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Original Article

Fracture Line Distributions of Undisplaced Distal Radius Fractures in Relation to Rupture of the Extensor Pollicis Longus Tendon

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Rupture of the extensor pollicis longus (EPL) tendon is a known complication after undisplaced distal radius fracture (DRF). However, no report has revealed the relationship between EPL tendon rupture and the fracture pattern. Thus, this study aimed to investigate the characteristics of fractures at risk of EPL tendon rupture using fracture line mapping of undisplaced DRFs. This study used computed tomography imaging data of undisplaced DRFs with (n = 18) and without EPL tendon rupture (n = 52). Fracture lines obtained from 3D reconstruction data were drawn manually after matching with a 2D template wrist model. Fracture maps represented the fracture line distribution by superimposing the fracture lines of all 70 patients. Heat maps showed the relative frequency of the fracture lines as a gradual color change. Fracture lines of cases with EPL tendon rupture were concentrated in the proximal border of Lister's tubercle. By contrast, fracture lines of cases without EPL tendon rupture were relatively dispersed.

Key words: distal radius fracture, rupture of extensor pollicis longus tendon, fracture mapping

Distal radius fractures (DRFs) are common fragile fractures, with over 640,000 cases reported in 2001 in the United States [1]. In Sweden, the incidence of DRFs among the elderly population has almost doubled over a 30-year period [2]. Although the proportion of DRFs receiving surgical treatment is increasing, the principal approach to cases with minimal dislocation is conservative treatment that can result in a good outcome [3]. In contrast, rupture of the extensor pollicis longus (EPL) tendon occurs more frequently in undisplaced or minimally displaced DRFs [4-8]. Based on previous reports, the incidence of EPL tendon rupture after undisplaced DRFs is 5% [6] whereas that after all types of DRFs is 0.3% [9].

Some etiologies of EPL tendon rupture have been assumed, such as tendon laceration by a sharp spicule of bone [10], injury to blood vessels in the area [9], local adhesions [10], or narrowing of the space for the EPL tendon caused by swelling, edema, and hematoma [8]. However, no report has examined the relationship between EPL tendon rupture and the location of undisplaced DRFs.

Thus, this study aimed to investigate the relationship between EPL tendon rupture and the fracture pattern of undisplaced DRFs and to determine the characteristics of those fractures at risk of EPL tendon rupture using fracture line mapping.

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Materials and Methods

Subjects. A retrospective search was conducted using computed tomography (CT) imaging data of patients treated for EPL tendon rupture with undisplaced DRFs between 2005 and 2021. Additionally, we selected CT imaging data of patients who were treated conservatively for undisplaced DRFs without EPL tendon rupture as controls. All patients who had a complete set of radiographic images, including a three-dimensional (3D) CT scan of the wrist, were included in this study. The included DRFs were subjected to OTA/AO classification using CT imaging. Classification was performed on the basis of the consensus of two authors (H.K. and R.N). Finally, the included DRFs with EPL tendon ruptures were confirmed as all extra-articular fractures (OTA/AO type 2R3A2 or 2R3A3). To align patient backgrounds, we excluded cases that had incomplete CT imaging data or intra-articular DRFs from the control group. This study was approved by the Ethics Committee of Kagawa Rosai Hospital (No. R417).

Fracture mapping. Digital Imaging and Communications in Medicine (DICOM) files of DRFs in selected cases were gathered via the Picture Archiving Communications System database. The DICOM files were reconstructed to 3D images using a medical workstation. Quantitative 3D CT modeling techniques were used to obtain DRF images needed for the two-dimensional (2D) fracture template. The images of the 3D reconstruction using the fracture map were obtained using the same viewpoint as the typical 2D template wrist model. Fracture lines were drawn manually on the template after aligning the anatomical landmarks of the case, including width, height, and Lister's tubercle with those of the model, to ensure the appropriate rotation (Fig. 1). Fracture maps represent the distribution of fracture lines created by superimposing individual fracture lines from the images onto the 2D template. For views of the right distal radius, the images were flipped to obtain mirror images and were aligned on the left template model.

Heat mapping. The initial diagrams were converted into heat maps with matrix laboratory (MATLAB, MathWorks, Natick, MA, USA) to provide a means for intuitive comprehension of the crowded 2D fracture maps. Heat maps showed the relative frequency of fracture lines as a gradual color change. All fracture lines were converted into coordinate data and imported into MATLAB. Heat maps were created after setting a standardized space of 30 (scale) units between points.

