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Outcomes of Silicone Arthroplasty Stratified by Fingers for the Rheumatoid Metacarpophalangeal Joints

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Abstract

Purpose—Previous studies have demonstrated that outcomes for the ulnar digits appear to be worse than the radial digits after silicone metacarpophalangeal joint arthroplasty (SMPA) for the rheumatoid hand. This study examines various components of hand deformities in an effort to understand SMPA outcomes in terms of metacarpophalangeal joint range of motion and alignment. We hypothesize that the ulnar fingers will have less improvement marked by greater ulnar drift, extension lag, and less metacarpophalangeal joint (MCPJ) arc of motion than the radial fingers.

Methods—68 surgical patients were recruited from 3 sites in this multi-center international prospective cohort study. All patients had a diagnosis of rheumatoid arthritis, were between the ages of 18–80, and were eligible to undergo SMPA based on measured hand deformities (extensor lag and ulnar drift). Ulnar drift, extension lag, and arc of motion for the MCPJ of each finger were measured at baseline (pre-surgical) and 1-year after SMPA.

Results—All fingers showed an improvement in ulnar drift from baseline to 1-year after surgery. The smallest improvement was in the index finger (12°) and the largest improvement was in the little finger (30°). Similarly, the largest improvement in extension lag was seen in the little finger (47°) and the smallest improvement was seen in the index finger (21°). In terms of MCPJ arc of

motion, all fingers moved to a more extended posture and gained an improved arc of motion, but the biggest improvement was observed in the 2 ulnar fingers and less so in the 2 radial fingers.

Conclusions—Our hypothesis that the ulnar fingers will have worse outcomes than the radial fingers is not proven by this study. Although past experiences have indicated that it is more difficult to maintain posture for the ring and little fingers after SMPA due to the deforming forces, sufficient correction of the deformities in the ulnar fingers is possible, if attention to adequate bone resection and realigning of the extensor mechanism are carefully performed during the procedure.

Key terms

Rheumatoid arthritis; Silicone Metacarpophalangeal Joint Arthroplasty; Hand Surgery; the Michigan Hand Outcomes Questionnaire

Silicone arthroplasty for the metacarpophalangeal joint (MCPJ) is a common procedure for reconstructing dislocated MCPJs in the rheumatoid hand. Typically the ulnar fingers (ring and little fingers) tend to have worse deformities than the radial fingers (index and middle). However, it is uncertain whether the ulnar fingers have worse outcomes than the radial fingers. Sufficient motion in the ulnar digits is particularly important because these fingers are crucial in performing power grip task that is essential for everyday activities. In previous studies, it has been demonstrated that the outcomes for the ulnar digits appear to be worse than the radial digits, with decreasing active flexion at the MCPJ.^{1–8}

In this National Institutes of Health-funded study for silicone metacarpophalangeal joint arthroplasty (SMPA), we have followed a large cohort of subjects with severe MCPJ subluxation to assess overall outcomes of hand function. This study provides a unique prospective patient sample to examine various components of hand deformities in an effort to understand precisely the range of motion and alignment of the MCPJs after SMPA. The specific aim of this paper is to evaluate outcomes for the fingers in terms of ulnar drift, extension lag, and MCPJ arc of motion. We hypothesize that the ulnar fingers will have less improvement, marked by greater ulnar drift, extension lag, and less MCPJ arc of motion than the radial fingers.

Materials and Methods

This is a multi-center international prospective cohort study. Study subjects were recruited from three sites: site A (location A), site B (location B) and site C (location C). The Institutional Review Board at each of the three sites approved all aspects of the study and all patients gave written informed consent to participate in this study. Patients diagnosed with rheumatoid arthritis (RA) were referred by their rheumatologists to one of the three centers. The study protocol has been described previously.⁹ Briefly, patients were eligible to participate in the study if they had a diagnosis of RA, were 18–80 years of age, and had the ability to complete questionnaires in English. The study subjects must meet the minimum deformity criterion in which the sum of their average MCPJ ulnar drift and average MCPJ extensor lag had to be equal to or greater than 50°. Specifically, the ulnar deviation and extensor lag of the index, middle, ring and small fingers were averaged, and the sum of the

