

ORIGINAL RESEARCH ARTICLE

Evaluation of severe radial translation of distal radius fractures which is a potential cause of distal radioulnar joint instability

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ABSTRACT

Purpose: This study aimed to (1) introduce a simple and reproducible method to assess severe radial translation of distal radius fractures (DRF) which is a potential cause of distal radioulnar joint (DRUJ) instability, and (2) to construct a treatment-oriented classification.

Materials and methods: From 2018 to 2023, stress test (ballottement test) was performed to detect DRUJ instability associated with DRF after treatment with locking plate fixation. Potential radiographic predictors of DRUJ instability focus on radial translation were accessed. The severity of radial translation was described by a readily and easily technique as 'point- baseline' method. According to this method, radial translation was categorized into three grades: no translation (the marking points not moved), moderate translation (the marking points moved, but were located on the ulnar side of the baseline), and severe translation (the marking points moved and reached the baseline position, or even completely moved to the radial side of the baseline). All these fractures were divided into two groups, namely Group A (cases with no translation or moderate translation) and Group B (cases with severe translation). Relationships between DRUJ instability and the radiographic parameter of radial translation were analyzed. To investigate the causes of DRUJ instability, all of the cases with DRUJ instability were further divided into two subgroups: subgroup A (cases with DRUJ instability in Group A) and subgroup B (cases with DRUJ instability in Group B). Practices to address DRUJ instability at the time of DRF fixation were explored.

Results: There were 226 patients enrolled in this study. According to 'point- baseline' method, there were 174 wrists in Group A and 52 wrists in Group B. There were 34 cases (19.54%) diagnosed as having DRUJ instability intraoperatively via manual stress testing in Group A, while 36 cases (69.23%) in Group B. There was significant difference in the incidence of DRUJ instability between the two groups ($p < 0.0001$). Of the 70 cases with DRUJ instability, 18 cases regained stability by ulnar styloid fracture fixation, 12 cases by dorsal ulnar corner fragment (sigmoid notch fracture) fixation, and 40 cases by arthroscopy-assisted triangular fibrocartilage complex (TFCC) repair. To investigate the causes of DRUJ instability, there were 34 wrists in subgroup A, while 36 wrists in subgroup B. There were no significant differences between the two subgroups regarding the causes of DRUJ instability including ulnar styloid process fracture, dorsal ulnar corner fragment (sigmoid notch fracture), and traumatic TFCC injury.

Conclusions: This study helped establish a 'point- baseline' method which can be readily and easily used to identify the severity of radial translation, which was a significant predictor of DRUJ instability. On the other hand, whether or not severe radial translation, treatment of DRUJ instability by the three major ways: (1) the ulnar styloid fracture fixation; (2) the dorsal ulnar corner fragment fixation; and (3) traumatic TFCC injuries repairing.

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Introduction

The stability of distal radioulnar joint (DRUJ) is primarily dependent on the normal osseous anatomy of the radius and ulna, the congruity of the convex and concave articulating surfaces throughout the range of joint motion, the static stability of intact joint ligaments, and the secondary dynamic stability from muscles acting to compress the joint [1, 2]. Displaced distal radius fractures (DRF) undermine the integrity of one or more of these stabilizing mechanisms and cause instability of the DRUJ [3]. It was reported that 37–84% of patients with DRF had DRUJ instability, and a substantial proportion of these

patients were symptomatic [4–8]. Therefore, it is important to identify DRUJ instability and treat it suitably, because it is now recognized as a major cause of chronic problems after bone healing [3, 9, 10].

Previous investigators have reported that the magnitude of fracture displacement and the severity of fracture pattern are important predictors of DRUJ instability. In particular, the magnitude of fracture displacement (radial translation), which results in the widening of DRUJ gap, slackening and even injury of the radioulnar ligaments, has been identified as a risk factor. Relevant studies have confirmed that only radial translation of the distal fragment of the

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radius was a significant independent risk factor of DRUJ instability, or correlated with an increased incidence of a foveal avulsion of the radioulnar ligament [1, 11–15]. Diagnosis of DRUJ instability relies on the surgeon having a high index of suspicion [16, 17]. Observation of the radiological sign and awareness of methods of assessment the parameter, it would be helpful in anticipating the DRUJ instability preoperatively and treat it suitably. However, radial translation (the seemingly simple radiographic parameter) is difficult to quantify because the actual dimensions of bones vary among individuals. We need to construct a treatment-oriented classification of radial translation which would readily and easily help determine the prognosis in an X-ray preoperatively. On the other hand, the treatment of DRUJ instability is complex. How to identify the exact cause of DRUJ instability and to simplify the treatment process are of great significance in clinical treatment.

