The Dorsal Tangential X-Ray View to Determine Dorsal Screw Penetration During Volar Plating of Distal Radius Fractures

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Purpose To evaluate whether the dorsal tangential view (DTV) allows for reliable and valid *in vivo* measurement of the distance between screw tips and the dorsal radial cortex (STCD) during volar plating of distal radius fractures.

Methods Subjects included 22 patients with displaced distal radius fractures who had volar plate osteosynthesis. We performed standardized DTV images intraoperatively. After surgery, we performed computed tomography (CT) scans with reconstructions parallel to the distal screws. Three independent observers blinded to the study protocol measured the STCD on the basis of the DTV images and CT reconstructions. We calculated inter- and intraobserver reliability and the correlation between STCD values measured with DTV images and CT scans.

Results Eleven screws were changed intraoperatively. We observed no cases of postoperative screw perforations. Inter- and intraobserver reliability of STCD measurement was good when measured with DTV images and excellent when measured on the basis of CT reconstructions. Statistical analysis showed a good correlation between mean STCD values measured with DTV and CT.

Conclusions The DTV allowed *in vivo* evaluation of the dorsal radial cortex and enabled reliable assessment of the distance between the screw tip and the dorsal cortex. It may allow detection of dorsal screw perforation during volar plating of distal radial fractures. *(J Hand Surg Am. 2015;40(1):27–33. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Diagnostic II.

Key words DTV, screw perforation, volar plating, distal radius, extensor tendon injury.

With increasing use of volar locking plates for distal radius fracture fixation, the incidence of extensor tendon injuries caused by screw perforation through the dorsal cortex of the distal radius is as high as 6%.[1–6] In apex-dorsal fractures in which the dorsal radial cortex is comminuted, measurement for appropriate screw length may be especially difficult.

Several authors have pointed out the limitations of standard anteroposterior and lateral fluoroscopic images in detecting dorsal screw penetration.[7–11] Therefore, the dorsal tangential view (DTV) has been proposed to

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visualize screw tips in relation to the dorsal radial cortex to detect screw perforation, especially at the area of the third extensor tendon compartment.[7–10] This technique may be used to locate screw perforations intraoperatively. In addition, it may represent a valuable postoperative alternative to computed tomography (CT) scanning with less radiation exposure in patients in whom standard postoperative x-rays show a concern for screw penetration.

Some studies have validated the DTV on the basis of human cadavers and found high sensitivity for detecting dorsal screw perforation with this technique.[7,10] Those cadaver studies used non-fractured human radiuses for evaluation.[7,10]

In clinical practice, fractures with an intact dorsal cortex are at lower risk for dorsal penetration compared with fractures with comminuted dorsal cortex.

If DTV images allow for clear visualization of screw tips and the dorsal radial cortex, the screw tip cortex distance (STCD) can be measured and may expedite replacement with a shorter screw when necessary.

Measurement of the STCD in the DTV has not been validated *in vivo* and information regarding the reliability of this method remains sparse. Both are important basic requirements for routine use of a diagnostic method.

The purposes of this study were to evaluate the inter- and intraobserver reliability of this technique and to validate this method *in vivo* on the basis of CT scans with multiplanar reconstructions.

We hypothesized that the DTV may enable reliable intraoperative measurement of the STCD during volar plating and that the measured STCD values would show a good correlation with the STCD measured by CT scanning.

MATERIALS AND METHODS

Our institution's human subject review board approved this study, which was in accordance with the Declaration of Helsinki. Between January and December 2012, we studied 22 consecutive patients (4 men and 18 women; mean age, 58 y; range, 25–79 y) with 9 right and 13 left dorsally displaced distal radius fractures. According to the AO/Orthopaedic Trauma Association classification,[12,13] 2 fractures were type A3, 3 were type B3, and 17 were type C (C1: n = 5; C2: n = 4; and C3: n = 8).

