In Vitro Kinetic and Kinematic Analysis of a New Total Wrist Implant

Salvatore M. Cavallaro[1], Brian J. Harley[1], Frederick W. Werner[1]
[1]SUNY Upstate Medical University, Syracuse, New York USA cavallas@upstate.edu

Disclosures: Salvatore M. Cavallaro (N), Brian J. Harley (N), Frederick W. Werner (4-Moximed, 9-HWBI)

INTRODUCTION: Total wrist arthroplasty (TWA) is a motion-preserving option for patients with radiocarpal disease. Unfortunately, the history of TWA has been plagued with challenges, including, but not limited to, aseptic loosening and dislocation. These challenges have prompted multiple generations of TWA implants with the hope of creating a durable, stable implant with improved clinical outcomes. The purpose of this study was to compare wrist range of motion (ROM) and tendon forces before and after implantation of the KinematX total wrist implant. Our hypothesis was that following TWR, the ROM would decrease and the tendon forces increase.

METHODS: Six cadaver wrists (ave age 79; 1 female, 5 male) were moved under computer control using a hydraulic wrist joint motion simulator by pulling on five wrist tendons through flexion/extension (FEM), radioulnar deviation (RUD), and three dart throw motions before and after TWR implantation. The orientation of the dart motions ranged from 45 degrees from the flexion/extension axis (Dart45), to 33 degrees (Dart33) and then to 18 degrees (Dart18). Maximum tendon forces in five wrist tendons (ECU – extensor carpi ulnaris, ECRB – extensor carpi radialis brevis, ECRL – extensor carpal radialis longus, FCR – flexor carpi radialis, and FCU – flexor carpi ulnaris) were determined during each cyclic motion. Maximum passive flexion, extension, and radial/ulnar deviation was determined, using standardardized measurements based on ASTM F1357-23, and a passive wrist circumduction motion was performed. Differences in the ROM and the tendon forces were compared using a paired t test.

RESULTS: Following TWA, the average total flexion/extension arc of motion was found to be 50.7 degrees (29.7 flexion, 21.0 extension) and the total arc of radial/ulnar deviation was 20.6 degrees (3.4 radial, 17.2 ulnar). When compared to native wrist motion, wrist extension, radial deviation, and ulnar deviation were significantly decreased by 45.7, 11.8 and 15.3 degrees respectively ($p<0.01$) after TWA. Wrist flexion had a trend to be decreased by 18.6 degrees ($p<0.15$). The centroid of the circumduction motion (figure 1) moved 5.3 degrees in an ulnar direction and 18.4 degrees in a flexion direction ($p<0.025$). The area of the circumduction motion decreased by more than 60% ($p<0.001$). While wrist tendon forces (table 1) did not show a statistically significant increase in any of the 5 tendons following implantation when compared to the native wrists, several had a trend for an increase - ECU during the radioulnar deviation motion ($p=0.06$, figure 2); FCR during the Dart45 motion ($p=0.14$); FCU during the Dart33 and Dart18 motions ($p<0.15$); and the ECRB and FCU during the FEM motion ($p<0.11$).

Table 1: Maximum Wrist Tendon Force During a Cycle of Different Wrist Motions (N)

Motion	Intact	Intact	Intact	Intact	Intact	TWR	TWR	TWR	TWR	TWR
	ECU	ECRB	ECRL	FCR	FCU	ECU	ECRB	ECRL	FCR	FCU
RUD	24.1	12.4	34.1	17.4	15.9	46.7	19.4	33.9	15.3	17.0
DART45	27.7	14.2	45.8	16.8	21.8	30.9	18.5	35.4	9.2	24.7
DART33	30.4	15.6	52.8	18.3	25.7	41.3	22.0	50.1	13.5	35.3
DART18	32.7	12.4	48.8	18.8	23.8	40.0	16.9	41.5	13.0	28.1
FEM	35.37	11.0	43.0	19.8	16.3	60.0	30.0	51.1	18.9	25.1

DISCUSSION: We observed an overall decrease in range of motion following TWA when compared to the native wrists. Reported ROM outcomes following TWA show variability in the literature with average flexion ranging from 26.6 to 37 degrees, extension from 25 to 49.2 degrees, radial deviation from 4 to 16.4 degrees, and ulnar deviation from 14.2 to 22 degrees [1-8]. The total arc of motion in our study is similar to these results, especially in terms of flexion and ulnar deviation, while extension and radial deviation was on the lower end. However, these other studies evaluated motion in live patients that have undergone TWA as compared to the passive cadaveric motion that we evaluated in our study. It is possible that our non-arthritic cadaver wrists had more pre-implant motion than what is typically seen in patients undergoing TWA and, as a result, our measured loss of motion following implantation does not reflect what is seen clinically. This is supported by studies that report on pre-operative ROM which show similar ranges of motion to post-operative values [1,2,5,6,7,8]. Additionally, some of our loss of motion may be attributed to increased soft tissue tension following capsular repair, technical issues during implantation, or simply implant design. For example, radial deviation was found to be limited by the carpal component flange contacting the radial component. With respect to tendon forces, we saw a trend towards increased magnitude following TWA, however it was not statistically significant. The force increases were far less than those reported for early wrist designs[9], where there were 200 to 400% increases in the tendon forces, suggesting this newer implant design may be less susceptible to loosening.

SIGNIFICANCE/CLINICAL RELEVANCE: This study provides kinetic and kinematic data for a new total wrist implant that can help improve our understanding of how these implants function, and how they may succeed or fail. Knowledge of tendon forces, range of motion, and implant design issues associated with a total wrist implant can help surgeons better educate patients as well as improve the function of subsequent generations of implants.

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Figure 1: Wrist Circumduction Motion in One Wrist

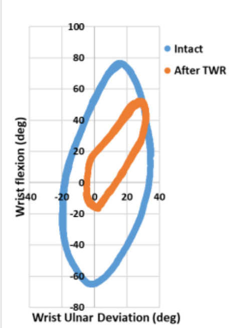

Figure 2: Ave ECU Force (N) During Wrist Radioulnar Deviation