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Assessment of penetration of dorsal screws after fixation of the distal radius using ultrasound: cadaveric study

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ABSTRACT

INTRODUCTION Volar locking plates are used to treat unstable and displaced fractures of the distal radius. Potential advantages of stable anatomical reduction (eg early mobilisation) can be limited by penetration of dorsal screws, leading to synovitis and potential rupture of extensor tendons.

Despite intraoperative imaging, penetration of dorsal screws continues to be a problem in volar plating of the distal radius. Ultrasound is a well recognised, readily available, diagnostic tool used to assess soft-tissue impingement by orthopaedic hardware.

In this cadaveric study, we wished to ascertain the sensitivity and specificity of ultrasound for identification of protrusion of dorsal screws after volar plating of the distal radius.

METHODS Four adult, unpaired phenol-embalmed cadaveric distal radii were used. A VariAx™ Distal Radius Volar Locking Plate system (Stryker, Kalamazoo, MI, USA) was employed for instrumented fixation. A portable SIUI CTS 900 ultrasound machine (Providian Medical, Eastlake, OH, USA) was used to image the dorsal cortex to ascertain screw penetration.

RESULTS Specificity and sensitivity of ultrasound for detection of screw protrusion through the dorsal cortex was 100%.

CONCLUSIONS Ultrasound was found to be a safe and accurate method for assessment of dorsal-screw penetration through the dorsal cortex of the radius after volar plating of the distal radius. It also aids diagnosis of associated tendon disorders (eg tenosynovitis) that might cause pain and limit wrist function.

KEYWORDS

Ultrasound – Radius – Dorsal screws – Volar plates

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Percutaneous pinning and plastering are established treatments for dorsally displaced fractures of the distal radius.[1–3] Fixation using volar plates is first-line treatment for unstable intra-articular or extra-articular distal fractures of the radius.[4–10] Penetration of the dorsal cortex leading to irritation or attrition of extensor tendons is a complication of fixation using volar plates.[12–21]

Screws can compromise the volume of the dorsal compartments. Chronic conflict between tendons and screws can result in local hyperaemia, tenosynovitis, and persistent impingement, eventually leading to tendon rupture.[21–23] Prevalence of tendon-related problems (irritation and tears) is 2–14%.[12,13,15] In a meta-analysis, Margaliot *et al*[22] reported the prevalence of tendon rupture to be 2.6% and that of tenosynovitis to be 5.2%. These values can lead to poor outcomes despite satisfactory reduction and fixation of fractures, as well as a delay to return to work in young, active patients.[16]

Conflict between orthopaedic hardware and soft tissue is difficult to visualise on standard radiographs owing to: overlying bone;[21,24] static nature of images; insufficient contrast for soft tissues; absence of real-time correlation between pain and the structures being observed. Ultrasound eliminates all of these problems and also offers excellent spatial resolution.[21]

We use ultrasound in the outpatient clinic to identify screw penetration of the dorsal cortex after volar plating of fractures of the distal radius. This simple test can be done with minimal training, and could be used to reduce the need for computed tomography (CT) and, as such, radiation exposure and cost. With the ready availability of sterile ultrasound units in theatres, this test could be done intraoperatively for difficult cases.

In this cadaveric study, we wished to ascertain the sensitivity and specificity of ultrasound for identification of protrusion of dorsal screws after volar plating of the distal radius.

Methods

Four adult, unpaired phenol-embalmed cadaveric distal radii were used. A VariAx™ Distal Radius Volar Locking Plate system (Stryker, Kalamazoo, MI, USA) was employed for instrumented fixation. Plates are contoured anatomically and have four options for variable-angle distal locking screws that allow for 15° of freedom. A portable SIUI CTS 900 ultrasound machine (Providian Medical, Eastlake, OH, USA) was used to image the dorsal cortex for screw penetration.

The volar aspect of four cadaveric distal radii was exposed using a modified version of Henry's approach. The pronator quadratus was exposed through the bed of the flexor carpi radialis tendon. Then, the pronator quadratus was reflected from its radial insertion.

Plates were applied to the volar cortex of the distal radius (just proximal to the watershed line) and fixed with a single cortical non-locked screw in the distal diaphysis. Distal screw holes were numbered from one to four starting from the ulna side (Fig 1).

Bi-cortical holes were drilled sequentially through the locking holes in the distal row of the plate without fluoroscopic guidance. The optimum length of each screw was measured using a standard depth gauge from Stryker VariAx instrumentation. Then, locking screws (2.3mm) were inserted at different lengths into all four distal locking holes. Screws were inserted at –2mm to the measured depth in cadaver specimen number (CSN)1, at 0mm in CSN2, at +2mm in CSN3, and at +4mm in CSN4.