The purpose of this study was to propose a simple and reproducible technique to identify the possible factors causing DRUJ instability, and guide treatment. We hypothesized that severe radial translation would be an important predictor of DRUJ instability.

Materials and methods

This was a retrospective study using prospectively collected data which revealed the relationship between radial translation of DRF and DRUJ instability. We performed a retrospective evaluation of patients who had undergone treatment for DRF with locking plate fixation through a palmar approach from 2018 to 2023. The inclusion criteria included those patients with closed fractures, who have undergone surgical treatment with locking plate fixation, and who underwent surgery within 2 weeks of injury. The exclusion criteria were patients who were less than 18 years, with open fractures, pathological fractures, previous ipsilateral wrist injuries, or any other wrist arthropathies. The institutional review board of our hospital approved this study.

All the patients in this study received the conventional surgical method including the volar Henry approach and volar locking palmar plates of distal radius under general anesthesia. Diagnosis of DRUJ instability was done following fixation of DRF by the ballottement test. The elbow of the patient was placed in 90° flexion and the forearm in neutral rotation. The examiner firmly grasped the radius and radial carpal bones by one hand, and tried to move the distal ulna in dorsal and palmar directions by the other hand. The same test was

repeated in the contralateral wrist as well to exclude patients with general joint laxity. The instability of the DRUJ was categorized into three grades. Normal (Grade 0) was defined as the same translation in comparison to the contralateral side. Moderate instability (Grade 1) was defined as conspicuous increased laxity in comparison to the contralateral side with firm end-point. Severe instability (Grade 2) was defined as conspicuous increased amplitude of the translation in comparison to the contralateral side without firm end-point. In this study, the cases of DRUJ instability were defined as a condition in which there were no solid end points in both volar and dorsal directions.

Treatment began once DRUJ instability was determined, Firstly, reduction of DRF was checked to ensure that radial length restored adequately and radial translation of the distal fragment was corrected. Secondly, special attention was paid to the dorsal ulnar corner fragment of the radius and fracture of the ulnar styloid (sigmoid notch fracture) to ensure that all these fragments were reduced and fixated. If there was not an ulnar styloid fracture or the dorsal ulnar corner fragment of the DRF requiring fixation, an arthroscopy of the radiocarpal joint was performed to assess for triangular fibrocartilage complex (TFCC) injury and to repair. The routine arthroscopic evaluation was performed via the 3–4 and 4–5 portals, or via the 3–4 and 6R portals. The vision of the articular surface was cleared by shaver synovectomy through the radiocarpal portals, and a tear of the TFCC disc can be confirmed. TFCC injuries were categorized in accordance with Palmer's classification.

To easily understand the osseous anatomy and stability of the DRUJ, let us illustrate it by a 'Gothic arch' model. In this model, the ulnar aspect of the radial shaft and the radial aspect of the ulna shaft are seen as two 'pillars' which support the 'roof' of the DRUJ (Figure 1A). The connection between the pillars on the distal side of the roof is the TFCC. On the proximal side of the roof is the distal oblique bundle of the interosseous membrane, and surrounding also cover the other soft tissues. If any of the pillars fail to support itself effectively, the roof may collapse. When DRF and radial displace, the carpal bones including the lunate will move with the displaced radius fragment. According to the description of radial translation by Ross [18], we draw a first line (parallel to the distal radial articulation) along the transverse width of the lunate, and the most ulnar end point of the lunate on the line was defined as the landmark point (Figure 1B). Then, we draw a second line along the radial pillar proximal to the metaphyseal flare and extended distally through the proximal row of the carpus, the second line was defined as the baseline (Figure 1B).

