

# How effective is skyline view for avoiding dorsal cortex penetration in volar plate fixation of intra-articular and dorsal cortex comminuted distal radius fractures



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## ABSTRACT

**Objectives:** The incidence of osteosynthesis is increased by volar anatomic plate used for treatment of distal radius fractures and this increases the incidence of wrist extensor tendon irritation, a postoperative complication of the aforementioned surgical technique. The purpose of this study; was to evaluate the intraoperative skyline view which is commonly used to prevent dorsal cortex penetration of distal screws during the surgical treatment of intra-articular distal radius fractures with comminuted dorsal cortex with CT (computed tomography) scanning to determine its effectiveness. In the literature review, no other study focused on similar fracture types was found.

**Methods:** 52 patients with a minimum follow-up of 13 months were included in the study. These patients were operated by two different national board certified surgeons. One of the surgeons unlike the other, adopted intraoperative skyline view method. X-ray and CT scans which were performed preoperative and postoperative first day, were evaluated by a senior author with a blind evaluation method. Fractures were classified according to AO/OTA (Orthopaedic Trauma Association) classification and postoperative dorsal cortex penetrations were registered.

**Results:** Intra-articular distal radius fractures with comminuted dorsal cortex (AO/OTA 2R3C2, C3) were detected in 25 of the patients and no significant difference between two groups for the distribution of these patients was found. The CT scan of 14 patients showed dorsal cortex screw penetration and this rate was significantly higher in the group, in which intraoperative skyline view was not used ( $p > 0,05$ ). In the postoperative CT examination, the most common dorsal cortex penetration was related to the 4th distal screw (42.9%) which were inserted the nearest ulnar hole of plate.

**Conclusion:** The insertion of a distal screw 2 mm (millimeter) shorter than the length measured with the help of skyline view is considered to be a more effective method than other intraoperative methods for preventing dorsal cortex penetration. In addition, more comprehensive studies are required in order to recommend the mono-cortex fixation, in which distal screws measuring 4 mm shorter are used.

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## Introduction

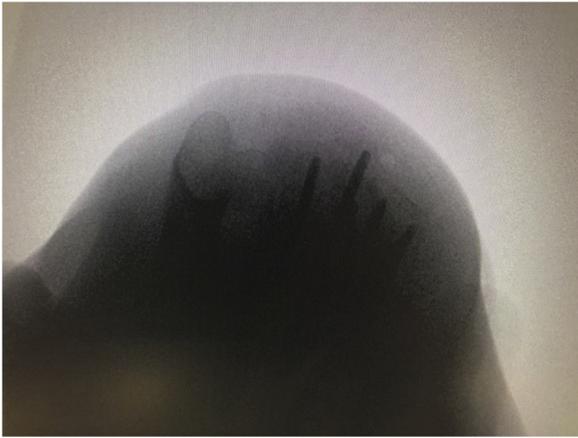
The distal radius fractures are among the most common fractures in emergency services and they are among the most common fractures operated by the orthopedic surgeons [1,2]. Nowadays, osteosynthesis with volar anatomic plate is gaining more popularity for these fractures' treatment [2]. However, extensor tendon injuries, which were reported 6% incidence in literature, due to dorsal cortex penetration are among the postoperative complications

of this surgical technique [3]. There are various intraoperative fluoroscopic imaging methods, intraoperative CT and USG (ultrasonography) were used to avoid these complications [4,5]. Nonetheless, skyline (dorsal tangential) view is the most widely used method among orthopedic surgeons, as it has high sensitivity (95%) in determination of 1 mm penetrations in the dorsal cortex and it is easy to perform [1,2,4,5].

