Fifteen-Year Outcome of Displaced Intra-Articular Fractures of the Distal Radius

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Purpose: We previously reported the functional and radiographic outcomes of 21 young adults at an average of 7 years after open reduction and internal fixation of an intra-articular distal radius fracture (original study). The purpose of the current investigation was to evaluate the same cohort at an average of 15 years after surgery to evaluate the effect of additional time on both function and radiographic appearance.

Methods: We re-evaluated 16 of the original patients at an average of 15 years after surgery. Subjective assessment was performed with the Musculoskeletal Functional Assessment and the Hand Function Sort questionnaires. Objective assessment included a detailed physical examination and strength measurement. Standardized radiographs and computed tomography were used to assess wrist morphology, residual articular step and gap displacement, and the presence and degree of arthrosis.

Results: Subjectively patients continued to function at a high level at the last follow-up evaluation: the average Musculoskeletal Functional Assessment score was 10 and 14 of the 16 patients functioned at a high level according to the Hand Function Sort. Strength and range of motion remained essentially unchanged from the original report. Radiocarpal arthrosis was noted in 13 of the 16 wrists and joint space was reduced an additional 67% compared with the 7-year follow-up evaluation. Nonetheless there continued to be no correlation between the presence or degree of arthrosis and upper-extremity function.

Conclusions: Radiocarpal arthrosis after intra-articular distal radius fractures can be expected to worsen over time. Despite joint space narrowing and evidence of advanced arthrosis, however, patients maintained a high level of function at the long-term follow-up evaluation. (J Hand Surg 2006;31A:633–639. Copyright © 2006 by the American Society for Surgery of the Hand.)

Type of study/level of evidence: Prognostic, Level II.

Key words: Arthrosis, distal radius, fracture, intra-articular, outcome.

We originally reported the intermediate-term functional and radiographic outcomes of a series of young adults treated surgically for intra-articular distal radius fractures.[1] Twenty-one patients with at least a 1-mm step or gap displacement of the distal radius articular surface were treated with open reduction and internal fixation between 1986 and 1990. The 14 male and 7 female patients were evaluated at an average of 7 years (minimum, 5.5 y) after surgery. Patients were assessed with the Musculoskeletal Functional Assessment (MFA), a physical examination, plain radiographs, and computed tomography (CT).[2,3]

In the original investigation osteoarthrosis of the radiocarpal joint was noted in 16 of the 21 patients and the development of arthrosis correlated with the presence of articular step and gap at the time of bony union. Function was good or excellent in all patients by both subjective (MFA) and objective measures. Patient function did not correlate with the presence of arthrosis.

Because of the possibilities that additional time would be associated with worsening arthrosis and that

Figure 1. (A) Posterior-anterior and (B) lateral injury radiographs showing a displaced intra-articular fracture of the distal radius.

this would affect function negatively, the current investigation re-evaluated the same cohort of patients at a longer-term follow-up evaluation (average, 15 y).

Materials and Methods

This investigation was a retrospective re-evaluation of 16 patients from an original cohort of 21 patients; the original results were published in 1997.[1] Five of those patients were not included in this investigation: 4 could not be located (despite an extensive search including medical records, Internet, and a private investigator) and 1, who lived out of state, would not participate despite several requests. All patients had been treated at a single institution with open reduction and internal fixation of a displaced ($\geq$1 mm) intra-articular distal radius fracture (Fig. 1). The technique of surgical intervention varied: 2 wrists were treated with plate fixation and the rest were treated with open reduction and K-wire fixation. All patients were younger than 45 years (range, 17–42 y) at the time of the surgery. Two of the fractures were open and 1 patient had associated acute carpal tunnel syndrome. The mechanism of injury was a fall in 10 patients, a direct blow in 3 patients, and a motor vehicle crash in 3 patients. The fracture classification was AO/ASIF B2 in 1 patient, B3 in 3 patients, C1 in 1 patient, C2 in 10 patients, and C3 in 1 patient.[4]

Eleven male patients and 5 female patients returned for evaluation at an average of 15 years (range, 13–17 y) after injury. Institutional review board approval was obtained for this investigation and informed consent for participation was obtained from all patients.

The average age at the time of injury was 32 years (range, 17–42 y) and the average patient age at follow-up evaluation was 47 years (range, 34–60 y).

