Postoperative Analysis of Patients Who Received the Universal 2 Total Wrist Implant System

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Third-generation total wrist arthroplasty devices have provided joint stability, relief from pain and increased wrist motion for patients suffering from severe arthritis. While reports of clinical follow-up appointments describe improved wrist function, the improvement in overall upper extremity function and patient perception remains a question. Therefore, the purpose of this study was to assess the upper extremity function in patients that received the Universal 2 total implant system. Eight patients participated in the complete protocol, which included testing activities of daily living as well as surveys to assess patient perception. The findings of the current study suggest that although patients exhibit motion that exceeds the needed amount, many still have a perceived disability.

Keywords: upper extremity, hand, wrist, kinematics, biomechanics, arthroplasty

Total wrist arthroplasty (TWA) has emerged as a viable treatment for those suffering from arthritis or other deformities of the wrist (Beckenbaugh & Linscheid, 1977). While previous studies have reported excellent postoperative performance of TWA devices, there are instances of device failure, altered wrist range of motion, awkward resting positions, and altered soft tissue interaction (Youm & Flatt, 1984; Takwale et al., 2002; Dennis et al., 1986). More recently, third-generation implants such as the Universal 2 total wrist implant system (Integra Life Sciences, Plainsboro, NJ, USA) have restored motion and stability to the wrist. While arcs of motion measured in the clinic show improvement postoperatively, the question still remains, does total wrist arthroplasty improve overall upper extremity function? To answer this question, as well as gain further insight into in vivo total wrist arthroplasty behavior, a study was designed to assess upper extremity function in patients undergoing TWA.

Currently, no report exists showing a clear relationship between clinical evaluation scores of TWA and actual ranges of motion during activities of daily living. Quantifying motion experienced by the implant is vital to the understanding of implant behavior. Patients frequently exhibit total arcs and combinations of motion during activities of daily living that differ from motion measured in the clinic. Therefore, the “functional range of motion” could in fact have unforeseen positive and/or negative effects on the surrounding tissues and implant performance. It is critical to understand these effects to aid clinicians and patients in understanding the pros and cons associated with TWA.

The goal of this study was to evaluate postoperative hand function in total wrist arthroplasty patients as quantified by perceived and actual function. It was hypothesized that these patients would not only gain relief from pain, but also show improved hand and wrist function. The protocol consists of three distinct components: the Jebsen hand function test, motion analysis using an optoelectronic motion tracking system, and qualitative surveys.

Methods

After obtaining approval from the University of Iowa institutional review board, patients treated with a Universal 2 total wrist implant system (Universal 2) from the Department of Orthopedics and Rehabilitation at the University of Iowa were invited to participate in the study. Overall, a total of 46 patients participated in the study through task analysis and/or survey completion. A total of eight patients, all with a diagnosis of severe RA or other deformities (eight women, mean age of 56.3 years, ranging from 47 to 68 years), completed the entire protocol. Each patient received the Universal 2 total wrist implant system and the same surgeon operated on all patients. The standard surgical approach as outlined by the manufacturer was followed for each surgery. At the time of the study, the minimum and maximum postoperative follow-ups were 12 months.
and 36 months, respectively. Postoperative management included initial immobilization followed by a general course of rehabilitation. Patients resumed normal activities approximately three months after the surgery (Adams & Burridge, 2004).

Questionnaires

Perceived difficulty with task performance was measured using a collection of questionnaires: Disability of the Arm Shoulder and Hand (DASH), Patient Rated Wrist Evaluation (PRWE), Arthritis Impact Measurement Scale 2 (AIMS2); and two study-specific surveys regarding the tasks performed in the Jebsen Test and ADLs. The DASH and PRWE questionnaires were modified to include only those questions regarding function, as we wanted to focus on the function of the upper extremity before and after surgery. Responses in the study-specific surveys were formatted to resemble the DASH to establish consistency: 1, no difficulty; 2, mild difficulty; 3, moderate difficulty; 4, severe difficulty; and 5, unable. Sixteen subjects completed the DASH. The PRWE response scale is 1 through 10 with 1 meaning no difficulty and 10 meaning unable to do, 17 patients completed the PRWE. The AIMS2 uses a 1-to-5 response scale where 1 is always and 5 is never; there were 29 subjects that completed the AIMS2.

