

## BIOMECHANIC ASPECTS AND PATIENT NEEDS LEAD THE PATH TO A UNIQUE WRISTJOINT FOR MYOELECTRIC PROSTHESIS

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### ABSTRACT

The wrist plays an important role for the function of the human hand. The wrist joint is a complicated anatomical unit, consisting of various bones, ligaments and muscles. The distal and proximal joints combined with the rotation of the forearm excite movements at various levels that bring the hand into different positions.

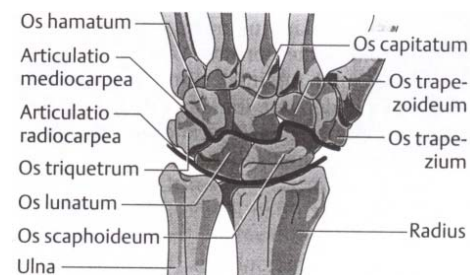
Apart from the rotation, the newly developed wrist with low construction height for myoelectric prostheses allows for volar and dorsal flexion at various locking positions. Besides those typical functions which allow positioning of the hand, the joint must meet further technical requirements. Therefore the prosthetic wrist joint clearly differs from its natural model. The most important difference is the exchangeability of the terminal device. This flexion joint with its additional degrees of freedom in motion considerably enhances the radius of action and thus increases the practical value of the myoelectric system to the patient.

### INTRODUCTION

The function of an arm prosthesis is primarily determined by the quality of the prosthetic hand. After all, the patient uses it to grasp objects and carry out different activities. To be able to grasp these objects the prosthetic hand must optimally be positioned. In the human hand these movements are mainly and often unconsciously carried out with the wrist joint. Even hand gestures are actively supported by the movements of the wrist joint. The patient, however, often has to integrate shoulder movements into the whole process of movement. To simplify the entire process of movement for the patient, a new flexion wrist unit for myoelectric prostheses has been developed.

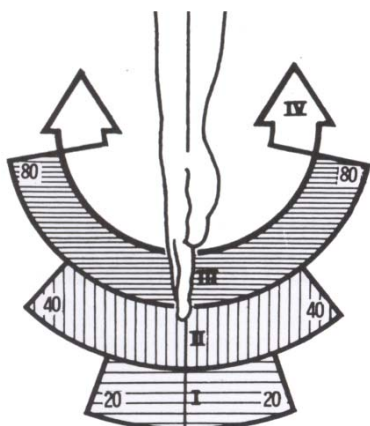
### ANATOMY

Anatomically, the human wrist divides into a proximal and distal joint (Fig 1). Both joints are responsible for volar and dorsal flexion. From the neutral 0-position, dorsal flexion, mainly produced by the distal wrist joint, normally is within the range of 35° to 60° and maximally possible up to 80°. The proximal wrist joint mainly supports volar flexion, which normally is in the range from 50° to 60° and maximally possible up to 85° [4]. The flexion movements are divided into four sectors (Fig. 2). The sector up to 20° (I) is the one mostly used. The ligaments remain relaxed with minor pressure forces being generated. In the sector up to 40° (II) movements are free. The ligaments are slightly tensed. In the sector up to 80° (III) the wrist joint reaches its physiological limit of movement. Movements in sector IV are always pathological and due to an overstretching or rupture of the ligaments [2].

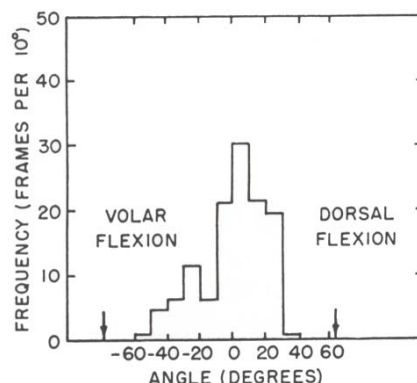


*Fig. 1: Proximal and distal wrist joint [1]*

Figure 3 shows the results of a study and depicts the frequency of the flexion angles of the wrist joint. It clearly shows that the movements assigned to sector II are the most often ones.



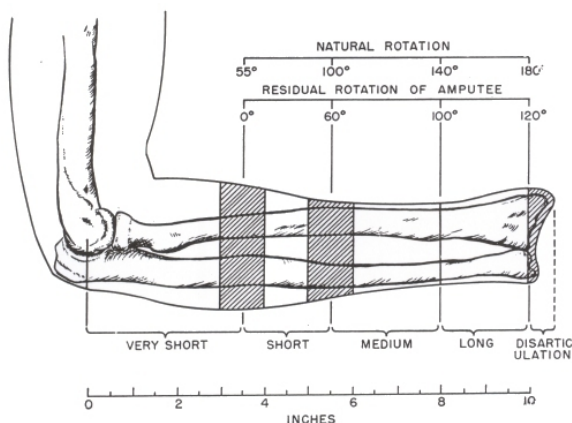
**Fig. 2:** The 4 sectors of volar and dorsal flexion [2]



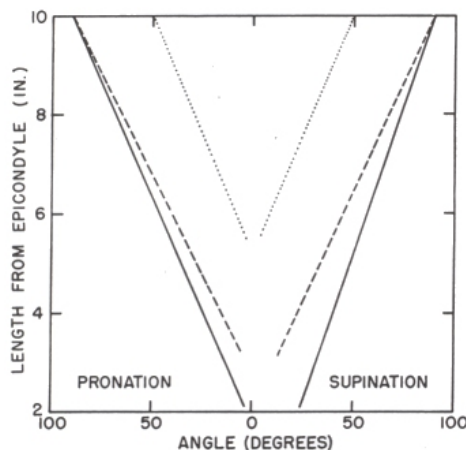
**Fig. 3:** Frequency of extreme wrist-joint positions. Histograms obtained from analysis of 128 frames taken from kinematic studies of one average nonamputee subject performing 51 daily-living activities [3]

Through shifting and rotation of the carpal bone, the hand can additionally be abducted radially by 25°-30° and 30° to 40° towards ulna [4].

