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ORIGINAL ARTICLE

Does skyline view prevent extensor tendon pathologies during volar plating of distal radius? An ultrasonographic evaluation

Sinan Yüksel[1], Ali Nazmican Güröz[1], Alper Öztürk[2], Yenel Gürkan Bilgetekin[1], Önder Ersan[1], Arda Halil Ceylan[3]

[1]Department of Orthopedics and Traumatology, Dışkapı Yıldırım Beyazıt Training and Research Hospital, Ankara, Türkiye
[2]Department of Orthopedics and Traumatology, Ankara Training and Research Hospital, Ankara, Türkiye
[3]Department of Radiology, Dışkapı Yıldırım Beyazıt Training and Research Hospital, Ankara, Türkiye

ABSTRACT

Objectives: This study aims to compare extensor tendon complications of volar plating in distal radius fractures between skyline and lateral views by using postoperative ultrasonography (USG).

Patients and methods: Between January 2019 and February 2020, a total of 82 distal radius fractures of 79 patients (39 males, 43 females; median age: 56±12.9 years; range, 23 to 79 years) who were operated with distal four-hole plates and had a follow-up period of at least three months were retrospectively analyzed. During distal radius locking plating, standard lateral fluoroscopic view was used in 36 distal radius fractures and skyline view in addition to lateral view was used in 46 cases. A median of five months later, the protruding screws and extensor compartments were evaluated with USG. The number of screws with dorsal penetration, extent of penetration, and extensor tendon complications were compared between skyline and lateral view groups.

Results: In the skyline view group, the rate of dorsal screw penetration was significantly lower than that of the lateral view group (7.3% *vs*. 14.7%, respectively; p<0.05). Additionally, the rate of extensor tenosynovitis was lower in the skyline view group than in the lateral view group (15% *vs*. 39%, respectively; p<0.05). No significant difference was seen in the extent of penetration between the groups (1.4 *vs*. 1.65 mm, respectively; p=0.089). The second compartment had the highest risk for dorsal screw penetration. One case of tendon rupture in the third compartment occurred in the lateral view group.

Conclusion: The skyline view seems to be an effective method to prevent extensor tendon complications caused by protruding screws.

Keywords: Radius fractures, tenosynovitis, ultrasonography, bone screws, tendon injuries.

Volar locking plates are widely used in the surgical treatment of distal radius fractures. In recent years, its usage has increased, as they can provide sufficient fixation with fewer extensor tendon complications in the fixation of dorsally displaced fractures and fractures with dorsal fragmentation.[1-3] However, direct trauma during volar plating or more often long screws penetrating the dorsal cortex are well-known complications causing extensor tendon pathologies.[4-6]

Standard lateral views remain insufficient to visualize the protruding screws from dorsal cortex due to complex, triangular dorsal surface of distal radius. Skyline view has been shown to be more effective and useful compared to lateral view.[7-10] Despite the knowledge that protruding screws from dorsal cortex cause extensor tendon pathologies, there are only a few studies comparing the complications between these two fluoroscopic methods.[11]

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Correspondence: Sinan Yüksel, MD. Dışkapı Yıldırım Beyazıt Eğitim ve Araştırma Hastanesi, Ortopedi ve Travmatoloji Kliniği, 06600 Altındağ, Ankara, Türkiye.

E-mail: yukselsinan@gmail.com

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In the present study, we aimed to compare extensor tendon complications of volar plating in distal radius fractures between skyline and lateral view by using postoperative ultrasonography (USG).

PATIENTS AND METHODS

Study design and population

This single-center, retrospective, comparative, cohort study was conducted at Dışkapı Yıldırım Beyazıt Training and Research Hospital, Department of Orthopedics and Traumatology between January 2019 and February 2020. The patients with distal radius fractures treated with a volar locking plate were screened. Inclusion criteria were as follows: age >18 years, internal fixation with a distal four-hole volar plate of distal radius fractures, operated in the post-traumatic first week, and at least three months of postoperative follow-up. Exclusion criteria were as follows: a history of fracture or surgery that could affect the anatomy of the distal radius, an open or pathological fracture, or treatment with other surgical methods such as dorsal approaches. Finally, a total of 82 distal radius fractures of 79 patients (39 males, 43 females; median age: 56±12.9 years; range, 23 to 79 years) were included. The distal radius fractures were classified according to the AO Foundation/Orthopaedic Trauma Association (AO/OTA) classification system.[12] According to the method used in the evaluation of the screw length after volar plating, the patients were divided into two groups: the lateral (standard fluoroscopic lateral and anteroposterior [AP]) view group (36 distal radius fractures of 35 patients) and the skyline (skyline plus standard lateral and AP) view group (46 distal radius fractures of 44 patients).