two averages (ulnar deviation and extensor lag) must equal 50° or more. This criterion was established based on a consensus of experts in RA hand surgery (as convened in our SMPA Study Group) as the minimum deformity that should prompt consideration of SMPA surgery. The following exclusion criteria were established because they are potential factors that would confound the homogeneity of the study sample. The exclusion criteria: are health problems that would prohibit surgery, extensor tendon ruptures in the study hand, swan-neck or boutonniere deformities that would require surgical correction, previous MCPJ replacement, and the initiation of disease-modifying anti-rheumatic drugs (DMARDs) within 3 months of enrollment (potential increased risk of surgical infection and may confound the functional outcomes). Patients chose whether they would like to enroll into the surgical group (to undergo SMPA on all 4 fingers) or the control group (to be followed medically only with no surgery).

In this study, the surgical technique is standardized across the three centers. The SMPA is performed without crossed intrinsic transfer procedures. Swanson silicone implants are used at all three centers. The surgical technique has not changed substantially since Swanson's initial description.¹⁰

All outcome measures were completed at enrollment (baseline) and each post-surgical follow-up evaluation (6 months, 1 year, 2 years, and 3 years). This paper will present the 1 year follow-up data for the surgical cohort.

Functional Assessment

All measurements were taken by hand therapists with a goniometer. Arc of motion was calculated as absolute flexion angle minus extension lag angle. Thus, if a patient had an absolute flexion angle of 80 degrees, but an extension lag of 16 degrees, his/her arc of motion would be 64 degrees. If a patient had hyperextension of the MCPJ, it was treated as zero extension in the calculation. Extensor lag of the metacarpophalangeal joint was measured with the wrist in neutral and the upper arm resting on the table at 90° flexion of the elbow. The goniometer was placed on the dorsal aspect of each finger. Ulnar drift of the metacarpophalangeal joint was measured with the subject demonstrating a resting posture. The goniometer was placed on the dorsal aspect of each finger.

Statistical Analysis

Analysis of Variance (ANOVA) was used to test for differences between the three study sites in the raw mean scores at baseline and at 1 year. A linear mixed-effects model was used to test for differences in improvement scores across fingers. In this model, the 1-year change-score was modeled as a function of the baseline outcome score and the finger type (index, middle, ring, little). A linear mixed-effects model was used to account for possible correlation among fingers of the same patient, using patient as a random intercept. Statistical analysis was performed using Stata 10.1 (College Station, TX).

Study Subjects

There were 162 total patients recruited into this study: 94 in the control cohort and 68 in the surgical cohort who had SMPA. The analysis consists of the surgical cohort only. The mean

age of all surgical participants at baseline was 60.0 years and there were 55 (81%) women enrolled. Forty-five surgical patients had completed their 1-year follow-up at the time of this analysis (n=180 arthroplasties based on 4 arthroplasties/patient*45 patients). There were no significant differences across sites in any of the measurements at baseline and 1-year. Thus, we were assured that the measurements were taken consistently at all 3 sites, allowing us to combine all patient data for the analyses.

Results

Table 1 shows ulnar drift angles pre- and post-operatively for the individual fingers. All fingers show an improvement in ulnar drift angle from baseline to 1 year after surgery. The smallest improvement is shown in the index finger with an average improvement of 12° and the largest improvement is shown in the little finger with 30°, and this change in the little finger was statistically significant ($p<0.001$). There was no statistically significant difference found across fingers with respect to ulnar drift improvement at the 1-year follow-up period ($p=0.59$).

Table 2 shows the extension lag angles pre- and post-operatively for individual fingers. Again, an improvement is seen in all four fingers. Similar to the ulnar drift angles, the largest improvement is seen in the little finger with 47°, followed by the ring finger with 38°, the middle finger with 27°, and the index finger with 21°. A significant difference was found in extension lag improvement across fingers ($p<0.001$), and all improvement scores were significantly greater than zero ($p<0.001$).

