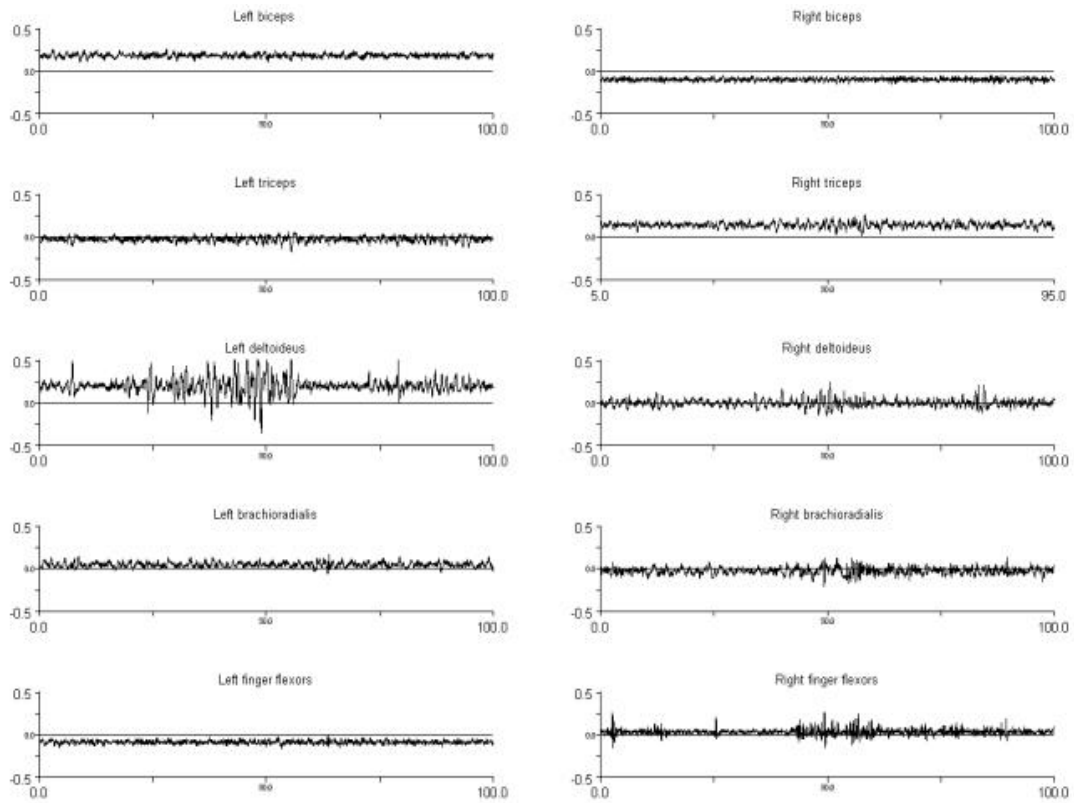
Fig. 5. EMG recordings of the upper extremity muscles during one gait cycle. In this example,
left side is the one with higher ranges of motion in the upper extremity joints. All EMGs are plotted in respect of a 100%
of the gait cycle, the *Y*-axis represents the level of raw signal in mV
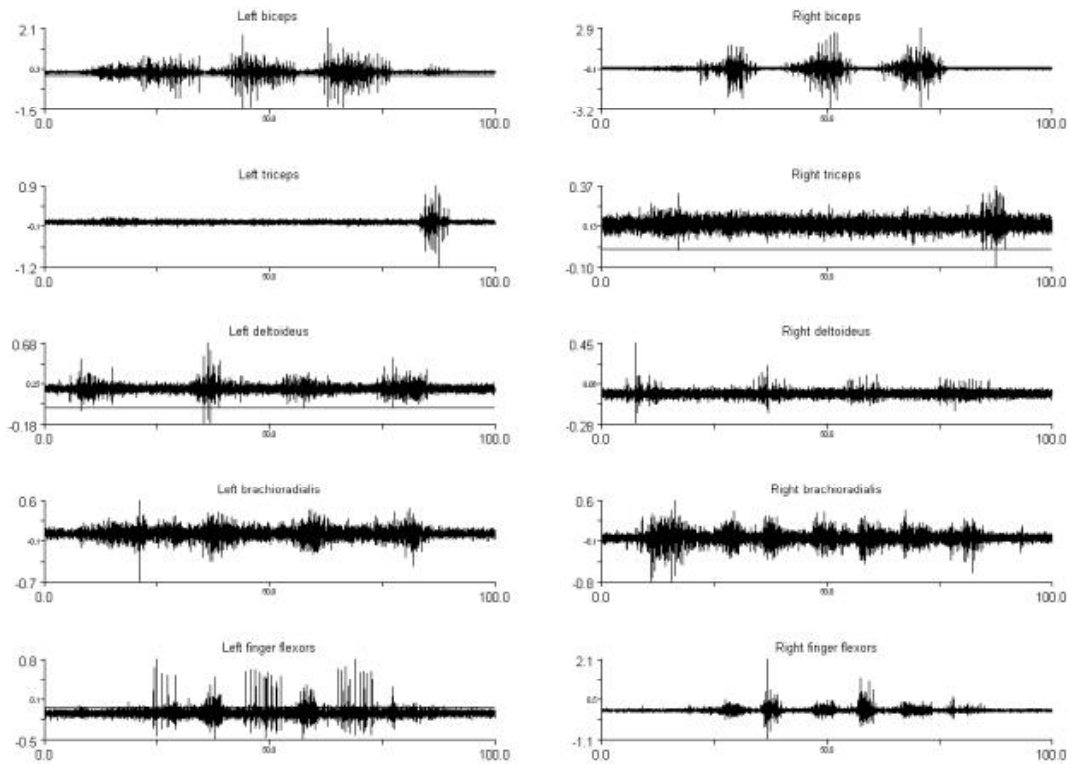