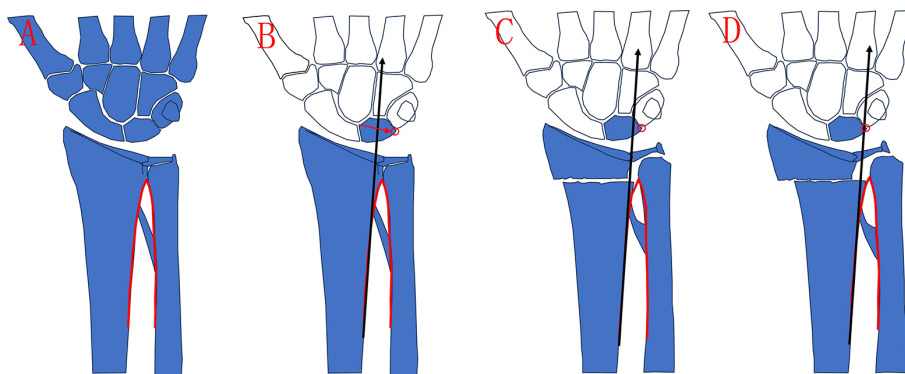


Figure 1. 'Gothic arch' model: the ulnar aspect of the radial shaft and the radial aspect of the ulna shaft are seen as two 'pillars' (red arc) which support the 'roof' of DRUJ (Figure 1A). Parallel to the distal radial articulation, the first line (red arrow) was drawn along the transverse width of the lunate, and the most ulnar end point of the lunate on the line was defined as the landmark point (red circle). The second line (black arrow) was drawn along the radial pillar proximal to the metaphyseal flare and extended distally through the proximal row of the carpus, and the line was defined as the baseline (Figure 1B). When distal radius fractures, the carpal bones including the lunate will move with the displaced radius fragment. The severity of radial translation will be indirectly assessed by the relative position of the marking point with respect to the baseline in the 'Gothic arch' model (Figure 1C and D). DRUJ: distal radioulnar joint.

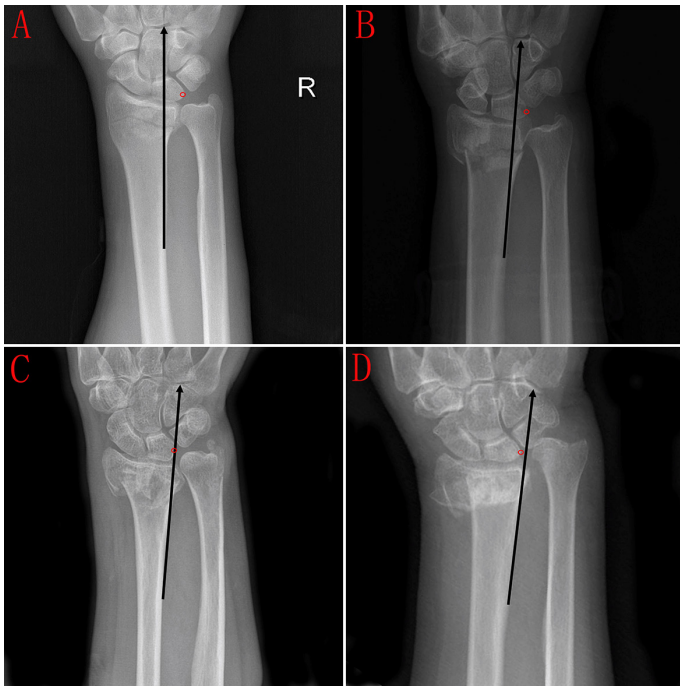


Figure 2. The severity of the radial translation was indirectly assessed by the relative position of the marking point with respect to the baseline. Radial translation was categorized into three grades: (A) no or slight translation, (B) moderate translation (the marking point moved, but was located on the ulnar side of the baseline), and (C and D) severe translation (the marking point moved and reached the baseline position, or even completely moved to the radial side of the baseline). Red circle: the marking point. Black arrow: the baseline.

The severity of radial translation will be indirectly assessed by the relative position of the displacement marking point to the baseline (Figure 1C and D). We describe this simple and reproducible technique as ‘point- baseline’ method. In this method, radial translation was categorized into three grades: normal (the marking point not moved) (Figure 2A), moderate translation (the marking point moved, but were located on the ulnar side of the baseline) (Figure 2B), and severe translation (the marking point moved and reached the baseline position, or even completely moved to the radial side of the baseline) (Figure 2C and D). This was a relative measurement and the parameter reflected the displacement of the fracture in the coronal plane by describing the relative position of the radius with respect to the lunate bone.

Based on the ‘point- baseline’ method, all cases were divided into two groups: Group A (those with normal or moderate translation) and Group B (those with severe translation). The two groups were compared regarding demographic data, type of the fracture (intra and extra-articular fracture), and incidences of an ulnar styloid fracture, dorsal ulnar corner fragment (sigmoid notch fracture), and DRUJ instability.

