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ORIGINAL STUDY

Measurement of ulnar variance and radial inclination on X-rays of healed distal radius fractures. With the axis of the distal radius or ulna ?

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Ulnar variance and radial inclination are radiological parameters frequently used to evaluate displacement of distal radius fractures. In most studies measurements are based on the long central axis of the distal radius, although the axis of the distal ulna can also be used. The purpose of this study was to determine which axis is more reliable. Four observers performed measurements on standard anteroposterior digital wrist X-rays of 20 patients taken 1 and 2 months after sustaining an extra-articular distal radius fracture. Intraobserver reliability was similar with both methods. No difference was found in interobserver reliability between both methods for ulnar variance, but for radial inclination it was better with the axis through the radius. Measurements on two X-rays of the same wrist taken at a different moment were similar with both methods. It can be concluded that the central axis of the distal radius can remain the basis to determine ulnar variance and radial inclination.

Keywords :

INTRODUCTION

Radiological parameters describe the morphology of the distal radius and may be helpful to diagnose, treat and predict functional outcome of distal radius fractures. Ulnar variance and radial inclination are parameters measured on anteroposterior wrist radiographs. Ulnar variance is the difference in length between the ulna and radius at the level of the distal radioulnar joint (*11*). It increases in case of radial shortening and/or tilting of the distal radius after a fracture (*14*). It has been recommended to correct an increase of more than 2 mm in young patients (*8*). Radial inclination is the slope of the articular surface of the distal radius. Normal values range between 19° and 29° (*22*). Radial inclination may decrease after a fracture. In contrast to increase in ulnar variance, changes in radial inclination usually did not correlate with functional

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outcome (*4*,*13*,*25*), or had functional repercussion only when the angle was less than 10° (*20*) or 5° (*2*).

When measuring radiological parameters such as ulnar variance and radial inclination several steps are required with inherent variability at each step. Another problem is that two-dimensional X-rays may not represent accurately the three-dimensional anatomy of the radius (*15*). Parameters measured on wrist X-rays at two different moments in time of the same patient may differ although there are no anatomic changes of the bone. Therefore, a good standardization of the position of the wrist and the X-ray beam angle is necessary (*7*,*19*,*28*). The error of measurement can also be caused by inaccuracy of the measurement tools, inconsistency of one observer (intraobserver variability) and differences between two observers (interobserver variability) (*15*). When several methods exist to measure a radiological parameter, information about intra- and interobserver reliability may help to decide which technique to choose. Many methods have been described to determine ulnar variance. Steyers *et al* found no significant difference between the project-a-line technique, the method of concentric circle and the method of perpendiculars, but with the latter intraobserver and interobserver reliability was better (*23*). Therefore the method of perpendiculars may be preferred to determine ulnar variance.

The long axis of the distal radius or ulna can be used as reference point for measuring ulnar variance and radial inclination on X-rays (*6*,*17*). In most studies evaluating distal radius fractures, the central axis of the radius was used (*4*,*10*,*13*,*15*,*18*,*26*) and less frequently the ulna (*1*,*3*,*27*).

The purpose of the present study was to investigate which axis was more reliable to determine ulnar variance and radial inclination in healed distal radius fractures on digital X-rays. The long axis of the ulna may be a better reference to start the measurements than the radius because it has not been broken and is a straighter bone. Inter- and intraobserver reliability was determined with radius and ulna as central axis. It was also investigated if measurements of ulnar variance and radial inclination on two different X-rays of the same wrist were more consistent with the central axis of the radius than with the axis of the ulna.

PATIENTS AND METHODS

Standard anteroposterior wrist radiographs of 20 patients were selected out of a database of patients who were treated for a displaced distal radius fracture. Only X-rays of extra-articular fractures were chosen. X-rays of 17 women and 3 men with a mean age of 57 years (range 32-85) were included in the study. Sixteen fractures had been treated with closed reduction and percutaneous K-wire fixation and 4 with a palmar plate. Exclusion criteria were intra-articular fractures and distal radius fractures associated with a fracture of the distal ulnar head. Per patient two radiographs of the healed distal radius fracture were used for measurements : at 1 and 2 months postoperatively.

