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Angle measurements of the distal radius: a cadaver study

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Abstract. The quality of reduction of distal radius fractures is assessed mainly by degree of restoration of radial angle and palmar tilt. This cadaver study investigates the effects of forearm rotation of these measurements. A 5° rotational change produces a 1.6° change in palmar tilt on the conventional lateral view and a 1.0° change on the 15° lateral view. Lateral radiographs could be rotated 15°–30° and still be considered acceptable. Therefore, rotation may produce up to a 4.0° (15° lateral view) or 6.4° (conventional lateral view) change in measured palmar tilt. To provide clearer measuring landmarks and minimize error due to rotation, we recommend obtaining the 15° lateral view routinely in fractures with significant dorsal angulation. We also studied the interobserver variability of different surgeons assessing radial angle and palmar tilt. The mean standard deviation between surgeons was 3.2° for radial angle, 3.6° for conventional lateral palmar tilt, and 2.1° for 15° lateral palmar tilt.

Key words: Distal radius fracture – Palmar tilt – Radial angle – Lateral wrist radiograph

Acceptability of fracture reduction of distal radius fractures is based in part on radial angle in the coronal plane (anteroposterior radiograph) and palmar tilt in the sagittal plane (lateral radiograph) [4]. Reliable measurements are needed to make sound therapeutic decisions and assess results of treatment.

Reliability may be affected by variability in selection of points for measurement. Forearm rotation may also affect reliability. The purpose of this study was to define the effects of interobserver variables and forearm rotation in measuring distal radius angles.

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Materials and methods

Five fresh cadaver arms were studied. Posteroanterior and lateral radiographs were made of each wrist. A lateral radiograph with the X-ray beam directed 15° cephalad was also made (Fig. 1) [2, 3]. Radiographs were randomly labeled so observers could not tell which, if any, were related. Fifteen orthopedic surgeons measured radial angle (Fig. 2) and palmar tilt (Fig. 3) and filled out a questionnaire assessing the quality of the radiographs.

The same specimens were used for the second part of the study. A Kirschner wire was placed in the radial aspect of the distal radius. A threaded Steinman pin was placed through the olecranon. The arm was mounted in a specially constructed jig incorporating a goniometer and positioned for a true lateral radiograph (Fig. 4). The position of the Kirschner wire against the goniometer was recorded. Lateral radiographs were taken at 5° rotational increments from 20° pronation to 20° supination. Lateral views with the X-ray beam directed 15° cephalad were also taken in each position [2, 3]. Palmar tilt was measured on all radiographs and plotted as a function of forearm rotation. We measured overlap of the distal ulna on the radius to assess "acceptability" of the lateral views. An "acceptable" lateral radiograph is generally regarded as one in which the head of the ulna is completely superimposed on the distal radius [2].

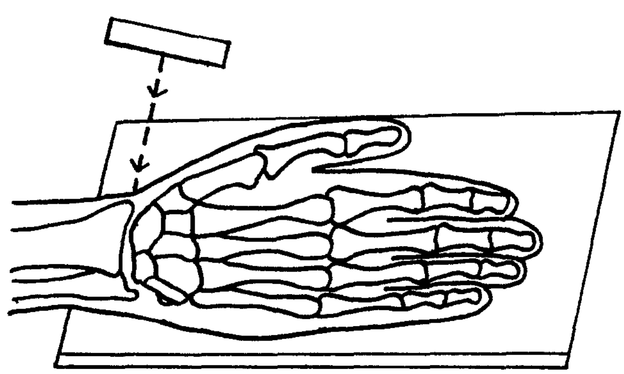

Fig. 1. Position of arm for 15° lateral radiograph. Wrist is positioned as for the standard lateral radiograph and the X-ray beam is directed 15° cephalad

