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Joint Leveling for Advanced Kienbock's Disease

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Abstract

PURPOSE—The use of joint leveling procedures to treat Kienbock's disease has been limited by the degree of disease advancement. This study was designed to compare clinical and radiographic outcomes of wrists with more advanced Kienbock's disease (stage IIIB) to wrists with less advanced disease (stage II/IIIA) following radius shortening osteotomy.

METHODS—This retrospective study enrolled 31 adult wrists (30 patients, mean age 39 years), treated by radius shortening osteotomy between two institutions for either stage IIIB (n=14) or stage II/IIIA (n=17) disease. Evaluation was carried out at a mean of 74 months (IIIB, 77 months; II/IIIA, 72 months). Radiographic assessment determined disease progression. Clinical outcomes were determined by validated patient-based and objective measures.

RESULTS—Patient-based outcome ratings of wrists treated for stage IIIB were similar to those with stage II/IIIA [QuickDASH (15 vs 12;p=.63), MMWS (84 vs 87;p=.59), VAS pain (1.2 vs 1.7;p=.45), VAS function (2.6 vs 2.1;p=.59)]. The average flexion/extension arc was 102° for wrists with stage IIIB and 106° for wrists with stage II/IIIA Kienbock's (p=.70). Grip strength was 77% of the opposite side for stage IIIB wrists versus 85% for stage II/IIIA (p=.25). Postoperative carpal height ratio and radioscapoid angle were worse (p<.05) for wrists treated for stage IIIB (0.46:65°) than stage II/IIIA (0.53:53°) disease. Radiographic disease progression occurred in 7 wrists (6 stage II/IIIA: 1 stage IIIB). The one stage IIIB wrist that progressed underwent wrist arthrodesis.

CONCLUSIONS—In this limited series, clinical outcomes of radius shortening using validated, patient-based assessment instruments and objective measures failed to demonstrate predicted "clinically relevant" differences between stage II/IIIA and IIIB Kienbock's. Provided the high percentage successful clinical outcomes in this case series of 14 stage IIIB wrists, we believe that static carpal malalignment does not preclude radius shortening osteotomy.

Level of Evidence—IV; retrospective case series

Keywords

joint leveling; lunate; Kienbock's; osteotomy; radius

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INTRODUCTION

The use of joint leveling procedures for the treatment of Kienbock's disease has been limited by the degree of disease advancement based on Stahl/Lichtman(1,2) and Goldfarb(3) criteria (TABLE 1). Prior clinical and biomechanical studies have suggested that joint leveling may provide less pain relief and less durable functional restoration in patients with advanced carpal collapse (beyond stage IIIA).(4–8) Several authors have expressed particular concern regarding the use of joint leveling procedures in stage IIIB Kienbock's disease because of the likelihood of persistent symptoms due to progressive carpal collapse, suggesting that joint leveling is likely to be most successful in wrists with stages I, II, and IIIA disease.(4,5,8)

Few studies have objectively evaluated the outcomes of joint leveling in patients with stage IIIB Kienbock's disease compared to those with earlier stages of disease. Prior studies have been limited in size with a mean of 8 (range, 3–13) patients treated with radius shortening for stage IIIB/IV disease in each investigation.(9–14) Additionally, there has been a failure to utilize validated patient-based outcomes instruments.(9,14–16) Despite these limitations, some authors have cautiously recommended joint leveling for wrists with stage IIIB citing possible improvements in pain, function, motion, and grip strength.(10–14,17)

This trial was conducted to compare the clinical and radiographic outcomes following radius shortening osteotomy of wrists with stage IIIB to stage II/IIIA Kienbock's disease. Our hypothesis was that patients treated for less advanced disease (stage II/IIIA) would demonstrate significantly better outcomes than patients with more advanced disease (stage IIIB).

MATERIALS AND METHODS

Institutional review board approval was obtained at the two participating institutions. This is a retrospective investigation of clinical and radiographic outcomes following radius shortening osteotomy for stages II, IIIA, and IIIB Kienbock's disease. All patients who had undergone radius shortening osteotomy for Kienbock's disease between January 1996 and December 2007 by one of four fellowship trained hand surgeons at two tertiary referral institutions were identified through a computerized database search by CPT code. Patients would have been excluded if they had prior serious injury to the carpus (carpal/distal radius fracture, carpal ligament tear, carpal dislocation), prior surgery on the involved wrist (excluding carpal tunnel release), or inflammatory arthropathy. However, no patient met these exclusion criteria. One patient with hemiplegic cerebral palsy affecting his contralateral side was enrolled but contralateral physical examination data was censored from analysis. Patients under the age of 16 were excluded due to the reported possibility of radius overgrowth following shortening in skeletally immature individuals.(18) Minimum follow up was 1 year.