Inclusion criteria were distal radius fractures that had been scheduled for open reduction internal fixation by volar plating and patients' consent to participate in the study. Exclusion criteria were prior injuries or surgeries that could have affected the

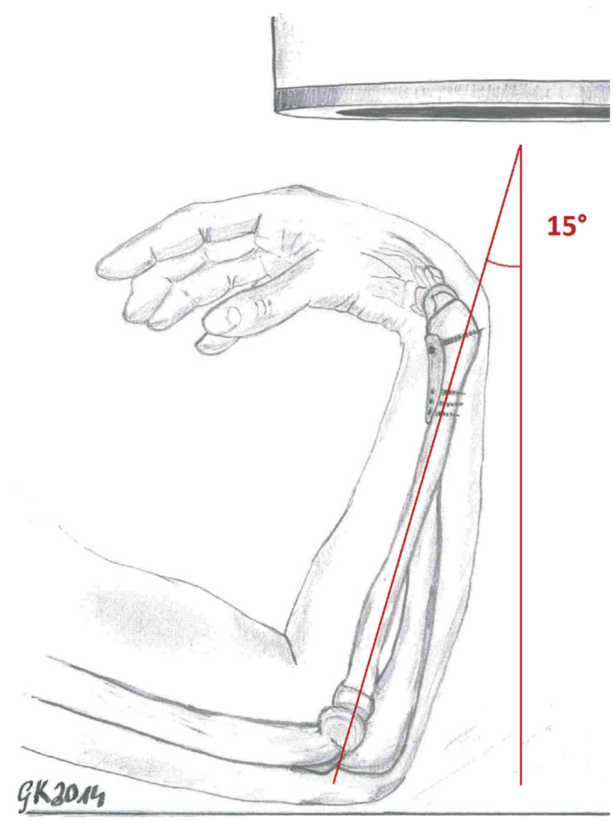

FIGURE 1: The DTV was performed with the wrist held in maximum flexion. The dorsal radial cortex was positioned with 15° inclination to the vertical x-ray beam of the fluoroscope.

anatomy of the distal radius, mental comorbidities that could affect informed consent, fractures that needed intraoperative augmentation, and Smith-type fractures.[14]

All fractures were surgically treated by senior consultants for orthopedic and trauma surgery. In 17 cases we used variable angle locking compression plates (VA-LCPs) (Synthes, Oberdorf, Switzerland) with 4 distal holes and in 5 cases VA-LCP with 5 distal holes. Before surgery we instructed surgeons regarding standardized intraoperative performance of the DTV.

Surgeons obtained the DTV images with the upper arm placed on a horizontal arm table. The proximal forearm was held with 75° of inclination to the horizontal arm table. The wrist was held in maximum flexion. As a result and according to the recommendation of Haug et al,[7] the dorsal cortex of the distal radius was positioned with 15° inclination to the vertical x-ray beam of the fluoroscope (Fig. 1). The surgeons used a sterile goniometer for precise adjustment of forearm inclination.

The tube voltage of the fluoroscope was 84 kV and we used a circular x-ray cover to reduce scattered radiation.

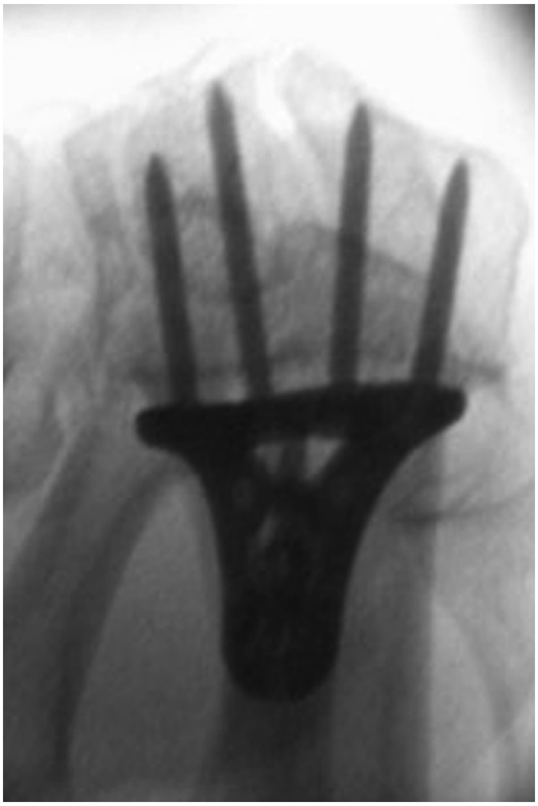

FIGURE 2: The DTV shows the tip of the screws relative to the dorsal radial cortex.

