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ORIGINAL ARTICLE

Is tendinitis in volar plating related to the dorsally protruding screw length and its compartment?

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ABSTRACT

Objectives: The aim of this study was to evaluate the relationship between the length of the protruded screws from the dorsal cortex and extensor tendon damage in all compartments.

Patients and methods: Between May 2020 and April 2021, a total of 29 patients (13 males, 16 females; mean age: 52.3±13.0 years; range, 30 to 78 years) who were operated and followed in our clinic for AO A2 and A3 distal radius fractures were included in this prospective study. Surface ultrasound (US) imaging was made to the dorsal sides of both wrists of the operated patients at different timepoints postoperatively. The length of screws with radius dorsal cortex penetration and the presence of tendinitis were recorded.

Results: In 15 of 23 patients, the presence of 29 protruding screws was accompanied by tendinitis and, in eight patients, no tendinitis was observed, despite the partial protrusion of screws. A statistically significant correlation was found between the screw protrusion and presence of tendinitis ($p<0.05$). The number of protruding screws and tendinitis were seen mostly in the second compartment. There was a statistically significant correlation between the protruding screw length of >1.6 mm and the presence tendinitis ($p<0.05$).

Conclusion: Dorsal cortex screw protrusions in the application of volar plate for distal radius fractures can cause tendinitis. Screw protrusions occur more frequently in the second compartment and the development of tendinitis in this compartment is associated with a screw length of >1.6 mm. Screw penetration can be easily identified with intraoperative US to prevent tendinitis and potential tendon ruptures.

Keywords: Distal radius fracture, extensor tendon, screw penetration, tendinitis, ultrasonography, volar plating.

Distal radius fractures (DRFs) are one of the common fragility fractures in the practice of orthopedic traumatology, and surgical treatment options include open reduction and internal fixation, external fixator application, and various combinations of these techniques.[1-3]

Osteosynthesis with a volar plate is currently frequently used in the treatment of unstable DRFs.[4-6] It allows early joint movement, provides functional healing, and is an extremely stable method biomechanically. Reported surgical complication rates show variability. Extensor tendon complications associated with screw penetration from the dorsal cortex have been reported in 1 to 15% of cases.[4-6] Ultrasound (US) is a reliable method for the follow-up of screw penetration and complications.[6,7]

The complex anatomy and irregular shape of the dorsal cortex of the distal radius make it difficult to confirm screw length.[7,8] It is, therefore, extremely difficult for orthopedic surgeons to decide on the length of screws and to reduce these complications. Fluoroscopic imaging, US, and computed tomography (CT) are used for this purpose.[9,10] The US is a rapid, non-invasive, low-cost imaging technique, which allows the evaluation of tendons and the

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measurement of protruding structures in the tendon grooves.[11] Its main advantage over fluoroscopy and CT is that it is free of ionizing radiation and is easily reproducible.

In previous studies, the length of the protruded screw causing damage to the extensor tendon is not known exactly. In addition, it is unclear whether tendon pathology develops in the early period after fixation.[12]

In the present study, we aimed to assess extensor tendon changes associated with dorsal cortex screw penetration on US and to evaluate the relationship between these changes and parameters such as screw length and number.

PATIENTS AND METHODS

This single-center, prospective study was conducted at Orthopedics and Traumatology and Radiology clinics of Hitit University Çorum Erol Olçok Training and Research Hospital between May 2020 and April 2021. A total of 29 patients (13 males, 16 females; mean age: 52.3±13.0 years; range, 30 to 78 years) who were operated and followed in our clinic for Arbeitsgemeinschaft für Osteosynthesefragen (AO) A2 and A3 DRFs were included in the study. In all patients, open reduction and plate-screw fixation was applied with a standard volar approach (Figure 1). The plates and screws used in all the patients were of the same type from the same manufacturer, and the distal screws were 2.4 mm in diameter. The screws used in our surgeries are self-drilling and self-tapping. In the postoperative period, no splint was applied leaving free wrist movement. Sutures were removed on postoperative Day 15. No surgical site infection was observed in any patient.