Fig. 6. EMG recordings of the upper extremity muscles during pronation/supination test without external load. In this example,
the left side is an affected one. All EMGs are plotted in respect of the beginning and end of the movement,
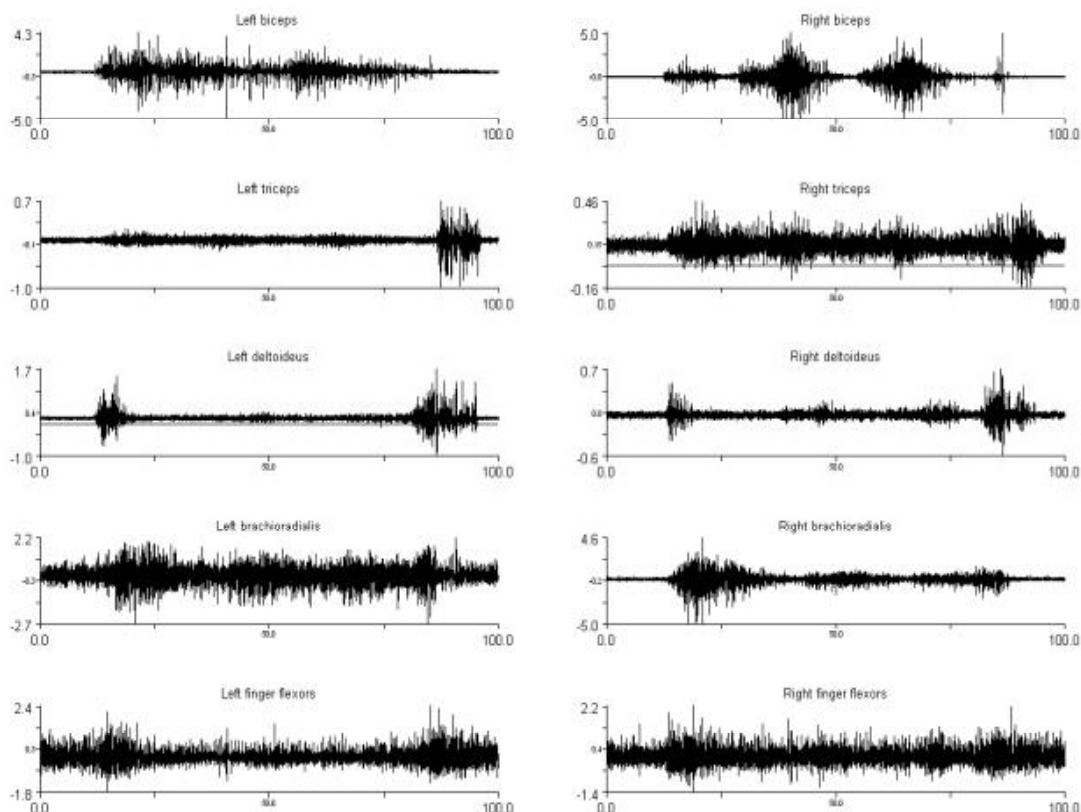the *Y*-axis represents the level of raw signal in mV