Data analysis. Patient characteristics, including age, sex, type of fracture, and time to rupture, were shown as proportions for categorical variables or as means and standard deviations for continuous variables. Statistical analyses were performed using bell curves (Social Survey Research Information Co., Ltd., Shinjuku-ku, Japan). Differences among dichotomous data were assessed using Fisher's exact test. Data with continuous variables were examined using the Student *t*-test. *P* values less than 0.05 were considered statistically significant.

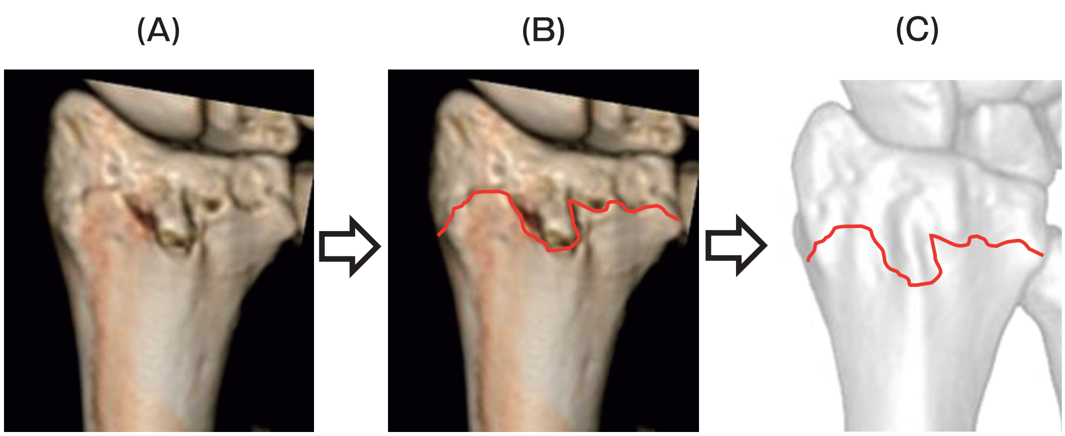

Fig. 1 Images showing two-dimensional fracture mapping. (A) Image of computed tomography. (B) Image with fracture lines drawn as red lines. (C) The fracture lines were drawn onto a standard two-dimensional template of an intact distal radius by matching landmarks.

Results

Patient characteristics. Table 1 shows patient characteristics in detail. This study included 70 undisplaced DRFs in 70 patients with an average age of 68.0 years (range, 28-84 years). Of the included patients, 87.1% (61/70) were women, and 12.9% (9/70) were men. Overall, 48.6% (34/70) of the patients had left DRFs. Based on the OTA/AO classification, 65.7% (46/70) and 34.3% (24/70) of the patients had 2R3A2 and 2R3A3 fractures, respectively. There was no statistically significant difference in fracture classification between the groups with or without EPL rupture. The average time to rupture of the EPL tendon after DRF was 24.1 days. All DRF cases were treated conservatively.

Distal radius fracture line with or without rupture of the EPL tendon. Table 2 presents the dorsal location of the fracture line. The locations were categorized into four groups: proximal to Lister's tubercle, through Lister's tubercle, distal to Lister's tubercle, and both proximal and distal to Lister's tubercle (Fig. 2). All cases with EPL tendon rupture had fracture lines located along the proximal border of Lister's tubercle. Among the cases, three had additional lines distal to Lister's tubercle. In the case of EPL tendon rupture, the fracture lines were significantly located in the proximal border ($p < 0.04$). Because of the fracture locations, heat maps showed a high concentration of fracture lines along the proximal border of Lister's tubercle (Fig. 3A). In contrast, in the cases without EPL tedom rupture, 32 and 9 fracture lines were located proximal and distal to Lister's tubercle, respectively. Moreover, 12 of the proximally located lines were separate from Lister's tubercle border. Six cases without EPL tendon ruptures had fracture lines located both proximal and distal to Lister's tubercle. Five fracture lines without EPL tendon rupture passed through Lister's tubercle. Thus, the fracture lines of the unruptured EPL group were relatively dispersed (Fig. 3B).