Radiological methods

Sonographic evaluation of the patients was performed by a single radiologist who was experienced in musculoskeletal system radiology on postoperative Day 1, then at three and six weeks. An Affiniti 70 US system (Philips Healthcare; WA, USA) was used with a 5 to 12-mHz frequency linear probe, with focal zone, depth and gain set appropriate for surface tissues. Transverse and sagittal slices were obtained at the level of the distal radius from the dorsal surface of the wrist. The lister tubercle in the distal radius was determined and evaluations were made of screw lengths protruding from the dorsal cortex and tendons within extensor compartments at the same level.

The thickness of extensor tendons and the thickness of the tendon sheaths were measured, and tendon integrity and echogenicity were evaluated. The presence of hypoechoic-anechoic fluid in the sheath and around the tendon was recorded. At the same time, the thickness of the same tendons and sheaths in the contralateral non-operated wrist were measured for comparison. In the US examination, the presence of at least 5-mm thickening in the tendon compared to the normal side and/or the presence of fluid in the sheath or around the tendon and thickening was accepted as “tendinitis”. Non-homogeneity, partial or complete breakage and retraction of the inner fibrils of the tendon were evaluated as “rupture”.[11,13]

The number of screws showing penetration in the defined compartments and the compartments where located were recorded, and the distance between the peak point of the screw and the dorsal cortex were measured sonographically.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD) or median (min-max) for continuous variables and in number and frequency for categorical variables. Conformity of the data

FIGURE 1. Two-way X-ray images on postoperative Day 1 of a 53-year-old female applied with volar plate for left-side distal radius fracture.

TABLE I
The relationship between tendonitis and the presence of protruding screw in patients and the number of protruding screws and tendonitis

	Tendonitis					
	Absent		Present			
	n	%	n	%	Total	*p*
Protruding screw						
Absent	6	42.9	0	0	6	
Present	8	57.1	15	100	23	0.006*
Total	14		15		29	
Number of protruding screws						
0	6	100	0	0	6	
1	2	28.6	5	71.4	7	
2	5	45.5	6	54.5	11	0.032*
3	1	25	3	75	4	
4	0	0	1	100	1	
Total	14	48.3	15	51.7	29	

* Fisher exact chi-square test.

to normal distribution was analyzed using the Shapiro-Wilk test. The Student t-test was used to compare two independent groups of numerical data with normal distribution and the Mann-Whitney U test was used in the comparisons of two independent groups of numerical data not showing normal distribution. Relationships between categorical variables were investigated with either the chi-square test or the Fisher exact test. The receiver operating curve (ROC) analysis was performed to protruding screw length. A *p* value of <0.05 was considered statistically significant.

RESULTS

The DRFs were on the right side in 12 (41.4%) cases and on the left side in 17 (58.6%) cases. The median time to surgery was 2 (range, 0 to 6) days, the median time to discharge was 5 (range, 1 to 9) days, and the median follow-up was 14.1 (range, 13 to 19) months.

Tendonitis was present in 15 patients and was not detected in 14 patients. While there was no screw protrusion in six patients without tendinitis, eight patients had screw protrusion. In 23 patients with a protruding screw, there was no statistically significant relationship between the screw protrusion and tendinitis (p<0.05, Table I).

The mean number of protruding screws in all the patients was 1.55±1.08 (range, 0 to 4). The mean number of screws not causing tendinitis was 1.07±1.07 (range, 0 to 3) and the mean number of protruding screws causing tendinitis was 2.0±0.92 (range, 1 to 4). A statistically significant relationship was found between the number of protruding screws and tendinitis, which did not increase proportionally to the increase in number of screws (p<0.05) (Table I).

TABLE II
Comparisons of the relationships between protruding screw length and tendonitis

	Tendonitis				
	Absent		Present		
	n	Mean±SD	n	Mean±SD	*p*
Protruding screw length (mm)					
All compartments	16	2.9±1.4	29	3.1±1.4	0.685[a]
2nd compartment	4	1.7±0.7	19	3.3±1.4	0.021[a]
3rd compartment	12	3.4±1.3	8	2.5±1.4	0.188[a]
4th compartment	0		2	3.3±0.1	

SD: Standard deviation; [a] Student's t test.

TABLE III

The success of cut-off values determined by ROC analysis in the prediction of second compartment tendinitis

		2nd compartment (Tendonitis)		
	Cut-off	No	Yes	Total
Protruding screw length	<1.6	3	1	4
	≥1.6	1	18	19
Total		4	19	23

ROC: Receiver operating characteristic.

