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Size and stabilization of the dorsoulnar fragment in AO C3-type distal radius fractures

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ABSTRACT

Introduction: Volar locking plate (VLP) fixation has become the gold-standard treatment for distal radius fractures (DRFs). Especially, internal fixation of the volar lunate facet fragment is essential for the treatment of AO C3-type DRFs. On the other hand, the necessity of the fixation of the dorsal lunate facet fragment (dorsoulnar fragment) remains unclear. The purpose of the present study was to measure three-dimensionally the size of the dorsoulnar fragments in AO C3-type DRFs using computed tomography (CT) images in detail, and to reveal relationships of the size and stabilization of the dorsoulnar fragment with postoperative fracture displacement after VLP fixation.

Materials and methods: We retrospectively reviewed the 101 consecutive Japanese patients who underwent surgical treatment for AO C3-type distal radius fractures. If patient had dorsoulnar fragment, the three-dimensional size of this fragment and the occupying ratio to the radiocarpal joint (RCJ) and the distal radioulnar joint (DRUJ) were anatomically evaluated using the preoperative CT images. In addition, we investigated the relationship of the size and stabilization of the dorsoulnar fragment with fracture displacement after VLP fixation. We statistically compared the size parameters and occupying ratio of the dorsoulnar fragment between the displaced group and the stable groups using a two-tailed t-test. We also statistically compared the numbers of screws inserted into the dorsoulnar fragments between the displaced and stable groups using a chi-square test.

Results: The mean dorsoulnar fragment size was 9.4 mm × 7.9 mm × 11.0 mm and the occupying ratio to the DRUJ and RCJ was 50% and 10%, respectively. The number of patients treated with volar locking plate fixation was 77, of which 12 patients had postoperative displacements. Although the size of the dorsoulnar fragment was not associated with postoperative displacement, stabilization following screw insertion into the dorsoulnar fragment was significantly associated with displacement.

Conclusion: Stabilization of the dorsoulnar fragment with at least one screw of the volar locking plate was necessary to prevent postoperative fracture displacement regardless of dorsoulnar fragment size in AO C3-type distal radius fractures.

Introduction

Recently, volar locking plate (VLP) fixation has become the gold-standard treatment for distal radius fractures (DRFs). Although 80% of all DRFs are complete intra-articular fractures, simple intra-articular DRFs have been successfully treated with a single VLP without loss of reduction [1]. However, comminuted intra-articular DRFs, such as AO C3-type, are still the most challenging to surgically treat with the VLP [2].

Melone emphasizes the importance of lunate facet stabilization in intra-articular DRFs. Therefore, internal fixation of the volar lunate facet fragment is essential for the treatment of AO C3-type DRFs, as volar carpal subluxation or dislocation can occur if the lunate facet is not appropriately stabilized [3–5]. On the other hand, the necessity of the fixation of the dorsal lunate facet fragment remains unclear. Some authors have reported that fixation of the dorsoulnar fragment played a critical role in maintaining appropriate sagittal radiocarpal alignment and preventing dorsal collapse because the dorsoulnar fragment occupies a part of both the radiolunate and the radioulnar articular surface [6–8]. Other authors have reported that fixation of the

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dorsoulnar fragment has no adverse effect on the clinical outcomes [2,9,10]. One of the reasons for the controversy relating to the stabilization of the dorsoulnar fragment is a poor anatomical understanding of this fragment in AO C3-type DRFs.

The purpose of the present study was to measure three-dimensionally the size of the dorsoulnar fragments in AO C3-type DRFs using computed tomography (CT) images in detail, and to reveal relationships of the size and stabilization of the dorsoulnar fragment with postoperative fracture displacement after VLP fixation.