Surgical procedure

All patients underwent surgery within one week of the injury. The procedures were performed under a tourniquet by two experienced surgeons using the same surgical technique. The surgeons preferred the modified Henry approach. Following the reduction of the fracture, temporary fixation was made with a Kirschner wire (K-wire). Then, a four-hole Acumed Acu-Loc (Hillsboro, OR, USA) volar distal radius plate was temporarily fixed with a K-wire proximal to the watershed line. Two types of plates, standard or wide, were used according to the distal radius anatomy and width. The reduction and plate position were confirmed by fluoroscopy. Fixation was applied using a 3.5-mm cortical screw from the shaft hole proximal to the plate and, then, using a drill guide block with 2.3-mm distal locking screws. These distal locking screws were fixed-angle screws and were placed at the measured length. The pronator quadratus muscle was sutured to cover the plate. The screws were numbered from 1 to 4 from the radial side to the ulnar side. Following the fixation, the reduction quality, screw length, dorsal cortex, and intra-articular screw penetration were checked intraoperatively with standard lateral and AP fluoroscopic views in the lateral group and the skyline view in addition to the lateral and AP views in the skyline group. In both groups, screws protruding to the dorsal cortex were exchanged for screws of appropriate length. Exchanged screws were checked again by fluoroscopy; finally, it was confirmed that no screws protruded. In the postoperative period, all patients used a wrist splint, and active wrist exercises were started in the second week. Complications were recorded.

Skyline view

The patient's arm was placed on a radiolucent hand table with the shoulder joint in 90° abduction. The wrist was moved into maximum supination and flexion. By placing the sterile draped C-arm (Ziehm Vario 3D, Ziehm Imaging GmbH, Nuremberg, Germany) vertically at a 15° inclination angle, as

FIGURE 1. Skyline view technique: The forearm held at 15° (α) from the vertical axis with maximal supination and flexion of the wrist.

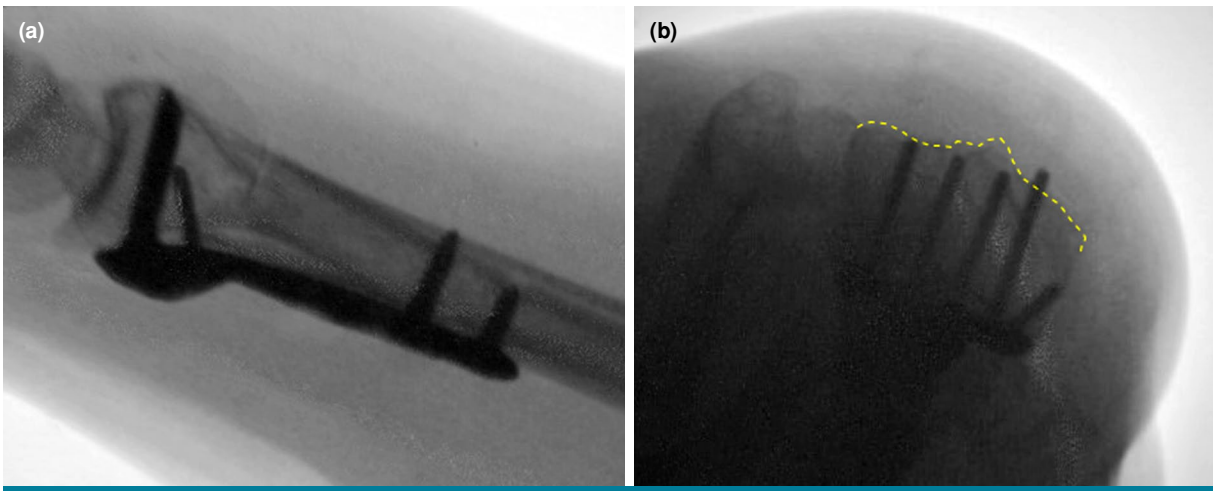

FIGURE 2. Fluoroscopic views of the distal radius: **(a)** No screws appear to cross the dorsal radial cortex on the lateral view. **(b)** Skyline view: The most radial screw crosses the dorsal cortex of the distal radius.

described by Haug et al.,[13] the skyline view image was obtained (Figure 1). Small changes were allowed in the inclination angle according to the visibility of the dorsal cortex (Figure 2).

