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ORIGINAL RESEARCH

Assessment of Volar Tilt Measurements with Variations in X-Ray Beam Centralization Along the Longitudinal Axis of the Radius

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ABSTRACT

Introduction: The need for adequate restoration of volar tilt to prevent potentially debilitating sequelae in fractures of the distal radius is well documented. The relationship of this measure to variations in X-ray beam centralization along the longitudinal axis of the radius was investigated.
Methods: Twenty-one healthy, skeletally mature male volunteers were selected. Radiographs of the distal radius using both a mini C-arm and a portable X-ray machine were taken at four positions: centered on the radial styloid, 3 cm distal, 3 cm proximal, and 5 cm proximal to the styloid. Two orthopaedic faculty independently measured volar tilt on each of the 16 remaining sets and inter- and intraobserver reliability were measured.
Results: On both the mini C-arm and the portable X-ray images, the measured volar tilt increased as the beam moved proximally along the longitudinal axis of the radius. The mini C-arm group averaged a difference of 1.4 deg/cm offset, with an average decrease in volar tilt of 11 deg from the most proximal to the most distal centralization. The standard X-ray group averaged a difference of 0.28 deg/cm of offset, with an average decrease of 2 deg of volar tilt from the most proximal to the most distal centralization.
Discussion: This study demonstrates a clear relationship between beam centralization and volar tilt measurement. As the beam is moved proximally, volar tilt increases. Owing to a greater angle of measurement, this variance is much greater when using the mini C-arm than with standard X-ray.
Keywords: Volar tilt; Radiography; Inter- and intraobserver reliability.

INTRODUCTION

Distal radius fractures are among the most common injuries encountered by orthopaedic surgeons. They account for 15-20% of all extremity fractures, and represent one-sixth of all fractures treated in emergency departments (1). Several radiographic parameters have been established to evaluate these fractures on both posteroanterior (PA) and lateral views. Parameters evaluated on the PA view include radial inclination, radial height, ulnar variance, and articular step-off.

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Volar tilt, as determined on the lateral view, is an angle formed by a line drawn perpendicular to the shaft of the radius and one drawn in the dorsal-to-palmar direction along the distal articular surface of the radius (Figure 1). Volar tilt has an accepted normal range of 0-28 degrees (average of 11-12) (1). The importance of re-establishing volar tilt to at least neutral for dynamic wrist function is well documented (1,2). Residual dorsal angulation results in such conditions as dorsal intercalated segment instability, persistent pain (3), dorsal carpal subluxation (4), decreased grip and pinch strength (5), altered pressure distribution at the radiocarpal joint (6), and incongruency of the distal radioulnar joint (7).

