Assessment of Wrist Function After Simulated Total Wrist Arthrodesis: A Comparison of 6 Wrist Positions

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Abstract

Background: There is poor consensus in the literature regarding associated functional limitation and the preferred wrist position for total wrist arthrodesis. The purpose of the current investigation was twofold: (1) to assess the functional limitations of wrist arthrodesis and (2) to determine the optimal position for wrist arthrodesis using a simulated wrist fusion model. **Methods:** Twenty healthy volunteers underwent simulated wrist arthrodesis in 6 different positions using custom-molded wrist splints: 15° extension with 0° radio-ulnar deviation, 15° extension with 10° ulnar deviation, 15° extension with 10° radial deviation, 0° extension with 0° radio-ulnar deviation, 0° extension with 10° ulnar deviation, and 0° extension with 10° radial deviation. Each volunteer was independently assessed for wrist function using the Jebsen-Taylor hand function test, grip strength, and satisfaction in the simulated wrist fusion positions. Comparisons between all simulated fusion wrists and the baseline unsplinted wrist as well as among the 6 simulated fusion positions were performed. **Results:** Turning over a card (5.1 vs 4.3 seconds), picking up small objects (7.1 vs 5.8 seconds), and simulated feeding (8.3 vs 7.1 seconds) as well as total Jebsen-Taylor test duration (41.8 vs 37.9 seconds) was significantly longer in simulated fusion wrists. Both grip strength (55.9 vs 80.7 kg) and satisfaction scores (6.4 vs 9.6) were lower in simulated fusion wrists. Wrists in 0° extension also demonstrated significantly shorter durations in stacking checkers than wrists in 15° extension. **Conclusion:** Our findings suggest that wrist arthrodesis may only compromise select wrist functions. Among the tested wrist fusion positions, wrists fused in neutral may demonstrate better function than wrist fused in slight extension. However, grip strength and satisfaction seem to be unaffected by wrist fusion position.

Keywords: arthrodesis, function, fusion, wrist

Introduction

Wrist arthrodesis is a well-established and durable procedure for the treatment of degenerative wrist arthritis, wrist instability, and functional wrist pain.^{5,8,9} It has also been described as a successful salvage procedure for failed wrist arthroplasty.^{1,3,17} However, wrist arthrodesis is not without drawbacks, namely, the sacrifice of wrist mobility and associated functional limitations.

Although numerous techniques and fusion fixation devices have been described, there is poor consensus in the literature regarding the optimal wrist position for arthrodesis. Both Haddad and Riordan as well as Boyes recommended fusing the wrist in extension.^{2,7} Other studies have reported satisfactory functional outcomes with 10° to 15° of wrist extension and slight ulnar deviation.^{8,15,20} To the contrary, Clayton and Smyth advocated fusion of the wrist in the neutral position.⁴

The purpose of the current investigation was twofold: (1) to quantitatively evaluate the functional limitations of wrist arthrodesis and (2) to compare functionality of different wrist positions for arthrodesis. We hypothesized that wrists with simulated fusion in slight extension would demonstrate better function compared with wrists in neutral. Our study hypothesis was tested using a simulated total wrist arthrodesis model employing healthy human volunteers and custom-molded circumferential wrist splints.

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Materials and Methods

Institutional review board approval and informed consent of the participating volunteers were obtained prior to the initiation of this investigation. Study exclusion criteria included volunteers with a prior history of ipsilateral upper extremity trauma, preexisting hand deformity, pregnancy, neuromuscular disorders, osteoarthritis, or rheumatoid arthritis. No compensation was offered for participation. All 20 initially recruited volunteers participated in the study. Of the 20 volunteers, 7 were men and were 13 women. Mean volunteer age was 31 years (range, 19-42) and all were right hand dominant.

