Intraoperative evaluation of dorsal screw prominence after polyaxial volar plate fixation of distal radius fractures utilizing the Hoya view: a cadaveric study

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Abstract

Background The irregular nature of the dorsal surface of the distal radius makes it difficult to detect prominent screws with volar plate fixation for distal radius fractures using standard fluoroscopic images. This study evaluates the accuracy of a new radiographic method, the Hoya view, for the assessment of dorsal cortical screw penetration with volar plate fixation.

Methods Eight cadaveric upper extremities underwent application of a volar distal radius plate with polyaxial locking screws placed distally. Utilizing a mini C-arm, lateral and Hoya views were obtained with notation of any dorsal cortical screw prominence. Dissection of the cadavers was then performed for direct visualization of screw prominence. The screws were then exchanged sequentially for screws 2-mm longer than their initial measurements with repeated imaging and direct visualization.

Results The Hoya view revealed that 9.4 % of the screws penetrated the dorsal cortex with an average screw prominence of 1.08 mm (range 0.5–2 mm). None of the six prominent screws were detected with lateral views. With the Hoya view, six of six prominent screws were identified. With

locking screws exchanged for screws 2-mm longer, 76.6 % of the screws had violated the dorsal cortex; of these, 24.5 % were detected with lateral imaging versus 100 % with the Hoya view.

Conclusions This study supports the intraoperative use of the Hoya view to evaluate screw length and dorsal cortical screw penetration in volar plate fixation of distal radius fractures. However, this view may be difficult to obtain in patients with limitations in elbow or shoulder range of motion.

Keywords Distal radius · Fracture · Hoya view · Screw prominence · Volar plate

Background

Open reduction with volar plate fixation is a common surgical procedure for the treatment of displaced fractures of the distal radius. Complications after volar plating may include tenosynovitis and extensor tendon rupture which may be increased with dorsal screw prominence due to repetitive trauma to the tendons from the screw [1, 3–5, 7, 10, 11]. Although uncertainty remains about the length of screw prominence that causes tendon pathology, it has been shown that screw prominences of 1.5 mm or greater in the third or fourth compartment may cause tendon pathology [11].

With standard radiographic and fluoroscopic imaging techniques, it is difficult to accurately detect actual screw length in relation to the irregular osseous morphology of the dorsal distal radial cortex, especially in the setting of fracture comminution. Difficulties with depth gauge measurements in highly comminuted fracture patterns or improper screw placement may lead to screw prominence that may not be clearly evident. The purpose of this study is to evaluate the Hoya view, a radiographic view commonly used at our institution, that allows quick and accurate assessment of dorsal cortical

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screw penetration and evaluation of proper screw length with volar plating of distal radius fractures. The Hoya view provides an axial presentation of the dorsal border of the distal radius, similar to an axial CT image, which delineates the dorsal cortical architecture.

The Hoya view, which we named after the Georgetown University Hoyas—the institution where it was developed—is performed with the shoulder abducted 90°, elbow flexed 90°, arm in 20° of external rotation, and the wrist flexed between 30 and 90°; the C-arm beam is then centered on the dorsal radial cortex. With this perspective, the distal screws on a volar plate may be evaluated for optimal length as well as any violation of the dorsal cortex. This technique may be performed intraoperatively with fluoroscopy, using either a miniature or full-sized C-arm with the methods described in our study (Fig. 1). The Hoya view allows for immediate intraoperative correction of any screw placed in a suboptimal position or of incorrect length with the goal of minimizing postoperative tendon irritation or rupture. The aim of this study is to evaluate the Hoya view, and compare the Hoya view to lateral radiographs, in detecting dorsal cortical screw prominence using a cadaveric model.

Materials and Methods

After Institutional Review Board approval was obtained, eight fresh frozen human male cadaveric forearms underwent application of a Medartis volar distal radius plate using a standard volar approach (Medartis Inc., Kennett Square, PA) by the study authors. Cortical screws were used to affix the plate in a proper position to the radial shaft with alignment of the distal portion of the plate along the watershed line of the distal

radius according to the manufacturer's recommended surgical technique. The distal locking screw holes followed by the proximal locking screw holes were sequentially drilled bicortically and measured with a standard depth gauge. Each measurement was confirmed by two of the study's authors, including the lead and/or senior author (DD, SE), before the corresponding 2.5-mm polyaxial locking screws were placed. After the two distal locking rows were filled with eight total locking screws, lateral and Hoya views were obtained utilizing an InSight Fluoroscanner mini C-arm (Hologic Inc, Bedford, MA). Any dorsal cortical screw penetration on each of the images was recorded by one of the study authors and confirmed by the lead and/or senior author. The Hoya view was performed with the cadaveric forearm in 20° of extension and the wrist flexed between 30 and 90°; the C-arm beam was then centered on the dorsal cortex of the radius. This position corresponds to an intact arm with the shoulder abducted 90°, elbow flexed 90°, the arm in 20° of external rotation, and the wrist flexed 30–90°.