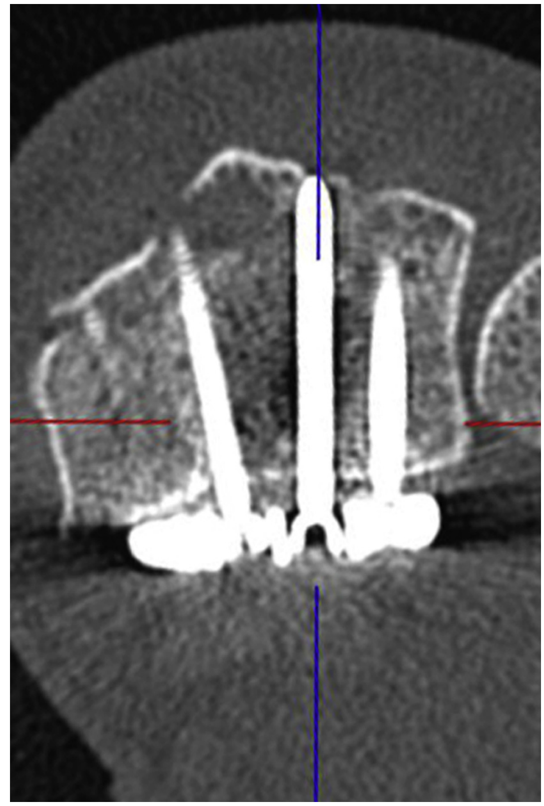

FIGURE 3: The distances between screw tips and dorsal radial cortex were evaluated on the basis of CT reconstructions parallel to the screws.

Postoperatively, we performed CT scans of all surgically treated distal radii with a slice thickness of 1 mm (Somatom Definition Flash, Siemens AG, Erlangen, Germany). Thereafter, we calculated multiplanar reconstructions with the plane parallel to the distal angular-stable screws of the VA-LCP. We used a picture archiving and collection system to assess the images (DTV fluoroscopy images and CT scans) interactively.

Inter- and intraobserver reliability

Three blinded observers measured the STCD of all screws on the basis of fluoroscopic DTV images (Fig. 2) and CT reconstructions (Fig. 3) in randomized order. The distance between the tip of a nonperforating screw and the dorsal cortex was defined as a positive STCD. If a screw perforated the dorsal cortex the STCD became negative.

To address any possible magnification factor of the DTV images, observers measured the distal width of each VA-LCP in the DTV. We calculated the magnification factor as the ratio between the real width and measured mean width of the VA-LCP. Measured STCD values were multiplied with this magnification factor to gain real STCD.

We numbered screws from 1 to 4 (or 5) respectively from radial to ulnar. No observers had been involved in the patients' treatment.

To consider any possible impact of observers' experience on the measurement, we chose a first-year orthopedic surgery resident, a fifth-year orthopedic surgery resident, and an attending orthopedic and trauma surgeon.

Before the study we randomly selected 3 sets of radiographs (DTV images and CT reconstructions) from the collective sample. The observers were instructed on the nuances and subtleties of STCD measurement by reviewing these 3 sets of radiographs as a group. Before the readings, we put these radiographs back into the collective sample in random order. Four weeks later, the readings were repeated to assess intraobserver reliability.

The order of the radiographs was randomized again to prevent possible recollection of the previous viewing. The observers were provided with no feedback and the radiographs were not available to them between readings.

Correlation analysis

We calculated mean STCD values (DTV and CT) from the 6 single values measured during reliability

TABLE 1. Mean STCD Values (in Millimeters) With Coefficient of Variation (CV), Range, and Probability of Normal Distribution Measured on the Basis of DTV and CT

DTV	Hole 1 (n = 22)	Hole 2 (n = 22)	Hole 3 (n = 22)	Hole 4 (n = 22)	Hole 5 (n = 5)	Mean
STCD (CV)	1.7 (0.9)	1.9 (0.8)	2.1 (0.7)	2.1 (0.7)	2.4 (0.7)	1.9 (0.5)
Range	(0−8.4)	(0.1−9.2)	(0.1−8.6)	(0−7.7)	(0.2−5.9)	(0−9.2)
Normal distribution (*P* value)	< .01	< .01	.15	.03	.13	.03
CT	**Hole 1 (n = 22)**	**Hole 2 (n = 22)**	**Hole 3 (n = 22)**	**Hole 4 (n = 22)**	**Hole 5 (n = 5)**	**Mean**
STCD (CV)	1.6 (0.7)	2.3 (0.7)	2.7 (0.8)	2.2 (0.9)	3.0 (1.0)	2.1 (0.5)
Range	(0.1−6.8)	(0.1−6.2)	(0.1−9.7)	(0.1−8.5)	(0−9.1)	(0−9.7)
Normal distribution (*P* value)	.06	.09	.01	.01	.39	.42