Using the SIUI CTS 900 ultrasound machine, the dorsal surface of the wrist was imaged to detect the site (extensor compartment) and length of screw penetration. Figure 2 shows a typical appearance of a screw penetrating the dorsal cortex. Ultrasound findings for each specimen were recorded.

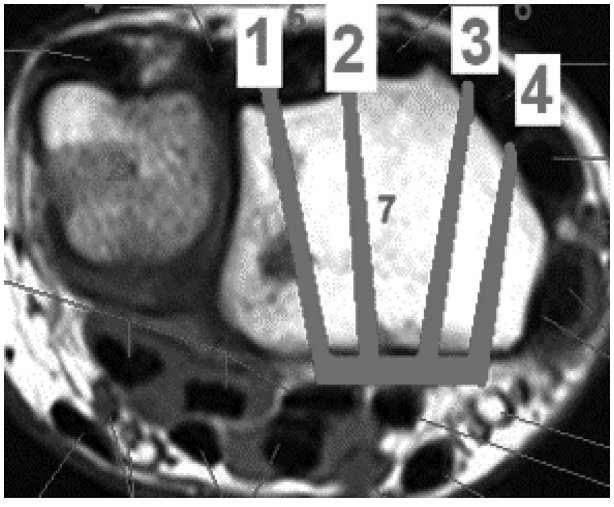

Figure 1 The volar cortex of the distal radius was divided into four zones from medial (ulnar) to lateral

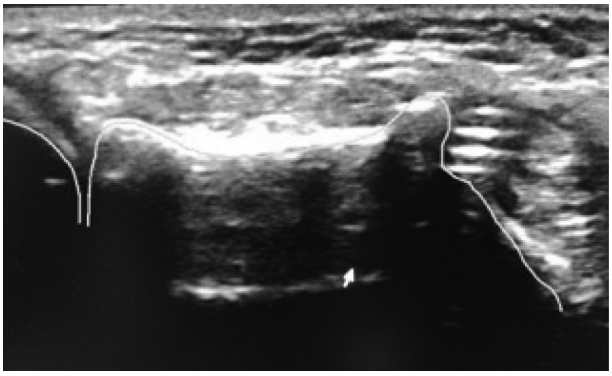

Figure 2 Ultrasound image showing screw penetration just radial to Lister's tubercle as a hyperechoic structure

Cadaveric specimens were dissected in the dorsal plane to identify and quantify screw penetration. Penetration of the extensor compartment and screw length were recorded.

Results

In CSN1, the depth was measured and screws were inserted 2mm short of the measured depth. No screws were found to be prominent of the dorsal cortex upon ultrasound or dissection. Upon dissection, the most ulnar-directed screw was found to have penetrated the distal radioulnar joint (DRUJ) but this phenomenon was not detected on ultrasound.

In CSN2, the screw lengths selected were the same as the measured depth. Ultrasound detected one screw in the second extensor compartment that was prominent by 1mm, and this phenomenon was confirmed upon dissection. Dissection

Figure 3 Axial CT of same patient in Figure 2 demonstrating screw penetration through the dorsal cortex of the distal radius just radial to Lister's tubercle

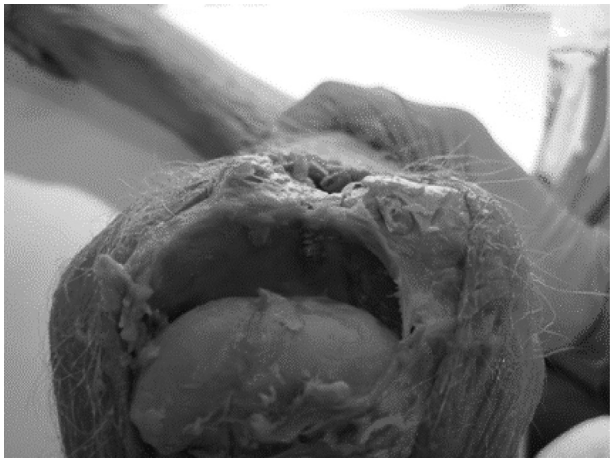

Figure 4 Screw protrusion in the radiocarpal joint upon dissection

Figure 5 Screw prominence revealed upon dissection

also revealed that one screw had penetrated the radiocarpal joint (RCJ) (Fig 3): this phenomenon was not detected on ultrasound.

In CSN3, 2mm-longer screws were inserted. Three of the four screws were prominent upon ultrasound and the fourth screw was at the level of dorsal cortex in extensor compartment four.

In CSN4, screws were inserted 4mm-longer than the measured depth. Three of the four screws were found to be long on ultrasound and dissection (Fig 5). All results are summarised in Table 1.