To investigate the causes of DRUJ instability, all of the cases with DRUJ instability were further divided into two subgroups: subgroup A (cases with DRUJ instability in Group A) and subgroup B (cases with DRUJ instability in Group B). We counted the number of patients who regained DRUJ stability by the ulnar styloid fracture fixation, the dorsal ulnar corner fragment (sigmoid notch fracture) fixation, or traumatic TFCC injuries repairing respectively. The two subgroups were compared regarding demographic data, the ways of regained DRUJ stability including the ulnar styloid fracture fixation, the dorsal ulnar corner fragment (sigmoid notch fracture) fixation, or traumatic TFCC injuries repairing.

Statistical analysis

Patient characteristics were summarized using descriptive statistics. Continuous variables (including age) were reported as means and standard deviations, while categorical variable (including gender, demographic data, type of the fracture, incidences of an ulnar styloid fracture, incidences of the dorsal ulnar corner fragment, and incidences of DRUJ instability) were reported as counts and percentages. Continuous normally-distributed variables were compared using Welch’s *t*-test, while differences among categorical variables were analyzed using the chi-squared test. Fisher’s exact test was used for the comparison of two independent groups. *P* values <0.05 were considered to be statistically significant.

Results

In this study, a total of 226 wrists in 226 patients – which consisted 167 women and 59 men – were enrolled. According to ‘point- baseline’ method, there were 174 wrists in Group A, while 52 wrists in Group B. There were 48 males and 126 females in Group A. The mean age was 58.83 ± 13.19 years. There were 11 males and 41 females in Group B; the mean age was 57.81 ± 11.93 years. The detailed demographic data of all the patients are shown in Table 1. There were no significant differences between the two groups regarding demographic data, incidences of intra- or extra-articular DRF, incidences of ulnar styloid process fracture, and incidences of the dorsal ulnar corner fragment (sigmoid notch fracture). However, there were 34 cases (19.54%) diagnosed as having DRUJ instability intraoperatively via manual stress testing in Group A, while 36 cases (69.23%) in Group B. There was significant difference in the incidence of DRUJ instability between the two groups (*p* < 0.0001).

Of these 70 cases with DRUJ instability, 18 cases regained stability by the fixation of the ulnar styloid fracture (Figure 3), 12 cases by the fixation of the dorsal ulnar corner fragment (Figure 4), and 40 cases by arthroscopy-assisted TFCC repair (Figure 5). To investigate the causes of DRUJ instability, all the cases with DRUJ instability were further divided into two subgroups, including subgroup A (DRUJ instability in Group A, including those with normal or moderate translation) and subgroup B (DRUJ instability in Group B; cases with severe translation).

Table 1. The detailed demographic data of all the patients and incidence of DRUJ instability between the two groups.

Groups	Group A	Group B	<i>P</i> value
Total	<i>n</i> = 174	<i>n</i> = 52	
Age, mean ± SD (range)	58.83 ± 13.19	57.81 ± 11.93	0.4060
Gender (male: female)	48:126	11:41	0.3541
Distal radius fracture type (extra-articular: intra-articular)	85:89	18:34	0.0705
Incidences of ulnar styloid process fracture	90 (51.72%)	32 (61.54%)	0.2128
Incidences of sigmoid notch fracture	41 (23.56%)	16 (30.77%)	0.3627
Incidences of DRUJ instability	34 (19.54%)	36 (69.23%)	< 0.0001**

Note: Group A: included those with normal or moderate translation; Group B: included those with severe translation. DRUJ: distal radioulnar joint.