Forty four patients (45 wrists) met the study inclusion criteria. Nine wrists were classified as Stage II, 21 as Stage IIIA, and 15 as Stage IIIB. Preoperative stage was documented in clinical notes for all cases prior to surgery by the attending orthopedic hand surgeon. Stage had been determined by applying the Stahl/Lichtman criteria to preoperative radiographs. (2) Stage IIIB was defined by radioscapoid angle greater than 60°. When pre-operative radiographs were available, repeated independent review of the images was performed (10 of 15 Stage IIIB, 9 of 16 II/IIIA). Surgery was performed using a volar (Henry) approach. A transverse diaphyseal osteotomy in the distal third of the radius was created to achieve 2–4 mm of shortening. Standard dynamic compression plates were placed on the volar radius for fixation.

Five patients (5 wrists) were lost to follow up despite an exhaustive search. Nine patients (nine wrists) declined to participate in the study. These patients denied undergoing any secondary surgical procedures. Patients either lost to follow up or declining participation included 1 patient with Stage IIIB disease, 9 patients with Stage IIIA disease, and 4 patients with Stage II disease.

Thus, 30 patients, (31 wrists: 1 bilateral stage IIIA), provided written consent and were enrolled in the study including 93% of wrists treated for Stage IIIB disease (14 of 15 wrists). The study cohort consisted of 4 stage II, 13 stage IIIA, and 14 stage IIIB wrists. Two patients provided incomplete final evaluations. One patient was leaving for a military assignment overseas, but completed patient-based instruments over the phone. One patient was homebound due to immunosuppression and was examined at his residence preventing radiographic assessment. Both of these patients were stage IIIB preoperatively. Therefore, patient-rated outcome measures were completed on 30 wrists, objective physical examinations performed on 29 wrists, and final radiographs completed on 28 wrists with the single wrist that had undergone arthrodesis having been excluded from further analysis.

Follow Up

Eighteen wrists were enrolled from (Blinded Institution) and 13 from (Blinded Institution). Demographic information for the wrists with stage II/IIIA was similar to wrists with stage IIIB disease (Table 2). Follow up examinations and data collection/radiographic interpretation was performed by investigators who did not participate in the operative procedure. Examiners included a senior orthopedic resident, an orthopedic hand fellow, and attending orthopedic hand surgeon.

Patients completed the QuickDASH and Visual Analog Scales (VAS) for current wrist pain and function. Patients also recalled preoperative pain and function levels on a Visual Analog Scale. VAS ratings (scale 0–10) were completed with lower scores indicating better outcomes (0=no pain or normal function). QuickDASH scores (scale 0–100) were rated with higher scores indicating greater disability.⁽¹⁹⁾ Modified Mayo Wrist Scores (MMWS) were calculated for each wrist.^(20,21) The MMWS is based on pain, range of motion, grip strength, and function. Scores of 80–100 are considered excellent, 65–79 good, 50–64 moderate, and less than 50 poor. Current employment and reasons for any change in employment postoperatively were recorded.

Wrist motion (flexion, extension, radial deviation, ulnar deviation, pronation, supination) was measured clinically using a hand-held goniometer. Grip strength was measured in pounds using the Jamar dynamometer (Jamar, Boling Brook, IL). Measurements were taken with the shoulders adducted to the side, elbows at 90° flexion, and forearms in neutral prono-supination as bilateral, single maximal efforts.

Neutral rotation posterior-anterior and lateral radiographs were obtained for determination of radiographic stage and calculation of ulnar variance, radioscaphoid angle (RS), carpal height ratio (CHR), modified carpal height ratio (MCHR), and carpal ulnar distance ratio (CUDR).^(22,23) Ulnar variance was calculated by perpendicular lines and radioscaphoid angle measured as described by Wada et al.⁽¹⁵⁾ Similar increase in ulnar variance was appreciated in each group following osteotomy (Stage II/IIIA –1.9mm preoperative, 0.24mm final; Stage IIIB –2.8mm preoperative, –0.30mm final). Images at each institution were evaluated independently by a hand fellow or senior orthopedic resident following explicitly defined measurement methods previously demonstrated to have substantial inter-observer reliability.⁽³⁾

Statistical Analysis

Statistical analysis compared data between the subgroups of wrists with advanced disease (IIIB) and those with less advanced disease (II/IIIA). Preoperative age, gender, employment status, duration of follow up, and hand dominance of each group were compared using unpaired t-test or Wilcoxon's test (continuous variables) or Fisher's exact test (categorical variables).