An intraoperative fluoroscopic imaging method, skyline view is very useful to avoid the 3rd extensor compartment injuries [3], as the apex of the Lister's tubercle is located 1.4 mm–6.6 mm higher than the dorsal radial cortex and it is superposed with the screws in the compartment located at ulnar side of Lister's tubercle in lateral view [1,6]. On the other hand, studies focused on effectiveness

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**Fig. 1.** Intraoperative skyline view of AO 2R3C.2 distal radius fracture. There is no dorsal cortex penetrated screw detected in this skyline view.

of skyline view were generally conducted on cadavers with intact dorsal cortex [1,4,7]. However, the decision on the size of the distal screw in the intra-articular distal radius fractures with comminuted dorsal cortex is rather challenging for orthopedic surgeons. In such cases, surgeons prefer screws which are 2 mm shorter than measured length due to recommendations in the literature. However, its effectiveness and effect on the postoperative fracture stability are still widely debated [8].

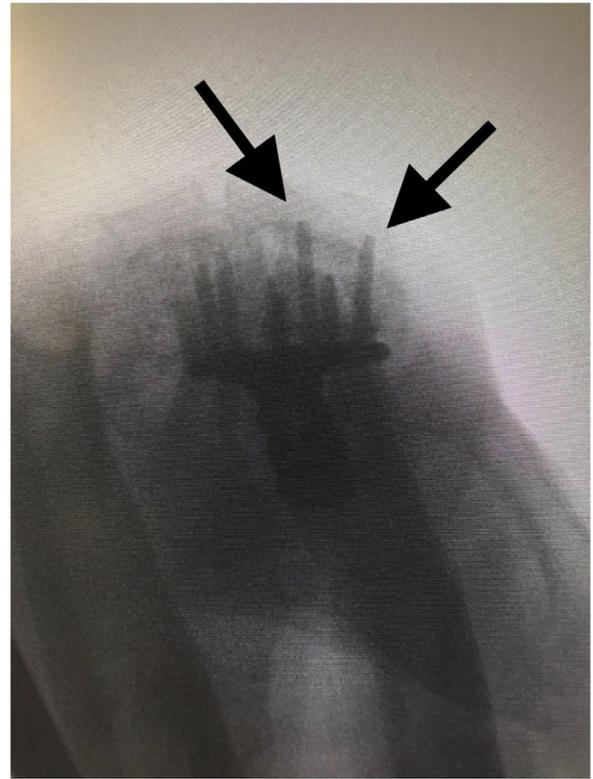
The purpose of this study, was to investigate the efficacy of the skyline view used in surgical treatment of intra-articular distal radius fractures with or without comminuted dorsal cortex for prevention of the dorsal cortex penetration and to prove it with CT. No other study focused on efficacy of the skyline view in this type of fractures is noted.

The hypothesis of this study, was that the concomitant use of skyline view with insertion of distal screws 2 mm shorter than the measured length is one of the most effective methods to avoid the dorsal cortex penetration in daily surgical practice.

## Materials and methods

Our study was planned as retrospective and approved by the Ethics Committee of the Bozok University Medical Faculty. 52 patients, who underwent osteosynthesis surgery with volar anatomic distal radius plate due to distal radius fracture in our clinic between January 2017 and November 2017, were included in the study. Only intra-articular distal radius fractures with or without comminuted dorsal cortex (AO/OTA 2R3B.1, 2R3B.3, 2R3C.1, 2R3C.2, 2R3C.3) were included in the study. Patients with dorsal Barton's fracture and previous distal radius fracture were excluded from the study. The preoperative X-ray and CT images were classified according to the AO/OTA classification [9].

All of the patients were operated by same experienced and national board certified two surgeons, using AAP (Berlin, Germany) volar anatomic distal radius plate with volar Henry approach. Fractures were reduced and temporary fixation was done with K-wires after that reduction and plate position was evaluate with fluoroscopic views. One of the surgeons inserted distal screws 2 mm shorter than the measured screw length and confirmed the screw length with AP (anteroposterior), lateral, lateral while elbow was 20° flexion and skyline wrist views (Group A, n = 25) (Figs. 1 and 2). The skyline view was displayed as described by Haug et al. while the dorsal cortex of the distal radius was positioned with 15 inclination to the vertical X-ray beam of the fluoroscope [10]. The second surgeon used distal screws 2 mm shorter than the measured screw length and confirmed the confirmed the screw length



