Volar locking plate fixation of distal radius fractures: use of an intra-operative ‘carpal shoot through’ view to identify dorsal compartment and distal radioulnar joint screw penetration

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Published online: 12 February 2014
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Abstract

Introduction We report our experience using a ‘carpal shoot through’ view of the distal radius to identify dorsal compartment screw penetration intra-operatively when performing volar plating of the distal radius.

Methods A prospective study of 42 patients (mean age 56 years) with acute distal radius fractures treated with open reduction internal fixation was undertaken. Surgical fixation was performed using a volar locking plate in all patients. After plate application, inclined posteroanterior and lateral radiographs were taken followed by the carpal shoot through view. **Results** In six cases (14 %), the carpal shoot through view revealed dorsal screw protrusion, which was not detectable on standard PA and lateral views. In one case, a screw had penetrated the distal radioulnar joint (DRUJ), which was only apparent on the shoot through view. The overall screw exchange rate was 17 %.

Conclusions Using the hand and carpus to minimise the contrast in X-ray penetration, the dorsal cortex of the distal radius may be imaged intra-operatively and dorsal compartment screw penetration detected in cases with significant multifragmentation when screw measurement is difficult. This view potentially reduces the risk of post-operative pain and extensor tendon injury and also provides excellent visualisation of the DRUJ.

Keywords Distal radius fracture · Volar locking plate · Dorsal cortex screw penetration · Distal radioulnar joint

Introduction

Displaced distal radius fractures are commonly fixed with volar locking plates [5, 9, 34]. Volar locking plate fixation may be used for both volarly and dorsally displaced fractures and provides fracture stability under axial loads encountered during early post-operative mobilisation despite the fixation being on the tension side of the fracture complex [7, 15, 18, 21, 26, 27, 37]. This method of fixation reduces the risk of dorsal soft tissue irritation and extensor tendon rupture compared with dorsal plate fixation [13, 14, 24, 25, 32, 33]. Iatrogenic causes of tendon injury have been recognised including drill-bit penetration or penetration of the dorsal compartment by screws [1, 3, 4, 7, 8, 17, 19, 30, 38]. Subsequent tendon rupture [17, 38] or tenosynovitis has reported incidences of approximately 2 % and 4 %, respectively [2, 7].

To avoid dorsal cortex penetration, surgeons have relied upon intra-operative measurement and confirmation with intra-operative fluoroscopy to determine whether screws inserted are too long or into the joint. Conventional lateral view fluoroscopy is unreliable because screw tips are often hidden by Lister’s tubercle [6, 12, 20, 23]. This bony prominence can vary in height ranging between 4 and 10 mm [6]. The mean screw length prominence required for radiographic detection may be up to 6.75 mm on a lateral view and 2.5 mm on a supinated oblique view [20]. Penetration of the third extensor compartment, resulting in extensor pollicis longus rupture, appears to be the most vulnerable dorsal region to unrecognised screw penetration [3, 6].

Additional views such as the dorsal skyline view have been employed for more accurate detection of dorsal screw penetration intra-operatively. This view requires that the wrist is palmar flexed, but we have had problems obtaining satisfactory imaging because of overexposure by the image intensifier. Instead, we have developed a different view, taken with the wrist in dorsiflexion, which we have termed the ‘carpal shoot

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through' view. We report the impact of this previously unreported technique upon intra-operative screw length selection with volar locking plate fixation for distal radius fractures.

Patients and Methods

A prospective study of 42 acute distal fractures in 42 consecutive patients was undertaken from February to December 2012. There were 29 females and 13 males with a mean age of 56.3 years (SD $\pm$ 16.6 years). The dominant wrist was injured in 20 cases (48 %). The mechanism of injury was a low energy fall in 31 patients and a high-energy injury in 11 patients. Fractures were extra-articular in 13 cases and intra-articular in 29 cases. Fractures were classified according to the AO classification as A2 ($n=3$), A3 ($n=10$), B1 ($n=2$), B2 ($n=1$), B3 ($n=6$), C1 ($n=5$), C2 ($n=9$) and C3 ($n=6$).

Surgical fixation was performed using a volar locking plate in all patients. In eight patients, an additional radial styloid plate was used and in one patient a distal ulnar fracture was also fixed. The primary surgeon was an orthopaedic consultant in 29 cases and an orthopaedic specialist registrar in 13 cases (six supervised by a consultant). Mean time to surgery from injury was 7.5 days (SD $\pm$ 5.3 days). Surgery was performed under general anaesthesia in 29 patients, general anaesthesia combined with a regional block in 12 patients and regional block alone in one patient. Mean tourniquet time was 61 min (SD $\pm$ 28 min).

