SAGITTAL WRIST MOTION OF CARPAL BONES FOLLOWING INTRAARTICULAR FRACTURES OF THE DISTAL RADIUS

M. LUTZ, A. RUDISCH, F. KRALINGER, V. SMEKAL, G. GOEBEL, M. GABL and S. PECHLANER

From the Department of Trauma Surgery, University of Innsbruck, Austria, Department of Radiology, University of Innsbruck, Austria, Department of Biostatistics, University of Innsbruck, Austria

Forty patients (mean age, 37 years) with intraarticular C2 and C3 Colles fractures were treated by open reduction, internal fixation and bone grafting. At a mean follow-up of 8 years radiocarpal and midcarpal motion was evaluated, the depth of the articular surface of the distal radius in the sagittal plane was measured and the presence of arthritis was noted. The fractures healed with a mean palmar tilt of 6°, a mean ulnar tilt of 18° and ulna variance within 1 mm of the contralateral side. The depth of the articular surface of the distal radius was 1.3 mm greater than the uninvolved side. Measurement of carpal bone angles relative to the radius in maximum flexion and extension revealed lunate extension of 23°, lunate flexion of 15°, capitate extension of 62°, capitate flexion of 40°. There was a significant correlation between articular surface depth and radiocarpal motion.

Journal of Hand Surgery (British and European Volume, 2005) 30B: 3: 282–287

Keywords: distal radius fracture, articular cavity depth, carpal bone motion

INTRODUCTION

Restoration of wrist motion, grip strength and painless load bearing are the aims of treatment for distal radius fractures. Several studies have demonstrated that such function is more likely when the normal anatomy of the distal radius is restored (Hastings and Leibovic, 1993; McQueen and Caspers, 1988; Trumble et al., 1994).

Whereas shortening of the radius impairs function at the distal radioulnar joint, radiocarpal dysfunction occurs if there is malunion of the radiocarpal articular surface or a significant ligamentous injury (Baratz et al., 1996; Kazuki et al., 1993; Short et al., 1995).

Extraarticular malunion with dorsal tilt and intraarticular malunion with an articular step in the lunate or scaphoid fossa disturb force transmission at the wrist and alter carpal bone motion (Baratz et al., 1996; Park et al., 2002; Short et al., 1987; Wagner et al., 1996). In addition ligament injuries, which frequently occur with distal radius fractures, are known to change carpal kinematics (Short et al., 1995). However their effect on carpal bone motion is uncertain.

Previous investigations on distal radius malunion have only studied extraarticular malunion or intraarticular step offs in the frontal plane and their effect on force transmittion and carpal kinematics. This report studies another type of malunion, one which is characterized by cavitation of the distal radius in the sagittal plane. The influence of this altered shape, which is a frequent sequel of complex intraarticular fractures, on carpal kinematics and force transmission has never been investigated.

PATIENTS AND METHOD

Between 1988 and 1995, 67 patients with intraarticular fractures of the distal radius underwent operative treatment in our trauma department. Forty patients, 11 women and 29 men, were available for follow-up examination. Their average age at the time of injury was 37 (range 18–50) years. Their fractures were classified using the AO system (C2 = 25, C3 = 15), and all were comminuted and displaced and had initially been treated conservatively. Redislocation had occurred in all cases such that there was more than 5° loss of palmar tilt, shortening of more than 3 mm or an articular step of more than 2 mm (Cooney et al., 1980; Knirk and Jupiter, 1986; McQueen et al., 1996).

Operative technique

All patients were initially treated by closed reduction under local anaesthetic and immobilization in a plaster splint. After the reduction had been lost and pre-operative planning, the fractures were managed by open reduction and internal fixation with a special T-plate. The articular cortex was reduced by indirect means, without opening the joint capsule (Pechlaner, 1993). Metaphyseal impaction defect zones on the dorsal side were filled with corticocancellous bone blocks from the iliac crest and supported the articular surface. Post-operatively, a forearm plaster cast was worn for 3 weeks. Restoration of the articular surface without step off or dorsal tilt was a requirement for inclusion in the present study.