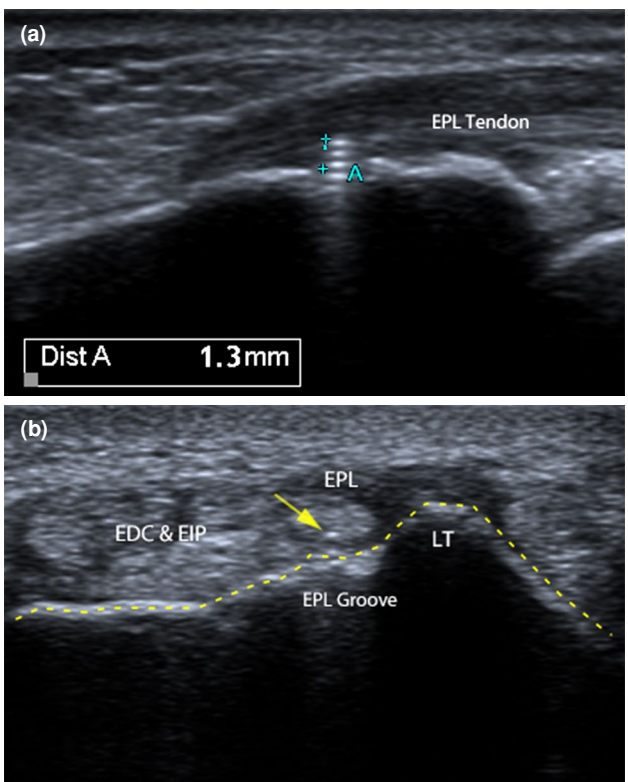

FIGURE 3. Ultrasonography examination: Longitudinal **(a)** and axial **(b)** sonograms showing a screw penetrating the dorsal cortex in the third compartment.

EPL: Extensor pollicis longus; EDC: Extensor digitorum communis; EIP: Extensor indicis proprius; LT: Lister tubercule.

USG evaluation

Postoperatively, USG was performed at a median of 5 (range, 3 to 7) months by a single radiologist experienced in musculoskeletal system radiology, who was blinded to the groups and clinical findings of the patients. The relationship between the dorsal cortex of the wrist and six extensor compartments was evaluated in the transverse and sagittal planes. A distance of ≥1 mm between the dorsal cortex and the screw tip piercing the cortex was accepted as protrusion. The number of screws penetrating the dorsal cortex, localization, extent of penetration, and the affected compartments were recorded. Tenosynovitis and the presence of partial or total tendon rupture were evaluated in the affected compartments. A diagnosis of tenosynovitis was made based on the thickening in the synovium of the tendon and/or the presence of effusion determined by USG. Partial tendon rupture occurred, if an incomplete gap with impairment to the normal fibrillar structure of the tendon was visualized, while total tendon rupture occurred, if the tendon was completely torn and the tendon end retracted (Figure 3).[14]

Statistical analysis

Power analysis and sample size calculation were performed using the G*Power version 3.1.9.7 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). Given a significance level of 0.2, effect size of 0.5, and statistical power of 0.75, the minimum desired number was calculated as 258 (129 distal screws each in the skyline view group and the lateral group).

Statistical analysis was performed using the IBM SPSS for Windows version 22.0 software (IBM Corp., Armonk, NY, USA). Continuous data were expressed in median (min-max), while categorical data were expressed in number and frequency. The comparisons between the two groups were analyzed using the independent samples t-test or the Mann-Whitney U test for continuous variables and the chi-square test or Fisher exact test for categorical variables. A *p* value of <0.05 was considered statistically significant.

RESULTS

The baseline characteristics of the patients are shown in Table I. No significant difference in the demographic and baseline features including age, sex, operation side, AO/OTA classification, and time of USG was found between the groups (p>0.05) (Table I).

In the skyline view group, in 26% (12/46) of 46 distal radius fractures (n=44), a screw was found to be penetrating the dorsal cortex by at least 1 mm. In one patient, two screws were protruding. Of the total 177 screws placed in the distal row, 7.3% (13/177) penetrated the dorsal cortex at a median length of 1.4 (range, 1 to 1.8) mm. Tenosynovitis was observed in 15% (7/44) of the patients in this group and 54% (7/13) of the screws with dorsal cortex protrusion.

Standard lateral fluoroscopic views were used during the fixation of 36 distal radius fractures of 35 patients. A protruding screw was identified in 53% (19/35) of the patients, including two screws in two patients, and in 14.7% (21/143) of the total 143 screws. The penetration length was measured as a median of 1.65 (range, 1 to 2.4) mm. Tenosynovitis occurred in 39% (14/35) of the patients in this group and 66% (14/21) of the screws with dorsal cortex protrusion. Extensor pollicis longus (EPL) tendon rupture occurred in one patient (Figure 3).