Methods

After approval by our institutional review board, we retrospectively reviewed the 402 consecutive Japanese patients who underwent surgical treatment for DRF in a single hospital from January 2011 to October 2017 (Fig. 1). Among them, 101 patients who had AO C3-type DRF were included in our series. All patients had preoperative CT images. Of these 101 patients, 13 patients did not have the dorsoulnar fragment, 3 patients were treated without VLP (percutaneous pinning: 1, dorsal plate fixation: 1, and wrist arthrodesis: 1), and 8 patients had a less than three months follow-up period. Finally, 77 patients who underwent VLP fixation for the AO C3-type DRF involving the dorsoulnar fragment were included in the study (Fig. 1). There were 54 females and 23 males of overall mean age 61.0 years (the range was from 24 to 96 years). There were 40 right hands and 37 left hands.

First, the three-dimensional size of the dorsoulnar fragment in the AO C3-type DRF was anatomically evaluated using Digital Imaging and communications in Medicine (DICOM) data (Zaiosoft inc. Tokyo) of the preoperative CT images (Fig. 2). We measured the radioulnar and the dorsopalmar lengths of the dorsoulnar fragment in the axial view in which the distal radioulnar joint (DRUJ) was most sharply defined. The proximal-distal length of the dorsoulnar fragment was measured in the coronal view in which the maximum length could be identified. We also calculated the occupying ratio of the dorsoulnar fragment to the radiocarpal joint (RCJ) and DRUJ. The occupying ratio of the dorsoulnar fragment to the RCJ was calculated from the articular surface area of the dorsoulnar fragment and whole distal radius in the axial view by freehand tracing using Ziostation (Zaiosoft inc. Tokyo). The occupying ratio of the dorsoulnar fragment to the DRUJ was calculated from the dorsopalmar length of the dorsoulnar fragment and the total length of the sigmoid notch in the axial view.

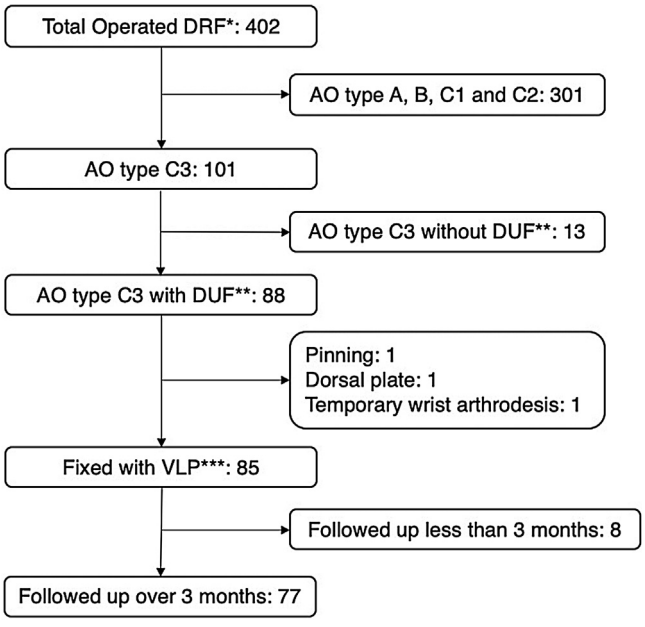

Fig. 1. Flowchart of the patients who met inclusion criteria for the study. *DRF; distal radial fracture, **DUF; dorsoulnar fragment, ***VLP; volar locking plate.

Secondly, we investigated the relationship of the size and stabilization of the dorsoulnar fragment with postoperative fracture displacement. Postoperative displacement of the dorsoulnar fragments were assessed with postoperative X-rays in 77 patients with VLP fixation for the AO C3-type DRF in the mean follow-up period of 12.2 months (the range of the follow-up period for the 77 included patients was from 3.1 to 38.1 months). Of the 77 patients, the dorsoulnar fragments were displaced in 12 patients (16%) (Displaced group) within the mean of 2.5 weeks (the range was from 1.1 to 5.7 weeks) post-operation. The dorsoulnar fragments were not displaced in 65 patients (Stable group). We statistically compared the size parameters and occupying ratio of the dorsoulnar fragment between the displaced group and the stable groups using a two-tailed t-test. We also statistically compared the numbers of screws inserted into the dorsoulnar fragments between the displaced and stable groups using a chi-square test. The numbers of screws inserted into the dorsoulnar fragments, which was assessed with postoperative X-rays, was none or at least one. A P-value <0.05 was considered statistically significant.