Surgical Technique

Via a volar, longitudinal incision, the distal radius was approached through the internervous plane between the flexor carpi radialis tendon and brachioradialis and the radial artery. The pronator quadratus muscle was detached from its lateral insertion on the radius and reflected medially to expose the volar cortex of the distal radius. An Aptus (Medartis, Switzerland) volar locking plate was used in all cases. In eight patients, an additional radial column plate was used to directly reduce and buttress the displaced radial styloid fragment. In one other patient, plating of a distal ulnar fracture was required. In all cases, bicortical drilling was performed. A depth gauge was used to measure each drill hole in both lateral and medial directions to account for the sloping nature of the dorsal cortex of the distal radius. Screw lengths selected measured 1 to 2 mm less than the lesser of the two measurements. Following plate application, 11° inclined PA and 22° lateral fluoroscopy views were taken using a standard C-arm image intensifier [29]. The carpal shoot through view was then performed. To obtain this, the patient's forearm is supinated, the elbow flexed to approximately 70° and the wrist dorsiflexed. The image intensifier beam is directed over the

base of the thenar eminence (Fig. 1). This view provides views of the dorsal cortex and distal radial ulnar joint (DRUJ) (Fig. 2). The dorsal cortex of the distal radius can be visualised with the carpal bones overlying. The correct view is obtained when the distal lip of the volar locking plate is seen perfectly end on. Inclined PA, lateral and carpal shoot through images were then saved to our picture archiving and communication system (PACS). All wrists were immobilised in a below-elbow volar Plaster of Paris slab in a 15° of wrist extension. Mobilisation was commenced following satisfactory review of the wound in the hand clinic in the week following surgery.

Results

The mean number of screws inserted into the volar locking plate distal to the fracture was four (range three to six). In six of the 42 cases (14 %), the carpal shoot through view identified dorsal screw protrusion, which was not detectable on standard PA and lateral fluoroscopy views (example shown in Fig. 3a–c). In all cases, screws were exchanged for shorter screws. In another case, the carpal shoot through view identified a screw penetrating the DRUJ, which was not seen on PA view (Fig. 4a–c). This screw was exchanged intra-operatively.

With reference to screw position within the plate, in three cases the protruding screws were positioned in the most medial hole, and in two cases the radial styloid screw was long. In one case the long screw was positioned just radial to

Fig. 1 Arm positioning to obtain the carpal shoot through view. The crosshairs on the laser guidance are aimed at the base of the thenar eminence

Fig. 2 **a, b** A carpal shoot through view demonstrating an excellent view of the dorsal cortex and DRUJ. This view confirmed satisfactory screw length and position

Lister's tubercle and in one case the screw was in the groove for extensor pollicis longus.

The reduction of the fracture was maintained intra-operatively in all cases following wrist extension to obtain the carpal shoot through image.

Discussion

Dorsal screw penetration with volar plate fixation occurs despite measurement using a depth gauge and despite the use of intra-operative fluoroscopy [6, 12, 20, 23]. It is well recognised that Lister's tubercle can hide penetrating screw tips. Factors such as the sloped dorsal cortex of the distal radius and dorsal multifragmentation can lead to errors measuring the required screw length accurately.

Dorsal screw protrusion should be avoided because extensor tendon irritation may lead to pain, tenosynovitis or tendon rupture [2, 7, 17, 38]. Persistent dorsal wrist pain secondary to prominent screw tips may require revision surgery or removal of metalwork. In the 42 cases we report, the carpal shoot

through view facilitated more accurate assessment of screw length compared with standard lateral fluoroscopy views alone, resulting in an overall intra-operative screw exchange rate of 17 % (seven cases). In one of the cases, the screw had penetrated the DRUJ. We believe the imaging technique we describe is a useful intra-operative adjunct for volar wrist plating because it clearly visualises the dorsal cortex. It also provides an excellent view of the DRUJ.

Accurate measurement of screw length is recognised to be difficult [36], with various reported fluoroscopic techniques to identify dorsal compartment screw penetration. Supinated and pronated views [20] are more sensitive than lateral only views, but even then, screw protrusion of up to 2 mm could remain undetected. Similar oblique views such as tilted PA and tilted lateral views are also recommended to detect inadvertent intra-articular screw placement [35].