Table 1 Patient characteristics

Variables	EPL tendon ruptures (n = 18)	NOT EPL tendon ruptures (n = 52)	Total (n = 70)	*P*-value
Sex (n)				0.28
Male	1	8	9	
Female	17	44	61	
Average age (y)	65.9 ± 13.2	68.7 ± 17.2	68.0	0.53
Side of injury (n)				0.88
Left	9	25	34	
Right	9	27	36	
OTA/AO classification (n)				0.50
2R3A2	13	33	46	
2R3A3	5	19	24	
Time to rupture (average, d)	24.1 ± 21.1			

Table 2 The dorsal location of fracture lines

Location of Fracture line	Proximal to Lister's tubercle	Through Lister's tubercle	Distal to Lister's tubercle	Both Proximal and Distal to Lister's tubercle
EPL tendon ruptures	15	0	0	3
NOT EPL tendon ruptures	32	5	9	6
Total (n = 70)	47	5	9	9

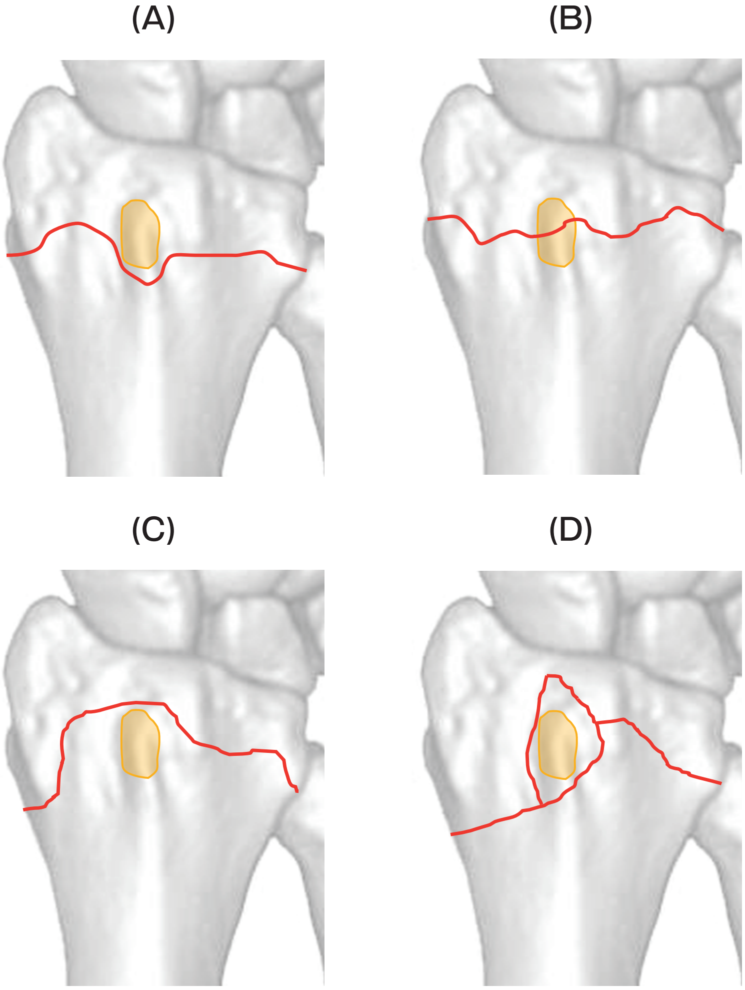

Fig. 2 Classification of dorsal fracture line. Fracture lines and Lister's tubercles are shown as red lines and yellow areas, respectively. (A) Proximal to Lister's tubercle. (B) Through Lister's tubercle. (C) Distal to Lister's tubercle. (D) Both proximal and distal to Lister's tubercle.

Discussion

This study revealed that the fracture lines of cases with EPL tendon rupture were located along the proximal border of Lister's tubercle.

Various mechanisms of DRF-induced EPL rupture have been proposed, including traumatic injury, interruption of tendon perfusion, local adhesion, and blood vessel injury [9,10]. In physiological condition, the extensor retinaculum holds the EPL tendon tightly against the dorsal surface of the radius. Therefore, the swelling, edema, hematoma, or callus caused by a DRF narrows the space for the EPL tendon in the third dorsal compartment when the retinaculum remains intact, as in an undisplaced fracture. Consequently, the incidence of EPL rupture is higher in undisplaced DRFs than in displaced DRFs [8]. Hirasawa *et al.* revealed that the distal area of the retinaculum (5 mm proximal to the distal end) had poor vascularization to the EPL tendon and the visceral layer of the tendon sheath [7]. Additionally, no mesondineum is found around the EPL tendon at this area. In contrast, the extensor carpi radialis longus, extensor carpi radialis brevis tendons, and their sheaths are well vascularized [7]. In the case of DRFs with fracture lines proximal to Lister's tubercle, the blood supply from the proximal side to the EPL tendon is interrupted by direct injury or edema. This appears to be why the EPL is particularly susceptible to