Results

Of the 101 patients with AO C3-type DRFs, 88 patients (87%) involved the dorsoulnar fragments. The length parameters of the dorsoulnar fragments showed that the mean radioulnar length of the fragment was 9.4 mm (the range was from 5.0 to 14.5 mm), the mean dorsopalmar length was 7.9 mm (the range was from 3.8 to 13.6 mm), and the mean axial length was 11.0 mm (the range was from 4.8 to 18.9 mm) (Table 1). The mean occupying ratio of the dorsoulnar fragment to the RCJ surface was 10% (the range was from 3 to 19%), and that to the DRUJ was 50% (the range was from 25 to 83%) (Table 1).

With regard to the relationship of the size of the dorsoulnar fragment with postoperative fracture displacement, the mean of the radioulnar length was 8.8 mm (the range was from 5.0 to 8.8 mm) in the displaced group and 9.5 mm (the range was from 5.3 to 14.5 mm) in the stable group (Table 2). The mean of the dorsopalmar length was 8.1 mm (the range was from 4.6 to 10.9 mm) in the displaced group and 7.9 mm (the range was from 3.8 to 7.9 mm) in the stable group. The mean of the proximal-distal length of the dorsoulnar fragment was 10.9 mm (the range was from 7.0 to 16.2 mm) in the displaced group and 11.0 mm (the range was from 4.8 to 18.9 mm) in the stable group. The mean of the occupying ratio of the dorsoulnar fragment to RCJ was 11% (the range was from 6 to 16%) in the displaced group and 10% (the range was from 3 to 19%) in the stable group. The mean of the occupying ratio of the dorsoulnar fragment to DRUJ was 51% (the range was from 25 to 71%) in the displaced group and 50% (the range was from 25 to 83%) in the stable group (Table 2). Of the five parameters of dorsoulnar fragment size, none were significantly different between the displaced and stable groups (Table 2). In short, the size of the dorsoulnar fragment was not associated with the occurrence of postoperative fracture displacement.

On the other hand, with regard to the relationship between dorsoulnar fragment stabilization with postoperative fracture displacement, the fixation with at least one screw for the dorsoulnar fragment involved five (42%) of 12 patients in the displaced group and 53 (82%) of 65 patients in the stable group (Table 3). The fixation without screws for the dorsoulnar fragment involved seven (58%) of 12 patients in the displaced group and 12