A total of 45 protruding screws were identified in 23 patients. Tendinitis was observed in 15 of these patients (Table I). There was a total of 29 protruding screws in these 15 patients and the presence of tendinitis in the relevant compartments. The distribution of the protruding screws was 23 in the second compartment, 20 in the third compartment, and two in the fourth compartment.

When all the compartments were evaluated together, no statistically significant difference was found between the length of the protruding screws and the presence of tendinitis ($p>0.05$). The relationship between the protruding screw length (mm) and the development of tendinitis was found to be statistically significant in the second compartment ($p<0.05$, Table II), but not statistically significant in the third compartment. P values could not be obtained for the fourth compartment, as there were only two screws protruding together with the presence of tendinitis, which was not sufficient for statistical analysis.

As the protruding screw length was statistically significant only in the second compartment ($p<0.05$), the ROC analysis was applied only to this parameter.

TABLE IV

ROC analysis results and the sensitivity, specificity, PPV and NPV of protruding screw length in the prediction of second compartment tendonitis

	Protruding screw length
AUC (95% CI)	0.868 (0.667-1.000)
P values	0.023
Cut off	≥1.6
Sensitivity (95% CI)	0.947 (0.718-0.997)
Specificity (95% CI)	0.750 (.219-0.986)
PPV (95% CI)	0.947 (0.718-0.997)
NPV (95% CI)	0.750 (0.219-0.986)

ROC: Receiver operating characteristic; PPV: Positive predictive value; AUC: Area under curve; CI: Confidence interval; NPV: Negative predictive value.

The cut-off values for the protruding screw lengths in the second compartment in the successful prediction of determining tendinitis, together with the number of patients related to these parameters and the confidence interval of the evaluations are shown in Table III and Table IV. The critical cut-off value for the length of protruding screws was determined to be 1.6 mm.

The presence of tendinitis in patients with screw protrusion and its change according to time is presented in Figure 2.

DISCUSSION

Several studies have been carried out before to identify the length of the overflowing screw causing tendinitis. We believe that the screw length causing tendinitis may be different in each compartment. In this study, we identified the 1.6-mm long screw overflow in the second compartment as the cut-off causing the tendinitis.

Gurbuz et al.[4] reported that the dorsal horizon view (DHV) was as sensitive as US in identifying 2-mm screw significance; however, this imaging tool was not found to be at a sufficient level for the determination of dorsal screw penetration and could not determine 1-mm screw penetration in the fourth compartment. The possibility of determining dorsal cortex penetration of <2 mm was reported by Sügün et al.[7] to be higher on US compared to four-plane radiography. Previous studies of measurements have also reported the smallest screw size causing symptoms in patients to be 1.8 mm.[6] In the current study, the smallest screw length causing tendinitis was 1.3 mm in the second compartment and 1 mm in the third compartment.

To be able to prevent extensor tendon complications following volar plate fixation of DRFs, it is important to identify screws protruding from the dorsal cortex. Radiography is used most for the detection of these screws in the peri- and postoperative periods.[14,15]

