Radiographic Measurements Following Surgery for Distal Radius Fractures in an Israeli Population

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ABSTRACT: **Background:** Fractures of the distal radius are the most common fractures in the upper extremity, and their incidence is increasing with the aging of the population. Despite anatomical reduction of the bones, many patients complain of residual pain. A reason for this may be ligament injury not addressed during surgery or conservative treatment. Radiographic measurements may allow assessment of ligament integrity but they may be population specific and differ among races.

Objectives: To assess radiographic wrist measurements in an Israeli population and to compare them to existing values.

Methods: Demographic data, previous diagnosis of osteoporosis, fracture classification, and radiologic measurements (radial height, radial inclination, ulnar variance, volar tilt, and d2/w2) were measured and compared.

Results: The study was comprised of 53 females and 27 males, mean age 64 years, with wrist radiographs following surgery. Of these, 13% were smokers and 38.5% had osteoporosis. According to the Arbeitsgemeinschaft für Osteosynthesefragen classification system, most of the fractures were comminuted and intra-articular. The mean values for all measurements did not differ significantly from values in the literature. The average d2/w2 ratio (describing the radiocarpal ligaments) was 0.42, significantly differing from this measurement in normal wrists as described in the literature, but similar to a population following surgery ($P = 0.002$).

Conclusions: Our population had more fragility fractures than other populations. Otherwise, our demographics and measurements did not differ from normal values described in the literature. This study supports the validity of any wrist radiographic study performed in our population.

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KEY WORDS: distal radius, bone fractures, population comparison, radiographic measurements, wrist

Fractures of the distal portion of the radius are the most common fractures in the upper extremity, and their incidence seems to be increasing with the ageing of the population [1,2]. In the adult population, many of these fractures are fragility fractures, possibly heralding the more debilitating osteoporotic hip fractures [3]. Furthermore, they are the most common cause of chronic regional pain syndrome (CRPS) in the upper extremity [4]. Because their location is anatomically part of the wrist joint, most of the distal radius fractures (DRFs) are intra-articular, either within the radiocarpal joint or within the distal radioulnar joint. As such, they are often accompanied by concomitant injuries to the joint soft tissues, the most commonly ligamentous injuries, and often require surgery to reduce the articular surface [5].

Techniques used to reduce and fix distal radius fractures continue to evolve and improve. As part of the standard of care, the vast majority of intra-articular fractures are treated surgically with open reduction and internal fixation of the bones. Yet, despite proper surgical and anatomical reduction of the bones, a significant number of patients complain of residual pain in the wrist, a major determinant of outcome [5-7]. This residual pain may be due to concomitant ligamentous injuries that were not addressed at the time of surgery. Although it is clear that these ligament injuries occur in tandem with the fractures, the predictability and need for treatment of the ligamentous injury itself has not yet been well defined.

A radiographic measurement of scaphoid translation may allow indirect assessment of radiocarpal ligament integrity [8]. These measurements have been made on radiographs of wrists following open reduction and internal fixation (ORIF) of distal radius fractures and have been found to differ significantly from the same measurements in normal wrists [8]. However, the clinical significance of these differences has not been clarified. Moreover, other radiographic measurements established in the evaluation of bony reduction have also not been proven in the literature to adequately reflect clinical outcomes.

Anatomical variations have been described between different human populations. These differences are true for the wrist as well as for other areas of the body and may affect radiographic measurements as well as clinical outcomes [9-11]. Due to these documented differences in anatomy and radiographic measurements between different populations, there is a need to first describe the population in which any morphological study is performed. The purpose of this study was to describe our patient population in terms of demographic characterization and radiologic measurements after surgery for DRFs and

to compare our population to the standard measurements and characteristics in the literature. We hypothesized that the radiographical measurements following ORIF of DRFs in our population would be similar to those found in the literature and therefore would form a good study population to evaluate post-operative DRFs.

PATIENTS AND METHODS

We retrospectively examined 115 posteroanterior and lateral radiographs of distal radial fractures following ORIF. All surgeries performed at one institution between 2012 and 2013 were eligible for the study. In all cases, fixation was applied after proper wrist and bony alignment. All of the fractures were treated with volar plate fixation. Radiographs were excluded if there were incomplete pre- or postoperative radiographs or radiographs from patients who had undergone treatment that was not plating. A total of 80 radiographs were eligible for the study.

We recorded patient-specific information such as age, gender, smoking status, and history of osteoporosis, as well as date of surgery, date of postoperative radiograph, and Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification of fractures [12]. Fragility fractures were documented and defined as fractures incurred from a standing height (low energy) and age above 30 years. The study was approved by the institutional review board prior to commencement.

The radial inclination, radial height, ulnar variance, volar tilt, radiocarpal interval, scaphoid width, and radiocarpal interval/scaphoid width (d2/w2) were measured. These dimensions were measured using the PACs Carestream Version 11.0 computer program (Carestream Health, USA). Data was obtained using different measurement functions of the PACs Carestream program and recorded to the second decimal.

