The Effects of Distal Radius Fracture Malalignment on Forearm Rotation: A Cadaveric Study

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Seven fresh cadaveric specimens were used to determine the loss of forearm rotation with varying distal radius fracture malalignment patterns. Uniplanar malunion patterns consisting of dorsal tilt, radioulnar translation, or radial shortening were simulated by creating an osteotomy at the distal end of the radius, orienting the distal fragment position using an external fixator, and maintaining the position with wedges and a T-plate. Rotation of the forearm was produced by fixing the elbow in a flexed position and applying a constant torque to the forearm using deadweights. Forearm rotation was measured with a protractor. Dorsal tilt to 30° and radial translation to 10 mm led to no significant restriction in forearm pronation or supination ranges of motion. A 5-mm ulnar translation deformity resulted in a mean 23% loss of pronation range of motion. Radial shortening of 10 mm reduced forearm pronation by 47% and supination by 29%. (J Hand Surg 1997;22A:258–262.)

Distal radius fractures are among the most common of upper-extremity injuries, comprising approximately 15% of all fractures that occur. Treatment of this condition consists of repositioning the fracture and maintaining position with cast immobilization and external and/or internal fixation.1–7 Several studies have shown that an appreciable number of patients have experienced suboptimal results from treatment of their fracture.5–10 Unreduced fractures or those with unrecognized loss of reduction lead to malunion, eventual arthrosis, and a resultant decrease in function of the forearm, wrist, and digits and may require an osteotomy to realign the radiocarpal and radioulnar joints and regain function.

Clinical retrospective or prospective studies as well as biomechanical tests11–14 have been performed to better understand the mechanics, treatment, and sequelae of this injury. Past studies have focused on the position of immobilization, conservative versus operative care, stability of fixation devices, and how resultant malreduction of the fracture can lead to the development of arthrosis. These studies have not addressed the relationship between specific positions of malalignment of the distal end of the radius and forearm rotation.

Patients can experience considerable disability due to loss of motion long before the effects of arthrosis are symptomatic. These patients are often enrolled in therapy programs to regain their range of motion (ROM). The fact that many patients do not regain full motion despite adherence to therapy regimens is possibly due to distal radioulnar joint malposition caused by distal radius malalignment, rather than
soft tissue scarring. If joint malalignment is the etiology of motion loss, then continued therapy would be of no benefit to the patient. We found no studies that determined the relationship between distal radial fracture malalignment (including dorsal tilt, radioulnar shift, or radial shortening) and forearm rotation. Therefore, a cadaveric model of the upper extremity was used to determine how varying degrees of fracture malalignment affect the limits of forearm rotation.

**Materials and Methods**

**Specimen Preparation**

Fresh cadaveric upper extremities, with intact hand, wrist, and elbow joints and sectioned at mid-humerus, were inspected visually and radiographically for degenerative or abnormal changes, and seven were selected for testing. After screening for gross abnormalities, each was wrapped in a wet towel and stored frozen in a plastic bag. On the day of testing, each specimen was thawed and a cross-locked rod was placed into the medullary canal of the humerus for mounting to a testing apparatus.

A highly adjustable wrist external fixator (Agee Wrist Jack, Hand Biomechanics Lab, Sacramento, CA) was applied to the specimen, with pins placed into the radial shaft and the second metacarpal. The fixator allows separate adjustments of hand flexion/extension, radioulnar deviation, and shortening/lengthening. A transverse osteotomy was performed 15 mm proximal to the dorsal lip of the articular surface of the distal radius, at the level of Lister's tubercle. The degree of dorsal tilt was controlled by insertion of a brass wedge of appropriate angle into the osteotomy site. Shortening was controlled by the amount of bone resected at the osteotomy. Radial and ulnar shift were measured directly using a caliper. Each malaligned position (tilt, shortening, or shift) was created one at a time, held by the external fixator. The distal component of the osteotomy was fixed in its malaligned position to the proximal radius with a 3.5 mm semitubular T-plate on the volar surface.

**Loading Frame**

A frame supported the extremity, which hung freely downward with the elbow in 90° flexion. The hand was placed within a U-shaped bracket and coupled to it by a pin passed through the distal part of the extremity and the bracket (Fig. 1). The bracket was connected to a turntable. The turntable had a cable wrapped around its perimeter; the cable was connected to the turntable on one end and to a 0.714-N deadweight on the other, allowing a 0.277-Nm torque to be applied to the extremity. The center of rotation of the turntable was aligned with the ulna of the specimen. Forearm rotation was measured using a protractor (360° range, ± 0.5° accuracy) fixed to the turntable. The apparatus did not allow for motions in directions other than axial rotation.

**Experimental Procedure**

Total rotation of the intact forearm was measured by applying a torque in one direction and then in the other and measuring angular motion in each direction. The midpoint of the total rotation was defined as the neutral pronation/supination position. These and all other measurements were repeated three times.

![Figure 1. Schematic diagram of an apparatus used to load and measure forearm rotation of upper extremity specimens. The humerus is fixed, but the forearm can rotate freely. The distal end is pinned to a pulley, through which a torque is applied by a deadweight.](image-url)
times. After eliminating sources of friction in the loading apparatus, rotation was repeatable to within the accuracy of measurement of the protractor. The fixator was then applied, the osteotomy was created, and the measurement was repeated with the cut component in anatomic position, to determine whether creation of the osteotomy and application of hardware affected forearm ROM. The distal radius fracture component was then located in each of the positions noted in Figure 2, with measurements made of forearm rotation: radioulnar shift of 0 mm, 5 mm, 10 mm radial and 5 mm ulnar, and then returned to anatomic position; dorsal tilt of 0°, 15°, and 30° and then returned to anatomic position; and radial shortening of 0 mm, 5 mm, and 10 mm.