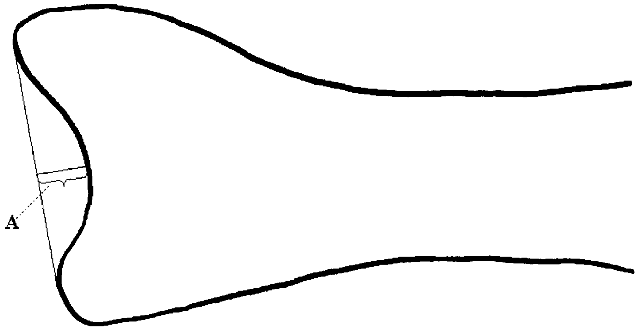

Fig 1 Measurement of the articular cavity depth of the distal radius.

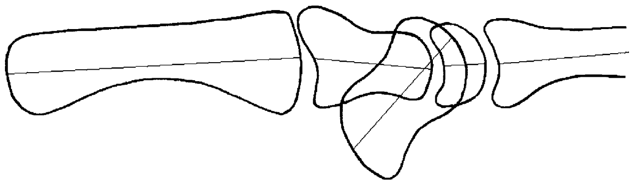

Fig 2 Measurement of the carpal bone angles in the sagittal plane.

Standard anteroposterior and lateral radiographs, as well as lateral views in full flexion and extension, were taken at an average follow-up of 8 years. The inclination of the articular surface in the sagittal and frontal plane and radial shortening, as defined by ulna variance, were measured (Palmer et al., 1984). In addition, the depth of the articular surface was determined by joining the palmar and dorsal lips of the distal radius on the lateral view and then drawing a perpendicular to the line at the deepest point of the articular surface. The width of the distal radius was also measured from the palmar to the dorsal lip of the articular surface. Both the depth of the articular cavity and the width of the distal radius were compared to the uninvolved contralateral side (Fig. 1).

Relative motion between the distal radius and the scaphoid, lunate and capitate was measured on the lateral views taken in flexion and extension. This was done by measuring the carpal and radial bone axes. The axis of the radius was defined by a line running parallel to the borders of the distal radius.

The axis of the lunate was determined by joining its palmar and dorsal poles with a line and then drawing a perpendicular to that line at its mid-point. The axis of scaphoid was drawn by joining the mid-points of the proximal and distal pole. The axis of the capitate was determined by joining the mid point of its head with the mid point of its base (Garcia-Elias et al., 1989) (Fig. 2).

Radiocarpal motion was determined as flexion and extension of the lunate. Midcarpal motion was defined as motion between the lunate and capitate. Radiocarpal arthritis was classified according to the Knirk and Jupiter classification system (Knirk and Jupiter, 1986).

Statistical analysis

Results are reported as mean and standard deviations. Correlation between articular cavity depth and carpal kinematics was analysed using the Pearson correlation coefficient. Differences between groups were assessed using the Mann–Whitney *U*-test.

RESULTS

At follow-up the mean palmar tilt was 6° (SD, 4) the mean ulnar tilt was 18° (SD, 4), and the ulna variance was within 1 mm (SD, 1) of the contralateral side. There were no obvious step offs in the articular surface of the distal radius.

The articular cavity depth of the distal radius measured 5.1 mm/(SD, 1) compared with 3.8 mm (SD, 1) for the contralateral side. Thus the difference between the sides was 1.3 mm (SD, 1). Arthritis of the radio-carpal joint was graded from 0 to 3 according to Knirk and Jupiter: Stage 0: 2 patients; Stage 1: 25 patients; Stage 2: 13 patients.