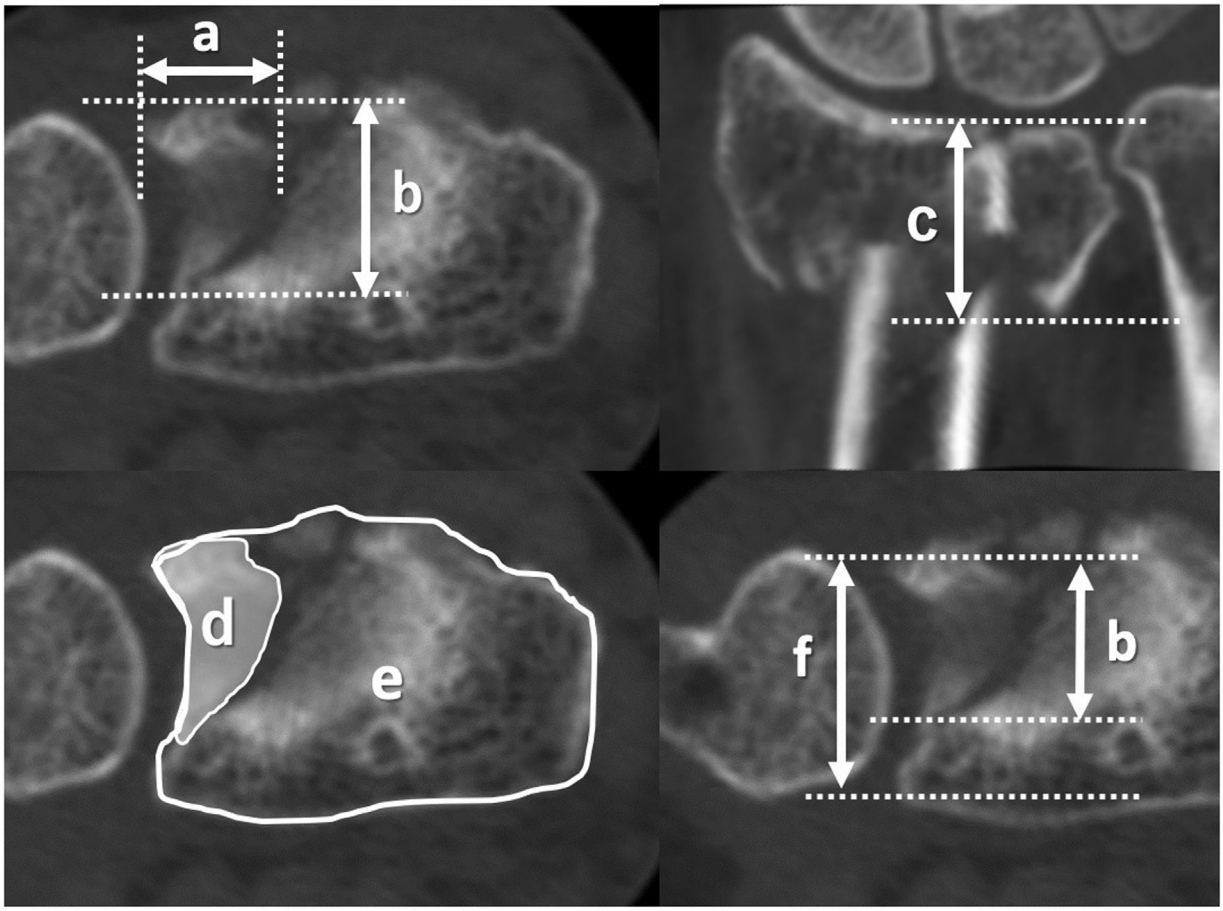

Fig. 2. Size parameters of the dorsoulnar fragment in the distal end of radius measured with computed tomography images. a: radioulnar length, b: dorsopalmar length, c: proximal-distal length, d: articular surface area of the dorsoulnar fragment, e: whole articular surface area of the distal radius, f: total length of the sigmoid notch.

Table 1
The size parameters of the dorsoulnar fragments.

Measured parameters	Mean value (range)
a: Radioulnar length, mm	9.4 (5.0-14.5)
b: Dorsopalmar length, mm	7.9 (3.8-13.6)
c: Proximal-distal length, mm	11.0 (4.8-18.9)
d/e: The occupying ratio to RCJ, %	10.4 (3.2-18.7)
b/f: The occupying ratio to DRUJ, %	50.3 (24.5-83)

Table 2
The size parameters of the dorsoulnar fragments in the displaced and stable groups.

	Displaced (n = 12)	Stable (n = 65)	P value
Radioulnar length, mm (range)	8.8 (5.0-8.8)	9.5 (5.3-14.5)	0.40
Dorsopalmar length, mm (range)	8.1 (4.6-10.9)	7.9 (3.8-7.9)	0.84
Proximal-distal length, mm (range)	10.9 (7.0-16.2)	11.0 (4.8-18.9)	0.91
The occupying ratio to RCJ, % (range)	10.6 (6.3-15.8)	10.3 (3.2-18.7)	0.76
The occupying ratio to DRUJ, % (range)	51.4 (25.1-70.7)	50.2 (24.5-83.1)	0.81

(18%) of 65 patients in the stable group. The number of postoperative displacements among those patients with no screw fixation was 7 (37%) compared to 5 (8.6%) among those with at least one screw fixation, and these are significantly different. Therefore, the stabilization of the dorsoulnar fragments with no screw fixation was significantly associated with postoperative fracture displacement.