Assessment

Subjective outcome was assessed with the MFA instrument, a reliable and valid questionnaire used to assess self-perception of physical, psychologic, and social well-being.[2,3] The MFA scores range from 0 to 100 (higher score indicates worse function) with an average score among healthy adults of 9.3.[2] The current group of patients, in contrast to the original investigation, also completed the Hand Function Sort (HFS) to assess functional outcome further.[5] This is a validated outcomes instrument designed to quantify patients' function in terms of the U.S. Department of Labor physical demand characteristic system. This is a 5-level ordinal system used to classify more than 12,000 occupations in the U.S. economy.[6,7] It therefore quantifies a patient's ability to work in terms of a formal standard that is used widely. The HFS has been validated and is used to evaluate kinesthetic sense of the hand after surgery for cervical disk herniation.[8,9] Patients evaluate their ability to perform 64 different tasks on a 5-point scale (from able to unable) When scored the HFS provides a separate percentage capacity score for 17 areas of function including carrying, lifting and lowering, manipulating objects, bimanual dexterity, hand range of motion,

Figure 2. (A) Posterior-anterior and (B) lateral radiographs (same wrist shown in Fig. 1) 8 years after open reduction and internal fixation and removal of implants.

strength, endurance, and other upper-extremity functions.[5]

The HFS was chosen over the Disabilities of the Arm, Shoulder, and Hand questionnaire for several reasons. The HFS provides a percentage score for each of the tasks that the patient is able to perform and the areas of function for each task, compared with all of the other areas of function. For example, upper extremity endurance can be examined separately from finger dexterity. In contrast the Disabilities of the Arm, Shoulder, and Hand questionnaire provides only a single score on disability, a single score on work, and a single score on sports. Given the complex nature of distal radius fractures and the subsequent surgery and therefore its effect on hand and upper-extremity function, a measure that was sensitive to specific changes was believed to be more useful.

One author who was not involved in the original care of any patient (C.A.G.) performed a standardized physical examination on all patients including forearm and wrist ranges of motion using a standard office goniometer. Grip strength was measured using a dynamometer (Jamar; Asimow Engineering, Los Angeles, CA) and pinch strength (3-point and lateral) was measured using a pinch meter (Therapeutic Instruments, Clifton, NJ). All data were compared with the opposite extremity and with data available from the original investigation.

Two authors not involved with the original investigation assessed the radiographs and CT scans in a blinded fashion (C.A.G., J.R.R.). Standardized plain radiographs including posteroanterior, lateral, oblique, and ulnar deviation were obtained for all patients. The same office goniometer was used to assess radial length, radial inclination, volar tilt, ulnar variance, articular step and gap (using the arc measurement technique), arthrosis of the radiocarpal and distal radioulnar joints (Knirk and Jupiter[10] method), and the status of the ulnar styloid (Figs. 2, 3).[11] All CT scans (Siemens Somatome Sensation 16; Siemens Inc, Iselin, NJ) were obtained using a standardized protocol that included 2-mm–thick continuous axial, sagittal, and coronal images with direct scanning (Fig. 4) The CT scans were evaluated with a loupe (Peak 10-X Loupe; Argraph Corporation, Carlstadt, NJ) for step and gap incongruity, radiocarpal and distal radioulnar arthrosis, and the minimal joint space of the scaphoid and lunate facets of the radiocarpal joint. Arthrosis was graded with a modification of the method of Knirk and Jupiter[10] (Table 1). The current radiographic measures were compared with the original measurements.

A statistical analysis was performed (SAS program; SAS Institute, Cary, NC). Significance testing was performed with paired t tests. Spearman rank correlations also were used to assess arthrosis changes.

Figure 3. (A) Posterior-anterior and (B) lateral radiographs (same wrist shown in Fig. 1) 15 years after injury.

Results

The average MFA score was 10 (SD, 9.2; range, 0–28). These data were compared with published normal data (mean, 9.3; SD, 8.9) and no difference was noted between the total scores or any of the subcategory scores ($p = .66$).[2] The HFS showed that 9 of the 11 males and all of the females ($n = 5$) functioned at the heavy physical demand level with scores at the 80th percentile or higher compared with normal patients. These 14 patients showed broad functional capacity with no areas of limitation. The other 2 patients showed modest functional limitations with fine-dexterity tasks and moderate limitations with heavy manual material–handling tasks. Patients who scored poorly on the HFS and were listed as performing at the medium- or light-demand level reported having considerable difficulty carrying crates of 22.7 kg for 15.2 m, using a mattock pick in rocky soil, and driving a stake with a sledgehammer. Only occasionally did patients performing at the heavy-demand level have difficulty performing these tasks. The lowest-functioning male was rated at the light physical demand characteristic level (15th percentile) and the other male was rated at a medium physical demand characteristic level (45th percentile).