**Fig. 2.** Intraoperative skyline view of AO 2R3C.3 distal radius fracture. Dorsal cortex penetrated 1. screw and suspicious dorsal cortex penetrated 2. screw are seen in skyline view.

with AP (anteroposterior), lateral while elbow was 20° flexion and lateral wrist views (Group B, n = 27). As all operations were performed due to the intra-articular distal radius fracture, CT imaging (Somatom® Perspective, Siemens, Germany) was obtained on the 1st postoperative day for the evaluation of the joint reduction as recommended in the literature [2,5]. Also postoperative first day wrist AP and lateral X-Ray imaging was ordered to evaluate reduction quality. There was no > 10 mm radial height loss, dorsal tilt was seen and anatomically reduced joint reduction was detected all patients' X-Rays. The CT images were evaluated by the senior author as described in the literature also senior author was blind for patients' group [3]. Dorsal cortical penetration of the screws and intra-articular penetrating screws were recorded during this evaluation. The complete bone union was observed the sixth week follow-up of all patients, whose wrists were mobilized at the early stage of the postoperative 2 weeks period, and no case of malunion or non-union was encountered. The postoperative complications and needs of explantation surgery were also recorded.

Statistical analysis was performed with SPSS v22.0 (Chicago IL). During the statistical analysis, categorical variables were expressed with numbers and percentages, and continuous variables were presented with the mean ± standard deviation (SD) and median (min-max values) for descriptive analyses. Pearson's chi-square, Fisher's and continuity correction chi-square tests were used for comparison of categorical variables between the groups. The conformity of the continuous variables to the normal distribution was evaluated using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests). Mann-Whitney U test was used for the comparison of datasets which were not normally distributed. Independent samples *t*-test was used for comparison of datasets which were normally distributed. The effects of the surgical technique on the screw penetration and intra-articular screws were evaluated by univariate binary logistic

regression analysis. The results of univariate binary logistic regression analysis were given with 95% confidence interval and crude odds ratio (OR).  $P < 0.05$  was considered statistically significant.

## Results

A total of 52 patients were included in the study. The patients were divided into two groups (Group A,  $n=25$  and Group B,  $n=27$ ). The characteristics of the distribution of the patients in the groups were not statistically significant different ( $p > 0.05$ ). The mean age of the participants was 43.5 years (18–65 years) and 26 of them were females (Table 1). The mean follow-up duration of the participating patients was  $15.8 \pm 2.7$  months. Intra-articular distal radius fractures with or without comminuted dorsal cortex were included in the study. There was no statistically significant difference between the groups regarding the fracture types ( $p > 0.05$ ). The distal radius fractures with comminuted dorsal cortex (AO/OTA 2R3C.1, 2R3C.2, 2R3C.3) and distal radius fractures without comminuted dorsal cortex (AO/OTA 2R3B.1, 2R3B.3) were equally distributed into two groups ( $p > 0.05$ ).

The CT scan was performed on the postoperative first day revealed that two patients had intra-articular screw penetration (Group A,  $n=1$ ; Group B,  $n=1$ ). The patient, who had 2 mm intra-articular penetration of screw, in Group A refused the revision surgery on the 1st postoperative day, but he did not have any complaints during the postoperative 15 months of follow-up. The other patient, who had 2 mm intra-articular penetration of screw, in Group B underwent revision surgery and had no complaints about his wrist during the 12-month follow-up.

Dorsal cortex screw penetration was determined in 14 of 52 patients (Group A,  $n=4$ ; Group B,  $n=10$ ) during the postoperative CT scan evaluation (Table 2). The rate of the dorsal cortex screw penetration was significantly higher in Group B compared to Group A ( $p < 0.05$ ). There was no statistically significant difference between the groups regarding the prominence length of these screws (Group A,  $1.3 \pm 0.4$  mm; Group B,  $1.5 \pm 0.6$  mm) ( $p > 0.05$ ). The numbering of the screw holes, which are located in the distal limb of the plate, from 1<sup>st</sup> to 4<sup>th</sup> starting from the radial side towards the ulnar side was done. Dorsal cortex screw penetration was observed most commonly in the 4th screw, which was located in the ulnar side of the Lister's tubercle ( $n=6$ , 42.9%) (Table 2).