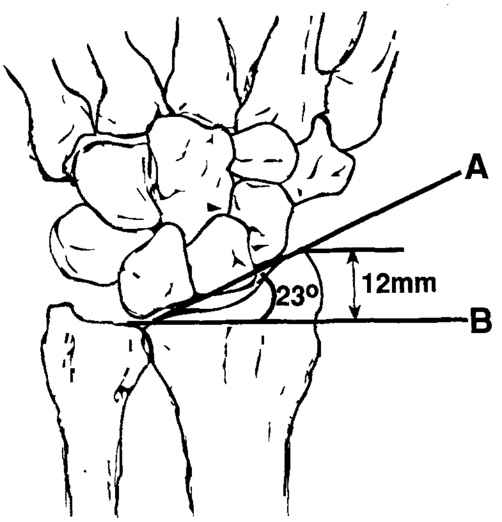

Fig. 2. Measurement of normal average radial angle and radial length. *A*, Line drawn from the tip of the radial styloid to the articular surface of the ulnar fossa. *B*, Line drawn perpendicular to the long axis of the radius. The angle between lines *A* and *B* (here 23°) is defined as the *radial angle*. The distance between *B* and the tip of the radial styloid (here 12 mm) is known as the *radial length*

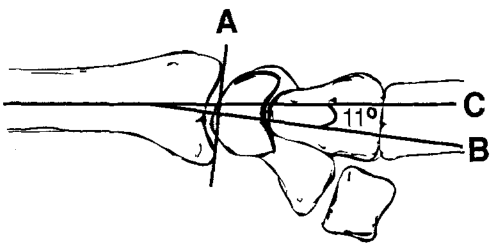

Fig. 3. Measurement of normal palmar angulation. *A*, Line drawn from the dorsal lip to the palmar lip of the distal radius. *B*, Line perpendicular to *A*. *C*, Line parallel to the long axis of the radius. The angle between lines *B* and *C* (here 11°) is defined as *palmar tilt*

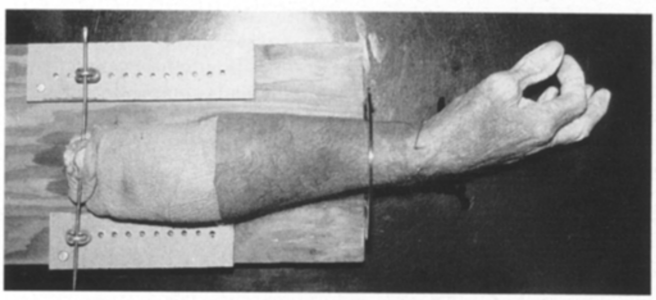

Fig. 4. Position of the cadaver arm mounted in the jig for obtaining lateral X-rays

Results

Fifteen orthopedic surgeons measured 15 radiographs for a total of 225 measurements. Mean standard deviation for palmar tilt on the 15° lateral view was 2.1° compared to 3.6° on the conventional lateral (Table 1). This indicates less variability in the 15° lateral view ($p < 0.01$). Mean value for palmar tilt was 2.5° more dorsal in the 15° lateral radiograph (Figs. 5, 6).

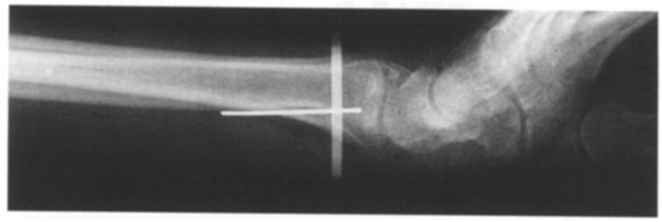

Fig. 5. Conventional lateral radiograph of the distal radius. Compare with Fig. 6

Fig. 6. Fifteen-degree cephalic tilt view of the same wrist as in Fig. 5. Measurement points are more clearly defined both palmar and dorsal