Data Analysis

Comparisons between forearm rotation intact and after osteotomy and anatomic or malpositioning of the distal radius component were made using an analysis of variance. Fisher's PLSD post-hoc comparison was used to compare the mean values of forearm rotation in anatomic and each malaligned position of the distal end of the radius. Significance was set at p < .05.

Results

The average arc of anatomic forearm rotation for the seven specimens was 181° (range, 146°–224°). Mean anatomic pronation angle for the specimens before osteotomy was 89.9° (SD = 14.8°), and supination angle was 91.1° (SD = 16.4°).

There was no significant change in forearm rotation with dorsal tilt of the distal radius to 30° (Fig. 3). There was no significant difference in rotation with translation of the distal radius up to 10 mm in the radial direction (Fig. 4). Ulnar translation of 5 mm led to a mean 23% loss of pronation (mean angle, 68.9°, SD = 9.6°) compared with 89.9° (SD = 14.6°) intact (p < .01). Supination angle was unchanged.

![Figure 3](image-url)  
**Figure 3.** Effect of dorsal tilt of the distal radius on forearm pronation and supination motions (n = 7).

![Figure 4](image-url)  
**Figure 4.** Effect of distal radial shift on forearm pronation and supination motions (n = 7; *p < .01 compared to anatomic).
Radial shortening of 5 mm or less had no effect on forearm rotation; however, shortening of 10 mm produced a mean of 47% loss of pronation (p < .0001) and 29% of supination ROM (p < .001) (Fig. 5). The average pronation angle was 46.4° (SD = 20.2°) and supination angle was 64.6° (SD = 11.3°). Radial shortening of 15 mm created ulnocarpal abutment, which effectively locked the distal radioulnar joint and prevented any forearm rotation.

Discussion

Our results revealed that an acute loss of forearm rotation can be expected if a radius fracture at this level is allowed to heal in a minimum of 5 mm of ulnar translation or 10 mm of radial shortening, while deformities in the plane of dorsal tilt and radial translation have no effect on forearm rotation. Using the American Medical Association guidelines for functional impairment15 our data would translate to an impairment rating of 3% for the effect of ulnar translation deformity on pronation and a combined additive rating of 10% for radial shortening of 10 mm. These numbers are only for illustrative purposes and obviously neglect the additional impairment resulting from any loss in radial and ulnar deviation or wrist flexion and extension motions, which were not measured in this study. It should also be pointed out that many of these deformities occur in combination (eg, dorsal tilt and shortening with comminution). Our study was designed to study each deformity separately to determine its individual effect.

There has been an interest in the rotational effects of diaphyseal forearm deformities after fracture. Matthews et al.16 investigated the effect of residual angulation from simulated fractures of both bones of the forearm. They found that residual angulation of less than 10° in midshaft forearm fractures does not limit forearm rotation but that angulation greater than 20° at this level contributed to a significant loss of forearm rotation. Tarr et al.17 studied angular and rotatory deformities of the distal and middle diaphyseal forearm. They found a loss in pronation-supination rotation of 13%, with a 10° simulated malunions in the distal forearm and a 16% loss in rotation with the same malunion in the midforearm. Supination losses were much less affected in forearms with deformities at the distal third level, while the losses were considered drastic for middle third deformities. They concluded that the fact that anatomic restoration of radial alignment, which is often obtained after fixation, does not always result in complete restoration of motion suggests that the residual impairment is due to soft tissue scarring. Our study would tend to agree with these conclusions by indirect deduction, since we found very few changes in motion due to distal radius malalignment in a radial direction in our specimens, which had bony deformities but unchanged soft tissues.

Fernandez18 described a technique for correction of post-traumatic malunion by osteotomy, bone grafting, and internal fixation. He noted that adequate painless function of the wrist can be expected after certain degrees of malunion, owing to the fact that this fracture occurs predominantly in elderly individuals. However, the younger, active patients who are still involved in strenuous activity have a lower tolerance for the loss of function. He states that symptoms can be expected if the deformity exceeds 20° in the sagittal frontal plane and if there is a length discrepancy of greater than 6 mm between the radius and ulna. Ten of 20 patients in the study with radial shortening experienced a average loss of 47° pronation and 59° supination. His osteotomy technique increased the range of pronation and supination to normal, compared with the uninjured contralateral side. One of his conclusions was that shortening of the radius relative to the ulna leads to subluxation of the distal radioulnar joint and painful impairment of pronation and supination. This observation was borne out in our study.

Pogue et al.19 studied the effects of distal radius fracture malunion on load transmission through the
radiocarpal joint using pressure-sensitive film. They noted that by angling the distal radius more than 20° in either the palmar or dorsal direction, they achieved a dorsal shift in the scaphoid, leading to more concentrated loads in the radiolunate joint, while the scapholunate load remained unchanged. They also noted that changes in radial inclination shifts the load from the scaphoid to lunate fossa. Their study was performed with the intent of predicting articular surface loading changes, which may be an indicator of early arthrosis. Therefore, even if ROM is unchanged, alteration in pressure distributions may provide a valid reason for obtaining anatomic reduction of these fractures.

Our data suggest that loss of forearm rotation can be expected acutely with ulnar translation of 5 mm and radial shortening of 10 mm owing to bony restraints that result from fracture malalignment. However, rotational loss in the presence of uniplanar dorsal tilt or radial translation most likely stems from resultant subacute capsular scarring, as there were no immediate restraints on motion in our study. These findings could assist the surgeon and therapist in differentiating the etiology of their patients’ limitations and to what degree it originates from the bony restraints of the healed fracture. This information can be used to set attainable return-of-motion goals to direct occupational therapy and to clarify the need for further surgery.

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References

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