The radial inclination was measured as the angle between the long axis of the radial shaft and a line connecting the tip of the radial styloid with the ulnar corner. The radial height was measured between two parallel lines perpendicular to the long axis of the radius. One line was drawn on the articular surface of the radius at the central reference point, and the other was drawn at the tip of the radial styloid [13-15]. The ulnar variance was measured as the difference in axial length between the ulnar corner of the distal radius and the most distal extent of the ulnar head. The volar tilt was measured as the angle formed between a perpendicular to the longitudinal axis of the radial shaft and a line formed by connecting the apex of the volar and dorsal rim [16]. The radiocarpal interval, d2, was measured as the distance between the ulnar volar border of the radial styloid and the radial volar border of the scaphoid half way between the level of the tip of the styloid and the level of the scaphoid base [Figure 1]. The scaphoid width, w2, was measured at the level of d2 [Figure 2]. The d2/w2 was calculated by dividing the d2 value by the w2 value.

Figure 1. Measurement of d2 on posteroanterior radiograph, method of measuring d2 (the distance at a midpoint between the radial styloid ulnar border and the radial border of the scaphoid bone)

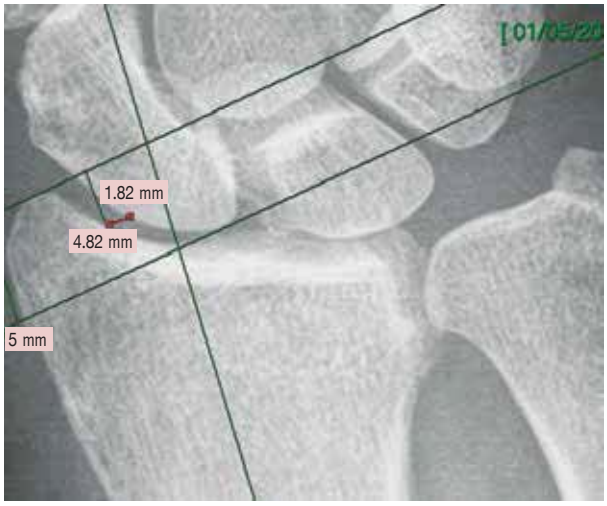

Figure 2. Measurement of w2 on posteroanterior radiograph, method of measuring w2 (the width of the scaphoid at the same point)

We also compared our results to those of two similar series in the literature [17,18].

STATISTICAL ANALYSIS

To compare means of d2/w2 measurements to normal values and values following ORIF of distal radius fractures, analysis of variants (ANOVA) with multiple comparisons was used [19].

RESULTS

Of the 80 radiographs evaluated in the study, 53 were females and 27 males. The mean age of the patients examined was 64 (43–89 years). Five of 39 patients (12.82%) were smokers and 15 of 39 patients (38.5%) had a history of osteoporosis. Eighty percent of the fractures were considered fragility fractures. Using the AO classification system, 19 fractures were classi-

fied as A2, 10 as A3, 6 as B1, 8 as B2, 13 as B3, 8 as C2, and 9 as C3 [12]. Both the B and C fractures are intra-articular fractures and therefore usually require surgery. Fractures included 36.25% class A, 33.75% class B, and 30% class C. The mean value for radial height was 12.35 mm, with a range of 5.09 mm to 18.08 mm. The mean value for radial inclination was 23.49°, with a range of 11.22° to 32.78°. The mean value for ulnar variance was 1.38°, with a range of -5.87° to 8.27°. There were 44 cases with a positive variance, 8 cases with a negative variance, and 27 cases with no/neutral variance. The mean value for volar tilt was 8.70°, with a range of 2.38° to 18.04°. The average calculated d2/w2 ratio was 0.42, with a standard deviation of 0.15. The measured d2/w2 ratio was different from the measurements on normal radiographs $P = 0.002$. Another postoperative DRF study showed a P value less than 0.0001 [8,19]. The comparisons of our radiographic values to some of the values in the literature are listed in Table 1. Comparison of our postoperative values to normal radiographic values is listed in Table 2.