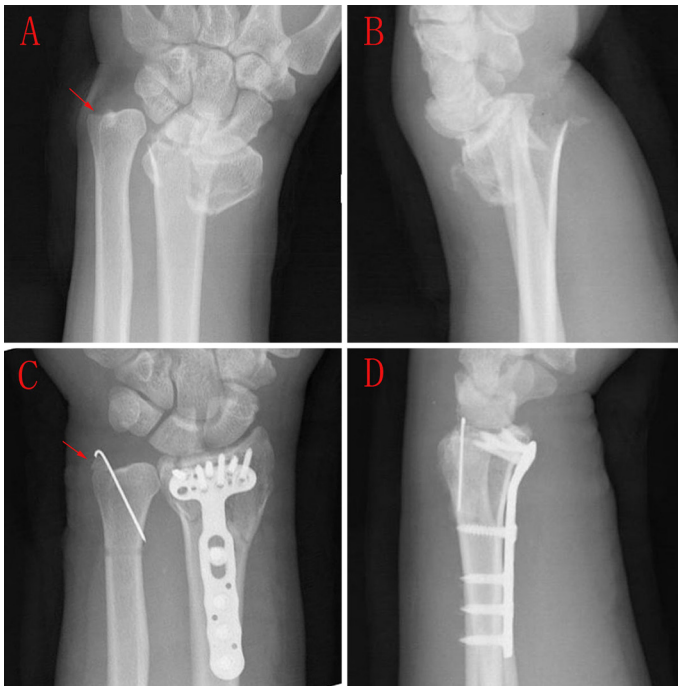


Figure 3. One case with DRUJ instability achieved stabilization intraoperatively by fixation of the base ulnar styloid fracture (red arrow) using a K-wire. (A) Posteroanterior radiograph preoperatively; (B) lateral radiograph preoperatively; (C) posteroanterior radiograph postoperatively; (D) lateral radiograph postoperatively. DRUJ: distal radioulnar joint.



Figure 4. One case with DRUJ instability achieved stabilization intraoperatively by fixation of the dorsal ulnar corner fragment of the radius using two K-wires. (A) posteroanterior radiograph preoperatively; (B) lateral radiograph preoperatively; (C) posteroanterior radiograph postoperatively; (D) lateral radiograph postoperatively. DRUJ: distal radioulnar joint.

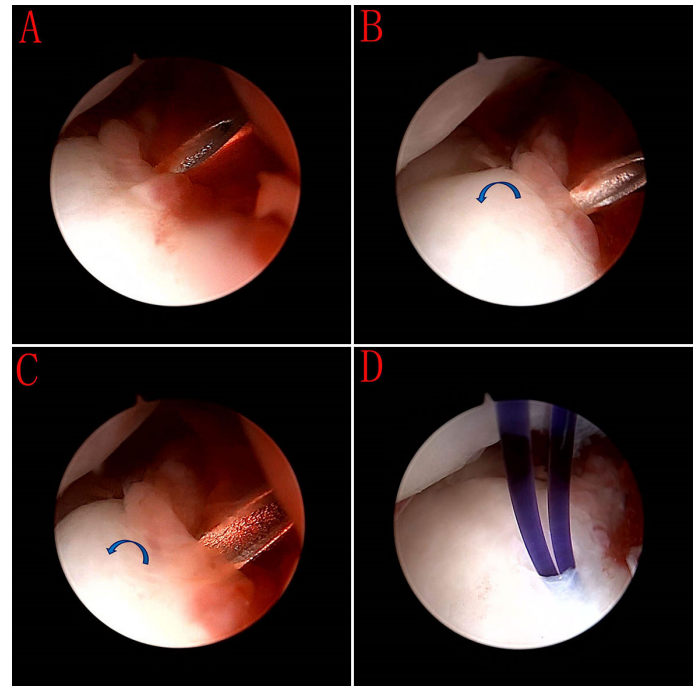


Figure 5. One patient with DRUJ instability was observed traumatic TFCC injury by wrist arthroscopy. Arthroscopically, avulsion of the ulnar-most border (Palmer class IB) was demonstrated, and a probe was inserted through the 6 R portal (A). The hook test was positive (B and C): the ruptured lateral border of the TFCC can be elevated upward and radially towards the center (curved arrows). After debridement, a suture was passing through the TFCC and ready for repair (D). DRUJ: distal radioulnar joint; TFCC: triangular fibrocartilage complex.

There were 34 wrists in subgroup A, while 36 wrists in subgroup B. There were 12 males and 22 females in subgroup A; the mean age was 56.06 ± 11.81 years. There were 6 males and 30 females in subgroup B; the mean age was 59.66 ± 11.35 years. The detailed demographic data of all the patients are shown in Table 2. There were no significant differences between the two subgroups regarding demographic data. Regarding to address DRUJ instability, 8 cases (23.53%) regained DRUJ stability by ulnar styloid process fracture fixation and 7 cases (20.59%) regained DRUJ stability by the dorsal ulnar corner fragment (sigmoid notch fracture) fixation in subgroup A intraoperatively, while 10 cases (31.58%) regained DRUJ stability by ulnar styloid process fracture fixation and 5 cases (13.16%) by the dorsal ulnar corner fragment fixation in subgroup B. 19 cases (55.39%) were observed to be having traumatic TFCC injuries and regained DRUJ stability by TFCC repair in subgroup A intraoperatively, while 21 cases (61.76%) in subgroup B. There were no significant differences between the two subgroups regarding the causes of DRUJ instability including ulnar styloid process fracture, dorsal ulnar corner fragment (sigmoid notch fracture), and traumatic TFCC injury.

