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ORIGINAL ARTICLE

Association between bone mineral density and ulnar styloid fracture in older Japanese adults with low-energy distal radius fracture

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Abstract

Summary We investigated the association of the ulnar styloid fracture (USF) with the bone mineral status and fractured radial displacement in elderly patients. The presence of USF correlates with decreased BMD and severe displacement of the radius. These findings are helpful in treating osteoporosis to prevent subsequent fragility fracture.

Purpose The pathogenesis of ulnar styloid fracture (USF), which often occurs with distal radius fracture (DRF), is unclear. This study aimed to investigate whether USF concomitant with low-energy DRF was associated with the bone mineral status and the degree of radiographically observed pretreatment radius displacement in Japanese adults above 50 years of age.

Methods The study subjects were 45 (44 female, 1 male) consecutive patients aged > 50 years with DRF caused by falls from June 2015 to May 2016. Fractures due to high-energy injuries were excluded. Patients were divided into two groups according to the presence or absence of USF. Radius displacement was assessed on anteroposterior and lateral radiographs by measuring ulnar variance, radial inclination, and volar tilt at initial examination before manual reduction of the bone. Bone mineral density (BMD) of the lumbar spine, femoral neck, and distal radius was also measured by dual-energy X-ray absorptiometry within 1 week of injury.

Results Significant differences in the BMD values of femoral neck, ulnar variance, radial inclination, and volar tilt were found between patients with USF and those without USF (all comparisons, $p < 0.05$). Logistic regression analysis of all subject data identified that volar tilt was significantly associated with the presence of USF ($p = 0.048$).

Conclusions The presence of USF in low-energy DRF correlates with the decreased BMD of femoral neck and severe displacement of radius in elderly patients. These findings are helpful for the treatment of osteoporosis to prevent subsequent fragility fracture.

Keywords Osteoporosis · Distal radius fracture · Ulnar styloid fracture · Radius displacement

Introduction

Distal radius fracture (DRF) is common among elderly people and associated with osteoporosis. We previously reported the incidence of osteoporotic fractures in an isolated area with an aging rate of over 40%, showing that the incidence of DRF was increasing with an increased proportion of elderly adults [1]. Although DRF has the second lowest overall incidence of the four major types of osteoporotic fragility fractures, it is the most common type of osteoporotic fragility fractures in patients between 70 and 80 years old [2]. It is also well known that the burdens of vertebral fractures and proximal femoral fractures affect patients' quality of life. Therefore, understanding the pathology of DRF and early preventive measures against subsequent vertebral fracture or proximal femoral fracture is very important to maintain quality of life in elderly people.

The ulnar styloid fracture (USF) often occurs with DRF [3]. Ayalon et al. reported that the presence of USF was a negative predictor for clinical outcomes after DRF [4], but the pathogenesis of its occurrence is unclear. A relationship with the degree of displacement of radius is presumed, but it

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has not been reported so far. Although the degree of displacement of DRF was reported to have a negative correlation with the bone mineral density (BMD) of the lumbar spine [5], the relationship between USF and bone mineral status has not been clarified. On the other hand, Ting et al. reported that patients with DRF had increased levels of bone formation and resorption markers [6], but a relationship between USF and bone metabolic marker is unknown.

With the aforementioned gap in information, this study aimed to investigate prospectively the association between the presence of USF concomitant with low-energy DRF and bone mineral status in elderly patients.

Methods

This study was reviewed and approved by the institutional review board (IRB) of our institution (2015–2373), and all patients provided written informed consent. Forty-five consecutive patients age 50 years or older who underwent surgery for DRF from June 2015 to May 2016 were enrolled immediately before surgery. Patients with fractures caused by high-energy trauma such as altitude falls were excluded. All patients underwent manual reduction on the day of the injury to reduce swelling, and surgery was performed within 1 week of the injury.

