Wrist Motion Correlation with Functional Outcomes and Progress in the Field of Total Wrist Arthroplasty

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Total wrist fusion has historically demonstrated efficacious and reproducible results as a treatment for alleviating the pain of severe wrist arthritis[1], but reduction of pain comes with significant loss of wrist range of motion and function[2-4]. In contrast, total wrist arthroplasty (TWA) has been shown to preserve range of motion but is currently not considered to be universally safe and effective due to traditionally high complication rates[5-7]. Recently improved models for total wrist prostheses attempt to address theses high complication rates and overcome previous design weaknesses to demonstrate increased potential for successful pain alleviation and maintenance of range of motion[8] (Figure 1). Patients have always demonstrated a preference for retaining wrist motion - presumably under the assumption that increased motion will yield increased functional performance - yet no studies have demonstrated a functional advantage of this retention of wrist motion as compared to a motionless wrist[9,10]. We have implanted these new generation TWAs into six of our patients, and we observed that those who chose to undergo this procedure display higher functional outcomes and satisfaction scores relative to patients with a total wrist fusion. Since this observation, our efforts have been devoted to determining the precise functional advantages of these devices when compared to total wrist fusion, and we hypothesize that limited motion wrists confer added functionality over motionless wrists. Our primary research activities have focused on the development, implementation, and validation of new outcome measures for the assessment of wrist function and using these tools to establish a correlation between wrist motion and functional abilities.

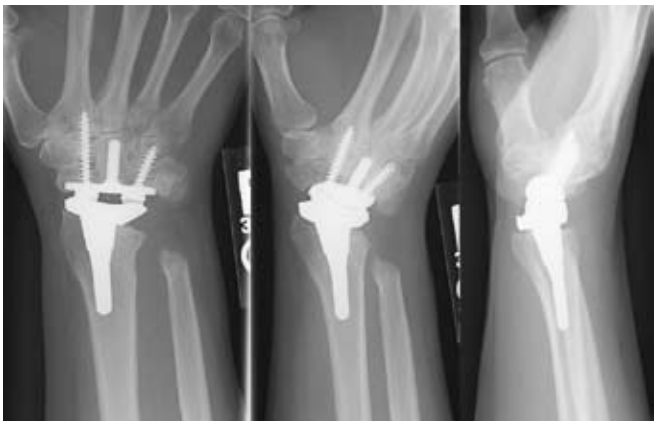

Figure 1. Postoperative AP, oblique, and lateral radiographs taken 6 months after a total wrist arthroplasty demonstrating a well-healed, well-aligned prosthesis.

Table 1: Modernized Activity Subjective Survey (MASS)

	FUNCTIONAL TASK	NO DIFFICULTY UNABLE TO DO
1.	TYPE ON A KEYBOARD	N/A 0 1 2 3 4 5 6 7 8 9 10
2.	USE A COMPUTER MOUSE	N/A 0 1 2 3 4 5 6 7 8 9 10
3.	DIAL A CELL PHONE / TELEPHONE	N/A 0 1 2 3 4 5 6 7 8 9 10
4.	TAKE A PHOTOGRAPH WITH A CAMERA	N/A 0 1 2 3 4 5 6 7 8 9 10
5.	PULL AN ITEM FROM A POCKET/PURSE	N/A 0 1 2 3 4 5 6 7 8 9 10
6.	WRITE A CHECK	N/A 0 1 2 3 4 5 6 7 8 9 10
7.	TAKE A DOLLAR BILL OUT OF A WALLET	N/A 0 1 2 3 4 5 6 7 8 9 10
8.	PLUG A CORD INTO A POWER OUTLET	N/A 0 1 2 3 4 5 6 7 8 9 10
9.	DO LAUNDRY / FOLD CLOTHES	N/A 0 1 2 3 4 5 6 7 8 9 10
10.	TYPE ON A HANDHELD DEVICE	N/A 0 1 2 3 4 5 6 7 8 9 10

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I. Modern Activity Functional Assessments

Patient-reported questionnaires available for assessing hand and wrist function include the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire[11], Patient-Rated Wrist Evaluation (PRWE)[12-15], Short-Form 36 (SF-36)[16,17], Michigan Hand Outcomes Questionnaire (MHOQ)[18-20], and Musculoskeletal Functional Assessment (MFA)[21-23]. While these surveys have all been validated as appropriate tools for subjectively measuring hand and wrist functionality, they vary with respect to specificity of the distal upper extremity, functional

Table 2:

Analysis of MASS criterion validity. Summary statistics and results of correlation analysis for MASS, PRWE and DASH surveys.