Fig. 7. EMG recordings of the upper extremity muscles during pronation/supination test with external load of 1 kg in each hand. In this example, the left side is an affected one. All EMGs are plotted in respect of a 100% of the gait cycle, the *Y*-axis represents the level of raw signal in mV

4. Discussion

The number of patients participating in this study is relatively low, which possibly can make the results obtained less representative. But this low number is a result of strict application of the inclusion/exclusion criteria. The number of implanted new modal/bipolar endoprostheses is low, as this model is now in the last stage of clinical assessment and its use requires the individual approval from both the patients and health care system. The exclusion of all the patients with accompanying diseases or problems which may influence additionally the upper extremities mobility made the final number of the RHE patients still lower. In our study, only two patients after reconstruction surgery were present. One of the reasons for such a low number is the same as for the RHE patients: exclusion of the patients with additional problems. The second one was the degree of the radial head destruction. In these two patients, the destruction was so massive that the elbow was nearly unreconstructible. Such strict approach, limiting the number of patients, ensured

high homogeneity of the subjects, and enabled to draw reliable conclusions.

POMIANOWSKI et al. [12] reported that 17 and 8 out of 32 patients who received the bipolar radial head prosthesis had respectively excellent and good results of clinical trials in Mayo Elbow Performance Score. In 7 patients, fair and poor results were revealed. The age of the patients examined in this study varied from 18 to 83 years, with a mean of 39 years. This suggests that due to their age some of the patients examined had various problems which could influence the final result of the surgery (degenerative or cardiovascular problems, etc.).

Based on the results obtained it may be inferred that during a normal walking the kinematics of the shoulder and elbow joints is similar to that achieved by PLASSCHAERT et al. [13] in 15 healthy males. In [13], the upper extremity joint angles were normalised to per cent of the gait cycle of the contralateral limb, while in our study the upper extremity joint angles were normalised to the limb gait cycle of the same body side. The actual values of the angles were also different due to the different definitions of the upper

extremity segments. But after accounting for these disparities, the shapes and ranges of the curves were similar. This suggests that the upper extremity motion of our patients (either after RHE or reconstruction) did not differ from that of the normal, healthy people. The ROM in upper extremity did not exhibit any uniform pattern: only one patient had symmetrical ROM, in all others the asymmetry was found, but the ROM values were higher both for affected and unaffected extremities. This suggests that the asymmetry observed was of a normal, physiological character, and not a result of the surgery or implantation.

During the pronation/supination test there were no differences in the kinematics between RHE group and patients after elbow reconstruction. In both groups, there was observed the asymmetry in EMG activity, which was more pronounced during the test with external load. In patients with RHE, this asymmetry in triceps muscle was higher than that in patients after radial head reconstruction, but this could be accounted for the slightly changed muscle insertions around the elbow joint. Thus the asymmetry was not reflected in the kinematics, which meant that the functional ability was not affected.

These preliminary results suggest that the new modal/bipolar endoprosthesis of the radial head fulfils the expectations. The functional abilities of RHE patients do not differ from the abilities of patients after the elbow reconstruction which allows the patients normal, daily activity with no restrictions and pain. The observation period was relatively short (2 to 5 years) in comparison with the life expectancy of the patients (they were all under the age of 40 years), therefore further studies are needed to assess the long-term effects of radial head endoprosthesis implantation.

Acknowledgement

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