Table 3 shows the MCPJ arc of motion angles pre- and post-operatively for individual fingers. Figure 1 illustrates the pre- and post-operative movement of the little finger. Table 3 shows that all the fingers moved from a more flexed posture pre-operatively to a more extended posture after SMPA. The most dramatic improvement is seen in the little finger, which had an arc of motion of 20° pre-operatively and an arc of motion of 35° 1-year post-operatively. The ring finger also had a large improvement from 18° pre-operatively to 33° post-operatively. The index and middle fingers had similar improvement to one another, but less so compared to the ring and little fingers. The linear mixed-effects model showed a significant difference in improvement across fingers in general ($p<0.001$).

In Table 4, we compared our results (mean arc of motion, mean extension lag, and mean absolute flexion) to those of published SMPA results. Our study had one of the largest number of surgical patients (n=180 arthroplasties), but the shortest follow-up (mean of 1.1 year, range 1–1.6). For the arc of motion in the index finger after SMPA, our result was 28° and published results ranged from 24–46°. The post-operative arc of motion for the middle finger in our study was 28° and published results ranged from 26–49°. The post-operative arc of motion for the ring finger in our study was 32° and published results ranged from 26–55°. The post-operative arc of motion for the little finger in our study was 35° and published results ranged from 26–41°.

Discussion

In this study we found that 1 year after SMPA, the ulnar fingers had similar ulnar drift, less extension lag, and better MCPJ arc of motion compared to the radial fingers. The ulnar fingers had worse pre-operative measurements, but improved 1 year post-operatively to similar or better outcomes compared to the radial fingers. Compared to other SMPA studies with longer follow-up, we achieved arc of motion in the radial fingers that was in the lower end of the range of results and arc of motion in the ulnar fingers that was in the higher end of published ranges.

Ulnar drift deformity is difficult to correct in the rheumatoid hand. The deforming forces caused by subluxation of the extensor tendon between the valleys of the metacarpals and the eccentric pull of the abductor digiti minimi tendon can cause excessive ulnar deviation of the little finger, making it difficult to correct. It has been postulated that although the extensor mechanism may be realigned after SMPA, the flexor tendon system cannot be corrected and the residual deforming forces over the flexor system may cause early recurrent ulnar deviation of the fingers, particularly on the ulnar side of the hand. In addition, the tight ulnar lateral bands can cause recurrent deformities of the fingers. Therefore, some have proposed performing crossed intrinsic transfer at the time of SMPA to maintain extensor tendon alignment and to prevent early subluxation of the extensor mechanism. In a retrospective study, Clark et al.¹¹ found that after approximately 4 years of follow-up, patients who underwent SMPA and crossed intrinsic transfer had significantly less ulnar drift versus patients who only underwent SMPA (6° versus 14°). On the other hand, Pereira et al.¹² found that after approximately 1.5 years of follow up, ulnar drift was identical between patients randomized to either an SMPA plus crossed intrinsic transfer group or an SMPA only group.

One technical feature of this study is that the insertion of the abductor digiti minimi is not routinely divided in an effort to decrease the ulnar deviation force over the little finger. We prefer to resect the head of the metacarpals proximal to the neck, which will decrease the ulnar tension of the ulnar lateral bands and the abductor digiti minimi tendons. By more aggressive resection of the head of the metacarpal, the tension over the tight ulnar lateral band is markedly reduced, which makes routine detachment of the ulnar lateral bands unnecessary. Care in reconstructing the extensor mechanism by reefing the radial sagittal band and in certain situations, by partially releasing the ulnar sagittal band can help the centralization of the extensor mechanism.

Our hypothesis that the ulnar fingers will have worse outcomes is not proven by this study. We found that the ulnar fingers have much better correction than the radial fingers. This finding has important clinical significance. The radial fingers are involved in fine pinch and the less than optimal arc of motion may not be a hindrance to patients in more precise activities. Therefore the 28° arc of motion for the index and for the middle finger, although not excellent, should position these radial fingers for fine pinch. However, the ulnar fingers participate in power grip and having more motion is particularly important in activities requiring a full grip. The increased motion for the ring and little fingers should be appreciated by the patient in order to have better cupping over larger objects. In addition, the