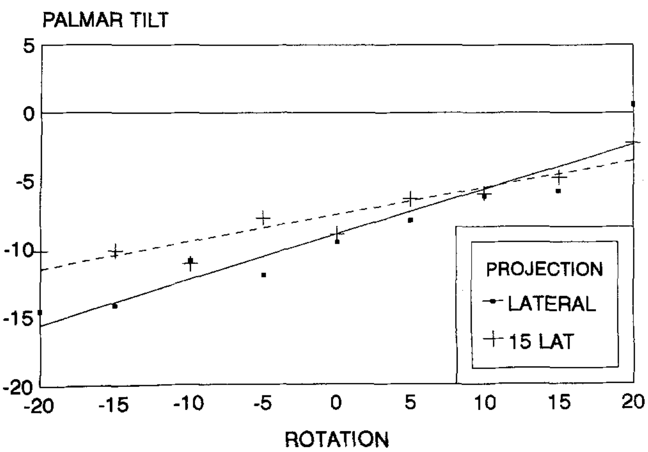

Fig. 7. Palmar tilt as a function of forearm rotation for mean values of five specimens. Negative values represent supination, positive values pronation

Table 1. Mean values and standard deviations of surgeons' measurements of radial angle and palmar tilt in five specimens and mean

Specimen	Radial angle	(°)	Conventional lateral	(°)	15° lateral	(°)
	Mean	SD	Mean	SD	Mean	SD
1	25.7	5.2	17.3	7.4	14.9	2.3
2	27.9	1.6	8.3	4.4	8.5	1.9
3	24.7	2.0	15.9	2.7	10.3	2.9
4	22.5	3.0	14.3	1.9	8.2	1.9
5	26.0	4.1	11.4	1.6	12.7	1.7
Mean	25.4	3.2	13.4	3.6	10.9	2.1

Fig. 8. Cephalic tilt view in 20° supination. Palmar tilt measures 9° in this specimen

Fig. 9. Cephalic tilt view in 20° pronation of the same specimen as in Fig. 8. Note that in this position the distal radial tilt is actually 2° *dorsal*

Table 2. Slopes and correlation coefficients on conventional lateral and 15° lateral views for five specimens and mean

Specimen	Conventional lateral		15° lateral	
	Slope	Correlation coefficient	Slope	Correlation coefficient
1	0.54	0.57	0.37	0.98
2	0.39	0.84	0.27	0.92
3	0.22	0.67	0.16	0.74
4	0.23	0.76	0.02	0.15
5	0.20	0.72	0.17	0.87
Mean	0.32	0.96	0.20	0.93

For the second part of the study, 18 measurements (9 each for the conventional and the 15° lateral view) were made on each of five specimens for a total of 90 measurements. Palmar tilt as a function of degree of rotation of the forearm with best-fit linear relationship is shown for the mean in Fig. 7. Supination increases measured palmar tilt (Fig. 8) whereas pronation decreases measured palmar tilt (Fig. 9). For the neutral rotation radiograph the 15° lateral palmar tilt averaged 1.5° more dorsal (less palmar tilt) than the conventional lateral.

Linear correlation coefficients are high except in the 15° lateral projection of specimen 4 (Table 2). Coefficients for the mean values are greater than 0.90, strongly indicating a linear relationship between forearm rotation and palmar tilt for both projections. Correlation coefficients for the 15° lateral were better than those for the conventional lateral view (except for specimen 4), indicating less variability with the 15° projection. In all cases slope values are less for the 15° lateral view, indicating that measured palmar tilt is less affected by forearm rotation on the 15° lateral ($p = 0.10$). A 5° change in rotation will produce a 1.6° change in measured palmar tilt on the conventional lateral and a 1.0° change on the 15° lateral radiograph. Standard deviations for the 15° lateral were less in seven of nine positions of rotation (Table 3). The mean standard deviation was 3.56° for the conventional lateral and 2.61° for the 15° lateral, indicating less variability with the 15° view ($p = 0.06$).

Table 3. Standard deviations for five specimens at each position of rotation and mean

	Conventional lateral (°)	15° lateral (°)
20° supination	3.38	3.06
15° supination	1.17	2.64
10° supination	4.10	2.57
5° supination	1.90	1.33
Neutral	4.76	2.10
5° pronation	5.30	2.06
10° pronation	5.56	2.28
15° pronation	2.86	4.26
20° pronation	3.01	3.19
Mean	3.56	2.61

Specimens could be rotated 15°–30° and still produce an acceptable lateral projection (distal ulna completely superimposed on distal radius). Therefore, even in an "acceptable" lateral projection, rotation may produce up to a 4.0° (15° lateral) or 6.4° (conventional lateral) change in measured palmar tilt.