To ensure consistency with regard to the correct positioning for the described Hoya view, the view was performed with the assistance of a radiopaque, leveled, variable-angled guide with an attached Empire polycast magnetic protractor (Fig. 2). This device was also used to evaluate alternate angles of external rotation in 10° increments from 0 to 30° for confirmation of optimal wrist position for maximum visualization of the dorsal radial cortex and distal screws. The ideal amount of external rotation was found to be between 10 and 20° to effectively clear the carpal bones while allowing dorsal visualization of the distal and proximal rows of locking screws.

Dorsal dissection of the cadaveric wrists was then performed by any one of the study's authors for direct visual evaluation of screw location and measurement of dorsal

Fig. 1 **a** Intraoperative demonstration of the Hoya view with the elbow flexed to 90°, the arm in 100° of external rotation, and the wrist flexed between 30 and 90°; the beam is directed at the dorsal surface of the wrist. **b** The Hoya view, after volar plate application, shows the two most radial screws penetrating the dorsal cortex of the distal radius

Fig. 2 The cadaveric Hoya views were performed with a radiopaque, leveled, magnetic protractor to ensure consistency with regard to positioning

cortical screw penetration (Fig. 3). Screw penetration was defined as any amount of screw protuberance beyond the dorsal cortical surface. This amount was measured in millimeters. After the prominent screws were identified and the length of cortical penetration was measured, the screw

positions, with regard to the locking plate, were verified by backing each of the prominent screws out several turns under fluoroscopic guidance. The distal locking screws were then exchanged sequentially for screws 2-mm longer and all fluoroscopic views were then repeated. Any dorsal cortical penetration on the imaging was recorded and subsequently confirmed or rejected with direct dorsal visualization. We analyzed the data for each view for sensitivity in evaluating dorsal cortical penetration.

Results

After initial measurements and placement of the volar plates and polyaxial locking screws, dorsal wrist dissections revealed 6 of 64 screws (9.4 %) penetrated the dorsal radial cortex. The average screw protrusion was 1.08 mm (range 0.5–2 mm) and was most frequently located at the two most radial screw positions of the distal and proximal rows (83.3 %). This region corresponded with the first and second dorsal compartments upon dissection. One screw penetrated the EPL groove radial to Lister's tubercle. On lateral views, none of the six screws (0 %) which penetrated the dorsal cortex were detected, whereas with the Hoya view, six of six prominent screws were detected.

With the distal and proximal rows of locking screws exchanged for screws 2-mm longer, 49 of 64 of the screws (76.6 %) violated the dorsal radial cortex. This was again

Fig. 3 No obvious screw penetration of the dorsal cortex is seen on the lateral image (**a**, *top left*). The Hoya view shows dorsal cortical screw penetration of two radial screws (**b**, *top right*). Dorsal dissection confirms the proximal and distal most radial screws are prominent (**c**, **d**)

confirmed with direct visual confirmation. The lateral and Hoya views were repeated with 12 of 49 screws (24.5 %) detected on the lateral image versus 49 of 49 screws (100 %) with the Hoya view.

On lateral images, the most frequently visible prominent screws were in the two most ulnar screw positions of the distal and proximal locking rows (75 %), with an average dorsal protrusion of 1.63 mm (range 0.5–2 mm). It was difficult to determine which screws were prominent on the lateral radiograph without the aid of direct visualization. The Hoya view was most effective in detecting screw prominence within the distal 2 cm of the distal radius and was able to detect all prominent screws with no false negative results in our study.

When using screws lengths equal to depth gauge measurements, the Hoya and lateral view were 100 and 0 % sensitive, respectively, in detecting dorsal cortical screw penetration. When using screws 2-mm longer than values measured with the depth gauge, the Hoya and lateral views were 100 and 24 % sensitive, respectively.

Discussion

Volar plating of distal radius fractures is a common treatment for distal radius fractures with potential complications that include flexor and extensor tendon rupture, intra-articular screw penetration, and neurovascular compromise [2]. In the operating room, standard anteroposterior (AP) and lateral radiographs of the distal radius are traditionally used to assess fracture reduction and determine proper hardware position. Standard AP and lateral radiographs, however, do not allow reliable visualization of the irregular osseous morphology of the dorsal cortex of the distal radius making it difficult to accurately interpret screw length and cortical penetration. This may be compounded with fractures that have dorsal comminution which further increases the difficulty in evaluating proper screw length and position.