TABLE 2. Interobserver Reliability of STCD Measurement on the Basis of DTV (ICC Values [95% Confidence Intervals])

Observers	Hole 1 (n = 22)	Hole 2 (n = 22)	Hole 3 (n = 22)	Hole 4 (n = 22)	Hole 5 (n = 5)	Mean
1/2	0.64 (0.31−0.83)	0.70 (0.39−0.87)	0.64 (0.30−0.83)	0.81 (0.60−0.92)	0.79 (−0.07 to 0.98)	0.71
1/3	0.74 (0.48−0.89)	0.71 (0.40−0.87)	0.58 (0.01−0.71)	0.74 (0.47−0.88)	0.73 (−0.20 to 0.97)	0.70
2/3	0.84 (0.66−0.93)	0.79 (0.55−0.92)	0.42 (0.23−0.80)	0.78 (0.54−0.90)	0.83 (0.04−0.98)	0.73
Mean	0.74	0.73	0.55	0.78	0.78	0.72

testing and the correlation between mean STCD measured with DTV and mean STCD measured on the basis of CT reconstructions.

Statistical analysis

We calculated the intraclass correlation coefficient (ICC) to evaluate the inter- and intraobserver reliability of STCD measurement.

According to the recommendations of Landis and Koch,[15] we considered an ICC value of more than 0.8 as excellent, between 0.6 and 0.8 as good, between 0.4 and 0.6 as moderate, and less than 0.4 as poor.

To evaluate any possible statistical difference between single ICC values, we calculated the 95% confidence intervals.

According to the recommendations of Doornberg et al,[16] we considered differences between single ICC values as significant when upper and lower boundaries of the 95% confidence intervals did not overlap.

We used a Student *t* test to calculate statistical differences between linear data. The coefficient of variation was calculated for mean STCD values and Shapiro−Wilk test was used to evaluate the probability of normal distribution of linear data (*P* value).

We performed a Spearman correlation analysis (rs) to evaluate the correlation between STCD measured with DTV and CT reconstructions. We considered a correlation coefficient of rs less than 0.3 as weak, between 0.3 and 0.7 as moderate, and more than 0.7 as high. Statistical significance was defined as $P \leq .05$.

RESULTS

During the surgeries, surgeons considered 11 screws to be perforating through the dorsal cortex in the DTV. These screws were changed. We found no cases of screw perforations in the final DTV images and CT reconstructions. Mean STCD was 1.9 mm (range, 0.0−9.2 mm) when measured on the basis of DTV images and 2.1 mm (range, 0.0−9.7 mm) when measured on the basis of CT scanning (Table 1). The probability of normal distribution was significant for mean STCD values when measured with DTV images ($P = .03$). Mean STCD values measured on the basis of CT did not show statistically significant normal distribution (Table 1). The difference between mean STCD values measured with DTV and mean STCD values measured on the basis of CT reconstructions was statistically significant ($P < .001$).

Inter- and intraobserver reliability

Interobserver reliability of STCD measurement was good when performed on the basis of DTV images. It

TABLE 3. Interobserver Reliability of STCD Measurement on the Basis of CT (ICC Values [95% Confidence Intervals])

Observers	Hole 1 (n = 22)	Hole 2 (n = 22)	Hole 3 (n = 22)	Hole 4 (n = 22)	Hole 5 (n = 5)	Mean
1/2	0.92 (0.81−0.97)	0.85 (0.67−0.94)	0.95 (0.88−0.98)	0.94 (0.85−0.97)	0.44 (−0.58 to 0.92)	0.82
1/3	0.93 (0.85−0.97)	0.95 (0.88−0.98)	0.96 (0.90−0.98)	0.98 (0.95−0.99)	0.96 (0.67−0.99)	0.96
2/3	0.92 (0.82−0.97)	0.91 (0.78−0.96)	0.94 (0.86−0.98)	0.94 (0.85−0.97)	0.43 (−0.59 to 0.92)	0.83
Mean	0.92	0.90	0.95	0.95	0.61	0.87

