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TRAUMA SURGERY

Comparison of lateral and skyline fluoroscopic views for detection of prominent screws in distal radius fractures plating: results of an ultrasonographic study

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Abstract
Introduction Extensor tendon rupture is a recognized complication of volar plate fixation of distal radius fractures due to screws protruding past the dorsal cortex. The aim of this study was to compare the Skyline view with traditional lateral fluoroscopic views using ultrasonography as a reference standard in the postoperative assessment.
Materials and methods A monocentric prospective study was conducted to identify screws penetrating the dorsal cortex after volar plating of distal radius fractures.
Patients and intervention Intraoperative anteroposterior (AP) and lateral views were used for group A (28 patients). AP, lateral and skyline fluoroscopic views were used for Group B (40 patients). Prominent screws were changed. Main outcome measurements: Ultrasound was done 6 months postoperatively to evaluate the number and length of prominent dorsal screws and any signs of extensor tenosynovitis.
Results The number of prominent dorsal screws exceeding 1 mm was 14 in group A (14.9%), and 16 screws (11.8%) in group B ($p = 0.487$). Average length of prominent dorsal screw was 1.9 mm (range 1–2.1 mm) for group A and 2.4 mm (range 1.1–4.8 mm) for group B ($p = 0.534$). The number of patients with extensor tenosynovitis was 11 for group A and 12 for group B ($p = 0.66$).
Conclusions The Skyline view does not provide sensitive and reliable detection of the dorsal screw penetration. Intraoperative ultrasound might be a better tool to detect screw prominence.

Level of evidence III, case–control study.

Keywords Distal radius fracture · ORIF · Skyline view · Tendon rupture · Wrist ultrasonography

Introduction

Volar locking plates are frequently used for the treatment of distal radius fractures. Volar plating creates a biomechanically stable construct that allows early mobilization and recovery of a normal wrist function [1–6]. Surgical complication rates reported range from 6 to 80% [7–11]. Extensor tendon irritation and rupture are a recognized complication of volar plate fixation of distal radius fracture reported in 0.8–12% of cases [7, 12–16]. It may result from direct trauma to the tendons while drilling the dorsal cortex [17] or from attritional rupture due to excessively long screws. Lateral fluoroscopic views alone were shown to be poorly sensitive to identification of these screws (Hill), due to superposition with Lister's tubercle.

The Skyline view (SLV) shows the dorsal epiphyseal cortex and was proposed as a tool to detect screw prominence intraoperatively [18–23]. The studies that have validated the SLV used intact human cadaver radius [19, 20, 23]. Measurement of prominent screws and secondary tendon complications has not been performed in vivo.

The aim of this study was to compare the SLV with traditional lateral fluoroscopic view in vivo using postoperative ultrasound.

Materials and methods

A case–control monocentric prospective study was conducted between January 2014 and June 2015. The study

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protocol was approved by our institutional review board. All patients gave their informed consent to participate in the study. Inclusion criteria were distal radius fractures scheduled for open reduction and internal fixation by volar plating. The surgical indication was established according to the displacement in the sagittal and frontal plane on the radiographs. According to the AO classification criteria, were included extra-articular (A), partially articular (B) and complete articular fractures (C) [24]. All patients were operated within a delay of less than 10 days after the fracture.

All patients had an open fixation using the same operative technique with a volar locking plate through a volar Henry approach [25]. Six senior surgeons participated. The implants used were the VariAx 2.7 Locking Plate (Stryker®, USA) or 2.4 Distal Radius Plate DRP (Depuy Synthes®, USA). Surgeons were free to insert unicortical or bicortical epiphyseal screws.

A fluoroscopy unit (Siremobil compact L, Siemens®, Germany) covered with a sterile drape and placed on top of the arm table was used for intraoperative imaging. Anteroposterior (AP) and lateral views were used from January 2014 to January 2015 (group A). AP, lateral and skyline fluoroscopic views (SLV) were used between February and June 2015 (group B). Before the second period, surgeons were trained to perform a standardized intraoperative SLV. Training comprised the interpretation of 10 separate skyline fluoroscopic views. The SLV was obtained with the elbow in a 70° flexed position with the forearm in full supination and the wrist held in maximal flexion [22] (Fig. 1). The position of the forearm was adjusted to properly visualize four anatomical landmarks: the radial styloid, the dorsal cortex of the radius, Lister's tubercle and the distal radio-ulnar joint space (Fig. 2).