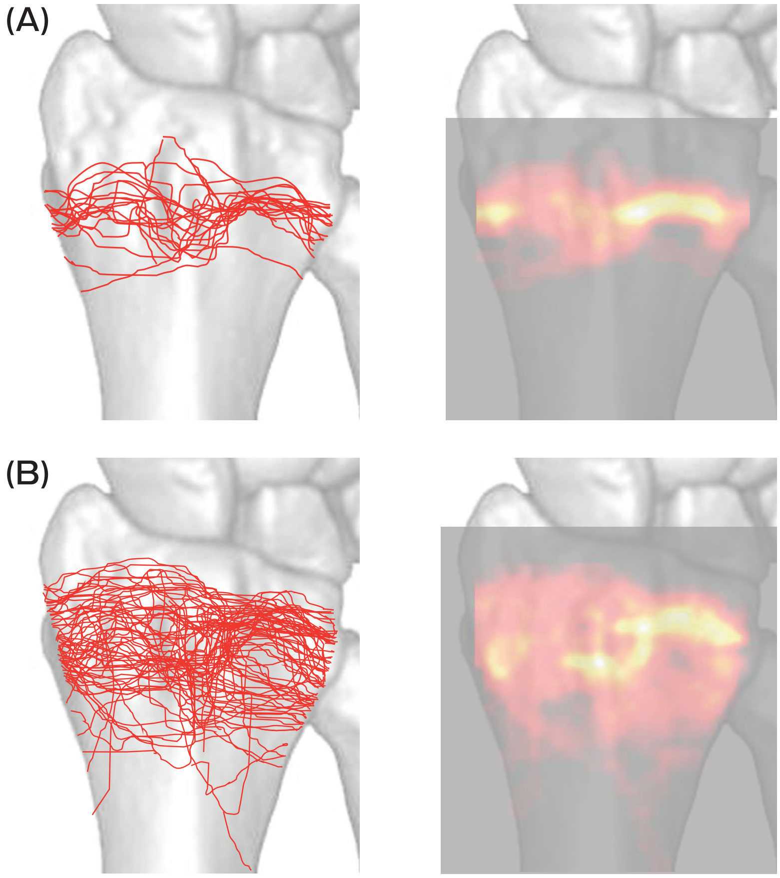

Fig. 3 Paired superimposing fracture lines and heat maps display the dominant fracture patterns. Fracture lines are shown as red lines on the template. The frequency of the fracture line is illustrated by heat maps. (A) EPL tendon rupture. (B) Unruptured EPL tendon.

rupture from loss of vascularization after an undisplaced DRF.

Owers KL *et al.* evaluated the EPL tendon and its surrounding structures after DRFs using ultrasound [11]. Their study revealed that the thickness of the extensor retinaculum and EPL tendon sheath significantly increased 6 weeks after DRFs. This increase may interrupt the tenuous blood supply of the EPL tendon, causing tendon rupture. Moreover, this study demonstrated that an ultrasound scan can detect attenuation of the EPL tendon after an undisplaced DRF. In such cases, the authors undertook prophylactic decompression of the tendon to avoid subsequet tendon rupture. EPL tendon rupture can occur with or without prodromes such as dorsal pain or weak retroflexion of the thumb [12,13]. Therefore, preventing EPL rupture after DRFs is difficult without prognostic analysis and identifiction of initial disease processes. The use of an ultrasound scan might be effective at preventing tendon rupture and is recommended for patients with undisplaced DRFs with fracture lines that pass along the proximal border of Lister's tubercle.

EPL tendon rupture can occur after a pediatric DRF, such as the reported case of a rupture after a Salter–Harris II DRF in a 16-year-old boy [14]. Although the youngest patient in the present study was 28 years old, orthopedic surgeons should consider the possibility of rupture even in pediatric cases.

This study has several limitations. First, the shape of Lister's tubercle was not considered as a factor despite its demonstrated heterogeneity [15]. Second, some cases had no EPL tendon ruptures despite their fractures being located proximal to Lister's tubercle. The protective factors in these cases were not examined. Nevertheless, in general, the fracture lines in the EPL tendon rupture group were significantly concentrated just proximal to Lister's tubercle. Finally, the number of cases in our series, particularly those with tendon rupture, might not have been sufficient to perform statistical analysis.

To the best of our knowledge, this study is the first to reveal the fracture pattern of undisplaced DRFs with EPL tendon rupture. The assembled data and fracture maps will help orthopaedic surgeons predict the occurrence of EPL tendon rupture and stratify patients for closer follow-up, *e.g.* with ultrasound examination. Furthermore, our results will help orthopeadic surgeons explain the possibility of tendon rupture to patients and their families during the informed consent process.

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