The number of screws penetrating the dorsal cortex and the rate of tenosynovitis were significantly lower in the skyline view group than in the standard lateral fluoroscopic view group (p=0.034 and p=0.015, respectively). However, no statistically significant difference was found in the degree of screw penetration between the groups (p=0.089) (Table II).

The second extensor compartment was found to be at the highest risk for dorsal penetration, as it involved 56% (19/34) of the total penetrating screws. Subsequently, the rates of dorsal screw penetration were 26% and 18% in the fourth and third compartments, respectively (Table III).

According to the AO/OTA classification, the rates of screws penetrating the dorsal cortex were 38% (6/16) in type 23A fractures, 38% (8/21) in type 23B, and 40% (34/85) in type 23C; however, no significant difference was observed between the fracture types (p=0.938).

TABLE I
Demographic and clinical characteristics of patients

	Skyline view group (n=46)				Lateral view group (n=36)				
	n	Mean±SD	Median	Range	n	Mean±SD	Median	Range	*p*
Age (year)		51.4±13.9	56.5	23-79		52.7±11.7	55	29-72	0.65
Sex									0.2
Male	19				20				
Female	27				16				
Side of fracture									0.37
Right	28				19				
Left	14				15				
Bilateral	2				1				
AO/OTA type									0.8
23A	9				7				
23B	10				10				
23C	27				19				
Time of USG (months)		5.4±1.8	5	3-9		4.8±1.6	4.5	3-8	0.34

SD: Standard deviation; AO/OTA: AO Foundation/Orthopaedic Trauma Association; USG: Ultrasonography.

TABLE II
Comparison of protruding screws and complications

	Skyline view group (n=44)				Lateral view group (n=35)				
	n	%	Mean±SD	Range	n	%	Mean±SD	Range	*p*
Number of patients/DRF	46				36				
Total distal screws	177				143				
Number of penetrating screws (%)	13	7.3			21	14.7			**0.034**
Average prominence of screws (mm)			1.44±0.24	1-1.8			1.65±0.38	1-2.4	0.089
Number of patients with tenosynovitis (% of DRF)	7	15			14	39			**0.015**

SD: Standard deviation; DRF: Distal radius fracture.

TABLE III
Summary of the protruding screws and tenosynovitis according to extensor compartments

Compartment	2			3			4			Total	
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	n	Mean±SD
Skyline view group											
Number of penetrating screws (%)	7	54		2	15		4	31		13	
Average prominence of screws (mm)			1.41±0.15			1.1±0.14			1.65±0.19		1.44±0.24
Number of patients with tenosynovitis	4			-			3			7	
Lateral view group											
Number of penetrating screws (%)	12	57		4	19		5	24		21	
Average prominence of screws (mm)			1.57±0.41			1.9±0.24			1.64±0.36		1.65±0.38
Number of patients with tenosynovitis	8			3			3			14	
Total number of tenosynovitis	12	57		3	14		6	29		21	
Total number of penetrating screws	19	56		6	18		9	26		34	

DISCUSSION

This study demonstrated that the skyline view was more effective than the lateral view in identifying screw penetration of the dorsal cortex in the surgical treatment of distal radius fractures. The rate of extensor tenosynovitis caused by dorsal prominence of distal screws was lower in the skyline view group, compared to the lateral view group and EPL tendon ruptured in one patient of the lateral view group.

Volar locking plates are biomechanically stable implants that are extremely successful in regaining a pain-free and functional wrist.[2,15] However, with technical errors, long screws penetrating the dorsal compartment can cause tenosynovitis and tendon rupture. To prevent these complications and the possibility of additional surgery, the screw length should be correctly determined intraoperatively. Previous studies conducted on cadaver and sawbone models have demonstrated that the skyline view has higher sensitivity and specificity than other fluoroscopic views.[8-10,16] Ozer et al.[17] reported the sensitivity of dorsal tangential views as 95% in 1-mm screw penetration and as high as 98% in 2-mm screw penetration. In a computed tomography-based clinical study by Özbek et al.,[17] all of the used screws were 2 mm shorter than measured and a penetrating screw was seen in 16% of the patients, although the skyline view was found to be better than the lateral view. On the contrary, Herisson et al.[18] showed that the skyline view was not more sensitive than the lateral view in a USG-based study. The results may vary, if the dorsal cortex is fragmented and there is a traumatic and swollen wrist. In our USG-based study, the rate of penetrating screws was 7.3% in the skyline group and 14.7% in the other group. Although not sensitive enough to visualize all the protruding screws, the skyline view was seen to be more successful than the lateral view. Lower sensitivity in clinical studies compared to cadaver and sawbone studies can be explained by several reasons: increased error risk of screw length measurement in the fractured distal

radius, and further variability of the radius and wrist anatomy due to increased number of patients.