better alignment of the ring and little fingers will make the aesthetic appearance of the hand much better, by alleviating the stigmata of the ulnar deviation of the ring and little fingers that is unappealing to RA patients. The importance of this study is that hand surgeons when reconstructing the hand of rheumatoid arthritis patients can assuredly indicate to the patients that all the fingers will have an equal chance of being aligned from the SMPA procedure. Although the ring and little fingers are much better corrected, they just meet the minimum metacarpophalangeal joint arc of motion of 33° necessary for the performance of activities of daily living.¹³ This is the main concern of the SMPA, in which the extended arc of motion after surgery may affect power grip because now the arc of motion is shifted into a more extended posture. Patients must understand this consideration when they are contemplating surgery because the tips of the ulnar fingers may not reach the palm, unless the motion of the proximal interphalangeal joints is close to normal.

Our study differs from other published studies in that all patients were followed prospectively with both pre- and post-operative measurements. Patients were enrolled into a strict protocol in which follow-up occurred 1-year postoperatively. Because of the retrospective nature of most other studies, the follow-up periods varied as much as 15 years. In this study, patients were recruited from 3 sites, which allowed us to increase our sample size. The protocol was standardized across sites to ensure consistent measurements. The patients included in our study may represent a more homogeneous sample because they all had RA, all had similar hand deformity, and all had 4 joints replaced. Other published reports did not indicate such strict criteria for study entry. However, a limitation of our study is that the homogeneity of our patient sample decreases the generalizability of our results for those with less severe deformities. Furthermore, our follow-ups are the shortest compared to other published studies and it is possible that over time, the ulnar fingers may suffer from worse outcomes. This longitudinal project should be able to provide long-term data when all the patients have reached the 3-year follow-up period. Thus, it is necessary to analyze the pending 2- and 3-year data from this study before reaching any final conclusions regarding its outcomes.

Although past experiences have indicated that it is more difficult to maintain posture for the ring and little fingers due to the deforming forces, it is certainly possible for adequate correction if attention to ample bone resection and realigning of the extensor mechanism is carefully taken during the surgical procedure. Although silicone has been used as an arthroplasty material for 40 years, its acceptability appears to be justified when compared to the traditional volar plate arthroplasty procedures that are prone to joint dislocation. The future development of implant arthroplasty designs for the rheumatoid hand must have sufficient stability to maintain MCPJ motion, particularly for the ulnar digits. The current interest in unconstrained pyrocarbon arthroplasty materials is not suitable for the MCPJ because of the lack of stability to maintain finger alignment over time.^{14–15} Therefore, although the silicone implant does not confer the same biomechanical properties of a normal joint, it does serve a purpose in preventing early ulnar subluxation of the proximal phalanges by the stability imparted with this one piece implant. This paper provides one of the few experiences in evaluating a prospective series of SMPA patients followed over the course of a 1-year period. We will continue to document this important cohort of patients over the course of three years to continue to evaluate outcomes for surgical correction of the ulnar

digits compared to the surgical outcome of the radial digits following silicone arthroplasty of the metacarpophalangeal joints.

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Figure 1.

This figure illustrates how the arc of motion in the little finger moves from a more flexed posture pre-operatively to a more extended posture post-operatively.

Table 1

Ulnar Drift Angles for Individual Fingers

Ulnar Drift [♣] (Degrees)	Index Finger	Middle Finger	Ring Finger	Little Finger	p-value [^]
Baseline	26 (15)	33 (16)	40 (17)	48 (22)	
6 Month	13 (12)	13 (12)	12 (12)	13 (14)	
1 Year	13 (11)	12 (12)	13 (13)	14 (16)	
Improvement [*]	12 (9, 16)	19 (16, 23)	23 (20, 27)	30 (27, 34)	0.59

♣ Cell values are means (SD)

^{*} Predicted mean for the 1 year difference score (95% confidence interval) based on a linear mixed-effects model with the change-score (= baseline - 1 year) as the response, and the baseline ulnar drift angle and finger dummy variables as predictors.

[^] Tests for a significant difference in improvement in ulnar drift angles across the four fingers from baseline to 1 year.