The range of movement of the various components of the wrist relative to the radius was as follows: In full wrist extension, the capitate extended 62° (SD, 13), the lunate extended 23° (SD, 9) and the scaphoid was in 10° (SD, 14) flexion. In full wrist flexion, the capitate flexed 40° (SD, 14), the lunate 15° (SD, 8) and the scaphoid 78° (SD, 9). Radiocarpal motion was thus 23° (SD, 9) extension and 15° (SD, 8) flexion. At the midcarpal joint there was 40° (SD, 9) extension and 25° (SD, 11) flexion.

There was a significant correlation between the shape of the distal radius and carpal bone motion with radiocarpal and total wrist motion reducing with increased articular cavity depth. A further decrease in motion was observed at the midcarpal joint, but only extension changed significantly (Figs. 3–5).

In wrists with an articular cavity depth which was less than 1 mm greater than the uninjured side the capitate extended 71° (SD, 5), the lunate extended 28° (SD, 6) and the scaphoid was in slight flexion of 2° (SD, 7) relative to the radius. In this group of wrists, the capitate flexed 48° (SD, 11), the lunate 20° (SD, 6) and the scaphoid 83° (SD, 7). Thus, the radiocarpal joint, extended 28° (SD, 6) and flexed 20° (SD, 6). At the midcarpal level, extension was 42° (SD, 6) and flexion was 28° (SD, 8) (Table 1).

In wrists with an articular cavity depth which was more than 1 mm greater than in the uninjured wrist, extension of the capitate measured 54° (SD, 14), the lunate extended 17° (SD, 8) and the scaphoid was in 17° (SD, 15) flexion. In full flexion, the capitate flexed 31° (SD, 13), the lunate flexed 10° (SD, 6) and the scaphoid flexed 73° (SD, 8). Radiocarpal motion amounted to 17° (SD, 8) extension and 10° (SD, 6) flexion. At the midcarpal joint, there was 37° (SD, 10) extension and 22° (SD, 13) flexion (Table 2).

Fig 3 (a) Unstable AO C2 distal radius fracture; (b) radiograph following open reduction, internal fixation and bone grafting. The articular cavity depth is increased on the lateral view; (c) the wrist in full flexion and extension: there is decreased radiolunate and total wrist motion.

Fig 4 (a) Unstable AO C3 distal radius fracture; (b) radiograph following open reduction internal fixation and bone grafting: the articular surface has been restored and there is no increase in its depth; (c) the wrist in full flexion and extension showing normal radiolunate and total wrist motion.