Discussion

Observer variability in measurement of distal radius angles has been addressed in two previous studies [1, 2]. Friberg and Lundstrom [2] measured radial angle and palmar tilt on 60 normal radiographs. Measurements were performed independently by the two authors. The average difference in measurement of palmar tilt was 3.2° on the conventional lateral and 1.5° on the 15° lateral view. They felt the 15° lateral view provided better defined measuring points, leading to less variability.

The standard deviation for palmar tilt on both conventional and 15° lateral views was slightly higher in our study. There were only two observers in Friberg and Lundstrom's study, compared to 15 in our study. We also found decreased variability using the 15° lateral projection, although for some specimens the conventional lateral view proved equally reliable. We agree with Friberg and Lundstrom's impression that measuring landmarks are better defined on the 15° lateral view.

DiBenedetto et al. [1] studied eight orthopedists' measurements of radial angle on eight posteroanterior radiographs. They found a standard deviation of 2° and concluded that surgeon variability in the measurement of radial angle is minimal. Their study did not address measurement of palmar tilt.

The standard deviation for radial angle measurements in our study was slightly higher at 3.2°. Radial angle measurement in our study had a 95% confidence factor of plus or minus 6.4°. This amount of variability may be significant in cases where the quality of reduction is not clearly adequate. However, standard deviations for the five specimens ranged from 1.6° to 5.2°. Clearly, the surgeon must obtain a radiograph with clear landmarks for measuring to avoid introducing significant error due to individual variability.

The effect of forearm rotation on distal radius angle measurements has been investigated in two previous studies [1, 3]. Friberg and Lundstrom [3] obtained conventional lateral and 15° lateral radiographs at 5° rotational increments from 10° pronation to 10° supination in 40 wrists with distal radius fractures. Supination produced an increase in palmar tilt on the conventional lateral but a decrease in palmar tilt on the 15° lateral projection. We demonstrate changes of similar magnitude in measured palmar tilt with rotation. However, supination increased measured palmar tilt on both conventional and 15° lateral views. We cannot explain the decrease in measured palmar tilt on the 15° lateral observed by Friberg and Lundstrom.

Significant rotation from neutral is frequently seen on lateral wrist radiographs. Friberg and Lundstrom found in all cases the criterion for an "acceptable" lateral radiograph allowed 10°–15° rotation. Our data demonstrate that up to 30° rotation may occur in an "acceptable" lateral radiograph. Significant changes in measured palmar tilt occur through this range of motion. The surgeon must evaluate rotation on the lateral radiograph critically in order to avoid introducing significant error when measuring palmar tilt. The 15° lateral projection minimizes error due to rotation.

DiBenedetto et al. [1] rotated a phantom forearm (skeleton embedded in a plastic matrix used to teach radiographic technique) and obtained posteroanterior radiographs. Such rotation does not accurately replicate forearm pronation and supination, where the forearm does not rotate as a unit but rather the radius rotates about the ulna. The radial angle remained within 1° through 11° of rotation. They did not investigate the effect of rotation on palmar tilt. We did not investigate the effect of forearm rotation on radial angle because significant forearm rotation on the posteroanterior radiograph is unusual.

The 15° lateral projection is more reliable than the conventional lateral for assessing palmar tilt. Standard deviations in surgeon measurement are less in this view (Table 1). Linear correlation coefficients are better for the 15° lateral projection (Table 2). Linear slope values are less for the 15° lateral view, indicating that less error occurs with rotation when this projection is used (Table 2, Fig. 7). Standard deviations between rotated specimens are also less in the 15° lateral view (Table 3). We found, in interpreting the large number of radiographs in this study, that the 15° view provided clearer landmarks for measurement of palmar tilt. This view is technically easy to obtain. We recommend that the surgeon obtain this view when an accurate assessment of palmar tilt is needed to direct treatment.

References

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