The radiological parameters were measured on standard X-rays of the wrist according to the method described by Kreder *et al* (*15*). Ulnar variance and radial inclination were measured on anteroposterior views taken with the shoulder in 90° abduction, elbow in 90° flexion and the forearm in 0° pronation and supination (*19*). The centre of the radius was determined at 3 and 5 cm below the mid-region of the proximal lunate articular surface (*15*) (Fig. 1). The central axis in the ulna was also determined at 3 and 5 cm below the distal ulnar articular surface (Fig. 2). Ulnar variance was the distance between two parallel lines perpendicular to the central axis of the

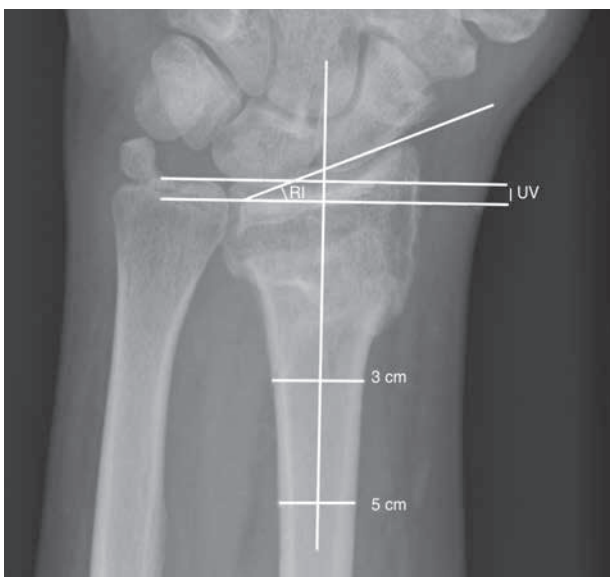

Fig. 1. — Measurement of ulnar variance and radial inclination with the central axis through the radius.
UV : ulnar variance, RI : radial inclination.

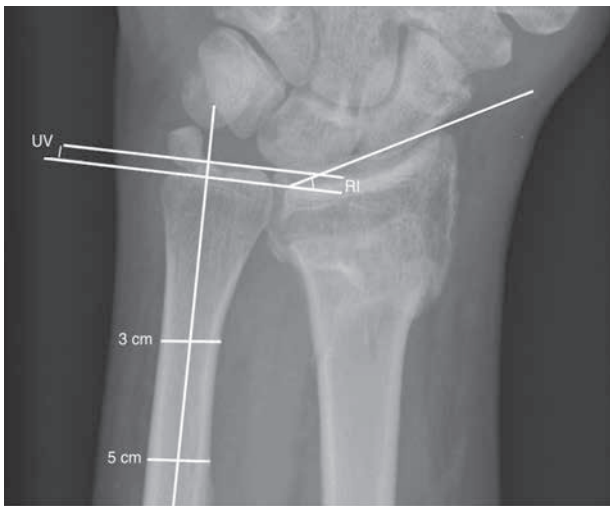

Fig. 2. — Measurement of ulnar variance and radial inclination with the central axis through the ulna.
UV : ulnar variance, RI : radial inclination.

radius or ulna, one line passed through the distal articular surface of the ulna and the other through the medial articular surface of the radius. Ulnar variance was negative when the ulnar articular surface was more proximal with respect to the radial articular surface and positive if it was more distally. Radial inclination was the angle between a line perpendicular to the central axis of the radius or ulna on a line through the ulnar limit of the articular surface of the distal radius, and a line connecting the radial and ulnar limits of the articular surface of the distal radius (*15*). The angles and distances were measured using a computer program (GE PACS, GE Healthcare, Milwaukee, USA) with accuracies of 0.1 mm and 0.1°.