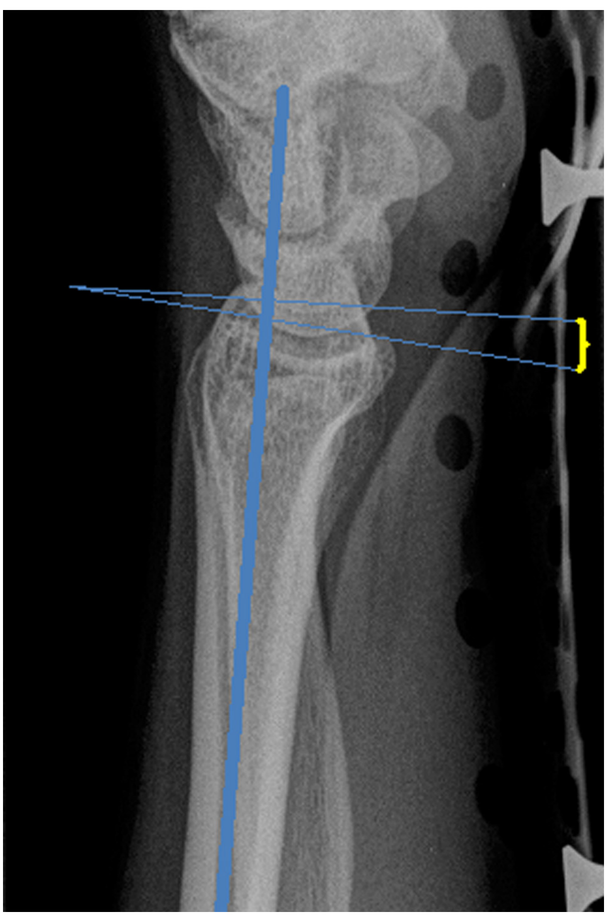

Figure 1. Volar tilt is measured on lateral view as an angle between a line perpendicular to the radius shaft and its distal articular surface.

Previous studies have demonstrated that variations in radiographic techniques alter volar tilt measurements. These alterations can involve positioning of the forearm or X-ray beam. Johnson and Szabo (8) showed that a 5-degree rotational change in the forearm caused a 1.6-degree change in volar tilt. Supination increased and pronation decreased the measure. Friberg and Lundstrom (9) demonstrated that directing the beam 15 degrees cephalad decreased volar tilt.

In clinical practice splints or casts often obscure anatomic landmarks, making it easy for the center of the beam to vary between X-rays. In the case of taking a lateral forearm film, it may be difficult to center the beam directly over the radial styloid. Thus, the centralization of the beam may change at follow-up visits. This variability may lead to variability in the measurement of volar tilt, which may erroneously influence treatment decisions. The present study aims to evaluate whether changes in centralization of the X-ray beam along the longitudinal axis of the radius affect measurements of volar tilt.

MATERIALS & METHODS

After IRB approval was obtained, 21 skeletally mature male volunteers with no prior history of fracture, operative intervention, congenital anomalies, or signs or symptoms of an upper extremity disorder were selected, and informed consent was obtained. A radiolucent jig was constructed. The jig ensured neutral forearm rotation by using a standard aluminum wrist splint, and enabled calibrated movements along the longitudinal axis of the radius.

The participants' arms were placed in 90 degrees of shoulder abduction, 90 degrees of elbow flexion and neutral forearm rotation (Figure 2), the standard position for a lateral radiograph of the distal forearm and wrist (10). Both the OEC 6600 mini C-arm and the Siemens Sireskop 5 portable X-ray machines were used to obtain radiographic images at four different positions. Position 0: centered on the radial styloid, position +3: centered 3 cm proximal to the radial styloid, position +5: centered 5 cm proximal to the radial styloid, and position -3: centered 3 cm distal to the radial styloid (Figure 3). To ensure that any variations in volar tilt were due solely to changes in beam position, the extent to which the cortices of the distal scaphoid pole and the capitate head were overlain by the palmar cortex of the pisiform was assessed for each set of radiographs. This scaphopisocapitate relationship needed to remain constant among the different films (10). Five sets of radiographs were excluded due to variation in this relationship, leaving 16 sets of X-rays.

Figure 2. For the standard position for a lateral radiograph of the distal forearm and wrist, the arm was positioned in 90 degrees of shoulder abduction, 90 degrees of elbow flexion, and neutral forearm rotation.