The rotation movement of the hand does not have its origin in the wrist joint. But this movement is important for positioning the hand. Pronation and supination movements of the hand, for example, are produced by the proximal and distal radioulnar joint. From neutral 0-position the forearm can be pronated and supinated by 80° to 90°. With amputated forearm the rotation movement is severely limited (Fig. 4). Depending on the amputation level this movement in the forearm is still existent but cannot be adequately used with the prosthetic socket (Fig. 5).



**Fig. 4:** Below-elbow amputee types, based on the forearm length, epicondyle to styloid [3]



**Fig. 5:** Forearm rotation. Solid lines, radioulnar rotation range of a skeleton; dashed lines, mean torsion of flesh in five none amputee subjects; dotted lines, estimated socket rotation, based on six amputees [3]

With increasing amputation level and a prosthetic fitting the natural freedom of movement becomes more and more restricted for the patient. The aim is to restore this freedom of movement to the greatest possible extent by means of artificial components. With additional degrees of freedom a wrist unit can contribute to reduce this restriction.

## WRIST UNIT

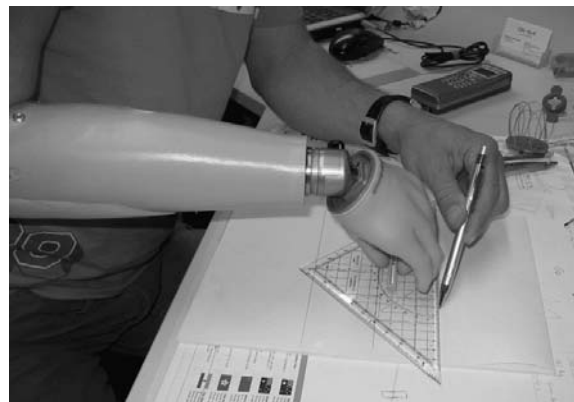
The artificial wrist joint of a prosthetic fitting offers several functions. On the one hand it connects the artificial hand to the prosthesis. Furthermore, a wrist unit allows different hands to be exchanged. To make it easier for the patient to grasp an object, the wrist unit brings the hand into the desired position. In this connection the rotation is a very important function for the patient. For a natural positioning of the hand a combination movement is required. Dorsal and volar flexion of the hand are helpful additional movements to rotation. Only these movements make it possible to grasp and hold objects with an expedient, overseeable position. Especially for above-elbow amputees and bilateral amputees this is a very important prerequisite for performing simple, daily activities. With artificial wrist units a radial and ulnar abduction of the hand can only be achieved with ball joints or, for example, with a Greifer.

## RESULTS

To offer these advantages also to all other patients, a new passive flexion wrist unit for myoelectric prostheses has been developed. Using this flexion wrist unit in combination with the Transcarpal Hand allows achieving a length that does not exceed the structural length of a normal myoelectric hand. Based on the model of the natural wrist joint, this flexion wrist unit allows for volar and dorsal flexion of  $40^\circ$ . For this range of motion there are five locking positions in increments of  $20^\circ$ . In these locking positions, a static torque of  $32 \text{ Nm} / 283 \text{ lbf-in}$  can be transferred. This corresponds to a weight to be carried in the hand (distance to the wrist unit approx.  $12 \text{ cm} / 4.7 \text{ in}$ ) of approx.  $27 \text{ kg} / 60 \text{ lb}$ . A manual pressure on the switch located on the medial side unlocks the wrist unit. An integrate ratchet system ensures that the joint is held in the current position when it is unlocked and that the hand does not automatically flex due to its own weight. Moreover, the defined ratchet points help to easily find the locking positions.

Due to the low weight of the wrist unit and of the Transcarpal Hand, the weight as well is similar to that of a normal myoelectric hand. This combination can therefore easily replace the myoelectric hand of an existent prosthetic fitting.

In case of short below-elbow residual limbs this wrist unit can be used in combination with the endoskeletal system. Especially in the case of such fittings as well as for above-elbow amputees, a flexion wrist unit is advantageous. The range of motion of these patients is largely restricted and only with unnatural shoulder movements they are able to grasp some objects with their prosthesis. With a flexion wrist unit many objects are more overseeable and easier to grasp, for example when getting on clothes or doing the dishes.



*Fig. 6: Patient with a new flexion wrist*

Up to now, a few patients have been fitted with such a flexion wrist unit. All patients immediately managed to cope with this new wrist unit and spontaneously found out new possibilities (Fig. 6). The switch is easy to manipulate due to its size. Even bilateral amputees were immediately able to manipulate the switch with their chin. The fact that the switch is located within the socket plane prevents unintentional manipulation of the switch.

## **CONCLUSION**

A lower extremity amputation always leads to a restriction of the patient's range of motion. This range of motion should be restored to the largest possible extent by means of artificial components. The artificial wrist joint is an important component of an arm prosthesis. Among other things, the wrist unit provides for the optimal gripping position of the hand and thus for a harmonious movement of the whole system. The flexion wrist unit for the Transcarpal Hand enlarges the possibilities for the patient. Due to its low height and weight, this wrist unit can be adapted to a normal, existent system. It thereby completes the entire prosthetic arm fitting and makes it easier for the patient to use their prosthesis.

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