**Table 1**

Results of patients demographic datas, distribution of AO/OTA fracture classes. Also distribution of all detected screws penetrating the dorsal cortex screws in holes of the volar anatomic distal radius plate.

|   | Group A         | Group B         | P Value |
|---|-----------------|-----------------|---------|
| <b>Age, Years</b>                             |                 |                 |         |
| Mean $\pm$ s.d.                               | 47,3 $\pm$ 10,9 | 40,7 $\pm$ 12,9 | >0,05   |
| Median (min-max)                              | 49 (25,0–65,0)  | 38 (18,0–63,)   |         |
| <b>Sex, n (%)</b>                             |                 |                 |         |
| Female  | 13 (52%)        | 13 (48,1%)      | >0,05   |
| Male  | 12 (48%)        | 14 (51,9%)      |         |
| <b>Follow-up, month</b>                       |                 |                 |         |
| Mean $\pm$ s.d.                               | 15,4 $\pm$ 2,5  | 16,1 $\pm$ 2,8  | >0,05   |
| Median (min-max)                              | 15 (13,0–22,0)  | 15 (13,0–23,0)  |         |
| <b>AO/OTA Classes, n (%)</b>                  |                 |                 |         |
| AO 2R3B.1                                     | 1 (4%)          | 0 (0%)          | >0,05   |
| AO 2R3B.3                                     | 6 (24%)         | 2 (7,5%)        |         |
| AO 2R3C.1                                     | 8 (32%)         | 10 (37%)        |         |
| AO 2R3C.2                                     | 6 (24%)         | 12 (44,4%)      |         |
| AO 2R3C.3                                     | 4 (16%)         | 3 (11,1%)       |         |
| <b>AO/OTA Classes, n (%)</b>                  |                 |                 |         |
| Others  | 15 (60%)        | 12 (44,4%)      | >0,05   |
| AO 2R3C.2 + AO 2R3C.3                         | 10 (40%)        | 15 (55,6%)      |         |
| <b>Dorsal Cortex Penetrated Screws, n (%)</b> |                 |                 |         |
| 1. Distal Hole                                | 0               | 0               | >0,05   |
| 2. Distal Hole                                | 2 (14,2%)       | 3 (21,3%)       |         |
| 3. Distal Hole                                | 1 (7,1%)        | 2 (14,2%)       |         |
| 4. Distal Hole                                | 1 (7,1%)        | 5 (35,5%)       |         |

On the other hand, there was no statistically significant difference between the distal radius fractures with comminuted dorsal cortex and with intact dorsal cortex regarding the dorsal cortex screw penetration ( $p > 0.05$ ).

In our clinic, we do not routinely perform explantation surgery after the distal radius fracture treatment. We prefer this surgery in patients with postoperative wrist extensor and/or flexor tendons irritation. Extensor tenosynovitis were observed in 5 patients (Group A,  $n=1$ , 4%; Group B,  $n=4$ , 14.8%) who also had dorsal

**Table 2**

Results of differences, which are about screws' dorsal cortex penetration and postoperative complications, between two groups.