Outcomes data, including QuickDASH, MMWS, grip strength, wrist motion, and radiographic measurements, were compared between the two groups by unpaired t-tests. Rank-transformed data was used when outlying data skewed the group mean. Change between pre- and postoperative VAS pain and VAS function were compared using ANCOVA where the postoperative value was the dependent variable and the pre-operative value was the covariate.

Spearman correlations were calculated to determine correlates with patient-rated wrist function (QuickDASH, VAS wrist function). Power analysis was performed to determine ability to detect a clinically meaningful difference in DASH score and wrist flexion-extension arcs between the two patient groups.

A power analysis demonstrated that we would have needed 29 patients per group to detect what we defined as clinically significant differences in the QuickDASH (15 points). For statistical significance, p values were required to be <0.05 on two-tailed tests. The single patient who proceeded to wrist arthrodesis was excluded from data analysis.

Source of Funding

There was no external funding source for this investigation.

RESULTS

There were no statistically significant differences in patient-rated clinical outcomes between patients treated for stage II/IIIA versus stage IIIB disease (Table 3). No patient changed employment due to wrist pain or function.

Mean range of motion (flexion/extension arc, radial/ulnar deviation arc, and pronation/supination arc) and grip strength at final follow-up were similar for each group (Table 4). Ulnar deviation was the only motion that differed significantly between groups. Wrists with stage II/IIIA had more ulnar deviation than wrists with stage IIIB (35° versus 25° , $p=0.02$). Grip strength was 63.5 lbs (85% contralateral) for stage II/IIIA versus 72.3 lbs (77% contralateral) for stage IIIB disease ($p=0.44$).

Radiographic outcomes differed significantly between groups. Although only one wrist with stage IIIB progressed to stage IV, wrists treated for stage IIIB disease continued to demonstrate decreased carpal height and increased radioscapoid angles than those treated for stage II/IIIA disease. The carpal ulnar distance ratio was similar between groups. Ulnar variance was similar between the groups both preoperatively and postoperatively. Radiographic progression of disease stage occurred in 7 wrists (6 stages II/IIIA and 1 stage IIIB). Table 5 presents the postoperative radiographic findings. Seven stage II/IIIA wrists and 3 stage IIIB wrists demonstrated ulnar positive variance following radius shortening.

Data was analyzed to determine clinical and radiographic measures that correlated with patient-rated wrist function (QuickDASH and VAS function)(Table 6). Both outcome measures showed superior ratings correlating with increased flexion/extension arc, radial/ulnar deviation arc, and decreased radioscapoid angle. Increased forearm pronation/

supination arc trended toward association with higher rated wrist function. Neither patient-based assessment significantly correlated with postoperative disease stage, grip strength, CRH, MCHR, or CUDR.

Complications

Two patients (both IIIA pre-operatively) developed ulnar-sided wrist pain that resolved following subsequent ulna shortening. These patients had baseline ulnar variance of 0mm and +2mm which increased to +2mm and +4mm respectively following radius shortening. The one stage IIIB wrist that progressed to stage IV underwent wrist arthrodesis for persistent pain. At the time of this study, that patient continued to report pain and dissatisfaction.