Circumferential wrist splints made from thermoplastic material were used to allow for custom anatomic contouring to limit wrist movement during testing (Orfit Industries America; Jericho, NY). The splints were used to simulate 6 different wrist arthrodesis positions: 15° of wrist extension with 0° of radio-ulnar deviation, 15° of wrist extension with 10° of ulnar deviation, 15° extension with 10° radial deviation, 0° of wrist extension with 0° of radio-ulnar deviation, 0° of wrist extension with 10° of ulnar deviation, and 0° extension with 10° radial deviation. The tested splinting positions were chosen due to a lack of consensus regarding the superiority of neutral versus 10° to 15° extension for wrist fusion.^{2,4,7} In addition, we sought to evaluate the functional effect of 10° ulnar, neutral, or 10° radial deviation as fusion in slight ulnar deviation has been described as desirable.⁸ Each splinted position was confirmed with the use of a goniometer. The order of tested wrist fusion positions was randomized for each volunteer with all testing performed using the dominant hand.

Each volunteer was independently assessed for wrist function, grip strength, and satisfaction in the simulated wrist fusion positions by one of three certified occupational therapists. Wrist function was quantitatively assessed using the Jebsen-Taylor hand function test, which evaluates performance duration of standardized tasks.¹⁰ This validated hand function test consists of 7 tasks.^{6,18,19} The tested tasks are timed in seconds and include writing a short sentence, turning over cards, picking up small objects, simulated feeding, stacking checkers, moving large empty cans (light objects), and moving large weighted cans (heavy objects; Figures 1 and 2). A total score was also calculated from the sum of the timed individual tasks. Grip strength was assessed using a Jamar dynamometer (Patterson Medical Holdings, Inc., Bolingbrook, Illinois) in the second position with the shoulder in 0° abduction and elbow in 90° flexion with neutral rotation.²¹ Three grip strength measurements were performed and averaged for each wrist position. Satisfaction of each simulated wrist fusion position was subjectively assessed by the study volunteers on a scale from 1 to 10, with 1 indicating the poorest satisfaction and 10 indicating the highest satisfaction. Unsplinted

Figure 1. Photograph of volunteer stacking checkers in simulated wrist fusion splint.

Figure 2. Photograph of volunteer moving heavy objects in simulated wrist fusion splint.

baseline assessments were performed prior to simulated wrist fusion.

Comparisons of Jebsen-Taylor task durations, grip strength, and satisfaction between all simulated fusion wrists and the baseline unsplinted wrist were performed using 2-tailed *t* tests. One-way analysis of variance (ANOVA) tests were used to compare Jebsen-Taylor score, grip strength, and satisfaction among the 6 simulated fusion positions. Two-tailed *t* tests were then used to perform

Table 1. Comparison of Jebsen-Taylor Functional Score, Grip Strength, and Satisfaction in Unsplinted and Simulated Fusion Wrists.

Test	Units	Unsplinted wrist	All simulated fusion wrists	P value
Jebsen-Taylor (SD)	seconds			
Writing		10.4 (3.2)	10.9 (3.2)	.523
Card		4.3 (0.7)	5.1 (1.6)	<.001
Small object		5.8 (1.1)	7.1 (1.3)	<.001
Simulated feeding		7.1 (1.4)	8.3 (1.9)	.003
Checkers		3.7 (0.8)	3.7 (1.1)	.920
Light object		3.3 (0.5)	3.2 (0.6)	.850
Heavy object		3.3 (0.5)	3.4 (0.6)	.271
Total		37.9 (5.1)	41.8 (5.6)	.004
Grip strength (SD)	pounds	80.7 (28.0)	55.9 (26.6)	.001
Satisfaction (SD)	N/A	9.6 (0.9)	6.4 (1.6)	<.001

Note. N/A, not applicable.

Table 2. Comparison of Jebsen-Taylor Stacking Checkers Subtest Among Simulated Fusion Wrists.

