THE EFFECT OF RADIAL HEAD ORIENTATION ON ELBOW KINEMATICS AND RADIOCAPITELLAR FORCE TRANSMISSION.

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Introduction

The main indication for implanting a radial head prosthesis is possible ulnohumeral instability, especially in the medial collateral deficient elbow. However, no radial head prosthesis design has been shown to reproduce the stability afforded by the native radial head.

Two potential problems with current prosthetic designs are the shape and orientation of the prostheses. All have a round radial head component, although the native radial head is elliptical. The purpose of this study was to determine the effect of the shape of the radial head and orientation on kinematics and load transfer in the radiocapitellar joint. This was achieved by altering the orientation of the radial head in the elbow and therefore essentially changing the shape.

Materials and Methods

Six fresh frozen human upper extremities were used. A supination/ pronation holder was fixed distally into both the ulna and radius to maintain forearm orientation. The humerus was mounted in a testing fixture. The medial collateral ligament was transected. Orientation of the radial head was marked. A custom-made 'native' radial head prosthesis with a modular design was used to allow altering of the orientation of the radial head. The radial neck was cut using custom made parallel saw blades. The native radial head was cemented on the proximal component and the stem was cemented into the radial neck. In this way a 'native radial head prosthesis' was created.
Three dimensional spatial orientation of the ulna and humerus were measured using an electromagnetic tracking device (3Space Fastrak, Polhemus, Colchester, VT) sampling at a rate of 40 Hz. Data were recorded with Motion Monitor software (Innovative Sports Training, Inc., Chicago, IL). The triceps tendon was loaded with 4 kilograms. A motor applied to the combined biceps and brachialis tendons pulled the forearm from extension to flexion at a controlled rate. Six DOF data were collected throughout simulated active motion of the elbow, with the elbow subjected to gravity valgus and varus stresses sequentially. All of the measurements were taken with the forearm fixed in neutral rotation, pronation and supination, and with the radial head in the 'native' orientation and rotated 90 degrees.

Range of motion, ulnohumeral laxity, and ulnar position and rotation were calculated. Total valgus-varus laxity was calculated by subtracting the displacement of the ulna in the varus stressed position, from the displacement in the valgus stressed condition in the corresponding position in the flexion arc. Valgus laxity was defined as valgus angulation in the gravity valgus stressed position and was normalized by subtracting the value obtained with the 'native orientation', from the corresponding value in the 90 degree orientated conditions. These calculations were also performed for axial rotational values of the ulna. A one factor ANOVA was used to compare the native and 90 degree orientated conditions throughout the flexion arc in the three forearm positions. A post hoc Tukey test was done to assess significance.

After this, a pressure sensitive sensor (Sensor 6900, I-Scan, Tekscan) was inserted into the radiocapitellar joint space. Force between the radial head and capitellum was measured under static loading at 5, 30, 60 and 90 degrees of flexion, in the valgus stressed position, for all three forearm rotations. The triceps tendon and the combined biceps and brachialis were each loaded with 4 kg. Force after radial head rotation was expressed as a proportional change from that measured in the native radial head orientation

Results

No statistical difference in total valgus-varus laxities was found comparing the native orientation of the radial head with that after rotating it 90 degrees., This was the case throughout the flexion arc, in any flexion angle and in all three forearm rotations ($p>0.05$). This was also noted for valgus laxity alone. Forearm rotation affected total valgus-varus laxity, and specifically valgus laxity, with pronation showing significantly lower values than neutral and supination.

Analysis of the ulnar axial rotation before and after rotation of the radial head showed no significant differences in any flexion angle ($p>0.05$), in any of the forearm rotations. Post hoc testing showed a significant effect of the forearm rotations. The ulnar axial rotation in neutral was significantly greater than when the forearm was fixed in pronation and significantly smaller when compared to the supinated position.

The average differences and the maximum absolute differences that occurred in any of the specimens at any flexion angle are shown in Table 1 for all parameters measured.

Average Difference in Ulnar Angulation [SD] (degrees)			
Forearm Rotation Position	*Neutral*	*Pronation*	*Supination*
Valgus Angulation	0.2 [0.5]	0.0 [0.5]	0.1 [0.4]
Ulnar Axial Rotation	0.1 [0.7]	0.2 [0.6]	0.2 [0.6]
Maximum Difference in Ulnar Angulation (degrees)			
Forearm Rotation Position	*Neutral*	*Pronation*	*Supination*
Valgus Angulation	2.0	1.4	0.6
Ulnar Axial Rotation	1.2	1.8	0.7

Table 1: Ulnar angulation, 90 degree orientation normalized to the native orientation of the radial head.

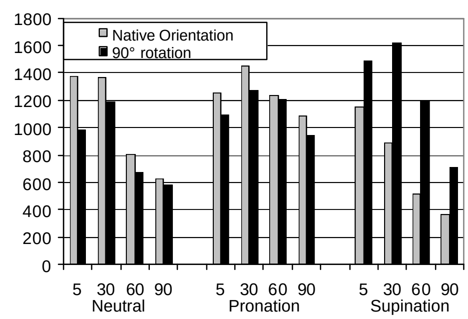

Figure 1: Average forces, shown in I-scan units, across the radiocapitellar joint in the neutral and 90° rotated position.

Force data showed an average change in pressure for all the flexion angles in all three forearm rotations (Figure 1). On average, the highest force in the neutral forearm orientation was found in pronation, followed by neutral and supination. With the radial head in the 90 degree orientation, supination showed the highest values, followed by pronation and neutral.

Discussion

The radial head is not round, but elliptical. While the orientation of the elliptical axis did not affect ulnohumeral kinematics in the present study, it did significantly influence force transmission across the radiocapitellar joint. This important finding has direct clinical implications, as an increased force on the capitellum may lead to erosion and early arthritic changes to the capitellum. Furthermore, we used the native radial head as a 'prosthesis'; a commercial metal prosthesis is likely to have an even greater effect on the forces through the capitellum. Therefore, restoring the correct orientation of the radiocapitellar articulating surfaces has to be a priority when replacing the radial head with a prosthesis to avoid potential complications.