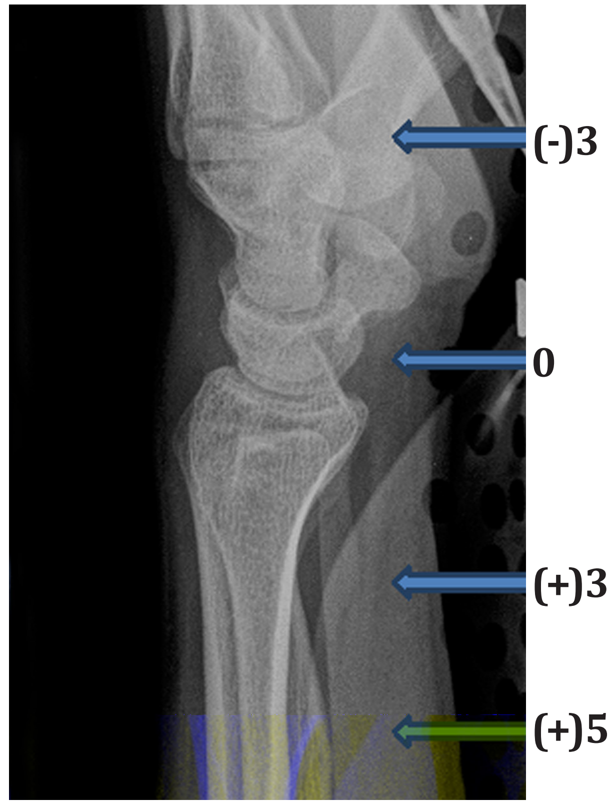

Figure 3. Images were taken at four different positions: position 0—centered on the radial styloid; position +3—centered 3 cm proximal to the radial styloid; position +5—centered 5 cm proximal to the radial styloid; position -3—centered 3 cm distal to the radial styloid.

After the acceptable sets of radiographs were determined, two orthopaedic faculty observers were chosen to measure volar tilt. The standard method of measurement as described above was used, and each radiograph was measured twice by both observers. The observers were blinded to the position of the beam.

As another measure to evaluate the centralization of beam position over the radial styloid, the distance between the shadow of the proximal articular surface of the scaphoid and that of the proximal articular surface of the lunate were measured. We termed this distance the scapholunate proximal articular surface (SPAS) distance.

RESULTS

The mean volar tilt values found at the four positions for both the mini C-arm and standard X-ray radiograph sets are listed in Table 1. Both of these data sets yielded linear relationships (Figure 4). The slope of the C-arm group can be described with the equation $y=1.3986x + 8.1517$ ($R^2=0.993$), and the same for the standard X-ray is $y=0.2776x + 8.5531$ ($R^2=0.9564$).

Table 1. The mean volar tilt measured at the four positions for both the mini C-arm and standard X-ray.

Mini C-arm Mean Palmar Tilt (degrees)	Position (degrees)	Position (degrees)	Standard X-ray Mean Palmar Tilt (degrees)
4.3	-3	-3	7.9
7.7	0	0	8.3
12.1	+3	+3	9.3
15.5	+5	+5	10.1

Statistical analysis of the mini C-arm data yielded the following information. Paired-samples t-test showed t-value of 6.89 ($p<0.0001$). This shows a statistical difference between observers (average measured difference 2.92 degrees). The average change in volar tilt measure for every 1 cm beam offset was 1.4 degrees, and an average increase of 11.2 degrees from -3cm (distal) position to +5cm (proximal) was found. One-way ANOVA showed a composite F value of 37.66 ($p<0.0001$) showing a significant difference between all data points (beam positions).

After applying statistical analysis to the standard X-ray data, the following information was found. No statistical difference between the two separate measurements made by individual observers or between the different observers was found. A statistically significant difference was found between the +5 and 0 position as well as between the +5 and -3 position ($p<0.05$). The average increase in volar tilt measurement from the -3cm (distal) to +5cm (proximal) position was 2.2 degrees.

The scapholunate proximal articular surface (SPAS) distance was also calculated on these films. The SPAS distance was found to increase as the beam moved from distal to proximal (Figure 5). A statistically significant difference was found between all groups ($p<0.05$) with the exception of +3 to +5 cm ($p=0.053$).