Jebsen Hand Function Test

Each participant performed the Jebsen Test, a well-established test of hand function (Craig, 2005). The test consists of seven timed tasks: writing, simulated page turning, picking up small common objects, simulated eating, stacking checkers, picking up large light objects, and picking up large heavy objects. The results are reported as the average times to complete the individual tasks. A total of 12 patients participated in the Jebsen Test.

Test of Activities of Daily Living

The participants performed a series of 18 tasks of daily living (ADL, Table 1) while being monitored by a motion analysis system. Thirteen of the tasks chosen for the test were taken from the literature (Nelson, 1997; Palmer et al., 1985; Tang et al., 2001), and five tasks (denoted by an asterisk) were included because the research team believed these activities represented common tasks typically using larger arcs of wrist motion.

Wrist and elbow ranges of motion were measured postoperatively using an Optotrak 3020 Motion System (Northern Digital Inc., Waterloo, Ontario, Canada). The system included two position sensors, each housing three cameras. A sampling frequency of 99 Hz was used. Motion Monitor (Innovative Sports, Chicago, IL) software was used for data collection and processing.

<table>
<thead>
<tr>
<th>Task</th>
<th>Origin of Task</th>
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</thead>
<tbody>
<tr>
<td>Answering telephone</td>
<td>Tang et al.</td>
</tr>
<tr>
<td>Pouring from a milk carton</td>
<td>Tang et al.</td>
</tr>
<tr>
<td>Wringing out a washcloth</td>
<td>Nelson; Palmer et al.</td>
</tr>
<tr>
<td>Eating soup with a spoon</td>
<td>Nelson; Tang et al.</td>
</tr>
<tr>
<td>Turning the pages of a newspaper</td>
<td>Tang et al.</td>
</tr>
<tr>
<td>Opening a Jar</td>
<td>DASH; Palmer et al.</td>
</tr>
<tr>
<td>Writing/signing name</td>
<td>DASH; Nelson; Palmer et al.</td>
</tr>
<tr>
<td>Unscrewing a light bulb</td>
<td>DASH</td>
</tr>
<tr>
<td>Stirring</td>
<td>DASH; Nelson; Palmer et al.</td>
</tr>
<tr>
<td>Pushing up from a chair</td>
<td>PRWE</td>
</tr>
<tr>
<td>Buttoning a shirt</td>
<td>Palmer et al.</td>
</tr>
<tr>
<td>Turning a doorknob</td>
<td>Nelson; Palmer et al.; PRWE</td>
</tr>
<tr>
<td>Drinking</td>
<td>Nelson</td>
</tr>
<tr>
<td>Screwing a nut onto a screw*</td>
<td></td>
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<tr>
<td>Beating an egg*</td>
<td></td>
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<tr>
<td>Scooping rice*</td>
<td></td>
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<tr>
<td>Tracing an ellipse*</td>
<td></td>
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<tr>
<td>Throwing a dart*</td>
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</tbody>
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*Denotes a task created by the research team.
prevent aliasing, a fourth-order, zero phase-shift Butterworth filter, with a cutoff frequency of 20 Hz was applied to the data after collection.

Care was taken to align three rigid-body sensors on each participant (Figure 1). With the elbow fully extended, and the thumb pointing upward, two sensors were placed along a line extending from the dorsal aspect of the hand, to the distal forearm. The third was placed at the center of the upper arm midway between the shoulder and elbow. The joint centers were located relative to each sensor by digitizing four points around the joint. Joint locations and segment lengths were calculated using the centroid method, as built into the software.