An additional intra-operative view to screen for dorsal penetration is the 'dorsal horizon' [11], 'tangential' [28] or 'skyline' [31] view which is performed with the wrist in palmar flexion. This technique has been validated in both

Fig. 3 **a** Dorsal cortex penetration: a complex distal radius fracture was fixed using a volar plate and additional radial column plate. Inclined lateral radiographs demonstrate acceptable length and position of the distal screws. **b, c** The carpal shoot through view identifies that the radial styloid screw is protruding from the dorsal cortex, allowing intra-operative exchange

Fig. 4 a–c A carpal shoot through view identified that the distal ulnar screw had penetrated the DRUJ. This screw was exchanged intra-operatively

clinical and cadaveric studies [10, 16], and in one series, excessively long screws were identified in three out of 15 patients with distal radius fractures, which was not apparent on standard imaging [11].

The image intensifier has an automatic exposure control and adjusts the dose of radiation according to the density of the object being screened. When attempting to use the dorsal horizon view, we encountered problems with overexposed images, requiring multiple attempts and prolonged surgical time to obtain the correct image using a manual setting. With the dorsal horizon view, there is a sharp contrast in density between air and distal radius, which may make it difficult for the image intensifier to obtain the correct exposure. Our technique uses the same inclination from the long axis of the imaging beam as the dorsal horizon view, but differs in that the carpal shoot through view requires that the wrist is dorsiflexed rather than palmarflexed, so that the carpus provides more similar background density compared with air, allowing the image intensifier to more reliably obtain the correct radiation dose to visualise the dorsal cortex of the distal radius. The learning curve to use our technique was short and the shoot through view was easily obtained by general orthopaedic trauma surgeons and trainee specialist registrars.

Once the carpal shoot through image has been obtained, it is possible for the surgeon to visualise the dorsal cortex of the distal radius with the carpal bones superimposed. As well as avoiding overexposure, this modified technique also avoids overprojection when the lunate or scaphoid is misinterpreted as the dorsal cortex of the radius resulting in incorrect screw sizing. The carpal shoot through view also has the advantage of providing excellent visualisation of the DRUJ, which is not seen well with the dorsal horizon view.

Periarticular osteoporotic and intra-articular high-energy distal radius fractures may be sufficiently stabilised using volar locking plate fixation without screws engaging the distal cortex. Screws are inserted at multiple angles supporting the subchondral bone. Therefore, for extra-articular fractures with normal bone density, drilling of the dorsal cortex may not be

required thus ensuring that screws do not protrude dorsally. If drilling of the dorsal cortex is performed, downsizing screw length by 1 to 2 mm has been recommended to reduce the risk of screw protrusion. It has also been suggested that leaving empty the screw hole which corresponds with the third dorsal compartment further reduces the risk to the rupture prone extensor pollicis longus [3, 22]. Longer screw length is required when fractures are multifragmentary or when there is a coronal split [11] to engage and stabilise the dorsal fragment.

We have demonstrated that the carpal shoot through view has a higher sensitivity compared with a lateral view in detecting dorsal compartment penetration. To minimise the risk of screw misplacement or excessive screw length, we also advocate routine measurement on both sides of the drill hole and to downsize screw lengths by 1 to 2 mm. Despite this conservative approach to screw selection, we still had a significant screw exchange rate based upon the increased sensitivity of the carpal shoot through view. Our study demonstrates that the surgeon must pay particular attention to screw length by using additional fluoroscopic techniques to increase accuracy.

There are certain limitations to our study, and the true sensitivity and specificity of our technique are unknown. Future cadaveric studies or follow-up ultrasound studies may be useful to validate our newly reported technique. Avoiding dorsal screw penetration theoretically reduces the risk of iatrogenic extensor tendon pathology, but tendon pathology is also caused by local ischaemia, increased pressure within the osseofibrous tunnel and mechanical impingement on bone fragments.

In conclusion, the carpal shoot through view is an easily obtained intra-operative fluoroscopic view. The learning curve is short even for surgeons in training. Our technique appears to eliminate exposure problems that we had encountered using the dorsal horizon view and is more sensitive than standard imaging for identification of excessive screw length. Through better detection of prominent screws intra-operatively, our technique potentially reduces the risk of dorsal wrist pain,

extensor tendon trauma and the need for subsequent removal of metalwork.

Conflict of Interest Daniel Marsland declares that he has no conflict of interest.

Chris M. Hobbs declares that he has no conflict of interest.

Philip S. Sauvé declares that he has no conflict of interest.

Statement of Human and Animal Rights No experiments were undertaken on humans or animals for this study. We describe a prospective study assessing an established surgical technique at our institution, and therefore ethical approval was not necessary.

Statement of Informed Consent No identifying information about patients is included in the current study, and therefore informed consent was not required.

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