With the Hoya view, we were able to accurately identify dorsal cortical screw penetration with 100 % sensitivity and routinely employ the view in practice to aid in difficult depth gauge measurements and assessment of dorsal cortical comminution. In our study, the sensitivity for lateral radiographs in detecting dorsal cortical penetration were 0 and 24 % for screws used of appropriate length, as measured by a depth gauge, and screws 2-mm longer.

Live rotational fluoroscopy has been used in an attempt to accurately evaluate for cortical and intra-articular screw penetration. A study by Tweet et al. showed that rotational fluoroscopy was more reliable than standard AP and lateral images alone [12]. However, live fluoroscopy increases radiation exposure to the patient and the surgical team.

Maschke et al. described supination and pronation views that aided in the radiographic analysis of dorsal screw

penetration. The average screw prominence required for radiographic detection was 6.5 and 2 mm on the lateral and supinated views for the first dorsal compartment. In the third dorsal compartment, screw prominences of 3.5 and 2.5 mm on the lateral and pronated views were required for radiographic detection of cortical penetration, and 4 and 2.5 mm of prominence on the lateral and pronated views were required for cortical penetration in the fourth dorsal compartment [8]. This study used non-standardized angles of supination and pronation, making it operator-dependent and difficult to reproduce.

Joseph and Harvey performed a retrospective case series of 15 distal radius fractures, proposing a dorsal horizon view. With this radiographic view, they reported visualizing screw protrusion at 2.25 mm on average and recommended the view in addition to supination and pronation views [6]. However, the authors failed to define patient and X-ray beam positioning required to reproduce the dorsal horizon view. The Hoya view is a modification of the dorsal horizon view providing an axial image of the distal radius. However, the Hoya view includes specific patient positioning parameters which ensure reproducibility with the Hoya view.

Ozer et al. evaluated lateral, supination, pronation, and dorsal tangential views to evaluate dorsal screw penetration during volar distal radius plating. The dorsal tangential view was performed with the wrist flexed 70° and the X-ray beam directed in the sagittal plane of Lister's tubercle [9]. Ozer et al. reported sensitivities for each view at each screw location and length of screw used. The sensitivity for the lateral and dorsal tangential views ranged 13–100 and 35–100 %, respectively. There was a wide variation in sensitivities based on screw location and length of the screw with longer screws having a better sensitivity for detecting cortical penetration. The dorsal tangential view described in this article is similar to the Hoya view in providing an axial image for fluoroscopic evaluation. However, aside from wrist flexion, patient positioning of the dorsal tangential view is not described. Also, the axial image obtained using the dorsal tangential view appears to be different from the axial image with the Hoya view and may provide different estimates of screw prominence.

Limitations to our study included the use of only eight unfractured specimens. This relatively small number of unfractured specimens may not show the full range of normal anatomic morphology and cortical variability present with fractures of the distal radius. The altered normal anatomy in traumatic situations may challenge the effectiveness of the Hoya view, but would likely do so with other techniques as well. Another limitation is the use of only one fixation system in this study. However, the polyaxial nature of this system created variability with regard to screw trajectories that could potentially encompass standard screw trajectories seen across multiple fixation systems. Another limitation to this study is patient positioning. Many distal radius fractures occur in the elderly that have limited shoulder or elbow range of motion

due to osteoarthritis, rotator cuff pathology, or other causes. In this patient population, it may be difficult to reproduce the Hoya view.

The Hoya view, a commonly used technique at our institution, provides a reproducible, fluoroscopic image for quick and accurate assessment of dorsal cortical screw penetration while in the operating room. In our cadaveric study, we were able to detect screw prominence with as little as 0.5 mm dorsal cortical penetration with 100 % sensitivity with the described view in intact bone. While the Hoya view may be difficult to obtain in patients with restrictions in elbow or shoulder range of motion, we believe that the routine use of the Hoya view, in addition to AP and lateral views, will help confirm screw positioning and reduce postoperative complications caused by protruding screws.

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Conflict of Interest Donald Dolce declares that he has no conflict of interest.

David Goodwin declares that he has no conflict of interest.

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Statement of Human and Animal Rights All procedures followed as part of this study are in accordance with ethical standards of the Institutional Review Board and with the Helsinki Declaration of 1975, revised in 2000.

Statement of Informed Consent Informed consent was not obtained as this is a cadaveric study. Figure 1 does include imaging of a patient;

however, no identifiable features are present and patient confidentiality is maintained.

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