Wrist fusion position	Checker stacking time in sec (SD)	Wrist fusion position	Checker stacking time in sec (SD)	P value
0° extension with 0° radio-ulnar deviation	3.2 (0.6)	15° extension with 0° radio-ulnar deviation	3.8 (0.6)	.007
0° extension with 0° radio-ulnar deviation	3.2 (0.6)	15° extension with 10° ulnar deviation	3.7 (0.8)	.048
0° extension with 0° radio-ulnar deviation	3.2 (0.6)	15° extension with 10° radial deviation	4.4 (1.7)	.011
0° extension with 10° radial deviation	3.3 (1.1)	15° extension with 10° radial deviation	4.4 (1.7)	.025

pairwise comparisons. The level of significance for all tests was $P < .05$. A post hoc power analysis was performed to determine the number of subjects necessary to adequately power our study given the distribution of our results.

Results

Comparison Between Unsplinted Baseline Wrist and Simulated Fusion Wrists

Average time to complete the Jebsen-Taylor tasks was significantly greater in all simulated fusion wrists as compared with unsplinted wrists in turning over a card (5.1 vs 4.3 seconds; $P < .001$), picking up small objects (7.1 vs 5.8 seconds; $P < .001$), and simulated feeding (8.3 vs 7.1 seconds; $P = .003$). Total Jebsen-Taylor test duration was also significantly longer in simulated fusion wrists (41.8 vs 37.9 seconds; $P < .001$). There were no significant differences in writing, stacking checkers, moving light objects, or moving heavy objects between simulated fusion wrists and the unsplinted wrist. Both grip strength (55.9 vs 80.7 lbs; $P = .001$) and satisfaction scores (6.4 vs 9.6; $P < .001$) were significantly lower in simulated fusion wrists. Mean Jebsen-Taylor test durations, grip strength, and satisfaction scores in

simulated fusion wrists as compared with the unsplinted wrist are summarized in Table 1.

Comparison Among All 6 Simulated Fusion Wrists

One-way ANOVA tests demonstrated a significant difference in stacking checkers among the 6 simulated wrist fusion positions ($P = .01$). There were no significant differences in any other subcategories of the Jebsen-Taylor test, grip strength, or satisfaction between simulated wrist fusion positions. Pairwise analysis revealed that wrists in 0° extension with 0° radio-ulnar deviation demonstrated significantly shorter durations in stacking checkers compared with wrists in 15° extension with 0° radio-ulnar deviation (3.2 vs 3.8 seconds; $P = .007$), wrists in 15° extension with 10° ulnar deviation (3.2 vs 3.7 seconds; $P = .048$), and wrists in 15° extension with 10° radial deviation (3.2 vs 4.4 seconds; $P = .011$). Wrists in 0° extension with 10° radial deviation also demonstrated significantly shorter durations in stacking checkers than wrists in 15° extension with 10° radial deviation (3.3 vs 4.4 seconds; $P = .025$). Pairwise comparison data among the 6 simulated wrist fusion positions are summarized in Table 2.

Discussion

The purpose of our study was to assess the functional limitations of wrist arthrodesis and to determine the optimal wrist position for arthrodesis. Our findings suggest that wrist arthrodesis may only compromise select wrist functions, whereas grip strength and satisfaction may be universally affected. In our study, no significant difference in the duration of writing, stacking checkers, moving light objects, or moving heavy objects was noted between simulated fusion wrists and the unsplinted wrist.

To the contrary, durations for turning over a card, picking up small objects, and simulated feeding as well as the total Jebsen-Taylor test were significantly greater in simulated fusion wrists as compared with unsplinted wrists. Jung et al reported similar findings in their functional wrist assessment of 16 study participants with and without wrist cock-up splint immobilization.¹¹ Using electromyographic testing of elbow flexor and extensor muscles, the authors found significant differences in muscle activation during simulated feeding, indicating functional impairment related to wrist immobilization. Several clinical studies also report some degree of functional limitation after wrist arthrodesis.^{14,16} In addition, both grip strength and satisfaction scores were significantly lower in simulated fusion wrists in our study. The combination of functional limitation and decreased grip strength likely resulted in the significantly poorer satisfaction scores during simulated wrist fusion.