To the best of our knowledge, our study is the second study comparing skyline and lateral views regarding extensor tendon complications. Although skyline view is shown to be better to demonstrate penetrating screws from dorsal cortex compared to the lateral view, there is no study showing that skyline view prevents from extensor tendon pathologies caused by these screws. There is an increasing number of studies indicating that USG is useful in detecting screw penetration and tendon complications.[19] In a cadaver study, the sensitivity and specificity of USG were found to be 100% in determining dorsal protruding screws.[20] Sügün et al.[21] performed USG to their patients with volar plating fixation and reported that 59 protruding screws (59/230) caused tenosynovitis in 18 cases, EPL tendon rupture in one case, and EPL partial rupture in one case. Herisson et al.[18] compared skyline and standard lateral views using USG with similar method of the present study; on the contrary to the findings of previous studies in the literature, the authors reported that both views had similar dorsal screw penetration, length of penetrating screws, and tenosynovitis rates. In contrast to the results of the aforementioned study, our results showed that the number of patients with tenosynovitis was significantly higher in the lateral view group (15% vs. 39%, respectively). In one patient of the lateral view group with 1.9-mm dorsal cortex penetration, EPL tendon rupture was determined. Our study has a greater and more homogeneous sample size than the study of Herrison et al.[18] The current study is the first to show that skyline view is more successful to prevent extensor tendon pathologies than the lateral view.

The second extensor compartment has the highest risk for dorsal penetration in our study, as 56% (19/34) of the total penetrating screws and 57% (12/21) of tenosynovitis were found to be in the second extensor compartment. No statistical risk analysis between the compartments was able to be performed due to the inadequate sample size. Sügün et al.[21] also found that the most frequent penetrating screws were seen in second compartment, although tenosynovitis was detected mostly in the fourth compartment. The difference of frequency of extensor tendon complications between the compartments in the literature can be attributed to that all protruding screws not to cause tenosynovitis and presence of only few clinical studies evaluating complications. It is still unclear how much contact is necessary with what length of screw to lead to tenosynovitis or rupture in extensor tendons, extensor complications developing after volar plating are seen most in the third and fourth compartments.[22] In a few clinical studies, complications can be seen in ≥1.5-mm protrusions in the third and fourth compartments, whereas longer screws in the second compartment do not cause a problem.[14,21] Similarly, in the present study, a 1.4-mm protrusion in the third compartment led to tenosynovitis, while no complication was observed with a 2.1-mm protrusion in the second compartment. Although no significant difference in the extent of penetration was found between two groups, the number of cases with tenosynovitis was higher in the lateral view group, supporting the opinion that tenosynovitis can occur, regardless of extent of screw penetration.

Nonetheless, this study has some limitations. First, it is a single-center, retrospective study. Second, USG, which was used as the reference, is an operator-dependent method. However, the study has certain strengths. First, USG evaluations were performed by a single, blinded radiologist experienced in the treatment of musculoskeletal system disorders. Second, in contrast to previous studies, the number of patients was higher, and real-life patients with homogeneous characteristics were included in the study groups. To the best of our knowledge, this is one of the few studies to compare not only screw penetration of the dorsal cortex, but also the complications.

In conclusion, the use of a fluoroscopic skyline view during the fixation of a distal radius fracture with a volar plate can decrease the occurrence of extensor tendon pathologies associated with dorsal cortex penetration. This simple imaging can be used routinely to avoid extensor tendon complications and potential additional surgery.

Ethics Committee Approval: The study protocol was approved by the Dışkapı Yıldırım Beyazıt Training and Research Hospital Ethics Committee Ethics Committee (date: 20.01.2020; no: 80/01). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept: S.Y., A.N.G.; Design: S.Y., Y.G.B; Data collection/processing: S.Y., A.N.G., A.H.C.; Analysis/interpretation: S.Y., A.Ö.; Literature review: A.Ö., Y.G.B., Ö.E. Drafting/writing: S.Y., A.Ö., M.Y.; Critical review: S.Y., Ö.E.; Materials: A.N.G., A.H.C.

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