Eulerian angles (Craig, 2005) are used to define three-dimensional angular joint motions. A specific sequence of rotations, namely YZX, was used to measure the Eulerian angles corresponding to rotations, flexion-extension, radial-ulnar deviation, and pronation-supination. The neutral position was defined as the position where all fingers and the wrist rested flat on a table with the elbow flexed 90°. Each test began and ended with the palm of the hand flat on the desk and the thumb positioned on a predetermined location on a table marked by tape. Overall ranges of joint motion were considered as opposed to motion in direction due to the absence of radiographically established neutral joint positions. Eight patients participated in the ADL study.

Test Protocol
Before testing, informed consent was obtained. The DASH, PRWE, and AIMS2 surveys were then administered. Each participant first completed the timed Jebsen hand function test and the associated survey to assess the difficulty in performing the tasks in the test.

Patients then performed the test of 18 ADLs at a self-selected pace. Before each task, the subject was given instructions for completing each task. If during an activity an object was mishandled (e.g., knocking over a cup, etc.) the task was immediately stopped and repeated. On occasion, the participant moved out of view of both cameras, resulting in a loss of data. If this dropout in the data occurred, the participant was repositioned and the task repeated. The associated ADL survey was administered following completion of all tasks.

Statistical Analysis
Reliability of the tasks was determined by calculating the value of Cronbach’s alpha for each variable of interest (i.e., wrist flexion-extension, wrist radial-ulnar deviation, elbow flexion-extension, elbow rotation). Alpha values greater than 0.7 were considered acceptable, meaning that the tool in question was reliable, whereas values less than 0.5 were considered unreliable.

Agreement between independent results was determined by the intraclass correlation coefficient (rho; I.C.C.) and the 95% confidence interval. Both the intraclass correlation coefficient and the confidence interval were calculated using data taken from two trials from the same subject.

The mean and standard deviations were tabulated for Jebsen times, ranges of motion during the activities of daily living, and responses to patient surveys for the one- and two-year follow-up periods. No analysis was conducted to examine gender, age, hand dominance, or occupational biases.

Results
The patients who participated in this study were at a minimum of one year and maximum of three years postoperation.

A total of 16 patients completed the DASH, 17 completed the PRWE, and 29 completed the AIMS2 survey describing hand function. Average scores of the DASH and PRWE, as well as the individual component scores of the AIMS2 at a minimum of one year postoperation times are shown in Table 2.

A summary of the results of the Jebsen test completion times and survey responses are shown in Figures 2. The longest completion time recorded was writing (37 s). While the Jebsen task with the shortest completion time was stacking checkers, which averaged 4.4 s.
As shown in Figure 2b, patients perceived the “writing” task as the most difficult task with an average response of 2 (2.33). Patients rated the tasks “picking up small common objects,” “stacking checkers,” and “lifting large light objects” as the least difficult, with an average response of 1 (1.08).

Average motions at the wrist and elbow can be seen in Figure 3. The average wrist motions across all subjects and tasks were total arcs of 28° and 18° flexion-extension and radial-ulnar deviation, respectively. Elbow motion was 42° and 44° respectively for flexion-extension and rotation.

The intraclass correlation coefficients were calculated for each variable of interest (i.e., wrist flexion-extension, wrist radial-ulnar deviation, elbow flexion-extension, and elbow rotation). All of the coefficients were considerably low (range of 0.208–0.474), while the 95% confidence intervals may be considered high as shown in Table 3.

Average ADL survey scores, across all subjects for each task are given in Figure 4. Average response rated “stirring rice” and buttoning a shirt as the most difficult tasks (score of 2), while lifting a phone was rated the easiest (score of 1.1).

**Discussion**

In an effort to explore the benefits of joint replacement, this study aimed to evaluate hand and upper extremity performance after TWA. Of equal importance was to understand patient perception and satisfaction, which led to the inclusion of patient surveys. One study (Cavaliere & Chung, 2008) recently reported on a survey of 175 members of the American Society for Surgery of the Hand (ASSH) that evaluated the adjusted quality of life, resulting from arthroplasty or arthrodesis procedures. They concluded that the survey indicated both procedures

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**Table 2** Average and standard deviations of survey scores for the DASH, PRWE, and AIMS2