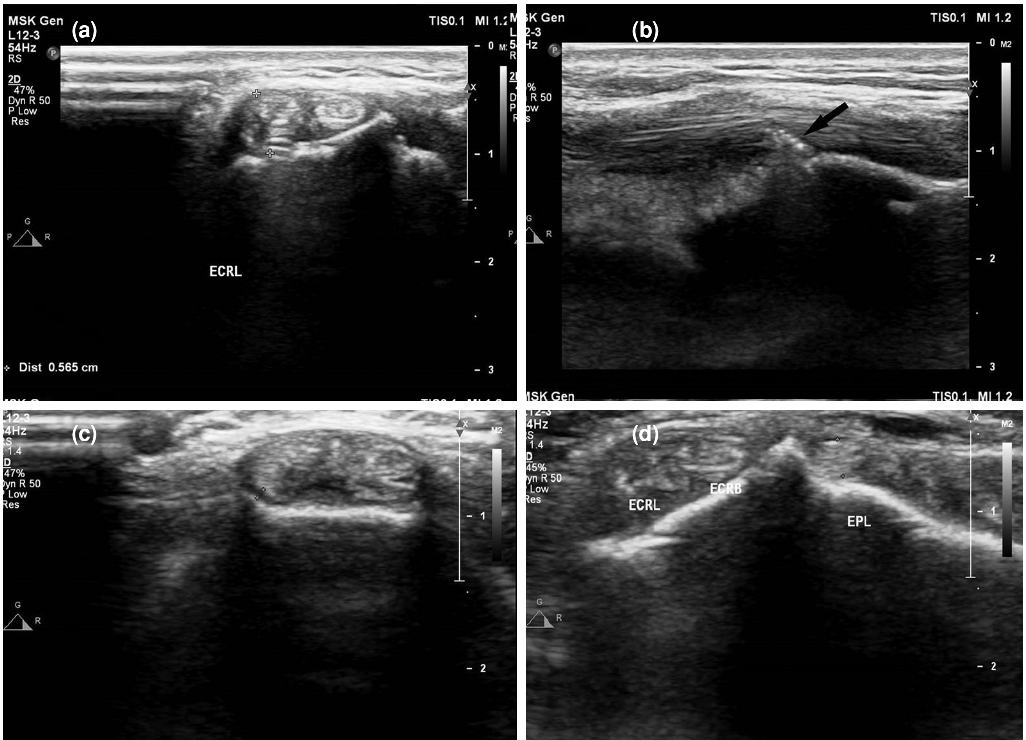

FIGURE 2. A 33-year-old male patient who was operated on the right wrist **(a)** Transverse section showing ECRL tendon thickness (5.6 mm) and the screw inside the tendon at 6 weeks postoperatively. **(b)** Longitudinal section of the ECRL tendon and the screw inside (black arrow). **(c)** ECRL tendon sheath thickness was measured 0.68 mm. **(d)** Normal side wrist transverse US image (ECRL thickness measured 3.2 mm, sheath thickness 0.5 mm).
ECRL: Extensor carpi radialis longus; US: Ultrasound.

As there is greater focus on fracture reduction during the surgical procedure, screws penetrating the distal cortex can be overlooked. For early movement and regaining extremity functions, problem-free healing of soft tissue is as important as the bone healing. The classic fluoroscopy imaging techniques used may not be sufficient to determine possible soft tissue complications or protruding screws causing these complications and their localization. Additional fluoroscopic images for the determination of dorsal screw penetration provide better results than traditional imaging.[16,17] In a cadaver study by Hill et al.,[18] radiography in 45° supination was reported to be the most sensitive method in the determination of screws protruding from the dorsal cortex with 88% sensitivity.

There is a need for methods with higher sensitivity to identify screws protruding from the dorsal cortex and associated extensor tendon changes that can develop. Bianchi et al.[11] reported that US showed 100% sensitivity and specificity in the determination of dorsal cortex screw penetration. That US is independent of compartments increases its utility in the determination of screw protrusion.[11,12,14,15,18,19]

In a cadaver study, Watchmaker et al.[20] showed almost equal values of US and dissection in the determination of screws penetrating the dorsal cortex. In contrast to magnetic resonance imaging (MRI), the efficacy of US is not restricted to implants in the examined area.[11,19]

Extensor pollicis longus tendon rupture has been reported in patients treated with volar plate, and tendinitis may be a significant risk factor for advanced tendon damage.[7,8] The risk of asymptomatic tendinitis progressing to tendon rupture is not fully known. It is also not known to what extent screw protrusion causes extensor tendon damage and associated with that, in how long a period tendon tears develop.[7,8,21]

In the current study, tendon rupture was not detected in any compartment in any patient during the follow-up period. However, a statistically significant relationship was found between the determination of tendinitis and a screw length of >1.6 mm protruding in the second extensor compartment. In other extensor compartments, no correlation was observed between the screw length and presence of tendinitis. Sügün et al.[7] reported that tendinitis symptoms were seen particularly in the third and fourth compartments with screws longer than 1.5 mm. In another study, in patients referred for US due to clinical suspicion of screw protrusion, there was more than 1.5 mm protrusion in six screws in the third compartment and in five screws in the fourth compartment, and there was tendinitis or damage in all of these cases.[11]