In our study, there were significant differences among the 6 simulated wrist fusion positions in stacking checkers. However, our hypothesis that wrists with simulated fusion in slight extension would demonstrate better function than wrists in neutral was not supported by our results. Our analysis demonstrated that wrists fused in neutral demonstrated significantly shorter durations in stacking checkers than wrists fused in slight extension, indicating better function among wrists fused in neutral. Understandably, extrapolation of this focused finding may be limited; however, reports in the literature support this conclusion. Clayton and Smyth recommended the neutral position for wrist arthrodesis and concluded that the neutral position allows for better supination and pronation while maintaining finger balance and strength.⁴

We found no significant difference in grip strength or satisfaction scores among the simulated wrist fusion positions. Clinical studies in the literature report similar findings. Rauhaniemi et al reported the outcomes of 115 patients who underwent total wrist arthrodesis.¹⁶ Of the 115 patients in their study, 78% (69/88) of patients reported satisfaction with their wrist fused in neutral, 92% (12/13) reported satisfaction with their wrist fused in slight extension, and 79% (11/14) reported satisfaction with their wrist fused in slight flexion. Lautenbach et al also concluded that wrist position has no effect on subjective satisfaction following wrist arthrodesis.¹² In their study, 34 patients underwent wrist

arthrodesis as described by Mannerfelt and Malmsten.¹³ The authors further suggest that a relatively wide range of wrist fusion positions may be accepted as all patients fused between 14° flexion and 10° extension in their study subjectively rated their outcome as excellent.

In addition to the findings of the current study, there are several other important factors to review when considering wrist position for arthrodesis. These include the functional status of the contralateral wrist, ipsilateral elbow and shoulder function, and patient vocational needs. In patients requiring bilateral wrist arthrodeses, some have recommended that one wrist be fused in slight extension whereas the contralateral wrist is fused in slight flexion.¹⁶ Alternatively, others have suggested that both wrists be fused in neutral to slight extension.²² Although there may be little consensus in the literature regarding the optimum wrist position for arthrodesis, most clinicians would agree that the fusion position should be determined on an individual case basis. One may also consider using molded splints preoperatively to determine the ideal wrist fusion position for patients who desire to continue specific activities.

There are limitations to our study. We performed simulated total wrist arthrodesis using custom-molded wrist splint immobilization. However, in contrast to wrist arthrodesis, wrist splint immobilization prevented some degree of supination and pronation, which is freely allowable in wrist arthrodesis. Thus, our results may exaggerate the degree of functional limitation associated with wrist arthrodesis. Similarly, the effect of pain relief on function following clinical wrist arthrodesis could not be accounted for using a simulated wrist fusion model. In addition, our study volunteers were substantially younger than patients who typically undergo wrist fusion. However, our study represents functional assessment in the best-case scenario and presents findings previously unreported in the literature. Last, post hoc power analysis revealed our study to be slightly underpowered. Group sample sizes of at least 32 subjects would have been necessary to achieve 80% power for the same results. Nevertheless, the significant differences presented in our study were substantial and identified despite this limitation.

In conclusion, our findings indicate that wrist arthrodesis may only compromise select wrist functions. However, the compromised functions may be substantially impactful. Furthermore, our results suggest that fusion of the wrist in neutral may offer greater function for select tasks than fusion in extension. Long-term clinical investigation of a large wrist arthrodesis cohort is likely needed to further delineate this finding.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed as part of this study were in accordance with ethical standards of the Institutional Review Board and with the Helsinki Declaration of 1975, revised in 2000.

Statement of Informed Consent

Informed consent was obtained for all volunteers prior to performing this research investigation.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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