DISCUSSION

Distal radius fractures are one of the most common fractures encountered by orthopaedists. They constitute approximately 15-20% of all extremity fractures (1). Failure to adequately reduce these fractures can lead to the development of several debilitating conditions. Volar tilt is one of the primary measures used to establish adequate reduction, and ensuring that it is measured correctly is of vital importance. Prior studies by Johnson and Szabo (8) showed that rotational changes can affect this measure, and Frieberg and Lundström (9) showed that tilting the beam cephalad also affected the measure. The current study clearly demonstrates that changes in

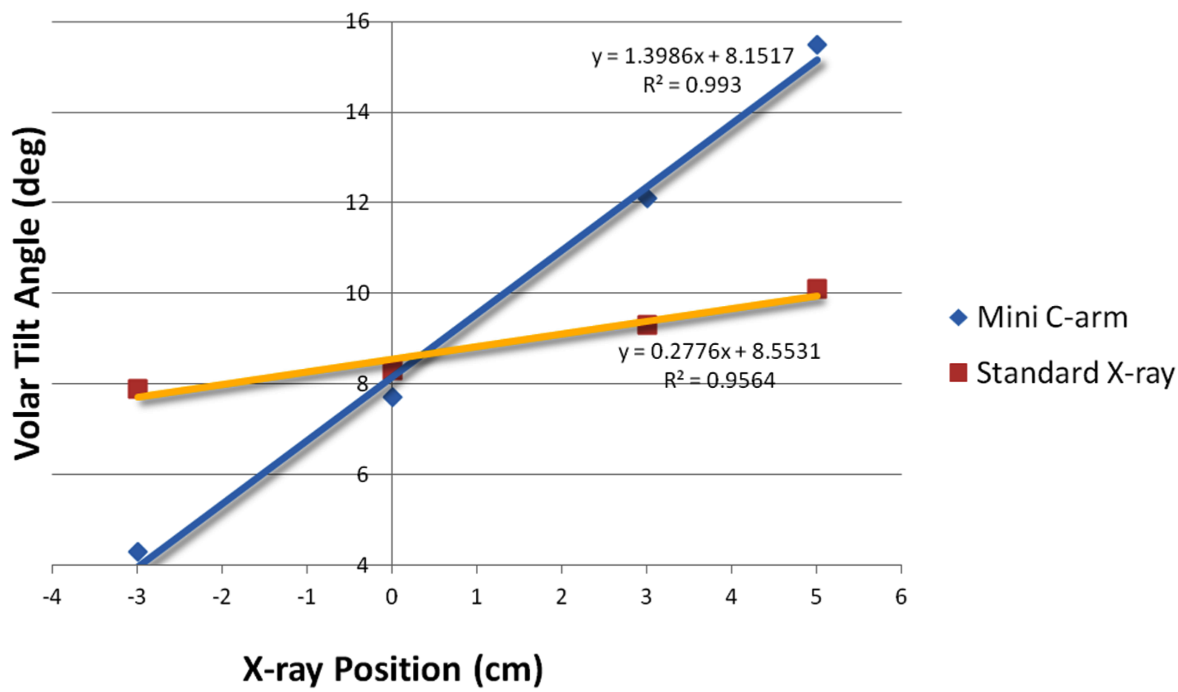

Figure 4. The average volar tilt at the four positions for both the mini C-arm and standard X-ray radiograph yielded linear relationships.