|  | Group A       | Group B       | P Value |
|--|---------------|---------------|---------|
| <b>Intraarticular Screw, n (%)</b>   |               |               |         |
| Positive   | 1 (4%)        | 1 (3,8%)      | >0,05   |
| Negative   | 24 (96%)      | 26 (96,2%)    |         |
| <b>Penetrated Screws, n (%)</b>  |               |               |         |
| Positive   | 4 (16%)       | 10 (38,5%)    | <0,05   |
| Negative   | 21 (84%)      | 17 (61,5%)    |         |
| <b>Distal radius fractures with intact dorsal cortex (AO/OTA 2R3B.1, 2R3B.3, 2R3C.1)</b> |               |               |         |
| <b>Penetrated Screws, n (%)</b>  |               |               |         |
| Positive   | 0             | 3 (27,3%)     | >0,05   |
| Negative   | 15 (100%)     | 8 (2,7%)      |         |
| <b>Distal radius fractures with comminuted dorsal cortex (AO/OTA 2R3C.2, 2R3C.3)</b>     |               |               |         |
| <b>Penetrated Screws, n (%)</b>  |               |               |         |
| Positive   | 4 (40%)       | 7 (46,7%)     | >0,05   |
| Negative   | 6 (60%)       | 9 (53,3%)     |         |
| <b>Prominence of Penetrated Screws, mm</b>   |               |               |         |
| Mean $\pm$ sd  | 1,3 $\pm$ 0,4 | 1,5 $\pm$ 0,6 | >0,05   |
| Median (min-max)   | 1,1 (0,9-1,9) | 1,3 (0,9-2,9) |         |
| <b>Tenosynovitis of Wrist's Extensor Tendons n (%)</b>                                   |               |               |         |
| Positive   | 1 (4%)        | 4 (14,8%)     | >0,05   |
| Negative   | 24 (96%)      | 23 (85,2%)    |         |
| <b>Implant Removal Surgery, n (%)</b>  |               |               |         |
| Positive   | 1 (4%)        | 4 (14,8%)     | >0,05   |
| Negative   | 24(96%)       | 23 (85,2%)    |         |

cortex screw penetration. They underwent explantation surgery in postoperative first year. Nevertheless, there was no statistically significant difference between the groups regarding the distribution of these cases ( $p > 0.05$ ).

## Discussion

The purpose of this study, was to investigate the efficacy of the skyline view used in surgical treatment of intra-articular distal radius fractures with or without comminuted dorsal cortex for prevention of the dorsal cortex penetration and to prove it with CT. Similar to the reports in the literature, the results of our study supported our hypothesis that skyline view is an effective method to avoid dorsal cortex penetration of the distal screws of volar anatomic distal radius plate during the surgery [1,2,4,5].

Since its introduction, the skyline view was compared with several intraoperative and postoperative imaging methods in the patients, who underwent distal radius fracture surgery, to avoid the dorsal cortex screw penetration [1,3,6,10–12]. Similar to our study, almost all of these studies showed that skyline view was more effective than other methods. Ozer K. et al. concluded that the skyline view was superior to intraoperative lateral and oblique views considering the prevention of the dorsal cortex penetration in patients, who underwent distal radius fracture surgery [6]. Brunner A. et al. conducted a study on 22 patients with distal radius fracture and reported that they did not observe screw prominence in the dorsal cortex in the postoperative CT imaging if the screw length was decided with the intraoperative skyline view during their surgery [3]. In the conclusion of the same study, the authors recommended skyline view as a reliable method for all distal radius fractures depending on its cost-effectiveness and easy intraoperative implementation [3]. Vernet P. et al. conducted a study on 10 forearms obtained from cadavers and reported that the skyline view as effective as USG regarding the avoidance of the dorsal cortex penetration [7]. However, there are also some studies, which suggested that CT and USG imaging were superior to the skyline view [2,4,7,13]. But the authors of these studies stated also that these methods were not cost-effective and easy-to-use. Gürbüz Y. et al. included 10 forearm specimens obtained from cadavers in their study and suggested that the USG was superior to the skyline view but also emphasized that the effectiveness of this method depended on the experience of the practitioner [4].

In our study, dorsal cortex screw penetration were observed in 14 patients and the average prominences of these screws were 1.3–1.5 mm according to the groups. Özer K. et al. concluded in their study, in which they investigated 10 cadaveric forearm specimens, that the skyline view successfully detected all dorsal cortex screw penetrations (1 mm, 2 mm and 3 mm) [12]. However, this study was conducted on specimens without distal radius fracture and therefore it could not represent the conditions of the daily practice. We included only the patients, who had distal radius fractures and almost half of these patients had concomitant comminuted dorsal cortex fracture.