Specificity of ultrasound at detection of prominent screws was 100%. No screws were classified as 'prominent' upon ultrasound and found subsequently not to be prominent upon dissection. Sensitivity of ultrasound was 100% for dorsal penetration of screws. One screw was found in the RCJ and another screw penetrated into the DRUJ, but this was not prominent beyond the dorsal cortex. We expect these to be picked up by fluoroscopy intra operatively. We did not use fluoroscopy for our cadaveric study. We wished only to investigate prominence of dorsal screws on ultrasound and correlate findings by dorsal dissection.

Discussion

The complex geometry of the dorsal cortex of the distal radius makes confirmation of screw length with fluoroscopic or standard radiographic imaging methods quite difficult.[24–26] Protrusion of distal locking screws on the dorsum of the distal radius can lead to attrition and rupture of extensor tendons.[15,16,27–30] and hence reduced function, pain and disability

The dorsal tangential view[31,32] has been adopted in many UK centres (including our unit) to assess screw length intraoperatively, and often results in a change of screw. Nevertheless, whether routine use can reduce the prevalence of penetration of dorsal screws is not known. The 'gold standard' for assessment of long screws is CT but is not practical intraoperatively as well as being time-consuming, expensive and exposes the patient to radiation. Ultrasound has two advantages for assessment of penetration of dorsal screws: (i) allows for dynamic examination; (ii) can be used if hardware limits use of magnetic resonance imaging.[17,31,32] The screw appears as a hyperechoic structure created by multiple, parallel, oblique echogenic lines that correspond to the screw thread (Figure 2). Figure 3 shows similar pathology on axial CT.

Bianchi *et al*[17] used ultrasound to detect penetration of dorsal screws after fixation of the distal radius using a volar plate. The diagnosis was confirmed surgically in all nine patients who had fixation using a volar plate. They correlated the ultrasound appearance in vitro with appearance of a protruding screw tip as multiple hyperechoic lines in vivo, similar to our findings. They concluded that, apart from detection of dorsal-screw penetration, ultrasound offers the added advantage of the diagnosis of tears to the extensor tendon and tendon disorders such as tenosynovitis.

Tenosynovitis can also affect outcomes after volar plating. Ultrasound has the advantage of detection of this disorder[14,17] (though this is operator-dependent). Thus, ultrasound can be helpful for the detection of associated tendon disorders, which can limit functional recovery of distal-radius fractures. In their clinical and cadaveric study, De Maeseneer *et al*[33] showed that ultrasound can be used to diagnose tears of the extensor pollicis longus, and similar findings were noted by Santiago *et al* in their comparative study.[34]

We found that the sensitivity and specificity of ultrasound was 100% for the detection of penetration of dorsal

Table 1 Ultrasound and dissection findings in cadavers using different screw lengths

Cadaver specimen number	Screw length* (mm)	Ultrasound protrusion (mm)	Dissection prominence	Extensor zone
1 (2mm–shorter screw)	–2	0	0	DRUJ
	–2	0	0	
	–2	0	0	
	–2	0	0	
2 (normal–length screw)	0	0	0	RCJ
	0	0	0	
	0	0	0	
	0	1	1	
3 (2mm–longer screw)	+2	1	1	4
	+2	0	0	
	+2	3	3	3 (in EPL groove)
	+2	0	0	
4 (4mm–longer screw)	+4	4	3	4
	+4	0	0	
	+4	4	4	2
	+4	4	5	1

* Screws inserted in order 1–4 as shown in Fig1.
DRUJ, distal radioulnar joint; EPL, extensor pollicis longus; RCJ, radiocarpal joint

screws after volar plating in fractures of the distal radius. Importantly, no screws were identified as being 'long' when they were in fact not prominent. These findings suggest that, if screws are found to be prominent on ultrasound, then undertaking CT before elective removal of hardware is not necessary.

Intra-articular penetration of screws occurred in our study because screws were placed without fluoroscopic guidance. Ultrasound could not be used to identify these screws as being intra-articular. We did not attempt to identify screws within the joint, but one would expect these screws to be readily identifiable using standard fluoroscopic views intraoperatively. Ultrasound can complement fluoroscopic views obtained intraoperatively, and its use may be helpful in difficult cases.

The method described here is an accurate and cost-effective way of identification of penetration of dorsal screws after volar plating of the distal radius. It could be used as a simple screening method to complement clinical examination in the outpatient setting.

Conclusion

Ultrasound is a quick, inexpensive and a non-traumatic imaging method that allows assessment of tendons and measurement of protruding dorsal screws. This method is simple, safe, can be undertaken with minimal training, and could be used for the early diagnosis of dorsal-screw prominence, thereby reducing the need for CT.

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