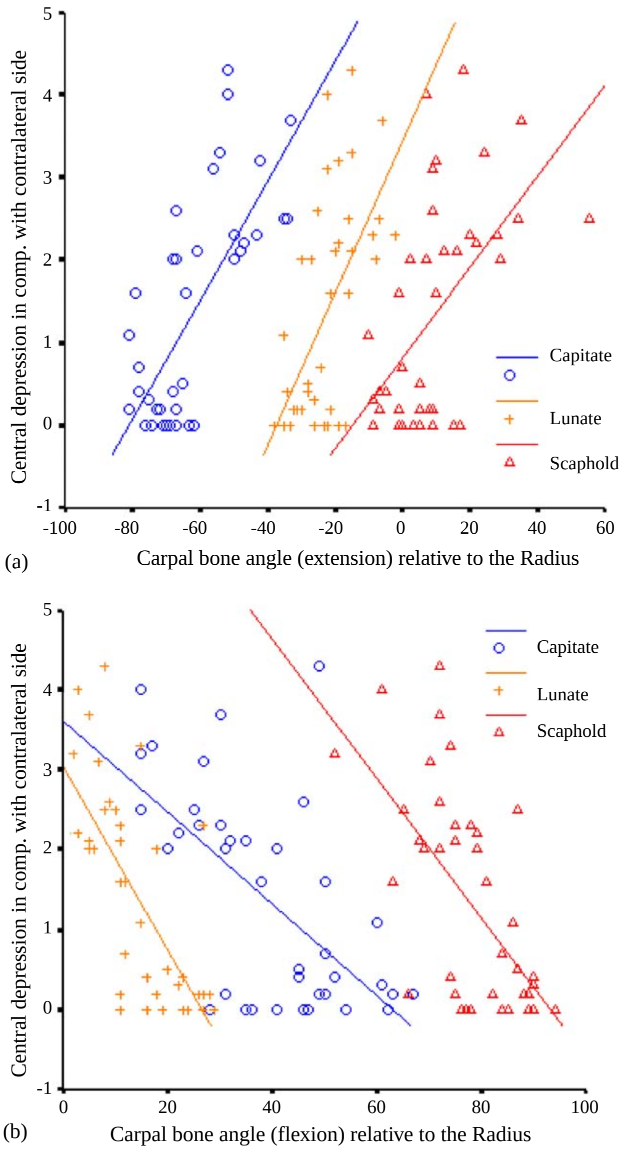

Fig 5 Correlation between central depression of the articular surface in the sagittal plane and carpal bone motion (extension and flexion).

Statistical comparison of these two groups revealed a significant difference in total wrist and radiocarpal, but not in midcarpal, motion. A further evaluation revealed a significant correlation between articular cavity depth and width of the articular surface ($r = 0.469$, $P = 0.002$) and a significant correlation between articular cavity depth and the presence of arthritis ($r = 0.438$, $P = 0.001$).

DISCUSSION

Extraarticular malunion with dorsal tilt causes changes in pressure distribution and wrist kinematics. A cineradiographic study by Kazuki et al. (1993) revealed a slight decrease in sagittal wrist motion in patients with dorsal tilt of less than 10°. In contrast, malunion with more than 20° of dorsal tilt restricted wrist flexion to 40° and extension 10°. Dorsal angulation of the articular surface also increases pressure concentration along the dorsal aspect of the radioscaphoid joint and unloads the radiolunate joint (Short et al., 1987).

Table 1—Range of movement (degrees) of the various components of the wrist in groups 1 and 2

	Group 1 (<1 mm side difference of articular depth) Range of movement relative to the radius (degrees) Means (SD)	Group 2 *(>1 mm side difference of articular depth) Range of movement relative to the radius (degrees) Means (SD)*
Scaphoid extension	2 (8)	17 (15)
Scaphoid flexion	83 (7)	73 (8)
Lunate extension	−28 (6)	−17 (8)
Lunate flexion	20 (6)	10 (6)
Capitate extension	−71 (5)	−54 (14)
Capitate flexion	48 (11)	31 (13)

Table 2—Range of movement (degrees) at the radiocarpal and midcarpal joints

	Group 1 (<1 mm articular depth) Range of movement relative to the radius (degrees) Means (SD)	Group 2 *(>1 mm articular depth) Range of movement relative to the radius (degrees) Means (SD)*
Radiocarpal extension	−28 (6)	−17 (8)
Radiocarpal flexion	20 (6)	10 (6)
Midcarpal extension	−42 (6)	−37 (10)
Midcarpal flexion	28 (8)	22 (13)

Interest in intraarticular malunion has focused on the significance of step-offs between the lunate and scaphoid fossa and it is known that there are increased contact stresses at the fracture site (Baratz et al., 1996 ; Wagner et al., 1996). This is in accordance with Knirk and Jupiter's (1986) clinical observation that post-traumatic arthritis occurred with radiocarpal incongruity of 2 mm in the frontal plane. Although altered wrist kinematics due to intraarticular step off can be hypothesized, there are no detailed studies on altered carpal bone motion.

Our investigation deals with intraarticular malunion in the sagittal plane which occurs frequently after complex intraarticular fractures of the distal radius. It is due to central impaction of the palmar ulnar fragment which is difficult to reduce, even with open techniques, and increases the depth and width of the distal radius articular surface (Melone, 1993). This form of malunion seems to restrict movement of the proximal row, particularly flexion. Similar results have been reported by Trumble et al.(1994) who observed worse function in patients with articular gaps. Increased articular cavity depth of the distal radius probably alters pressure distribution as well as restricting motion of the proximal carpal bones. This would be consistent with the observation that post-traumatic arthritis develops in a higher proportion of patients with central impaction.