<table>
<thead>
<tr>
<th>Follow-up Between 12 and 36 months</th>
<th>DASH</th>
<th>PRWE</th>
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<tr>
<td></td>
<td>41.9 (21.0)</td>
<td>41.1 (20.8)</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Physical</th>
<th>Affect</th>
<th>Symptom</th>
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<tr>
<td>AIMS2</td>
<td>2.6 (1.4)</td>
<td>3.3 (1.4)</td>
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**Table 3** Intraclass correlation coefficients and the 95% confidence intervals

<table>
<thead>
<tr>
<th></th>
<th>Wrist Flexion-Extension</th>
<th>Wrist Radial-Ulnar Deviation</th>
<th>Elbow Flexion-Extension</th>
<th>Elbow Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.C.C.</td>
<td>0.474</td>
<td>0.438</td>
<td>0.375</td>
<td>0.208</td>
</tr>
<tr>
<td>Confidence Interval</td>
<td>35.17 ± 8.00</td>
<td>25.39 ± 7.82</td>
<td>46.55 ± 22.41</td>
<td>56.57 ± 21.55</td>
</tr>
</tbody>
</table>

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**Figure 2** — Average time (top panel) and survey responses (bottom panel) for each Jebsen task at a minimum 12 month and maximum 36 month follow-up period.

**Figure 3** — The average motion across all subjects and all tasks. This data are taken from patients with a minimum follow-up period of 12 and maximum of 36 months.
yield a higher value than nonsurgical management. The authors also report that the surgeons in that study did not view arthroplasty as having increased utility over arthrodesis. However, the authors mention the potential lack of awareness on the part of the responding surgeons, with regard to the benefits of arthroplasty, highlighting the need for more information on the benefits of wrist arthroplasty.

Jebsen (Jebsen et al., 1969) developed a test comprised of seven tasks to measure hand function. During the execution of the Jebsen Test, individual completion times of the seven tasks representing a variety of activities associated with daily living are recorded. In his initial study, significant differences in hand performance were found between dominant and non-dominant hands, as well as between the two age groups. It was concluded that large deviations in completion times for all the tasks, are a result of the diversity within the patient population's lifestyle, occupation, and hand dominance. Recorded times from patients in the current study were all greater than the values reported by Jebsen (Jebsen et al., 1969). Average times reported here for card turning, small common objects, and stacking checkers fell within one standard deviation of the values reported by Jebsen for females between the ages of 60 and 94. Direct comparisons of the current study’s outputs to those reported by Jebsen may be difficult, as the population in the current study consists of RA patients. This is an important consideration when evaluating hand function. Wrist pain is expected to decrease after surgery, leading to improved function. However, pain and dysfunction at the fingers or other joints in the upper extremity may have prevented a greater improvement in performance.

Adams and colleagues (2003) quantified disability in the upper extremity resulting from reduced wrist motion. Each subject was fitted with a custom brace that essentially eliminated radial-ulnar deviation and controlled the amount of flexion extension in the wrist. After wearing the brace for 24 hr, subjects completed the Jebsen Test, as well as 13 ADLs. An electromagnetic motion tracking system was used to measure motion at the wrist, elbow, shoulder, and torso. As with the current study, subjects were given surveys assessing the difficulty in completing daily tasks, as well as those completed during the test. The results of that study suggested that subject’s perceived disability was higher than actual disability. The results reported in the current work also show variations in the ranges of motion of the joints studied during activities of daily living. This variation can be explained by the fact that patients complete tasks differently, even after total wrist arthroplasty. In general, the arc of wrist flexion-extension and radial-ulnar deviation used to complete the tasks, increased after surgery. Surprisingly, motion at the elbow also increased postoperatively. The responses to the ADL surveys were not indicative of the motion used for some tasks. For example, tasks rated with a high level of difficulty (i.e., survey responses of 2 or higher) did not show the highest amounts of wrist motion nor compensation at the elbow. Such results again suggest that perceived disability is in fact greater than actual disability. Average range of motion values reported in the current study were much smaller than those reported by Adams et al. (2003); however, such differences are not surprising as Adams used healthy subjects. Divelbiss and colleagues (2002) examined the early performance of the Uni2 using goniometer measurements, the DASH version 2.0, and the Wrightington and Simmen systems. A total of 19 patients were evaluated preoperatively, at 6 months, 1 year, and 2 years postoperatively. The authors note significant improvement in scores as each follow-up.
period with the exception of the 2 year postoperative assessment. DASH values in the study by Divelbiss are slightly lower than scores reported here, meaning patients in the study by Divelbiss perceived greater improvement in function of their upper extremity compared with the participants in the current study. Anderson and Adams (2005) reviewed the progress of 25 patients that had the Uni2 wrist replacement. Once again, the authors reported a 20% improvement in DASH scores. Traditional clinical motion assessment yielded arcs of 70° and 31° of flexion-extension and radial-ulnar deviation, respectively. Arcs of motion used by patients during ADLs in this study were lower than clinically measured arcs reported by Anderson, agreeing with other studies that report a smaller functional range of motion.