DISCUSSION

Prior studies on the results of joint leveling procedures for wrists with early stage Kienbock's disease have shown excellent results.(5,10,13,15,17,24,25) The outcomes of radius shortening osteotomy performed in patients with static carpal malalignment (marked by increased scaphoid flexion) have been debated in the literature. Clinical success in small series of patients with stage IIIB disease has been presented. However, in this subset of wrists, concern for progression of collapse, radiographic degeneration, and recurrent symptoms has led some investigators to recommend partial or complete wrist fusion or proximal row carpectomy as the operative treatment of choice.(26–28)

Our results compare favorably to prior outcomes of radius shortening in advanced Kienbock's disease.(10,13,17,29) Iwasaki et al (29) published good to excellent outcomes of radius shortening in 9 wrists with advanced Kienbock's disease (8 stage IIIB, 1 stage IV). At a mean of 31 months these wrists had a mean flexion/extension arc of 114° with grip strength reaching 85% of the contralateral side despite a lack of radiographic improvement. Weiss et al(13) reported that radius shortening effectively alleviated pain, improved motion, and increased grip strength in 4 patients with stage IIIB Kienbock's disease at 3–5 years, while Rock(17) noted that clinical outcomes were equivalent regardless of disease stage at similar follow up. The current study adds to these data as it enrolled a greater number of patients than each of the above investigations and our case series was reviewed comparing radius shortening osteotomy for stage IIIB and stage II/IIIA disease using objective, validated, patient-based outcome measures.

Based upon 3 patients followed long term by Watanabe et al.(10) we would expect these outcomes to be maintained over time. At over 10 years follow up, the mean DASH score was 11, MMWS was 73 and the mean wrist flexion/extension arc was 92°. No wrists that progressed to stage IV arthritic degeneration. However, the authors suggested that results may have been less favorable in wrists with stage IIIB disease compared to wrists with earlier stage disease.

Wintman et al(5) followed a cohort of patients for an average of 31 months following radius shortening osteotomy. They reported improved motion, grip strength, and pain. However, they reported worse outcomes in 8 wrists with stage IIIB disease compared to wrists with earlier stages of disease. In contrast to other studies, 4 of the 8 wrists with stage IIIB disease preoperatively progressed to stage IV. The authors concluded that stage IIIB disease may not be well suited for radius shortening due to risk of radiographic progression of disease. Our series documented a lower rate of radiographic disease progression at longer duration follow up. Only 1 patient with stage IIIB disease in our study developed stage IV degeneration. Taken together with the preponderance of prior literature, our findings indicate that radiographic disease progression may occur following radius shortening.

However, it appears that the majority of wrists treated for stage IIIB disease in this sample did not progress to stage IV disease over short to mid-term follow up.

Radiographic progression of disease was more common among those patients with stage II or IIIA disease in our series. Despite this progression, these patients demonstrated clinical improvement in pain and function. This finding concurs with the report of Watanabe et al who with long term follow up documented no radiographic progression of disease in IIIB wrists (n=3) but progression in 6 of 9 wrists treated for stage II or IIIA disease.(10) No patient in their series or the current study progressed from II/IIIA to stage IV. Thus, radius shortening may result in clinical relief despite failing to prevent radiographic progression. Alternatively, these investigations suggest infrequent arthritic degeneration (stage IV) following radius osteotomy. Thus, we could speculate that the biomechanical effect of the osteotomy may be sufficient to provide pain relief and protect against arthritic degeneration but fail to prevent isolated lunate collapse.

To our knowledge, no prior investigation of Kienbock's disease has sought to identify those factors correlating with postoperative patient-rated wrist function (QuickDASH and VAS function). Iwasaki et al.(11) performed a regression analysis of 41 patients with stage II, IIIA, and IIIB Kienbock's and reported that radiographic stage, radioscapoid angle, and carpal height ratio were not predictive of clinical outcomes. However, Iwasaki et al defined clinical outcome as a combination of wrist pain, range of motion, and grip strength without consideration to patient's self-assessment of function. Our data demonstrate superior functional ratings by patients correlated with increased wrist range of motion and correlated inversely with radioscapoid angle. The correlation with wrist arc of motion argues for pursuing treatment that maximizes postoperative motion. Finding an inverse correlation with radioscapoid angle, without significant correlation with postoperative disease stage, CHR, MCHR, or CUDR may result from several factors. A lack of statistical correlation with disease stage may have occurred as disease classifications artificially divide otherwise continuous variables (e.g. radioscapoid angle) into defined stages such that each stage incorporates a range of radioscapoid angles. Second, radioscapoid angle as a single measure has been shown to be more reproducible than calculations of carpal height.(3) Therefore, the recorded radioscapoid angle may more accurately mirror disease progression than other radiographic measurements. However, even in patients with radioscapoid angles $>60^\circ$, our data indicated successful pain reduction and restoration of function.