In the studies focused on the distal radius morphology, Lister's tubercle and EPL (extensor pollicis longus) groove were often examined [14]. Clement H. et al. conducted a study with this purpose and concluded that the distal screw length should be cautiously selected due to the possible superposition in the standard lateral and oblique imaging because Lister's tubercle tip is located approximately 18.3 mm higher and EPL groove is located approximately 2.8 mm deeper relative to the dorsal radial cortex [14]. Our results showed that dorsal cortex penetration was most common in the 4th screw (42.9%). This result might be explained with the superposition of this screw upon the Lister's tubercle in the lateral imaging. Another study, in which this topic was investigated on the cadaver specimens, was conducted by Cha S.M. et al. They

concluded that - in consistency with our study - the skyline view was superior to other standard intraoperative imaging methods in respect of the determination of the 4th screw penetration [15].

In our study, the comparison of the intra-articular distal radius fractures with the comminuted dorsal cortex and with intact dorsal cortex showed that the penetration risk of the distal screws was similar for both fracture types. However, we believe, that this result might be misleading in light of the limited number of subjects compared to the literature [12,16]. Mısırlı A. et al. mapped the intra-articular fracturing of this type fractures with CT imaging in 34 patients with AO2R3C.3 fracture. They reported that in 14% of the cases, the dorsal articular face was involved in the fracture [16]. In light of these results, a precise screw measurement in the intra-articular fractures with comminuted dorsal cortex is rather difficult, and erratic measurements seem to be related to higher penetration risk. Therefore, insertion of screws 2–4 mm shorter than the measured length was suggested in the literature to decrease this risk in this type of fractures [13,17,18].

The evaluation of the studies focused on the complications of the distal radius fractures showed that there could be other factors to blame besides the dorsal cortex screw penetration for the emergence of the postoperative EPL rupture [14,16,19]. Cha SM et al. followed 314 patients with island-shape fracture of the Lister's tubercle and concluded that the callus tissue of the Lister's tubercle might narrow the EPL groove [19]. In our study, we did not observe postoperative EPL rupture. We believe that this finding depended on the implementation of the explantation surgery in patients with the development of the wrist extensor tenosynovitis as recommended in the literature [20].

Our study had several strength characteristics which were both groups in our study were homogeneous, involved the patients who were encountered in the daily practice and the blind interpretation of the postoperative CT images by a senior surgeon. However, there were also certain limitations in our study. First of all, it was retrospective study. Secondly, the distribution of the patients in the groups was not based on a real randomization; however, the patients were grouped according to the shifts of the surgeons in emergency service. Another limitation of the study was the small subject size, although it was close to the subject size in the literature.

The discussion about the superiority of the skyline view to other intraoperative and postoperative imaging methods regarding the avoidance of the dorsal cortex screw penetration in the distal radius fractures is still on-going in the literature. Nevertheless, it seems to be a cost-effective, easy-to-use and independent from the practitioner method considering the decision on the distal screw length in patients with intra-articular distal radius fracture and comminuted dorsal cortex. In line with these results, all authors started to use the combination with the screw insertion 2 mm shorter than the screw length measured with the skyline view in the distal radius fracture surgery. In addition, although there are some studies, in which mono-cortex, 4 mm shorter than the measured length screws were suggested, we believe that studies which are focused on the postoperative fracture stabilization and include large subject size, are needed before the routine implementation of this method. The insertion of a distal screw 2 mm (millimeter) shorter than the length measured with the help of skyline view is considered to be a more effective method than other intraoperative methods for preventing dorsal cortex penetration.

## Ethics

The study was approved by Ethics Review Board of Bozok University.

Each author certifies that he has no commercial associations (e.g. consultant-cies, stock ownership, equity interest,

patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

### Declaration of Competing Interest

Each author certifies that he has no commercial associations (e.g. consultancy, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

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