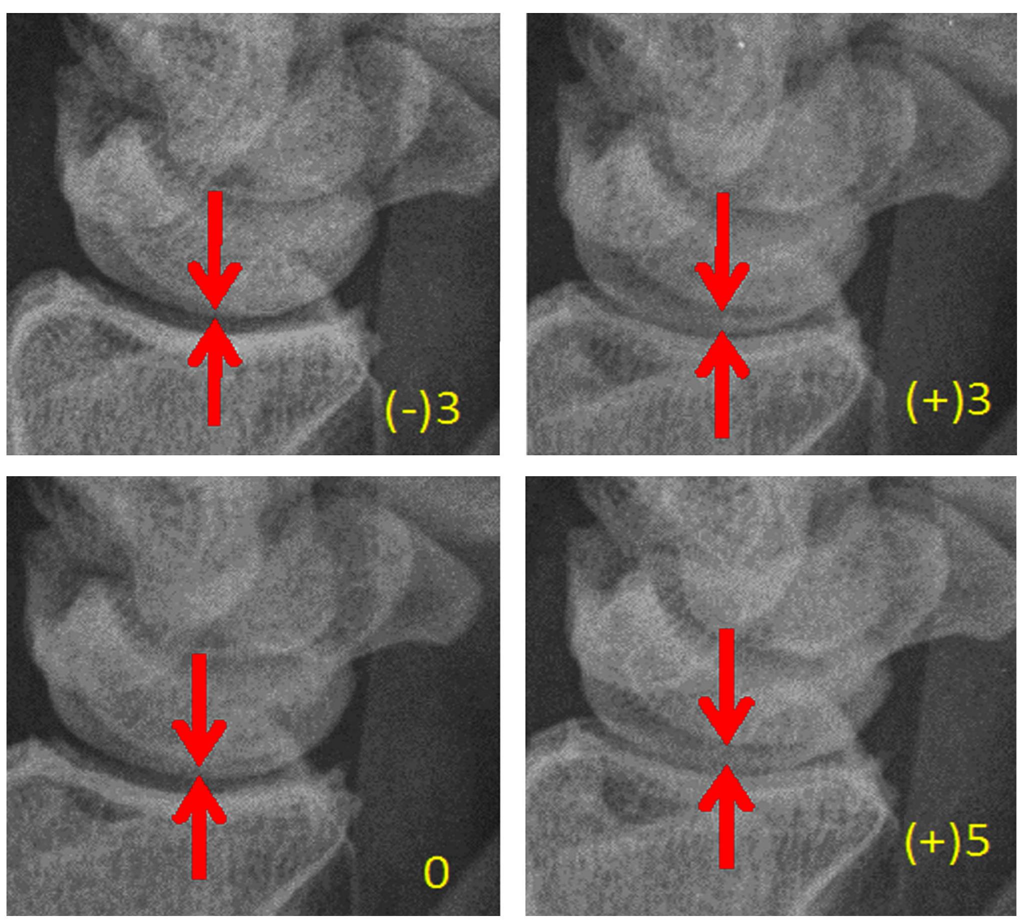

Figure 5. The scapholunate proximal articular surface (SPAS) distance was found to increase as the beam moved from distal to proximal.

beam centralization along the longitudinal axis of the radius causes variability in volar tilt measurements, with an increase in volar tilt as the beam is moved proximally.

The great disparity in volar tilt variance (11.2 degrees vs 2.2 degrees) between the mini C-arm and the standard X-ray can be explained mathematically. The distance from wrist to beam source when using the mini C-arm was 36 cm, and when using standard X-rays was 110 cm. Thus, moving the respective beams along the longitudinal axis of the radius had a much greater effect on the angle between the beam source and wrist when using the mini C-arm vs the standard X-ray. This increased angle variance over the longitudinal excursion of the mini C-arm beam led to an increased variance in volar tilt measurement.

The SPAS distance as described above also varies with longitudinal changes in beam position. Thus, this distance can be used to estimate consistency of beam position between images. This measurement could be of particular usefulness in the case of comparing mini C-arm images, which are more prone to variations in volar tilt measures with inconsistent beam positions. Clinically, this implies that standard X-rays should be chosen over the mini C-arm to evaluate palmar tilt because they are less sensitive to changes in beam centralization. For standard X-rays, an 8 cm variance produces only 2.2 degrees of difference in volar tilt, and this difference is less likely to affect a decision about treatment.

CONCLUSIONS

This study demonstrates a clear relationship between beam centralization and volar tilt value. As the beam is moved proximally, volar tilt increases. Owing to a greater angle of measurement, this variance is much greater when using the mini C-arm than with standard radiography. Thus, it is our recommendation that standard X-rays be preferred over the mini C-arm to evaluate palmar tilt. However, if the mini C-arm is used, the distance between the proximal articular surfaces of the scaphoid and lunate can be used as an approximation of the consistency of beam position.

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