Four observers (one student, one trauma surgeon, one orthopaedic surgeon in training and one orthopaedic surgeon with experience in hand surgery) measured ulnar variance and radial inclination twice on the 20 radiographs taken one month postoperatively at two different moments. There was at least a period of 2 weeks between the first and second round of measurements. At each round ulnar variance and radial inclination were determined with the central axis in the ulna and radius. Ulnar variance and radial inclination were also measured once on X-rays taken two months postoperatively. Bone healing takes place one month after sustaining a closed uncomplicated distal radius fracture and therefore it can be expected that ulnar variance and radial inclination have the same values at 1 and 2 months postfracture. In the present study was investigated which method resulted in smaller differences in ulnar variance and radial inclination when comparing measurements on X-rays of the same wrist taken at different moments.

Intra- and interobserver reliability was determined with the intraclass correlation coefficient on 20 X-rays taken 1 month postoperatively. Interobserver reliability was also determined with Cronbach's alfa. An intraclass correlation coefficient of more than 0.8 indicates excellent reliability, between 0.6 and 0.81 reliability is substantial, between 0.41 and 0.60 moderate, between 0.21 and 0.40 fair and between 0 and 0.20 slight (*15*). Cronbach's alfa values of more than 0.7 suggest a good reliability, but for clinical application it should be greater than 0.9 (*5*). Paired student's t-test was used to determine

Table I. — Intraobserver reliability for ulnar variance with the central axis through the radius and ulna measured by four observers

Central axis	Observer	UV round 1		UV round 2		Mean difference	SD of difference	ICC
		Mean	SD	Mean	SD			
Radius	1	1.2	2.1	0.9	1.9	-0.2	1.2	0.91 (0.77-0.96)
	2	0.1	2.2	0.4	1.9	0.3†	0.5	0.98 (0.95-0.99)
	3	0.3	2.0	0.4	2.4	0.1	0.9	0.96 (0.90-0.98)
	4	1.0	1.9	0.9	1.8	-0.2	0.7	0.97 (0.92-0.99)
Ulna	1	0.8	1.9	0.7	2.0	-0.2	1.4	0.87 (0.69-0.95)
	2	-0.1	2.3	0.1	2.1	0.1	0.5	0.99 (0.97-1)
	3	0.8	1.8	0.6	2.1	-0.2	0.7	0.96 (0.91-0.99)
	4	0.6	2.0	0.6	1.9	0.1	0.5	0.98 (0.95-0.99)

N = 20, UV : ulnar variance, mean UV in mm, SD : standard deviation, ICC : intraclass correlation coefficient (95% confidence interval), † $P < 0.05$.

Table II. — Intraobserver reliability for radial inclination with the central axis through the radius and ulna measured by four observers

Central axis	Observer	RI round 1		RI round 2		Mean difference	SD of difference	ICC
		Mean	SD	Mean	SD			
Radius	1	22.2	5.2	22.6	4.3	0.5	2.2	0.96 (0.86-0.98)
	2	21.5	4.4	22.0	3.6	0.5	1.5	0.96 (0.91-0.99)
	3	23.0	4.6	23.9	4.1	0.2	2.2	0.93 (0.82-0.97)
	4	22.0	4.7	22.6	4.5	0.6	2.4	0.93 (0.81-0.97)
Ulna	1	25.8	5.2	25.8	4.8	0.0	1.9	0.97 (0.92-0.99)
	2	24.9	4.7	25.1	4.1	0.2	2.2	0.94 (0.84-0.97)
	3	23.3	3.7	24.3	4.0	1.1†	1.9	0.92 (0.80-0.97)
	4	25.6	4.8	25.5	4.2	-0.1	1.3	0.98 (0.95-0.99)

N = 20, RI : radial inclination, mean values RI in degrees, SD : standard deviation, ICC : Intraclass correlation coefficient, † $P < 0.05$.

Table III. — Interobserver reliability for ulnar variance and radial inclination with the central axis through the radius and ulna

	Central axis	ICC	Cronbach's alfa
UV	Radius	0.93 (0.85-0.97)	0.95
	Ulna	0.93 (0.87-0.97)	0.94
RI	Radius	0.95 (0.90-0.98)	0.95
	Ulna	0.73 (0.47-0.88)	0.74

N = 20, UV : ulnar variance, RI : radial inclination. ICC : intraclass correlation coefficient (95% confidence interval).

if there were significant differences in ulnar variance and radial inclination between measurements at round 1 and 2 and between radiographs taken at 1 and 2 months post-operatively. Differences among the four observers were investigated with analysis of variance (ANOVA). Statistical significance was defined as $P \leq 0.05$.