Discussion

DRF are frequently associated with DRUJ instability, which is an important cause of residual ulnar sided pain, grip strength weakness, and forearm rotation range restriction after bone healing [19]. DRF are generally accompanied by radial translation, radial inclination, radial shortening, and dorsal angulation. Severe radial translation of the distal radius not only alters the orientation of the sigmoid notch

Table 2. The detailed demographic data of all the patients, incidence of ulnar styloid fracture, dorsal ulnar corner fragment or TFCC injury between the two subgroups.

Subgroups	DRUJ instability in Group A	DRUJ instability in Group B	P value
Total	n = 34	n = 36	
Age, mean ± SD (range)	56.06 ± 11.81	59.66 ± 11.35	0.1919
Gender (male: female)	12:22	6:30	0.1022
Stabilization of the ulnar styloid	8 (23.53%)	10 (31.58%)	0.5991
Stabilization of sigmoid notch fracture	7 (20.59%)	5 (13.16%)	0.5298
Repair of traumatic TFCC injury	19 (55.39%)	21 (61.76%)	> 0.9999
1B	14	15	
1A & 1B	4	4	
1B & 1D	1	2	

Note: Subgroup A: patients with DRUJ instability in Group A; Subgroup B: patients with DRUJ instability in Group B. TFCC: triangular fibrocartilage complex; DRUJ: distal radioulnar joint.

which causes incongruity with the ulnar head, but also widens the DRUJ gap, which increases the risk of radioulnar ligament tear. Omokawa and coauthors [20] reported that only the radial and sagittal translation were significant predictors of DRUJ instability. More than 5 mm widening of the DRUJ gap is the most important predictor of DRUJ instability. Nakamura and coauthors [21] reported that only radial translation of the distal fragment of the radius was correlated with an increased incidence of a foveal avulsion of the radioulnar ligament. Identifying the radiographic factor associated with DRUJ instability would be helpful in diagnosing DRUJ instability by raising the index of suspicion among surgeons.

Severe radial translation – the seemingly simple radiographic parameter – is difficult to quantify because the actual dimensions of bones vary among individuals. Fujitani and coauthors [11] reported radial translation as a risk factor for DRUJ instability. Radial translation was expressed as a ratio of increased DRUJ clear-space to radial shaft dimension proximal to the fracture line. However, the fact that the technique is complicated and difficult to reproduce, because these landmarks as a ratio to radial width are difficult to calculate. Furthermore, the utility intraoperatively is questionable, because the numerator (DRUJ clear space) is very small compared with the denominator (radial width), decreasing the sensitivity in an intraoperative environment potentially.

To easily understand the osseous anatomy and stability of the DRUJ, we illustrate it using a ‘Gothic arch’ model. In this model, the ulnar aspect of the radial shaft and the radialis aspect of the ulna shaft are seen as two ‘pillars’ which support the ‘roof’ of the DRUJ. When DRF and radial displace, the carpal bones including the lunate will move with the displaced radius fragment. At present, the main question virtually is how to define a large radial translation (severe radial translation). According to the description of radial translation by Ross [18], we define the most ulnar end point of the lunate as the landmark point, and the line along the radial pillar proximal to the metaphyseal flare and extended distally through the proximal row of the carpus as the baseline. The severity of radial translation will be indirectly assessed by the relative position of the displacement marking point to the baseline. We describe this simple and reproducible technique as ‘point-baseline’ method. In addition, severe decreased radial inclination also may be a contributing source of the marking point reaching the baseline or even completely moved to the radial side of the baseline (Figure 6). Therefore, the severity of the displacement of the marking point moved to the radial side of the baseline may be not only due to the severity of radial translation, but also the radial inclination. This is a relative measurement and the parameter reflects the displacement of the fracture in the coronal plane by describing the relative position of the radius with respect to the lunate bone. In this way, it is easy for us to count the number of patients with severe displacement of the DRF clinically.