Ours was a radiological study which could not assess the impact of concomitant ligament injuries or articular cartilage damage which may have also restricted wrist motion. Injuries to these structures are known to occur, especially in severe fractures, and may lead to intra articular scar formation which restrict carpal bone motion, despite accurate reduction of the articular surface. However, restricted wrist motion also occurs with less severe fractures which unite with an increased articular depth. Thus, it is important to restore the normal articular contour so as to allow rotation and translation of the proximal carpal row on the distal radius.

References

Baratz ME, DesJardins JD, Anderson DD, Imbriglia JE (1996). Displaced intraarticular fractures of the distal radius: the effect of fracture displacement on contact stresses in a cadaver model. Journal of Hand Surgery, 21A: 183–188.

Cooney WP, Dobyns JH, Linsheid RL (1980). Complications of Colles fractures. Journal of Bone and Joint Surgery, 62A: 613–619.

Garcia-Elias M, An KN, Amadio PC, Cooney WP, Linscheid RL (1989). Reliability of carpal angle determinations. Journal of Hand Surgery, 14A: 1017–1021.

Hastings H, Leibovic J (1993). Indications and techniques of open reduction internal fixation of distal radius fractures. Orthopaedic Clinic of North America, 24: 309–326.

Kazuki K, Kusunoki M, Yamada J, Yasuda M, Shimazu A (1993). Cineradiographic study of wrist motion after fracture of the distal radius. Journal of Hand Surgery, 18A: 41–46.

Knirk JL, Jupiter JB (1986). Intra-articular fractures of the distal end of the radius in young adults. Journal of Bone and Joint Surgery (Am), 68A: 647–659.

McQueen M, Caspers J (1988). Colles fractures: does the anatomical result affect the final function. Journal of Bone and Joint Surgery, 70B: 649–651.

McQueen MM, Hajducka C, Court-Brown CM (1996). Redisplaced unstable fractures of the distal radius: a prospective randomised comparison of four methods of treatment. Journal of Bone and Joint Surgery, 78B: 404–409.

Melone CP (1993). Distal radius fractures: patterns of articular fragmentation. Orthopedic Clinics of North America, 24: 239–253.

Palmer AK, Glisson RR, Werner FW (1984). Relationship between ulnar variance and triangular fibrocartilage complex thickness. Journal of Hand Surgery, 9A: 681–682.

Park MJ, Cooney WP, Hahn ME, Looi KP, An KN (2002). The effect of dorsally angulated distal radius fractures on carpal kinematics. Journal of Hand Surgery, 27A: 223–232.

Pechlaner S (1993). Distale intraartikuläre Radiusfrakturen. Indikation und Technik der offenen Reposition und Plattenosteosynthese. Orthopäde, 22: 46–51.

Short WH, Palmer AK, Werner FW, Murphy DJ (1987). A biomechanical study of distal radial fractures. Journal of Hand Surgery, 12A: 529–534.

Short WH, Werner FW, Fortino MD, Palmer AK, Mann KA (1995). A dynamic biomechanical study of scapholunate ligament sectioning. Journal of Hand Surgery, 20A: 986–999.

Trumble TE, Schmitt SR, Vedder NB (1994). Factors affecting functional outcome of displaced intra-articular distal radius fractures. Journal of Hand Surgery, 19A: 325–340.

Wagner WF, Tencer AF, Kiser P, Trumble TE (1996). Effects of intraarticular distal radius depression on wrist joint contact characteristics. Journal of hand Surgery, 21A: 554–560.

Received: 18 June 2003
Accepted after revision: 29 December 2004
Dr Martin Lutz, Univ. Klinik für Unfallchirurgie Innsbruck, Anichstr. 35, 6020 Innsbruck, Austria.
E-mail: martin.lutz@uklibk.ac.at

doi:10.1016/j.jhsb.2004.12.012 available online at http://www.sciencedirect.com