TABLE 4. Intraobserver Reliability of STCD Measurement on the Basis of DTV (ICC Values [95% Confidence Intervals])

Observers	Hole 1 (n = 22)	Hole 2 (n = 22)	Hole 3 (n = 22)	Hole 4 (n = 22)	Hole 5 (n = 5)	Mean
1	0.93 (0.84−0.97)	0.86 (0.67−0.94)	0.75 (0.48−0.89)	0.81 (0.59−0.91)	0.51 (−0.52 to 0.93)	0.82
2	0.74 (0.46−0.88)	0.82 (0.60−0.93)	0.54 (0.16−0.78)	0.93 (0.84−0.97)	0.95 (0.62−0.99)	0.77
3	0.85 (0.68−0.94)	0.82 (0.61−0.93)	0.66 (0.34−0.84)	0.55 (0.18−0.76)	0.77 (−0.11 to 0.97)	0.72
Mean	0.84	0.83	0.65	0.76	0.74	0.77

improved significantly ($P < .001$) to excellent when measured on the basis of CT reconstructions (Tables 2, 3).

Likewise, intraobserver reliability was good when measured with DTV images and improved significantly ($P < .001$) to excellent when measured on the basis of CT reconstructions (Tables 4, 5). We found no statistical differences regarding single ICC values between different observers or different screw positions (different holes in the VA-LCP).

Correlation analysis

Correlation analysis showed a good and significant mean correlation ($rs = 0.764$; $P < .001$) between mean STCD values measured with DTV images and CT reconstructions (Table 6). Excellent correlations were found for screws in the third and fifth plate holes. These screws are usually the ones that penetrate the third and fourth extensor tendon compartments. Screws in the first plate hole, which are usually situated at the second dorsal compartment, showed the lowest correlation. Overall, mean correlation between DTV and CT reconstructions was good for all screw positions independent of the plate hole through which the screws had been introduced (Table 6).

DISCUSSION

Our results confirmed the hypothesis that both DTV and CT scans enable reliable measurement of the STCD. Furthermore, STCD values measured with DTV images showed good and excellent correlations with those measured on the basis of CT reconstructions.

In cases where patients present after open reduction internal fixation with extensor tendon symptoms and where standard postoperative x-rays raise the concern of screw perforation, the DTV method may be an adequate and cost-effective alternative to CT scanning with minimal radiation exposure.

We changed 11 screws intraoperatively because they protruded beyond the dorsal cortex. In the postoperative evaluation with CT, none of the changed screws perforated the cortex. This suggests that the proposed technique may have good sensitivity in detecting screw perforation. Because it is unknown how many screws actually perforated the cortex before they were changed, the specificity of DTV imaging cannot be estimated.

As expected, inter- and intraobserver reliability of STCD measurement was slightly but significantly better when assessed on the basis of CT reconstructions. This could be because in cases of dorsal comminution precise localization of the dorsal cortex may be easier with CT compared with DTV images.

Overall, assessment of the STCD with DTV images showed good ICC values in almost all single measurements.

Mean STCD values measured on the basis of the DTV were slightly lower compared with those measured with CT reconstructions. This difference (0.2 mm) may be because measurement of the STCD with multiplanar CT reconstructions was performed in the plane of the angular stable screws along the axis of the screws, whereas the DTV images were performed with the dorsal radial cortex in 15° inclination to the

TABLE 5. Intraobserver Reliability of STCD Measurement on the Basis of CT (ICC Values [95% Confidence Intervals])

Observers	Hole 1 (n = 22)	Hole 2 (n = 22)	Hole 3 (n = 22)	Hole 4 (n = 22)	Hole 5 (n = 5)	Mean
1	0.62 (0.27−0.82)	0.72 (0.41−0.88)	0.95 (0.87−0.98)	0.94 (0.86−0.98)	0.99 (0.87−1.00)	0.82
2	0.88 (0.73−0.95)	0.94 (0.84−0.97)	0.71 (0.42−0.87)	0.94 (0.87−0.97)	0.31 (−0.67 to 0.90)	0.84
3	0.91 (0.81−0.96)	0.80 (0.57−0.92)	0.87 (0.71−0.94)	0.96 (0.90−0.98)	0.98 (0.83−0.99)	0.89
Mean	0.80	0.82	0.84	0.95	0.76	0.85