In both groups, screws visible beyond the dorsal cortical bone were changed and new fluoroscopic views were taken till no screws were seen beyond the dorsal cortical bone.

After surgery, the limb was immobilized using a volar splint. Active-assisted exercises were started 2 or 3 weeks after surgery.

Group A included 28 patients with 94 epiphyseal locking screws. There were 12 men and 16 women with a mean age of 62.6 years (range 30–77 years). There were 26 dorsally and two volarly displaced fractures. Fourteen fractures were intra-articular and 14 were extra-articular. Group B included 40 patients with 135 epiphyseal screws. There were six men and 34 women with a mean age of 57.3 years (range 20–82 years). There were 36 dorsally displaced and four volarly displaced fractures. Twenty-two fractures were intra-articular and 18 were extra-articular.

All patients were reviewed with ultrasound assessment 6 months postoperatively (range 4–8 months). Three senior hand surgeons performed ultrasonography

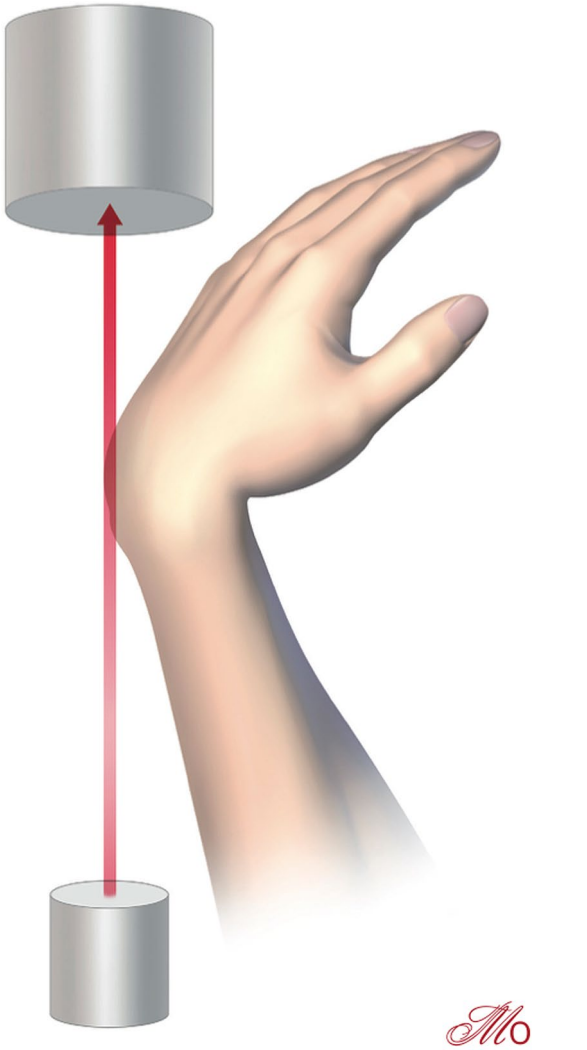

Fig. 1 Skyline view technique: SLV was performed with the wrist held in maximum flexion and supination and with the elbow at 70° of flexion

examinations using a broadband 15–6 MHz linear transducer (M-Turbo, Sonosite Fujifilm®, USA). They had received formal training in wrist ultrasound (US) and were independent from the original surgical team. The dorsal aspect of the wrist was examined on transverse and sagittal US obtained with a pronated wrist resting on an examination table. All six compartments were carefully analyzed. The number and length of prominent dorsal screws were identified. The length of a protruding screw was measured as the distance between the dorsal cortex and the tip of the screw. Any protrusion greater than 1 mm was considered inappropriate. The OMERACT score was used to evaluate extensor tendon tenosynovitis [26]. Initially developed to evaluate the severity of rheumatoid arthritis, the OMERACT score is a measure of the tenosynovitis. Tenosynovitis includes 3 grades of