	Mean ± SD	Median	Correlation with MASS	p-value
MASS	29.0 ± 29.9	16.8	--	--
PRWE	39.4 ± 30.7	35.0	0.80	$p<0.001$
DASH	29.0 ± 29.9	30.0	0.84	$p<0.001$
N	363	363	363	

assessment, measurement of pain, and completion time[24]. Moreover, none of these surveys provide a rubric for quantifying functional limitations of performing high-frequency modern daily activities – i.e. using a computer, dialing on a cellular phone, and other common tasks.

Our research group has developed two new assessment tools to critically assess functionality in the hand and wrist with respect to modern daily tasks. Our first goal was to design and validate a short subjective functional assessment of the wrist and hand that would allow physicians to quantify the functional limitations of patients while performing high-frequency modern activities (Table 1). Validation of a use functional assessment survey requires the establishment of criterion validity, construct validity, and test-retest reliability. Development of the survey, titled Modern Activity Subjective Survey (MASS), included administration to over 200 patients presenting to our hand clinic and correlating the responsiveness of the MASS to the DASH and to the PRWE (Table 2) to establish criterion validity. Test-retest reliability was confirmed by showing no significant difference for MASS scores between two visits ($p>0.20$), and construct validity was evaluated via correlation of the MASS to range of motion ($p<0.01$).

Our second purpose was to design and implement a new set of timed tasks in order to objectively and quantitatively assess the functional ability of subjects executing commonplace, contemporary activities. This set of eight tasks, named the Modernized Activity Timed Test (MATT), closely reflects tasks included in the MASS and provides a tool for comparing objective functional abilities for patients while performing these activities.

II. OBJECTIVE RANGE OF MOTION ASSESSMENT

Unlike early total wrist arthroplasty designs based on two-dimensional hinged joints, modern implants allow patients to maintain post-operative circumductive (circular) motion[25]. Typically, however, objective range-of-motion measurements used by hand surgeons to quantify function include flexion, extension, ulnar- and radial-deviation, all of which are single-plane movements. Thus, the added functionality due to circumductive motion cannot be quantified and evaluated by these conventional range-of-motion measurement techniques. The necessity for a quick, objective measure of circumductive wrist motion was our motivation to develop a novel circumduction machine (Figure 2). The device is designed to measure the total circumferential movement allowed by the wrist by quantifying the largest circle a person can circumscribe on a page using a writing utensil (pencil) held firmly in the axis of the 3rd metacarpal. Graph paper is used to calculate this area, and the distance between the palmar wrist crease and the pencil tip is standardized to control for variation in hand size. The area, reported in square inches, serves as a quantitative proxy for measuring circumductive wrist motion. Preliminary data collected by our research team demonstrates that the circumduction measurements are both valid and reliable, suggesting that this novel device has the potential to play a critical role in the clinical assessment of these patients.

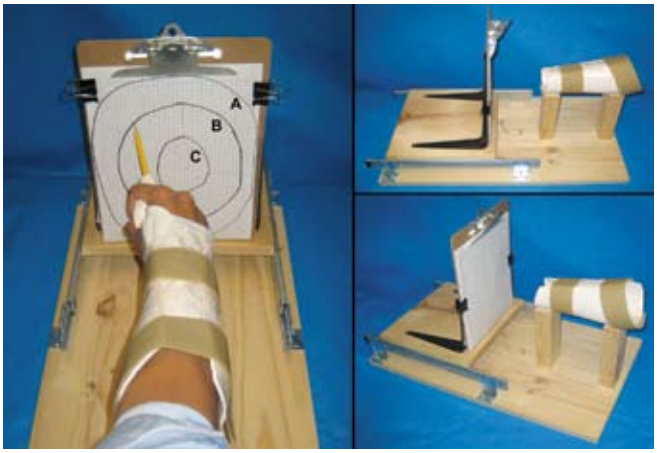

Figure 2: The custom-built machine used to measure the circumductive wrist motion. The three circles are representative of the range of motion allowed under normal (A), partially restricted (B), and highly restricted (C) splinted conditions. The circles were drawn by the subject in pencil, but have been outlined with marker for clarity.

III. CORRELATION OF MOTION WITH FUNCTIONAL ACTIVITY

As mentioned above, previous studies have demonstrated the wrist's ability to perform a wide variety of daily activities, even under the most highly restricted conditions[9]. Moreover, other recent studies have shown no functional difference between partially and highly restricted wrist motion[9,10]. These results imply that even if the complications associated with total wrist arthroplasty match the pain relief and reliability of wrist fusion patients would have little to gain with regards to functional outcomes. However our previous clinical observations encouraged us to prove otherwise.

In order to assess a correlation between functional outcomes and wrist motion, we conducted a prospective, randomized, crossover trial measuring wrist functional outcomes under two conditions of restricted wrist motion[26]. Custom-made wrist splints of two different restrictive conditions were used to model the limitations of each respective condition (total wrist fusion vs. total wrist arthroplasty). In contrast to previous studies[10], we utilized volunteers with no prior wrist pathology from the same age cohort as that of the arthritic patient population, custom-made low-profile splints, and the new assessment tools as discussed above. We hypothesized that restricted wrist motion directly correlated with functional impairment.