TABLE 6. Spearman Correlation Coefficient (rs) Between STCD Values Measured on the Basis of DTV and CT

	Hole 1 (n = 22)	Hole 2 (n = 22)	Hole 3 (n = 22)	Hole 4 (n = 22)	Hole 5 (n = 5)	Mean
Spearman rho	0.713	0.776	0.818	0.718	0.900	0.764
P	< .001	< .001	< .001	< .001	< .001	< .001

x-ray beam of the fluoroscope. This resulted in a slightly different projection of the STCD. As a result, in cases where the screw tips were close to the cortex they may have projected as slightly perforated. Haug et al[7] stated that the length of screws that did not perforate the dorsal cortex could be adequately measured on the basis of CT scans. In contrast, the length of screws that perforated the cortex was overestimated in their study. This phenomenon has been previously described as the "blooming effect," which makes objects with higher densities appear larger in CT scans compared with objects with low density.[7,17,18]

In our study, no screws perforated the dorsal cortex, and therefore we do not think that the blooming effect compromised our results.

The most recent study performed by Haug et al[7] evaluated the correlation between the actual penetration length of the screws measured with a digital caliper under direct visualization and the penetrating length measured on the DTV image. They evaluated different projection angles between 5° and 20° of inclination. The highest correlation between actual screw length and projected screw length in the DTV was at 15° inclination of the forearm relative to the x-ray beam. They concluded that the ideal angle of inclination required to minimize the risk of implanting over-long screws was 15°. According to this recommendation, we used 15° inclination as the standard setting for our study. However, in daily clinical practice, DTV images should be performed as a live view while changing the angles between 5° and 20° to see whether screw tips penetrate the dorsal cortex.

Several studies evaluated the value of the DTV image in detecting dorsal screw perforation.[7−10] Ozer and Toker[9] performed intraoperative DTV images and standard anteroposterior and lateral images in 27 patients during volar plating of distal radius fractures. They performed a series of DTV images in different angles until the Lister tubercle was seen in its full height. With this technique 11 cases of dorsal screw perforations were detected that could not be visualized on standard anteroposterior and lateral views. However, the authors did not validate the detected cases of screw perforation by CT or 3-dimensional fluoroscopy. Therefore, neither the sensitivity nor specificity of this method could be assessed.

More recently, Ozer et al[10] evaluated DTV imaging on the basis of human cadaver radiuses. They inserted screws penetrating 1 to 3 mm into un-fractured distal radiuses. Two board-certified surgeons evaluated anteroposterior, lateral, oblique, and DTV images for screw perforation. They found a high sensitivity of the DTV to detect screw perforation at the third and fourth dorsal compartments. For detection of screw perforation into the second dorsal compartment, the 45° supination view showed higher sensitivity compared with the DTV. Therefore, the authors concluded that in addition to DTV images, intraoperative 45° oblique images should be performed to avoid screw perforation.

This is in accordance with our findings. In our study, screws in the third and fifth screw holes, which are usually situated at the areas of the third and fourth dorsal compartments, showed the highest correlation between STCD values measured by DTV and CT. Likewise, screws in the first hole, which are at risk of perforating the second compartment, showed the lowest correlation between DTV and CT. We agree with the recommendations of Ozer et al[10] that additional oblique supination and pronation views may improve visualization of screw perforation.

Our study has several limitations. We calculated the magnification factor of the DTV images according to the ratio of real width of the VA-LCP and measured width of the VA-LCP. In cases of improper (not perpendicular) projection, the measured width of the plate could be too small, which would result in overestimation of the measured STCD values.

We included 3 type B3 and 5 type C1 fractures in the study. These fracture patterns usually include simple fractures of the dorsal cortex. In our experience, measurement of the appropriate screw length is easier in these fractures compared with multi-fragmentary type A3 or C2/C3 fractures, and as a result could bias our findings. Mean STCD values measured by CT were not normally distributed. Furthermore, mean STCD values showed coefficients of variation between 0.5 and 0.99. This suggests a relevant heterogeneity in the distribution of single STCD values that may compromise their statistical comparability.

We obtained DTV images with the forearm in 15° inclination to the x-ray beam. As previously discussed, owing to variation in anatomy, this projection may not have been optimal in all cases. Instead, in daily clinical practice we recommend performance of a live view while changing angles between 5° and 20° to assess whether screw tips penetrated the dorsal cortex.

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