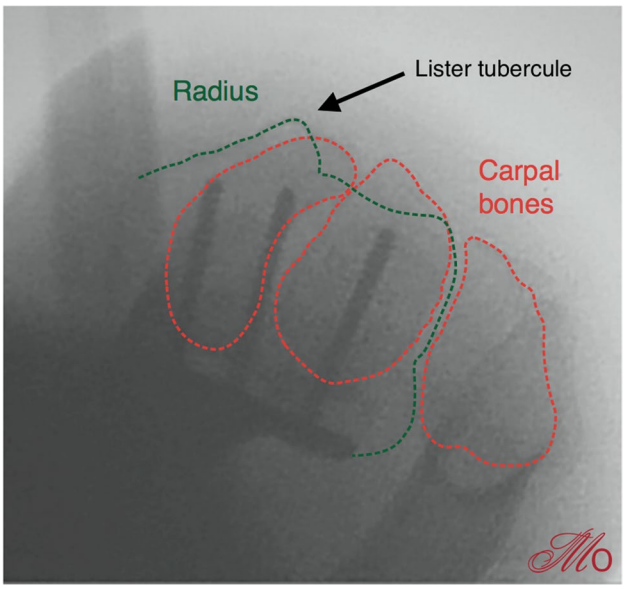

Fig. 2 Intraoperative fluoroscopic skyline view showing the tip of the screws relative to the dorsal radial cortex

Table 1 Results of the comparative study between group A (standard lateral fluoroscopic view) and group B (skyline fluoroscopic view) regarding the accuracy to detect screws penetrating over the dorsal cortex during volar plating of distal radius fractures

	Group A	Group B	*p*
Patients (*n*)	28	40	
Epiphyseal screws	94	135	
Number of prominent screws	14 (14%)	16 (14%)	0.49
Average prominence of screws (mm)	1.59 (1–2.1)	2.4 (1.1–4.8)	0.53
Number of patients with tenosynovitis	11	12	
OMERACT score	0.56	0.45	0.66

diagnosis: from asymptomatic mild effusion around the tendon (Grade 1) to massive synovitis leading to tendon rupture (Grade3).

Statistical analysis compared the number and length of prominent dorsal screws, and the OMERACT score between the two groups. The student's *t* test was used for statistical analysis with a significant *p* value threshold of 5%.

Results

In group A, 14 (14.9%) screws were prominent on US: two in the second compartment (1.4 and 1.5 mm), six in the third compartment (range 1.4–1.6 mm) and six in the fourth compartment (range 1–2.1 mm) (see Table 1).

For group B, 16 (11.8%) dorsal screws exceeded 1 mm in prominence; one in the first compartment (4.8 mm), six in the second compartment (range 1.6–4.9 mm), three in the third compartment (range 1.6–4.1 mm) and six in the fourth compartment (range 1.1–2.6 mm) (Fig. 3).

Negative predictive value to detect excessively long screws was, respectively, 88 and 85% in groups A and B. The number of patients with extensor tenosynovitis was 11 in group A and 12 in group B. The OMERACT score in group A was one for five patients, two for five patients and three for one patient. In group B, it was one for seven patients, two for four patients and three for one patient. Three patients required implant removal for tendon irritation prior to US: two in group A and one in group B with an extensor pollicis longus tendon rupture. The average time to remove these three plates was 12 weeks. The extensor pollicis longus tendon rupture was related to the protrusion of a screw in the third compartment. Ultrasonographic control after plate removal showed no residual tenosynovitis.

Discussion

This study aimed at identifying the most accurate intraoperative view to detect excessively long screws, comparing skyline view to standard lateral view. Non-invasive, ultrasound was used as the diagnostic reference tool, as it showed excellent sensitivity for detection of screw protrusion [27], as well as assessment of tenosynovitis.

The shape of the dorsal surface of the distal radius is complex and variable and this is likely to be the main contributing factor to unrecognized screw penetration using the latter view. The image intensifier may be poor at detecting prominent screws under the shadow of the Lister's tubercle [28, 29]. Pichler et al. showed in computed tomography (CT) studies that the height of the Lister's tubercle ranged between 3.3 and 6.6 mm [17, 30]. The distance between the lowest point of the EPL groove and the peak of Lister's tubercle averaged 7.1 mm (range 4–10 mm) [31]. The groove in the intermediate column between Lister's tubercle and the sigmoid notch of the distal radius makes it difficult to judge screws length on the lateral fluoroscopic views [28, 29]. A cadaveric study revealed that standard lateral and oblique fluoroscopic views had a sensitivity as low as 56% for detecting dorsal ulnar cortical penetration, even when screws penetrated the dorsal cortex by 2 mm [28].