The fracture type was classified according to AO/OTA classification. Patients were divided into two groups according to the presence or absence of USF, i.e., USF group and non-USF group. Age at operation, bone mineral status, and radiographic parameters were investigated and compared between the two groups. The BMDs and T-scores of the lumbar spine from L2 to L4, femoral neck, and ultra-distal radius were assessed using dual-energy X-ray absorptiometry (Hologic Discovery QDR Series Densitometer; Hologic Inc., Bedford, MA, USA) as standard of care. The T-score was defined as the number of standard deviations from the mean BMD for healthy young adults. In accordance with the World Health Organization (WHO) criteria, osteopenia was defined as a T-score between − 1.0 and − 2.5, and osteoporosis was defined as a T-score < − 2.5 [7]. We also measured the serum levels of bone turnover markers as standard of care, including N-terminal propeptide of type 1 procollagen (P1NP) and isoform 5b of tartrate-resistant acid phosphatase (TRACP-5b), within 1 week after injury. The degree of radius displacement was assessed by measuring the angle of radial inclination (Fig. 1a, d; normal angle, 21° to 25°), angle of the volar tilt (Fig. 1b, e; normal angle, 2° to 20°), and length of the ulnar variance (Fig. 1c, f; normal range, − 4.2 to + 2.3 mm) at initial visit and before manual reduction, based on standard anteroposterior and lateral projection radiographs [8].

Statistical analysis

Statistical analyses were performed using the statistical software EZR on R commander (ver. 1.35, Saitama Medical Center, Jichi Medical University, Saitama, Japan) [9]. Continuous variables had normal distribution using Shapiro-Wilk test ($p > 0.05$) and were expressed as mean values and standard deviation. Statistical comparisons between USF and non-USF groups were performed using two-sample t test for continuous variables or Fisher's exact test for categorical variables. Additionally, a stepwise logistic regression analysis was performed to identify independent risk factors for the presence of USF. Independent variables with $p < 0.05$ in the univariate analyses were included in the multivariate analysis. A p value < 0.05 was considered statistically significant.

Results

This study analyzed the data of the 45 patients (1 male and 44 female) with an average age of 71.1 (range 50–89) years. Fracture types of AO classification were 23: A in 22 patients, B in 2, and C in 21. Among them, a combination of USF was confirmed in 24 patients. Based on the WHO criteria, 24 patients (53.3%) had osteoporosis, 17 (37.8%) had osteopenia, and 4 (8.9%) were normal, and no significant differences were found in the distribution of bone mineral status between the two groups. There were 24 patients in the USF group and 21 in the non-USF group. No significant difference was detected in the age at operation (USF group, mean 71.9 years; non-USF group, mean 68.5 years), BMD of the lumbar spine and ultra-distal radius, P1NP, and TRACP-5b between the two groups, whereas a significant difference was noted in the BMD of the femoral neck between the USF group (0.52 g/cm^2) and the non-USF group (0.58 g/cm^2) ($p < 0.05$) (Table 1). With regard to the radiographic parameters, the mean radial inclination (USF group, 15.5°; non-USF group, 20.2°), volar tilt (USF group, − 20.6°; non-USF group, − 10.3°), and ulnar variance (USF group, 2.59 mm; non-USF group, 1.35 mm) demonstrated significant differences between the two groups (all comparisons, $p < 0.05$) (Table 1).

In the multivariate analyses, the volar tilt was determined as an independent contributing factor for the presence of USF (OR, 0.938; 95% CI, 0.88–0.99; $p = 0.048$) (Table 2).

Discussion

This study showed that the mean BMD of the femoral neck in DRF patients with USF was significantly lower than that in