RESULTS

Intraobserver reliability for ulnar variance and radial inclination is shown in table I and II. Good to excellent correlations were found both for measurements with the central axis through the radius and ulna. There was a significant difference in ulnar variance for observer 2 with the central axis through the radius ($P = 0.02$) and in radial inclination for observer 3 with the central axis through the ulna ($P = 0.02$).

Interobserver reliability is represented in table III. An excellent reliability was found for measurements with both axes for ulnar variance. However, intraclass correlation and Cronbach's alfa were better for radial inclination with the central axis through the radius than through the ulna.

Differences in ulnar variance and radial inclination between X-rays taken 1 and 2 months post-operatively are shown in table IV and V. Differences in ulnar variance and radial inclination were similar with the central axis through the radius and ulna, however, they were significant for ulnar variance with the axis through the ulna and for radial inclination with the axis through the radius.

ANOVA revealed no significant difference among the four observers with the radius as central axis (ulnar variance $P = 0.15$, radial inclination $P = 0.33$) and with the ulna as central axis (ulnar variance $P = 0.32$, radial inclination $P = 0.16$).

DISCUSSION

Goldfarb *et al* measured ulnar variance based on the long axis of the ulna in normal adolescent wrists and reported an excellent intra- and interobserver reliability. Intraclass correlation for single measures

Table IV. — Differences in ulnar variance measured on X-rays taken 1 and 2 months postoperatively of the same wrist, with the central axis through the radius and ulna by four observers

Axis	Observer	Month 1		Month 2		Mean diff	SD of Mean diff	95% CI of the mean		P-value
		Mean	SD	Mean	SD			Lower	Upper	
Radius	1	1.2	2.1	1.6	1.7	0.4	1.3	-0.2	1.0	0.19
	2	0.1	2.2	0.7	1.9	0.6	1.1	0.1	1.1	0.02
	3	0.3	2.0	0.1	1.9	-0.2	0.5	-0.4	0.0	0.08
	4	1.0	1.9	1.0	1.5	0.0	1.2	0.6	0.6	1.00
Total (N = 80)		0.6	2.1	0.8	1.8	0.2	1.1	0.0	0.4	0.11
Ulna	1	0.8	1.9	1.2	1.4	0.4	1.2	-0.2	0.9	0.17
	2	-0.1	2.3	0.4	1.8	0.5	1.1	0.0	1.0	0.05
	3	0.8	1.8	0.6	1.8	-0.2	0.5	-0.4	0.0	0.05
	4	0.6	2.0	0.9	1.7	0.3	1.0	-0.2	0.8	0.20
Total (N = 80)		0.5	2.0	0.8	1.7	0.3	1.0	0.0	0.5	0.03

N = 20, UV : ulnar variance, mean UV in mm, CI : confidence interval.

Table V. — Differences in radial inclination measured on X-rays taken 1 and 2 months postoperatively of the same wrist, with the central axis through the radius and ulna by four observers

Axis	Observer	Month 1		Month 2		Mean diff	SD of Mean diff	95% CI of the mean		P-value
		Mean	SD	Mean	SD			Lower	Upper	
Radius	1	22.2	5.2	22.4	4,5	0.2	3.3	-1.3	1.8	0.70
	2	21.5	4.4	22.2	4.1	0.7	1.4	0.0	1.3	0.05
	3	23.1	4.6	24.5	4.1	1.4	3.0	0.0	2.8	0.05
	4	22.0	4.7	22.3	4.0	0.3	2.4	-0.8	1.5	0,49
Total (N = 80)		22.2	4.7	22.9	4.2	0.7	2.6	0.1	1.3	0.02
Ulna	1	25.8	5.2	25.6	4.5	-0.2	3.4	-1.9	1.3	0.72
	2	24.9	4.7	25.0	4.2	0.1	2.6	-1.1	1.3	0.86
	3	23.3	3.7	24.8	4.1	1.5	2.1	0.5	2.5	0.004
	4	25.6	4.8	24.7	4.4	-0.9	3.2	-2.4	0.6	0.24
Total (N = 80)		24.9	4.6	25.0	4.3	0.1	3.0	-0.5	0.8	0.73