A number of strategies have been proposed to reduce the risks of excessively long screws. Many authors have confessed routine downsizing of screws to avoid dorsal prominence [7, 32, 33]. Benson et al. suggest a dorsal incision ulnar to Lister's tubercle to inspect the third compartment

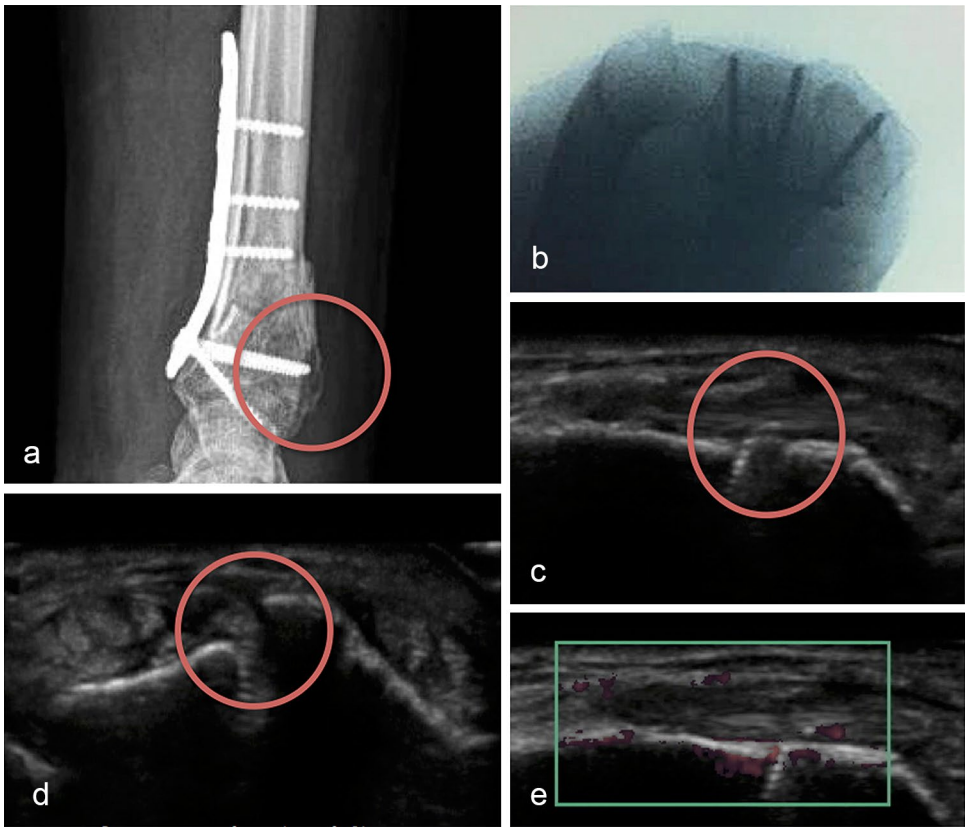

Fig. 3 Imaging of a distal radius fracture osteosynthesis by a volar locking plate. On the postoperative lateral standard X-ray (**a**) and skyline view (**b**), no screw appears to cross the dorsal radial cortex. On ultrasonography examination, a screw was visible penetrating the floor of the third dorsal compartment in longitudinal view (**c**) and the fourth dorsal compartments in view (**d**). On Doppler examination, tenosynovitis was visible around the tip of the screw (**e**)

[32]. Maschke advocated supinated views to evaluate the radial aspect of the wrist and pronated view to visualize the ulnar part of the wrist. The study showed that, on average, 6.5 mm of protrusion of radial-most screw was required before detection on the lateral view [34]. Ljungquist recommended the use of the lunate depth measure on X-ray to estimate the length of their longest screw [35]. Early plate removal has also been suggested to prevent tendon ruptures for patients who develop tenosynovitis. According to Snoddy et al., the most common reasons for removal are tendons complications: tenosynovitis (27%) and tendon rupture (3%) [36].

Recent studies focused on newly described intraoperative fluoroscopic views for a better evaluation of the screw length. Two skyline views techniques have been described: one with supinated forearm and vertically placed fluoroscope and the other with pronated forearm and horizontally placed fluoroscope [18, 20, 21, 23]. We favored the supinated view because it does not require moving the fluoroscope and it is, therefore, less subject to errors in a sterile environment.

