A NOVEL METHOD OF MODELLING WRIST KINEMATICS

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Introduction: The wrist is kinematically the most complex joint in the body and is essential for optimal hand function (1,2). An increased prevalence of rheumatoid arthritis in the wrist has resulted in a greater need for research into prosthetic replacements. While arthroplasty of the larger joints such as the knee and hip is a mature technology, providing excellent long-term results, the same cannot be said for the wrist joint. This is because it is difficult to find a satisfactory approximation to the joint within the limitations of a bi-articular system. Consequently, fusion is the preferred treatment for arthritis of the wrist.

The wrist joint may be represented as two roughly orthogonal hinge axes, providing flexion-extension and radio-ulnar deviation (3). The location and orientation of these axes with respect to the underlying anatomy is essential for the design of successful joint prostheses. The objective of this work here discussed was to test a new method for determining the configuration of two hinge axes that best describes the kinematics of the wrist from an in-vivo population study.

Methods: The study received ethical committee approval. A Fastrak (Polhemus Inc.) electromagnetic motion-tracking device was used to collect data regarding right wrist movements in 108 volunteers with no history of wrist pathology. Sensors were firmly fixed to the dorsal aspect of the distal radius and the distal third metacarpal head in positions chosen to minimise skin motion effects. A custom-made arm immobiliser was used in order to isolate wrist motion and minimise involuntary pro/supination. Bony landmark coordinates were recorded for a standardised starting position. Subjects were instructed to move the hand through maximum extension to maximum flexion at intervals of radial to ulnar deviation and then to perform an inwardly spiralling motion starting at maximum circumduction. Each subject performed this movement pattern twice. In order to minimise the effect of variations in finger posture, subjects lightly gripped a 30mm diameter cylindrical bar throughout the test.

Data was recorded at 5Hz as a series of three-dimensional coordinates relative to the Fastrak global origin. For each pair of recorded points the displacement of the forearm sensor was subtracted from that of the metacarpal sensor. This resulted in a pattern representing hand motion relative to a ‘fixed’ forearm. The pattern contained 300 to 1000 points depending upon the speed with which movements were performed. The dataset was then reduced to fifty point recordings in the in-vivo data sets. The mean age of volunteers was 29 years (range 18-63).

The computer-generated “best fit” axes showed considerable variation between individuals. The mean position of the flexion-extension axis was found to be 4.1mm distal (SD 5.5mm) and 7.0mm volar (SD 2.4mm) to the recorded position of the distal radial styloid tip. The mean orientation of this axis was in 0.2° (SD 10.8°) of supination and 3.2° (SD 6.9°) of ulnar deviation in relation to a line placed transversely across the wrist. The mean position of the radio-ulnar deviation axis was 20.0mm ulnar (SD 4.5mm) to the distal radial styloid tip and 2.2mm (SD 12.3mm) distal to the flexion-extension axis (SD 12.0mm, range 29.6mm proximal to 26.1mm distal). The mean orientation of this axis was 2.0° (SD 3.6°) of dorsal tilt and 0.1° (SD 0.9°) of supination in relation to a line placed vertically through the wrist.

Discussion: This is the first study to examine global wrist motion in vivo in a large number of normal volunteers. The method used to analyse the data is novel. The principal advantage of the method is rapid data collection when compared with alternative in-vivo methods such as three-dimensional computed tomographic imaging. Furthermore, data analysis requires no user intervention.

The mean position and orientation of the axes that were calculated correlate well with previous studies that have considered wrist motion using a two-hinge model (3,4,5). The principal limitations of the method relate to skin movement effects, reliable alignment of the anatomical coordinate system with that of the motion tracking device and the time required to perform the optimisation (one hour per dataset).

The method developed will be a useful tool to assist the design of wrist joint prostheses and can also be envisaged to have wider possible applications such as detection of abnormalities in wrist function.

References:

Figure 1. Joint configuration for a typical dataset after 100 iterations of optimisation. Filled circles represent experimental data, crosses represent nearest computer-generated match. Image of hand for illustrative purposes only, source: http://www.ulb.ac.be/project/vakhum.