N = 20, RI : radial inclination, mean RI in degrees, CI : confidence interval

was 0.98 and 0.97 and Cronbach's alfa 0.97 and 0.98 (*12*). By our knowledge no previous studies reported the reliability of radiological parameters measured with the ulna as central axis in healed distal radius fractures. In the present study intraobserver reliability for ulnar variance ranged between 0.87 and 0.99 and between 0.92 and 0.98 for radial inclination. Interobserver reliability was excellent for ulnar variance (0.93) and substantial (0.73) for radial inclination.

In the study of Kreder *et al* 16 raters performed measurements based on the long axis of the radius on 6 X-rays of healed distal radius fractures with a wide range of deformity. An intraobserver reliability of 0.85 was reported for ulnar variance but only of 0.39 for radial inclination (*15*). Thomason and Smith used the same methods as Kreder *et al* but measurements were performed on digitized X-rays of acute distal radius fractures before treatment. An intraclass correlation coefficient of 0.73 was found

for radial inclination and 0.74 for ulnar variance (*24*). It was not described if X-rays were taken with the arm and wrist in a standardized position in the two previous studies. In the present study a better intra-observer reproducibility was found with intraclass correlations ranging between 0.91 and 0.99 for ulnar variance and between 0.93 and 0.96 for radial inclination. Kreder *et al* reported an intraclass correlation coefficient for interobserver reliability of 0.82 for ulnar variance and of 0.38 for radial inclination (*15*). Thomason and Smith found 0.70 for ulnar variance and 0.79 for radial inclination (*24*). In the present study interobserver reliability was 0.93 for ulnar variance and 0.95 for radial inclination. The poorer results for radial inclination in the study of Kreder *et al* may be explained by the fact that measurements were performed on non digitized X-rays. In the study of Thomason and Smith this may be caused by the fact that measurements were determined on acute fractures before reduction. In these circumstances it may be more difficult to find landmarks. The differences in reproducibility may also be influenced by the fact that in the present study only extra-articular fractures were included in contrast with the studies of Kreder *et al* and Thomason and Smith.

In the present study the central axis of the radius was determined by measuring the middle of the radius at 3 and 5 cm distance below the mid-region of the proximal lunate articular surface of the distal radius as has been described by Kreder *et al* (*15*). Others used a distance of 4 and 8 cm (*6*) or 3 to 6 cm (*9*). Others did not describe how the central axis of the radius was determined (*10*,*26*). In the present study the axis of the ulna was determined with the same method as the central axis of the radius. When measuring radial inclination in wrists with Kienböck's disease, Matsushita *et al*, used the long axis of the ulna and determined the centre of the ulnar shaft at 2 and at 4 or 5 cm proximally from the articular surface of the ulnar head (*17*). In other studies using the long axis of the ulna to evaluate distal radius fractures was not exactly described how the central axis of the ulna was determined (*1*,*3*,*27*).

Measurements on X-rays taken at 1 and 2 months postoperatively of the same wrist were similar in the present study and differences were not greater with the axis through the radius than through the ulna. It was assumed that fractures had healed at 1 month and that the morphology would remain unchanged one month later. This may not be correct because it has been shown that ulnar variance and radial inclination still may change up to 3 months after sustaining a distal radius fracture (*16*). In the present study a small increase in ulnar variance was found at 2 months, but no loss in radial inclination.

Using the long axis of the ulna instead of the radius did not improve intra- and interobserver reliability when determining ulnar variance and radial inclination in healed distal radius fractures. In most studies the central axis through the radius has been used and therefore the method with a line through the long axis of the radius can remain the standard method. Another reason the keep on using the central axis of the radius is that radiological parameters determined with different axes may not be comparable. In the present study slightly higher values of radial inclination and lower values of ulnar variance were found with the axis of the ulna than with the axis of the radius.

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