A representative case (DISPLACED group)

An 69-year-old man fell from the stairs in a station and injured his right wrist. The X-ray at the time of injury showed intra-articular AO C3-type DRF with dorsal displaced fracture (Fig. 3A, B). The size of the dorsoulnar fragment of the distal radius measured on the CT image was 10.1 mm (radioulnar length), 5.1 mm (dorsopalmar length), 10.1 mm (proximal-distal lengths), 7% (occupying ratio to the RCJ), and 37% (occupying ratio to the DRUJ). A VLP fixation was performed, but no screws had been inserted into the dorsoulnar fragment that were found in the postoperative radiograph and CT image (Fig. 3C, D). At two weeks post-operation, the dorsoulnar fragment started to displace proximally. Finally, radius shortening occurred because the volar fragment was also displaced proximally (Fig. 3E, F).

Discussion

The present study investigated the three-dimensional size of the dorsoular fragments in AO C3-type DRF to reveal relationships of the size and stabilization of this fragment with postoperative fracture displacement after VLP fixation. The mean dorsoulnar fragment size was 9 mm × 8 mm × 11 mm and the occupying ratio of the dorsoulnar fragment to the DRUJ and RCJ were 50% and 10%, respectively. The size and occupying ratio of the dorsoulnar fragment was not associated with the occurrence of postoperative fracture displacement, but the stabilization of the dorsoulnar fragment with at least one screw of VLP was necessary to prevent postoperative fracture dislocation regardless of the dorsoulnar fragment size.

Table 3
The stabilization with the inserted screws in the displaced and stable groups.

		Displaced (n = 12)	Stable (n = 65)	Displacement rate (%)
Numbers of the inserted screws	0	7	12	36.8
	≥1	5	53	8.6

(※p = .003).