PROTOCOL

The study consisted of three assessments during a 48-hour randomized protocol; each assessment included range of motion testing, three subjective surveys, and a functional timed test. Each volunteer was randomized to wear one of the two wrist splints (highly restricted or partially restricted) on their right wrist between days 0 and 1, and the other splint between days 1 and 2, followed by an assessment on each day. Our primary endpoint was to evaluate the functional limitation of wrist motion between a partially restricted and a highly restricted range of motion condition.

The use of splinting as a model for wrist arthroplasty and wrist arthrodesis was verified through range of motion measurements. Wrist flexion/extension, radioulnar deviation, and supination/pronation were all measured using a standard goniometer by a single investigator (OIF). The fourth motion axis recorded was wrist circumduction using the custom-designed and custom-built device described previously (Figure X). The three subjective surveys used to measure subject satisfaction under each splinted condition included the DASH, PRWE, and MASS. Objective functional outcomes were measured using the newly developed MATT survey.

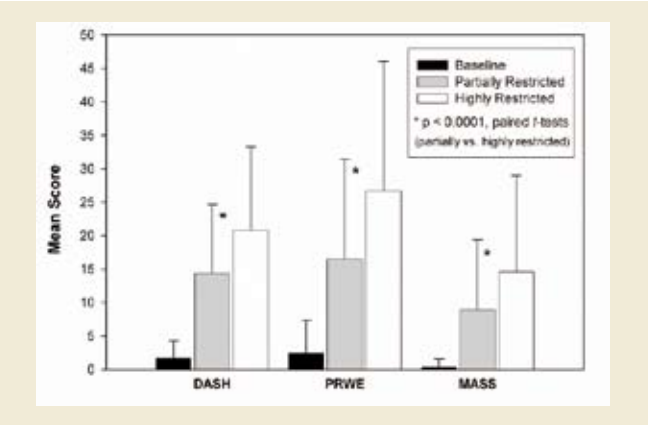

Figure 3: Subjective survey score results for the DASH, PRWE, and MASS under all three restricted conditions. All three subjective survey scores were significantly higher for the highly restricted condition relative to the partially restricted condition. This suggests a perceived subjective disability associated with decreased wrist motion.

RESULTS

Baseline and splinted subjective survey results for each condition were collected and analyzed (Figure 3). Median DASH, PRWE, and MASS scores increased among the normal, partially restricted, and highly restricted conditions ($p<0.001$). MATT results matched the perceived difficulty reflected by the subjective surveys, demonstrating increases in performance time with increased survey scores. Six of the eight individual MATT item scores showed a significant increase in performance time (relative to the un-splinted condition) for all items ($p<0.05$) except for items #2 and #3. The total MATT score, reported as a sum of the individual 8 tasks, was significantly different between the highly and partially restricted conditions ($p<0.001$).

Outcome measurements—including survey scores (DASH, PRWE, MASS), functional timed test scores (MATT), and range of motion variables—were compared using various statistical analyses to ascertain whether differences in these measures depended on age, gender, order of splinting, or day of baseline measurements, and no significant differences were found ($p > 0.05$). This analysis revealed that the average difference between partially and highly restricted conditions was independent of age, gender, order of splinting, or baseline data.

From these results we concluded that progressive loss of wrist motion creates incrementally significant functional limitation, and we advise surgeons to consider recommending motion-preserving procedures for their patients when such a choice exists.

IV. UNI2 PATIENTS

Based on previous findings, our next step is to apply these same evaluation tools to the appropriate patient population. Upcoming research activities include using these newly constructed and validated tools to evaluate the functional outcomes of the six total wrist arthroplasty patients at our clinic and comparing those to the functional outcomes of motion-reducing salvage procedures (ie: total wrist fusion and proximal row carpectomy). As stated above, we believe that our newly developed devices can quantify the functional advantage that newer wrist prostheses have over motion-limiting and motion-ablating procedures. Preliminary results from all six total wrist arthroplasty patients have demonstrated that patients retain a high degree of range of motion, satisfaction, and objective functional outcome scores. Average flexion-extension arcs following the procedure are 93% of the contralateral side, and circumductive wrist motion is 63% of the contralateral side. In addition, grip strength is 99% of the contralateral hand following surgery, and all patients would elect to undergo the procedure again.

We believe that the development of these new tools and the verification of functional differences between total wrist arthroplasty and total wrist fusion will help in paving the way for more research and better development of wrist arthroplasty designs. The development of effective and reliable wrist prostheses has the potential to provide an alternative to patients suffering from severe wrist arthritis and debilitating wrist pain, providing potentially dramatic improvements in quality of life.

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