Current forearm and wrist range-of-motion data and strength data were compared with the unaffected side and compared with the original data. The average degree of motion and SDs, as measured on the involved and uninvolved sides, respectively, were $63° \pm 14°$ and $71° \pm 11°$ for wrist flexion, $61° \pm 12°$ and $74° \pm 8°$ for wrist extension, $18° \pm 6°$ and $23° \pm 4°$ for radial deviation, $36° \pm 10°$ and $42° \pm 7°$ for ulnar deviation, $76° \pm 7°$ and $78° \pm 5°$ for pronation, and $73° \pm 9°$ and $78° \pm 6°$ for supination. There was no significant difference in the affected and unaffected sides and there was no change in forearm motion, wrist flexion/extension, or wrist radial/ulnar deviation compared with the original data ($p > 05$). Grip strength measured 37 ± 15 and 42 ± 16 kg, lateral key pinch measured 12 ± 4 and 14 ± 5 kg, and 3-point pinch measured 11 ± 5 and 12 ± 6 kg These strength values were not significantly different between sides and were unchanged compared with the original measurements except for a decrease in 3-point pinch ($p = .05$) (Table 2).

The plain radiographic measures of deformity (radial length, inclination, tilt, ulnar variance, step, gap) essentially were unchanged when compared with the original study. The radial length averaged 13 mm (± 3 mm), radial inclination averaged 23° ($\pm 6°$), volar tilt averaged 0° ($\pm 16°$), and ulnar variance averaged 2 mm (-2 mm). Maximum step deformity (as assessed by both radiograph and CT) did not change significantly compared with the original measurements. Maximum gap deformity was significantly smaller on both CT and plain radiograph compared with the 1996 data ($p < 0.05$) (Table 3).

The arthrosis worsened from the time of the original assessment to the time of the most recent assess-

Figure 4. Coronal CT scan image at the time of the most recent follow-up evaluation. Despite the presence of advanced arthrosis (joint space narrowing, cyst formation) the patient continues to function at the heavy demand level.

Table 1. Modification of OA Grading System

Grade	Subjective Findings on Radiographs or CT	Minimum Joint Space as Measured on CT
0	None	>1.5 mm
I	Slight narrowing or irregularity of joint space	1.0–1.5 mm
II	Marked narrowing of joint space, formation of osteophytes and early formation of cysts, mild subchondral sclerosis, or scalloping of lunate or scaphoid facet	0.5–1.0 mm
III	Bone on bone, formation of osteophytes and cysts, marked subchondral sclerosis, or scalloping of lunate or scaphoid facet	<0.5 mm

Grading system of Knirk and Jupiter.[10]

ment. Seven patients had advancement of their radiocarpal arthrosis including 6 patients who had advancement of their arthrosis by 1 grade and 1 patient who had advancement by 3 grades. This radiographic grade of the radiocarpal arthrosis advancement was statistically significant ($p = .02$). The worsening grade of arthrosis by CT scan evaluation approached significance ($p = .06$). The scaphoid facet joint space and the lunate facet joint space both decreased significantly as assessed by CT scan ($p = .02$) The joint space decreased by approximately 67% for both facets of the radiocarpal joint (Table 3). There was no significant change in distal radioulnar joint arthrosis (Table 4).

Despite progression of arthrosis the patients showed a high level of function on the MFA and HFS. There was no statistical correlation noted between radiographic or CT scan radiocarpal arthrosis and function. Specifically there was no correlation with MFA scores, range of motion (pronation, supination, wrist extension, radial deviation, ulnar deviation), or strength measures. Wrist arthrosis did correlate with a decrease in wrist flexion ($p = .02$) by radiograph and approached significance on CT ($p = 06$).

Discussion

This investigation evaluated patients longitudinally at intermediate- and long-term follow-up periods and documented the progression of joint arthrosis by CT scan. By documenting the presence of arthrosis in the