Our study has several limitations, most of which are inherent to any retrospective investigation. We relied upon medical records for preoperative examination data and do not have preoperative patient-rated functional measures available for analysis. Thus, we focused on a detailed comparison of postoperative outcome measures between patient groups divided by disease stage at the time of treatment. In presenting patients' estimates of preoperative pain and function recall bias is possible. While it is preferable to have these estimates from the time of surgery, we have included the data as an attempt to quantify the change in pain and function following surgery. Although some patients were lost to follow up, all but one of those lost were treated for less advanced Kienbock's disease. Therefore, our study, which had near complete inclusion of all stage IIIB wrists from two institutions, provides reassurance that our data accurately reflects the authors' experience in patients with Stage IIIB Kienbock's disease. Additionally, this investigation was designed only to determine the applicability to, and results of, radius shortening osteotomy for advanced Kienbock's disease. As such, we have focused on comparing the outcomes of this surgery for those with and without static carpal instability. Especially in earlier stage disease, some surgeons would pursue direct lunate revascularization. (30,31) We have not attempted, and cannot claim, superiority of radius osteotomy over revascularization or other surgical treatments of Kienbock's disease.

Despite combining the experience from two tertiary referral centers, our study remained underpowered. This limitation is one commonly encountered when investigating uncommon diseases. When studying a rare event or disease state, investigators are often forced to perform retrospective analyses to capitalize on the cumulative experience with that process leading up to an investigation. In addition to the prohibitive duration necessary to conduct a prospective investigation, researchers confront a fixed, and generally limited, sample size of potential subjects. Thus, even when performing a priori power calculations for detecting what is deemed a “clinically relevant” difference between the study group and a comparison population, the necessary number of subjects may neither exist nor be expected to be available in the near future. This was the case for this investigation. Specifically, we could not enroll the number of patients necessary to statistically differentiate between groups of patients with a difference in mean QuickDASH scores of 15 points or wrist flexion/extension arcs of 15°. Therefore, even if the two study groups (II/IIIA versus IIIB disease) had differed by those amounts our statistical analysis would have failed to detect significant differences (i.e. type II error: failing to detect a difference between groups when a difference truly exists). Accepting this statistical limitation, the differences noted between mean values of the QuickDASH (12 versus 15), VAS wrist pain (1.7 versus 1.2), wrist flexion/extension arc (106° versus 102°) between patients with II/IIIA versus IIIB disease are unlikely to be of clinical significance. The data suggest that in a larger cohort, the outcomes of radius shortening may be slightly diminished in IIIB wrists and may not compare favorably to wrists with less advanced disease. To our knowledge, this study presents the largest series of wrists with stage IIIB disease treated with radius shortening osteotomy to have been reported.

Our results confirm that radius shortening is a reliable procedure for stage II/IIIA Kienbock’s disease. Clinical outcomes defined by objective measurements and patient-rated outcome measures are similar in wrists with stage IIIB disease. Radiographic outcomes for wrists treated for stage IIIB disease were distinguished by persistently reduced carpal height ratios and increased radioscapoid angles. Based upon the high percentage of successful clinical outcomes in this limited case series, radius shortening osteotomy can be performed for symptomatic stage II, IIIA, and IIIB Kienbock’s disease.

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Table 1

Staging of Kienbock's disease*.

Stage	Findings
I	Normal lunate architecture (x-ray), linear or compression fracture present
II	Increased lunate density (x-ray), no bony collapse
IIIA	Lunate with bony collapse, normal carpal alignment (radio-scaphoid angle $\leq 60^\circ$)
IIIB	Lunate with bony collapse, abnormal carpal alignment (radio-scaphoid angle $>60^\circ$)
IV	Pan-carpal arthrosis

* Based upon Stahl/Lichtman and Goldfarb criteria.

TABLE 2

Demographic data of study participants.

	Stage II/IIIA	Stage IIIB	p-value
Follow-up (months)	72 (13–151)	77 (18–135)	0.75
Age (years)	40 (16–86)	39 (21–54)	0.94
Gender			0.71
Male	10 (59%)	9 (69%)	
Female	7 (41%)	4 (31%)	
Dominant affected*			
No	6 (35%)	5 (42%)	1.0
Yes	11 (65%)	7 (58%)	
Employment Level			0.75
Light	10	7	
Moderate	2	3	
Heavy	4	1	
Unemployed	1	2	

* One ambidextrous patient excluded from this section.

TABLE 3

Patient-rated outcome measures as a function of disease stage.