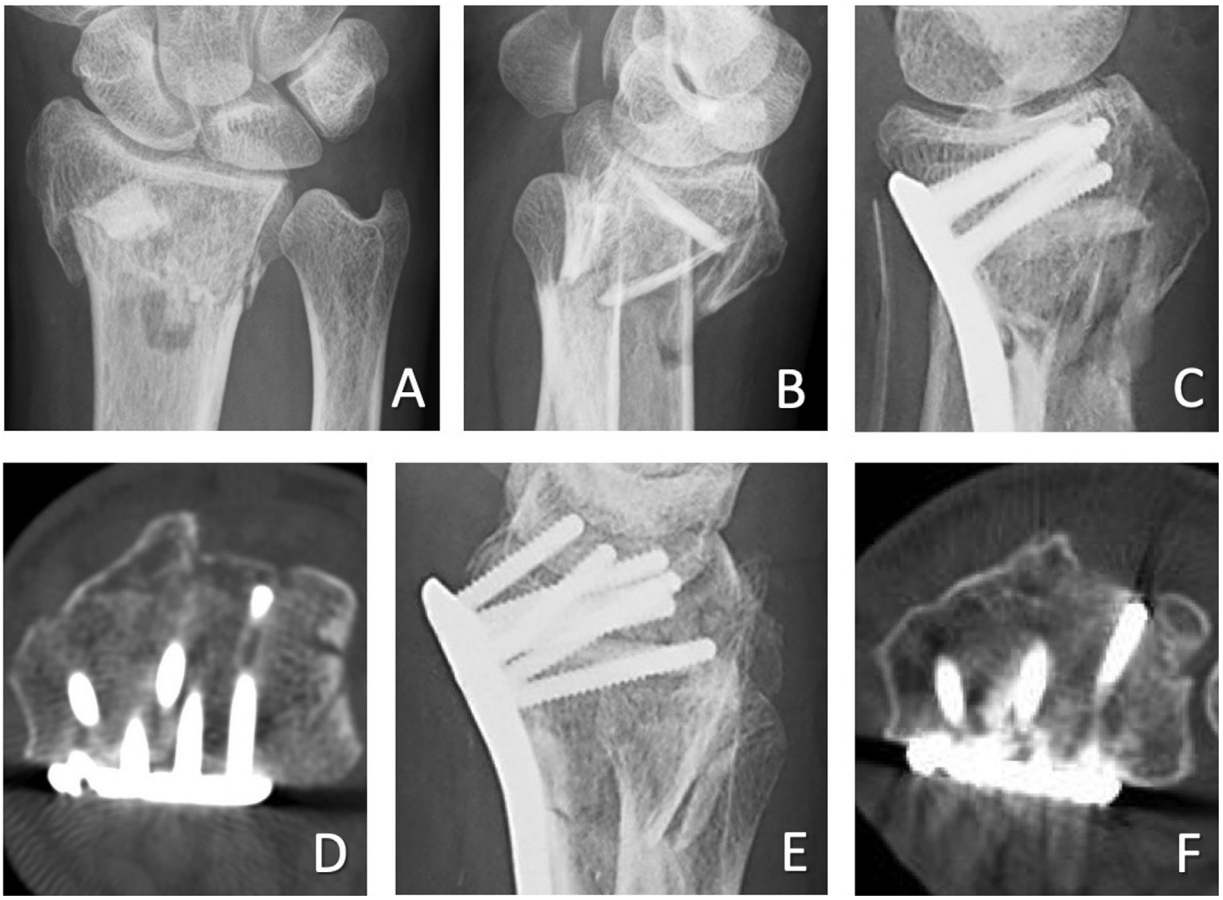

Fig. 3. Pre- and postoperative images of the representative case in the displaced group. Preoperative radiographs (A and B). The radiographic (C) and computed tomography (D) images immediately after the operation. The radiograph two weeks after operation (E) and the computed tomography image 4 months after operation (F).

Unlike the volar lunate facet fragment, anatomical characteristic and reduction of the dorsal lunate facet fragment has received little attention in AO C3-type DRFs. Few studies have been reported on the size of the dorsoulnar fragment of DRFs. Kim et al. measured the dorsopalmar length of the dorsal rim fragments in intra-articular DRFs using preoperative CT images of 26 patients [10]. The mean of the dorsopalmar length was 2.7 ± 1.1 mm, which was shorter than the present study. This is because they only enrolled patients who had a dorsal rim fragment that was displaced by more than 2 mm after VLP fixation and were, therefore, different from those patients included in our survey. The present study is the first to show that 87% of AO C3-type DRFs involved detailed total size of the dorsoulnar fragment which had a mean three-dimensionally measured size of 9.4 mm × 7.9 mm × 11.0 mm, both in displaced and undisplaced AO C3-type DRFs.

The present study also demonstrated that the size and occupying ratio of the dorsoulnar fragment was not associated with the occurrence of postoperative fracture displacement, although very few studies have focused on relationships of the dorsoulnar fragment size and fracture displacement. The investigation also revealed that the occupying ratio of the dorsoulnar fragment to DRUJ was more than 50%, compared to the ratio of that to RCJ, which was only 10%. Considering that the dorsoulnar fragment makes up a main portion of the distal radioulnar joint surface [11], stabilizing the dorsoulnar fragment might play a critical role in maintaining adequate radioulnar alignment. The dorsoulnar fragments should be stabilized and their stabilization was achieved by inserting locking screws with at least one screw of VLP from palmar side because the dorsoulnar fragments were large enough and, indeed, larger than previously thought.