Table 2. Physical Examination

Measure	Average	Mean % of Opposite Side	SD	p Value
Original wrist flexion	69° (±12°)	87	15	
Current wrist flexion	63° (±14°)	89	12	.66
Original wrist extension	53° (±15°)	79	23	
Current wrist extension	61° (±12°)	82	13	.71
Original radial deviation	13° (±3°)	84	19	
Current radial deviation	18° (±6°)	79	26	.62
Original ulnar deviation	20° (±3°)	90	13	
Current ulnar deviation	35° (±10°)	87	26	.66
Original pronation	81° (±8°)	95	9	
Current pronation	76° (±12°)	97	7	.56
Original supination	83° (±7°)	97	5	
Current supination	73° (±9°)	94	10	.31
Original grip strength	42 (±16) kg	86	12	
Current grip strength	37 (±15) kg	87	14	.60
Original key pinch	21 (±5) kg	92	11	
Current key pinch	12 (±4) kg	95	13	.26
Original 3-point pinch	20 (±7) kg	99	12	
Current 3-point pinch	11 (±5) kg	91	13	.05

original investigation and confirming its advancement in the same patient cohort 8 years later we have confirmed and expanded on the known correlation between residual articular displacement and joint arthrosis.[1,10–20] The arthrosis that is associated with step and gap displacement after fracture has been shown for the distal radius by plain radiograph and CT scan.[1,10,12,13,15,17–20]

Despite the presence of arthrosis and its worsening at the 15-year follow-up evaluation, patient function remained high and did not correlate with the degree of the arthrosis. In our original investigation we used the MFA and a thorough physical examination to assess function; we have reapplied those tools and added the HFS questionnaire as a means of refining our assessment of function. All tools showed a high

Table 3. Comparison of 1996 and 2003 Images

Measure	Mean	SD	p Value
Original radial length	12 mm	3	
Current radial length	13 mm	3	.26
Original radial inclination	22°	4	
Current radial inclination	23°	6	.14
Original ulnar variance	1 mm	3	
Current ulnar variance	2 mm	2	.22
Original SL angle	47°	7	
Current SL angle	45°	12	.49
Original maximum step, x-ray	1.3 mm	1	
Current maximum step, x-ray	1.2 mm	1.1	.25
Original maximum step, CT	1.9 mm	1.2	
Current maximum step, CT	1.7 mm	1.3	.39
Original maximum gap, x-ray	0.3 mm	0.9	
Current maximum gap, x-ray	1.2 mm	1.6	.03
Original maximum gap, CT	4.3 mm	4	
Current maximum gap, CT	2.6 mm	2.3	.01
Original scaphoid facet joint space, CT	1.2 mm	0.6	
Current scaphoid facet joint space, CT	0.8 mm	0.4	.02
Original lunate facet joint space, CT	1.4 mm	0.6	
Current lunate facet joint space, CT	0.9 mm	0.5	.02

SL, scapholunate.

Table 4. Progression of Arthrosis

	Radiocarpal Arthrosis Grade		Distal Radioulnar Arthrosis Grade	
	Original	Current	Original	Current
Radiograph				
No arthrosis	4 (27)	0 (0)	8 (57)	5 (36)
Grade 1	6 (40)	6 (40)	3 (21)	3 (21)
Grade 2	5 (33)	7 (47)	3 (21)	6 (43)
Grade 3	0 (0)	2 (13)	0 (0)	0 (0)
Difference in p value		.02		.19
CT evaluation				
No arthrosis	3 (20)	0 (0)	7 (50)	5 (36)
Grade 1	3 (20)	4 (27)	2 (14)	3 (21)
Grade 2	9 (60)	8 (53)	4 (29)	4 (29)
Grade 3	0 (0)	3 (20)	1 (7)	2 (14)
Difference in p value		.06		.52

Values are reported as n (%).

level of patient function, essentially equivalent to an uninjured population, without a decrease in function since the original evaluation. Only wrist flexion was found to correlate with narrowed joint space by plain radiograph ($r = 0.058$, $p = .02$); the correlation approached significance on CT scan ($p = 06$).

This investigation had several limitations. First, the measurement of articular displacement and the measurement and quantification of arthrosis is difficult. We used CT scans to increase the reliability of these measures but recognize that measurements of less than 1 mm by loupe assessment are difficult. Second, a true assessment of function is difficult. We added the HFS assessment in an attempt to improve our ability to detect subtle differences in upper-extremity function. The HFS confirmed high levels of function as shown by the physical examination and the MFA. Finally, it is uncertain whether the arthrosis that is present at the radiocarpal joint after a distal radius fracture ever will become functionally significant; however, one goal of this investigation was to determine whether the additional follow-up time (7–15 y) and the advancement of arthrosis affected function. Although the level of function remained high at 15 years, if the arthrosis continues to progress then function may be affected eventually.

The findings of this investigation do not change our management of displaced distal radius fractures. We continue to seek an anatomic restoration of the joint surface to minimize the development of joint arthrosis.

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