Based on the ‘point-baseline’ method, all cases were divided into

two groups: Group A (included those with normal or moderate translation) and Group B (included those with severe translation). The result showed that there were 34 cases (19.54%) diagnosed as having DRUJ instability intraoperatively via manual stress testing in Group A, while 36 cases (69.23%) in Group B. There was significant difference in the incidence of DRUJ instability between the two groups, and further confirmed that severe radial translation was a significant predictor of DRUJ instability. Therefore, compared to those with no or moderate DRUJ instability, patients with severe DRUJ instability were significantly more likely to have severe radial translation, which suggested that severe radial translation (or severe radial inclination) increased the risk of DRUJ instability.

Regarding to address DRUJ instability, there is no accepted algorithm for management following fixation of the DRF [22]. Previous investigators [4, 5] have reported that worse outcomes after DRF fixation in patients with DRUJ instability or TFCC injuries diagnosed arthroscopically but treated with immobilization rather than fixation. Therefore, we adopt the practice of Poppler LH [23] to address DRUJ

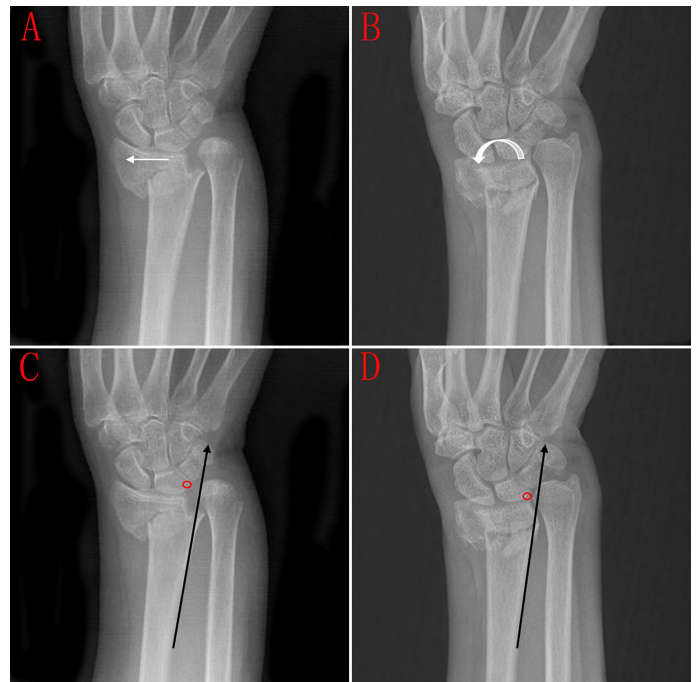


Figure 6. The severity of the displacement of the marking point moved to the radial side of the baseline may be not only due to the severity of radial translation, but also the radial inclination. Radiographs of one patient (A and C) with radially displaced (white arrow) fragment, while another patient (B and D) with severely decreased radial inclination (white round arrow).

instability at the time of DRF fixation. Firstly, reduction of the DRF was repeatedly checked to ensure that radial length restored adequately and radial translation of the distal fragment was corrected. Secondly, special attention was paid to the dorsal ulnar corner fragment of the radius and fracture of the ulnar styloid to ensure that all these fragments were reduced and fixated. If there was not an ulnar styloid fracture or the dorsal ulnar corner fragment of the radius requiring fixation, an arthroscopy of the radiocarpal joint was performed to assess for TFCC injury and to repair.

In this study, all the cases with DRUJ instability (70 cases) were further divided into two subgroups, including subgroup A (cases with DRUJ instability in Group A) and subgroup B (cases with DRUJ instability in Group B). There were no significant differences between the two subgroups regarding the causes of DRUJ instability including ulnar styloid process fracture, dorsal ulnar corner fragment (sigmoid notch fracture), and traumatic TFCC injury. This also indicated that whether or not severe radial translation, treatment of DRUJ instability by the three major ways: (1) the ulnar styloid fracture fixation; (2) the dorsal ulnar corner fragment (sigmoid notch fracture) fixation; and (3) traumatic TFCC injuries repairing.

Strengths and limitations of the study

The main strength of this study is the use of 'point-baseline' method. This is a simple and reproducible technique which enables us to define severe displacement of the DRF clinically. However, there are some limitations for this study; for example, the technique previously described by Ross such drawing this line is relatively arbitrary and not standardized, which needs further improvement. The second limitation is that we only assessed the magnitude of fracture displacement focus on radial translation, which does not completely explain the reasons of DRUJ instability. Therefore, further investigations should be conducted.

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