In a study using a sawbones model, the sensitivity of the skyline view was 83% in detecting a screw crossing the dorsal cortical bone up to 1 mm while the pronated oblique and lateral views sensitivity were 77 and 55%, respectively [20]. According to Ozer, the skyline view showed 95% sensitivity for detecting screw penetration of 1 mm and 98% for 2 mm when crossing the floor of the third dorsal compartment [37]. For the second compartment, the 45° supination view showed higher sensitivity compared with the SLV [23]. Three clinical studies using the SLV without US confirmation, showed a change in screw length in 14–40% of patients [21–23]. A recent CT scan study performed by Brunner et al. confirmed that SLV allowed reliable and valid in vivo measurement of prominent dorsal screws [38].

Our study is the second one evaluating the accuracy of the skyline view in real clinical conditions [38]. We observed that the SLV was not sensitive enough to visualize all screw tips protruding past the dorsal cortex, raising doubts about the conclusions of the previous studies [18–23, 38]. As the SLV cannot be a perfect dorsal tangential view due to the volume of the forearm soft tissues, the variability of the angle in which screws are positioned limits the visualization on the same transversal plane (Fig. 4). In addition, the height of the radius plate depends upon the nature of the radius fracture and upon the surgeon's preference; it also depends upon each patient's bony anatomy thus impacting the length of the screws (Fig. 4). The superposition of the dorsal rim of the radius with the screws may sometimes lead to a false comforting image on X-ray.

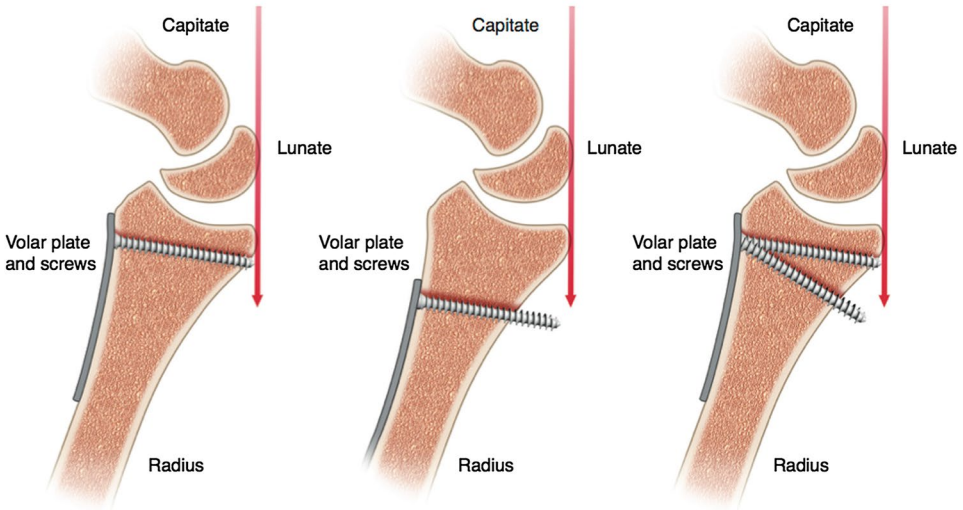

Fig. 4 Variability of the height of the radius plate and of the angle between the screw and the plate explain the difficulty to see the tip of the screws on the same skyline fluoroscopic view

Disadvantages of the SLV are the additional time (6.7 min according to Vaiss et al.) and irradiation (19.3 cGy/cm^2) [39]. This view is also difficult to perform with a mini-C arm amplifier. Intraoperative US might be a better tool to analyze screw prominence. It is easily available in operating rooms as most of wrist surgical procedures are conducted under ultrasound-guided regional anesthesia. However, it would require training of orthopedic and trauma surgeons. Moreover, the duration of the ultrasound device installation and the realization of the ultrasonography examination are longer than the duration of realization of the skyline view.

Another solution could be to consider intraoperative screw replacement when SLV shows less than 2 mm between the dorsal cortex of the radius and the tip of the screw.

This study has several limitations. There is an evaluation bias linked to the retrospective design of the study and the historical comparison of two patient cohorts. Secondly, patients were operated by multiple surgeons with different techniques. In addition, even if surgeons were trained, their experience in skyline view realization and interpretation could differ from one to another. It was not a blinded study, so surgeons could have been more cautious in the group B when choosing the length of the screws. However, it would have led to an overestimated accuracy of the SLV which was not shown to be superior to standard view. Intra and extra-observer variability were not tested for US.

In conclusion, the current study suggests that SLV is not sensitive enough to detect all dorsal screw prominence. A randomized prospective study is required to evaluate feasibility and superiority of intraoperative US comparatively to SLV.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Informed consent Informed consent was obtained from all individual participants included in the study.

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