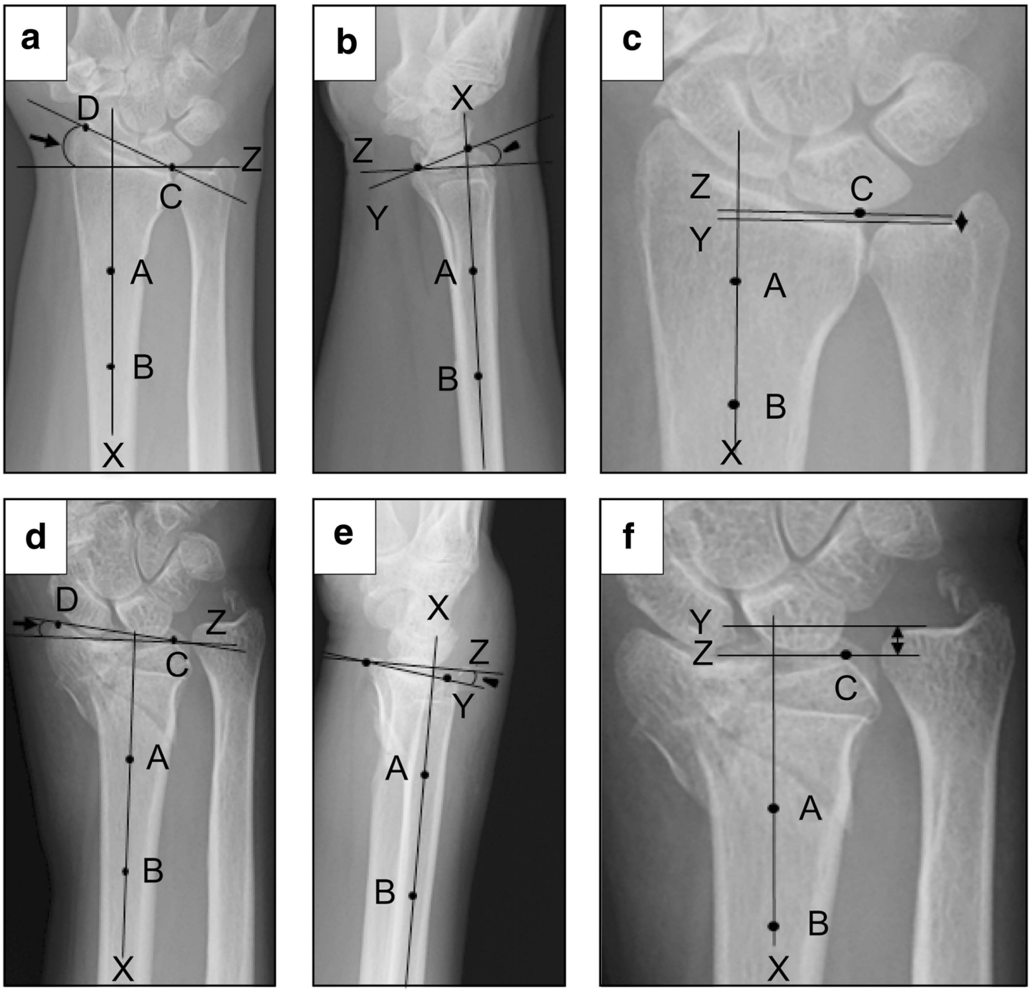

Fig. 1 Radius displacement assessed by plain radiography. **a**, **b**, and **c** are representative X-rays from a patient with normal measurements and no USF. **d**, **e**, and **f** are representative X-rays from a patient with displaced measurements and USF. **a**, **d** Radial inclination angle (arrow) is measured by drawing a perpendicular line (line Z) to the radial axis (line X) through the central reference point of distal sigmoid notch (the ulnar edge of the lunate fossa) and by drawing another line (line DC) joining the distal tip of the radial styloid and the central reference point distal sigmoid notch. These two lines form the radial inclination angle (normal angle, 21°–25°). **b**, **e** Volar tilt angle (arrowhead), which is the angle created between the line (Y) joining the most distal points of the dorsal and ventral rims of the distal articular surface of the radius and the line (Z) drawn perpendicular to the long axis (line X) of the radius(normal angle, 2°–20°). **c**, **f** Ulnar variance (double arrow) is measured by drawing a perpendicular line (line Z) to the radial axis (line X) through the central reference point of the distal sigmoid notch (the ulnar edge of the lunate fossa) and by drawing a perpendicular line (line Y) to the radial axis (line X) through the distal articular surface of the ulna

patients without USF, and radiographic radius displacement was significantly greater in patients with USF. The results of this study implied that the presence of USF was associated with the high risk of subsequent femoral neck fracture.

With regard to the serum bone metabolic markers, no associations between serum levels of bone metabolic markers and presence of USF were found in this study. Previous studies reported that increased serum P1NP level correlated with decreased BMD of the femoral neck and increased risk of hip or any non-spine fragility fracture [10, 11]. In addition, increased serum TRACP-5b level correlated with increased risk of hip or vertebral fragility fracture [11]. We speculated that our subject with DRF was relatively young compared to subjects with other types of osteoporotic fragility fractures [8, 12]; hence, the abnormal levels of these markers were not very high.