Table 2

Extension Lag Scores for Individual Fingers

Extension Lag 🍄 (Degrees)	Index Finger	Middle Finger	Ring Finger	Little Finger	p-value ^
Baseline	53 (20)	65 (25)	68 (26)	72 (33)	
6 Month	30 (16)	32 (18)	25 (17)	19 (19)	
1 Year	32 (15)	35 (17)	27 (15)	20 (20)	
Improvement *	21 (17, 26)	27 (22, 32)	38 (33, 43)	47 (42, 52)	<0.001

🍄 Cell values are means (SD)

* Predicted mean for the 1 year difference score (95% confidence interval) based on a linear mixed-effects model with the change-score (= baseline - 1 year) as the response, and the baseline values of the extension lag and finger dummy variables as predictors.

^ Tests for a significant difference in extension lag scores across the four fingers from baseline to 1 year.

Table 3

Metacarpophalangeal Joint Arc of Motion Scores for Individual Fingers

MCPJ Arc of Motion (Degrees)	Index Finger	Middle Finger	Ring Finger	Little Finger	p-value [^]
Baseline	22 (17) {53, 75}	20 (16) {65, 85}	18 (19) {68, 86}	19 (24) {72, 91}	
6 Month	29 (17) {30, 59}	33 (17) {32, 64}	34 (21) {25, 59}	35 (23) {19, 53}	
1 Year	28 (15) {32, 60}	28 (17) {35, 63}	32 (17) {27, 60}	35 (20) {20, 55}	
Improvement [*]	8 (3, 13)	9 (3, 14)	15 (10, 20)	13 (8, 18)	<0.001

Cell values are means (SD) {mean extension lag, mean absolute flexion angle}

^{*} Predicted mean for the 1 year difference score (95% confidence interval) based on a linear mixed-effects model with the change-score (= 1-year - baseline) as the response, and the baseline values of the arc of motion and finger dummy variables as predictors.

[^] Tests for a significant difference in arc of motion scores across the four fingers from baseline to 1 year.

Table 4
Published Postoperative Metacarpophalangeal Joint Arc of Motion Means for Individual Fingers

Author	Year Published	Number of Joints at Follow-Up (N)	Mean Follow-Up Years (Range)	Index Finger	Middle Finger	Ring Finger	Little Finger
Chung	2009	180	1.1 (1–1.6)	28 {32, 60}	28 {35, 63}	33 {27, 60}	35 {20, 55}
Bieber [†]	1986	210	5.3 (2–8)	41 {18, 59}	43 {20, 63}	36 {22, 58}	35 {23, 58}
Goldfarb	2003	208	14 (6–21)	37 {23, 60}	39 {27, 66}	36 {24, 60}	33 {16, 49}
Kirschenbaum (R)	1993	68	8.5	36 {15, 50}	41 {14, 55}	43 {15, 58}	40 {13, 54}
Kirschenbaum (L)		76	(5–16.3)	46 {21, 67}	49 {20, 69}	55 {18, 74}	40 {14, 54}
Mannerfelt	1975	144	2.5 (1.5–3.5)	43 {8, 51}	43 {12, 55}	40 {10, 50}	35 {4, 39}
Parkkila [*]	2005	75	4.8 (3.1–6.7)	38 {16, 54}	45 {14, 59}	45 {13, 59}	41 {4, 44}
Vahvanen ^{††}	1986	107	3.7 (1–10)	36 {6, 42}	30 {10, 40}	36 {6, 42}	34 {6, 40}
Wilson (R) [†]	1993	185	9.6 (5–14.3)	26 {21, 47}	28 {16, 44}	27 {19, 46}	26 {14, 40}
Wilson (L) [†]				24 {31, 55}	26 {29, 55}	26 {25, 51}	31 {17, 49}

☛ Cell values are means {mean extension lag, mean absolute flexion angle}

(R)=Right hand, (L)=Left hand for studies that reported results for each hand

^{*} Results from patients with Swanson implants only

[†] Mean absolute flexion calculated from published extension lag and arc of motion data (sum of mean extension lag + mean arc of motion)

^{††} Mean arc of motion calculated from published absolute flexion and extension lag data (mean absolute flexion – mean extension lag)