	Stage II/IIIA (n=17)	Stage IIIB (n=13)	p value**
QuickDASH			
Mean ($\pm$ SD)	12 ($\pm$ 15)	15 ($\pm$ 9)	0.63
MMWS			
Mean ($\pm$ SD)	87 ($\pm$ 11)	84 ($\pm$ 19)*	0.59
Excellent (%)	13 (76%)	9 (82%)	
Good (%)	3 (18%)	1 (9%)	
Poor (%)	1 (6%)	1 (9%)	
VAS pain ($\pm$SD)			
Pre-op	6.9 ($\pm$ 2.5)	7.3 ($\pm$ 2.1)	0.60
Post-op	1.7 ($\pm$ 2.0)	1.2 ($\pm$ 1.6)	0.45
Mean Change	-5.1	-6.1	0.32
VAS function ($\pm$SD)			
Pre-op	6.8 ($\pm$ 2.3)	7.6 ($\pm$ 1.5)	0.30
Post-op	2.1 ($\pm$ 2.1)	2.6 ($\pm$ 2.3)	0.59
Mean Change	-4.7	-5.0	0.68

* MMWS calculated for 11 patients; 2 missing at least one element necessary for scoring.

** Study statistically underpowered for outcome analysis

TABLE 4

Postoperative wrist motion as a function of disease stage.*

	Stage II/IIIA	Stage IIIB	p value**
Flexion (°)			
Mean (Range)	52 (20–80)	53 (20–65)	0.88
% Contralateral (Range)	85.33 (50–100)	81 (25–100)	0.53
Extension (°)			
Mean (Range)	54 (30–75)	49 (0–70)	0.43
% Contralateral (Range)	93 (62–109)	84 (0–107)	0.16
Flex/Ext Arc (°)			
Mean (Range)	106 (55–150)	102 (20–135)	0.70
% Contralateral (Range)	88 (69–100)	82.5 (13–100)	0.37
Pronation (°)			
Mean (Range)	83 (65–90)	73 (10–90)	0.84
% Contralateral (Range)	97 (88–107)	100 (48–107)	0.98
Supination (°)			
Mean (Range)	77 (60–90)	76 (40–90)	0.76
% Contralateral (Range)	94 (86–107)	94 (50–114)	1.0
Pro/Sup Arc (°)			
Mean (Range)	161 (127–180)	150 (80–175)	0.96
% Contralateral (Range)	97 (91–100)	97 (50–100)	1.0
Radial Deviation (°)			
Mean (Range)	24 (15–40)	22 (0–40)	0.64
% Contralateral (Range)	98 (56–200)	90 (0–133)	0.59
Ulnar Deviation (°)			
Mean (Range)	35 (20–45)	25 (5–45)	0.02
% Contralateral (Range)	86 (56–113)	72 (11–100)	0.09
Rad/Ulnar Arc (°)			
Mean (Range)	59 (35–85)	48 (10–75)	0.09
% Contralateral (Range)	88 (64–117)	77 (33–100)	0.14

* excludes 1 patient who completed telephone interview only

** Study statistically underpowered for outcome analysis

TABLE 5

Radiographic outcomes as a function of disease stage.*

	Stage II/IIIA	Stage IIIB	p value
CHR			
Mean (Range)	0.53 (0.44–0.64)	0.46 (0.36–0.52)	0.008
MCHR			
Mean (Range)	1.49 (1.30–1.80)	1.37 (1.19–1.47)	0.02
RS(°)			
Mean (Range)	53.18 (30–69)	64.64 (51–75)	0.002
CUDR			
Mean (Range)	0.35 (0.24–0.42)	0.33 (0.27–0.44)	0.50
Ulnar Variance (mm)			
PostOp	0.24	−0.30	0.33

Carpal height ration (CHR), modified carpal height ration (MCHR), radioscapoid angle (RS), carpal ulnar distance ratio (CUDR)

* excludes two patients without final radiographs

TABLE 6

Correlates with patient-rated wrist function.

	QuickDASH		VAS Function	
	r	p	r	p
Flex/Ext, % Contralateral	-0.61	<0.001	-0.73	<0.001
Radial/Ulnar Dev, % Contralateral	-0.43	0.023	-0.45	0.020
RS	0.43	0.023	0.53	0.004
Pro/Sup, % Contralateral	-0.51	0.007	-0.36	0.065