These days, use of the VLP fixation has become a reliable standard technique for the treatment of DRFs [12,13]. Even comminuted intra-articular DRFs can be successfully treated with VLPs and accurate reduction of the articular congruities importantly determines the outcomes of DRFs [1,14,15]. When comminuted intra-articular fragments are stabilized, fixation of the lunate facet has been considered to be most critical [5]. Biomechanical studies have demonstrated that 40% of the force through the wrist is transmitted through the radioscaphoid fossa, 53% through the radiolunate fossa, and 7% through the triangular fibrocartilage complex in the functional wrist position, showing that the lunate facet bears the biggest load in the wrist joint [16,17]. Thus, it is quite reasonable to achieve subchondral support of the

lunate facet using the screws of VLP. When the volar lunate facet was not adequately stabilized, poor outcomes and devastating complications have been well documented [3,18,19].

It is controversial whether the dorsoulnar fragment should be stabilized. Ikeda et al. recommended using a low-profile dorsal mini plate for the fixation of the dorsoulnar fragment if the fragment was irreducible and difficult to fix from only a volar approach [7]. Lee et al reported that a compression screw from the dorsal side could reduce the distance between the dorsoulnar fragment and the distal radius as a simple treatment option to immobilize a dorsoulnar fragment [2]. These authors shared a common interpretation that it was sometimes difficult to hold dorsoulnar fragments by locking screws from the volar side without additional dorsal procedures and that stability of them from the dorsal side could lead to good clinical outcomes. On the other hand, Kim et al. reported that displaced dorsal rim fracture did not adversely affect clinical and radiographic outcomes after VLP fixation of dorsally displaced DRFs [9,10]. Kawasaki et al. recommended the double-tiered subchondral support (DSS) procedure, which involved a two-row fixation in which proximal screws supported the dorsal subchondral bone, whereas distal screws supported the volar central subchondral bone, using only variable-angle VLP to achieve better anatomical reduction in AO C3-type DRFs [20]. These authors thought that a single VLP fixation is enough to stabilize AO C3-type DRF with the dorsoulnar fragments. Rikli et al. advocated a three column theory, which divided distal radius and ulnar into three parts (ulnar, intermediate, and radial column), and emphasized the necessity of stabilizing of each column [21]. We also think that fixation both of the palmar and dorsal lunate facet fragment, especially in the intermediate column, was most important to prevent postoperative displacement of the fragments.

The strengths of the present study included that the 402 consecutive Japanese patients who underwent surgical treatment for DRF in a single hospital were enrolled and dorsoular fragment size in AO C3-type DRF was evaluated three-dimensionally. However, the present study has several limitations. This was a retrospective study. The intra- and interobserver reliability was not evaluated in the measurement of each of the parameters of the distal radius. Because the postoperative displacements of the dorsoulnar fragments were assessed with only postoperative X-ray images, displaced group might be underestimated. The exact number of screws inserted into the dorsoulnar fragment was not evaluated. Moreover, postoperative clinical results were not assessed, and postoperative therapy was inconsistent and dependent upon the surgeons. Thus, displaced group did not always have unsatisfactory clinical results. To overcome these problems, further studies should include a prospective larger sample size with multicenter, postoperative radiography and clinical results after consistent postoperative rehabilitation, and evaluation of the intra- and interobserver reliability.

In conclusion, this study has shown that 87% of the AO C3-type DRFs involved the dorsal lunate facet fragment, which had a mean three-dimensionally measured size of 9.4 mm × 7.9 mm × 11.0 mm and had an occupying ratio to the DRUJ of 50% and to the RCJ of 10%. The size and occupying ratio of the dorsoulnar fragment was not associated with the occurrence of postoperative fracture displacement, but the stabilization of the dorsoulnar fragment with at least one screw of VLP was necessary to prevent postoperative fracture dislocation regardless of the dorsoulnar fragment size.

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Ethical approval

The study was approved by the institutional review board at Seikeikai Hospital

Declaration of Competing Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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