It can be considered that drilling and tapping performed during the operation may be a potential factor for acute tendon rupture. To prove this, there is a need for additional studies with drilling performed under US guidance. Drilling must be performed with care and the dorsal cortex must not be pierced to prevent iatrogenic damage to extensor tendons. It is 1.6 mm recommended that shorter epiphyseal screws are used in dorsal fragmented osteoporotic bone, particularly.[21] Some studies recommend that a screw 2-mm shorter than the measured length is applied or that the dorsal cortex is not pierced, as plate distal screws applied close to the subchondral region protect the reduction.[4,7,8,12] Riddick et al.[22] reported that it was not known whether or not a small degree of penetration increased the incidence of tendon rupture and, if screw penetration was determined in any compartment, these screws should be changed.[22]

The different number of screws in the compartments is thought to be due to the fixed orientation of the standard screw holes in the plates applied anatomically. In addition, as the rate of tendinitis development did not increase proportionally, when the number of penetrating screws increased, and this was thought to be due to the distal radius dorsal anatomy having different grooves and projections and some screw protrusions occurring in these grooves.

The absence of tendon rupture was also clinically detected in patients who did not undergo any splint in the early postoperative period. The presence or development of tendinitis was in agreement with the US findings, with a clear resolution between the sixth-week and third-month follow-up visits. Postoperative first-day and third-week findings were more subjectively confused with wrist and postoperative pain. This can be considered as the weakness of the study.

Dorsal cortical screw penetration in surgically treated DRFs can be safely identified with US. Although the visualization of protruding screws seems to be similar on different radiographic images to US, US is superior in terms of being able to show tendon damage. Moreover, the status of tendon and soft tissue pathologies that can develop over time can be easily observed with US which is a significant advantage. In addition to the sensitive measurement of US independently of compartments, screws protruding from the dorsal cortex can be measured up to 1 mm which is another advantage.

The fact that the number of screws protruding from the dorsal cortex and tendinitis were identified mostly in the second compartment suggests that surgical sensitivity is necessary while applying screws in this compartment, dorsal cortical drilling should not be performed, and if necessary, it would be appropriate to apply screws 2 mm shorter.

The extensor compartments, particularly the second, third, and fourth compartments, have a tight relationship with the bone surface anatomically and this closed space does not tolerate any additional volume occupation. Previous studies have shown that these compartments are the most violated by plate and screw applications in distal radial fractures. The extensor pollicis longus tendon is the most commonly ruptured tendon, due to the limited area of the third compartment, its relatively long extension, and the course of the tendon with a sharp curve around the Lister tubercle.[7,8] Unlike in our study, no rupture was observed in any tendon.

Nonetheless, there are some limitations to this study. In our study, measurements were made with a single radiologist with 10 years of experience in the musculoskeletal system. Although the lack of agreement between observers is seen as a limitation of the study, we believe that it is an advantage to have follow-ups by a single radiologist. In addition, since we included only AO A2-A3 fractures in our study, we evaluated it with a smaller number of patients, which can be seen as another limitation of the study. However, AO A2-A3 fractures could cause false results, as they would cause higher-energy trauma and more soft tissue damage. Types B and C could be another study topic. Finally, although using a different imaging method with US would have made the study more valuable, it would have added additional cost. Further studies are needed to draw more reliable conclusions on this subject.

In conclusion, although tendinitis associated with screws penetrating from the dorsal cortex recovers over time, it is obvious that this may have a negative effect on movement functions. Therefore, despite the resolution of tendinitis over time, screw penetration of more than 1.6 mm, particularly in the second compartment, can be seen as a problem requiring revision. Similarly, studies are needed to determine the cut-off value in other compartments. However, these problems can be overcome with intraoperative US evaluation. It is reasonable to mention that CT is the gold standard in the evaluation of the bone-screw relationship. However, we believe that screw length measurements via CT may lead to extra-radiation exposure in postoperative patients, for comparison purposes only. As US is effective and safe, it should have a wide area of use in the practice of orthopedic surgery. In this way, the harm to both patient and surgical team of the use of fluoroscopy imaging can be minimized.

Ethics Committee Approval: The study protocol was approved by the Hitit University Faculty of Medicine Clinical Research Ethics Committee (date: 05.05.2020. no: 231). 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: Conceptualization: N.F.; Data curation: E.H.; Formal analysis: T.A.; Investigation: E.H.; Methodology: S.Z.; Resources: N.F.; Supervision: S.Z.; Writing-original draft: T.A.; Writing-review & editing: T.A.

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