Table 1. Comparison of radiographic characteristics among an Israeli population and populations from the U.S. states of Tennessee and Michigan

Population qualities	Our population	Tennessee sample population	Michigan sample population
Number of participants excluding those with incomplete data	80	137	79
Mean age of patients	64	35	49
% of males	33.75	52	43
% A class AO fracture	36.25	37	42
% B class AO fracture	33.75	8	9
% C class AO fracture	30	91	49
Deviation from radial height literature value (mm)	2.36	10.5	1.7
Range of values for radial height deviation from literature value	0.03–7.08	0–8.6	0–6
Deviation from radial inclination literature value (°)	4.02	0	4
Range of values for radial inclination deviation from literature value	0.06–10.78	2.42–20	0–9
Deviation from ulnar variance from neutral (°)	1.38	0.9	0.06
Range of values for ulnar variance deviation	-5.87–8.27	-5.6–8.2	-3–7
Deviation from volar tilt literature value (°)	3.81	7	4
Range of values for volar tilt deviation from literature value	0.04–8.61	0–20	0–13

AO = Arbeitsgemeinschaft für Osteosynthesefragen classification system

Table 2. Radiographic comparison of an Israeli population to normal literature values

Radiographic measurements	Israeli population after ORIF of DRFs (averages)	Normal values in literature of healthy wrist (averages)
Radial height	12.35 mm	11 mm
Radial inclination	23.49°	22°
Ulnar variance	1.38°	0°
Volar tilt	8.70°	4°

ORIF = open reduction and internal fixation, DRFs = distal radius fractures

DISCUSSION

Evaluating predictors of functional outcomes after surgical or conservative (immobilization alone) treatment of DRFs is difficult because ultimate function is affected by many variables of which the quality of our reduction as measured on radiographs is just one. Since these measurements may differ significantly between populations, the purpose of this retrospective pilot study was to describe our patient population compared to those depicted in the literature [13] in terms of patient characteristics and quality of radiographic reduction.

When comparing our population characteristics to those in other studies that evaluated pre- and postoperative radiographic values, we found the populations to be comparable. However, despite occurring at all ages, distal radial fractures primarily occur in a bimodal age and gender distribution; young, predominantly male patients present following high energy trauma and elderly patients, predominantly female, following low energy trauma [21]. Our patient population seemed to be representative of the elderly female DRF demographic, as our mean age was 64 years old, and 66.25% were female. This outcome could explain the high occurrence of fragility fractures in our population, since they are more common in the elderly female population. Osteoporosis most likely does not affect the healing after DRFs, yet its affect on function is unknown [22]. Moreover, our population had a 12.85% smoking status, which is similar to other smoking rates around the world [23,24].

The radiographic measurements documented in this study were similar to values found in the literature [13] of healthy wrists with regard to radial inclination and height. However the distribution of ulnar variance and volar tilt postoperatively differed from the distribution in the normal population. When performing surgery, the main objective is to reduce the articular surfaces. Since the distal ulna often remains intact, in order to reduce the distal radioulna joint, the distal radius must be pulled out to length. Since the mean ulnar variance in the general population is 0.9 mm (range -4.2 to 2.3) and our mean was 1.38 (range -5.87 to 8.27), we had a higher occurrence of ulna positive radiographs in our postoperative population, possibly indicating that we failed to completely correct the length of the radius during surgery. This result may be due at least in part to the quality of the bone. Since most of our fractures were fragility fractures, the bone of the distal radius, which is often involved on the osteoporotic process, tends to collapse. This situation may explain the loss of radial length despite appropriate fixation. In a recent meta-analysis, Ju and colleagues [20] compared fractures treated with ORIF with those treated conservatively with casting. They found that ulnar variance was greater in the groups that were treated conservatively. This finding may suggest that, had these patients not had surgery, their ulnar variance would

be greater. The literature is not clear as to how much deviation from normal ulnar variance is clinically significant [21].

Postoperative volar tilt measurements also deviated from normal values. Despite some controversy in the literature, postoperative neutral tilt is acceptable. Some studies have demonstrated that postoperative volar tilt values were closer to the normal uninjured values than in radiographs of patients treated conservatively [6,7,21].

The d2/w2 values from our study were statistically different from literature values. The values differed from normal values, and this finding is in tandem with previously published results. However, our mean was higher than the normal value, and in another post-operative DRF study, the values were lower [8,19]. The clinical significance of this result is unclear, although we think that this value reflects the integrity of the radiocarpal ligaments. This study may be a first step toward evaluating the importance of accompanying ligamentous injury and its significance in fractures of the distal radius.

We compared our results to two other similar studies from U.S. states: one evaluating a population from Michigan and another based on a group of subjects from Tennessee. The values from our study were similar to these two studies [17,18].

It is possible that inclusion of a different demographic, such as a cohort of military recruits, with distal radius fractures (this population would be mostly young males with good quality bone and high-energy mechanisms of injury) may have changed our postoperative radiographic measurements. The effect of bone quality and fracture mechanism (energy) should be investigated in a separate study.

CONCLUSIONS

In summary, our population is representative of other cohorts of radiographs following ORIF of distal radius fractures supporting our hypothesis. More study is needed to better understand the true clinical significance of these measurements in the function of the wrist after a fracture.

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"Don't be seduced into thinking that that which does not make a profit is without value"

Arthur Miller, (1915-2005), American playwright and essayist

"When you reach the end of your rope, tie a knot in it and hang on"

Franklin D. Roosevelt, (1882-1945), American statesman and political leader who served as the 32nd President of the United States