Ryu et al. (1991) quantified the functional range of motion in the wrist with a biaxial electrogoniometer, and monitored motion patterns at the wrist during several ADLs. This study concluded that the minimum amount of motion needed at the wrist was 54° of flexion, 60° extension, 40° ulnar deviation, and 17° of radial deviation. Palmer et al. (1985) followed 10 healthy subjects in an attempt to measure functional range of motion, which was defined as the minimum amount of motion needed to complete basic activities of daily living. A triaxial electrogoniometer was employed to measure wrist motion as each subject performed 52 ADLs. It was concluded that the wrist should be considered a triaxial joint as carpal rotations in an axial direction ranged from 2.2° to 11.8°. It was determined that a “functional” range of motion was 5° flexion, 30° of extension, 10° radial deviation, and 15° of ulnar deviation.

To further address the issue of hand function, Nelson (1997) limited and eliminated wrist motion in healthy subjects as they completed 125 tasks and evaluated the difficulty in performing each task under the different conditions. Nelson concluded that the 125 ADLs tested could be completed with a very limited range of motion (i.e., 5° flexion, 6° extension, 7° radial deviation, 6° ulnar deviation). The present study—along with the works by Palmer et al. as well as Nelson—support the idea that hand/wrist function is not linearly related to available wrist range of motion, which may explain why some patients with fused wrists are able to perform ADLs and are satisfied with their hand function.

Limitations of the study included slight loosening at the skin/sensor interface as all the sensors were attached using adhesives and Velcro, which potentially impacted angle measurements. An additional limitation was that only wrist flexion-extension had alpha values greater than 0.7, while other motions were below 0.5. The intraclass correlation coefficients were also considerably low, as values greater than 0.75 were considered acceptable for a population of this size. However, many of the tasks used were taken from other validated studies focusing on activities of daily living. Future studies should include more subjects, at multiple follow-up periods, to determine if the differences in the Jebsen times, ranges of motion, and survey responses were significant. As analysis of upper extremity use during ADLs is studied further, systems like the Strathclyde Upper Limb Activity Monitor (Anderson & Adams, 2005; Vega-González & Granat, 2005) and the Upper Extremity Physical Performance Battery (Vega-González et al., 2007) have been developed. Such systems could prove to be useful in the assessment of upper extremity function after TWA, as they are able to record data outside the confines of a laboratory. When discussing patient satisfaction or perceived disability, pain and patient preconceived notions regarding wrist function can significantly affect scores on outcome surveys. Neither pain nor previous ideas regarding wrist function were qualified or quantified, in this study. However, patient rated surveys were included to assess overall patient satisfaction as it relates to use of their wrist.

Kinematic analysis of activities of daily living of patients that underwent TWA with the Universal 2 total wrist system was paired with patient surveys. The information reported here highlighted the amount of wrist motion used by patients postoperatively. While the importance of wrist motion is evident, the quantification of wrist and upper extremity motion as well as patient perception after surgery is important when considering these procedures. Though total function may in fact be less than that of younger healthy control, the motion at the wrist does contribute to improved hand function.

References