Sakai reported that the degree of radiographic radius displacement was closely associated with decreased BMD of the lumbar spine [3]. In the present study, only the decreased BMD of the femoral neck showed significant correlation with the presence of USF. The reason why the presence of USF had no significant correlation with the BMD of lumber spine

Table 1 Comparison of demographic data between the two groups in distal radius fracture patients

	Ulnar styloid fracture	Non-ulnar styloid fracture	*p* value
Number of patients	24	21	
Age [years], (range)	71.9 ± 11.4 (50–89)	68.5 ± 9.5 (53–88)	0.294
Sex [% female]	100%	95.2%	1.000
BMD [g/cm^2]			
Of lumbar spine	0.67 ± 0.14	0.72 ± 0.13	0.184
Of femoral neck	0.52 ± 0.10	0.58 ± 0.09	0.029*
Of ultra-distal radius	0.27 ± 0.07	0.31 ± 0.07	0.078
Diagnoses			
% osteoporosis	45.8	61.9	0.373
% osteopenia	41.7	33.3	0.759
% normal	12.5	4.8	0.611
P1NP [ng/mL]	63.7 ± 22.1	71.1 ± 58.8	0.599
TRACP-5b [mU/dL]	499.9 ± 158.0	486.2 ± 141.0	0.772
Radial inclination [°]	15.5 ± 8.0	20.2 ± 5.7	0.028*
Volar tilt [°]	− 20.6 ± 13.0	− 10.3 ± 12.9	0.010*
Ulnar variance [mm]	2.59 ± 1.65	1.35 ± 1.71	0.018*

BMD, bone mineral density

* Significant

appeared to be influenced by degenerative changes in the lumber spine [13]. Furthermore, previous studies using high-resolution peripheral computed tomography of the distal radius reported that patients with recent DRF have worse trabecular microarchitecture compared to non-fracture controls, despite no difference in the BMD of distal radius. It appeared that DRF was influenced by trabecular microarchitecture at the distal radius rather than by BMD which contained both the cortical and trabecular compartments [14, 15]. It could be the reason of no correlation between the presence of USF and BMD of the distal radius. The pathogenesis of USF has been considered to represent traction injuries by the ulnocarpal ligaments or shear fractures from the direct impact by the carpus [16]. In the present study, the presence of USF in low-energy DRF was associated with the degree of the volar tilt as an independent contributing factor. From these results, we considered that lower bone mineral status caused severe dislocation of the radius, which subsequently result in the occurrence of USF.

Table 2 Logistic regression analysis of factors correlated with USF in DRF patients

Factor	Odds ratio	95% CI	p value
BMD of femoral neck [g/cm^2]	0.0006	0.81×10^{-7}–5.03	0.108
Radial inclination [°]	0.9210	0.83–1.03	0.147
Volar tilt [°]	0.9380	0.88–0.99	0.048*
Ulnar variance [mm]	1.1700	0.75–1.82	0.500

BMD, bone mineral density; CI, confidence interval; DRF, distal radius fracture; USF, ulnar styloid fracture

* Significant

This study has two novel points. First, to the best of our knowledge, this is the first prospective case-control investigation to clarify the pathogenesis of USF concomitant with frequently encountered DRF. Second, the pathogenesis of USF could be assessed and comprehensively compared with bone mineral status including BMD of various sites and bone metabolic makers and radiographic severity of DRF. However, this study has some limitations to take into account. First, this study involved a relatively small sample size. However, this is the first prospective investigation of USF which could provide informative data regarding the relationship with bone mineral status. Second, we could not classify the USF into base and tip fracture sites, which might have different mechanisms between the two fracture sites in USF [17]. Unfortunately, our subjects included only six patients with tip fracture of the ulnar styloid, which could not be compared using statistical analysis.

In conclusion, the presence of USF concomitant with low-energy DRF is caused by the severe dislocation of the distal radius and possibly by a lower BMD of femoral neck. These findings are helpful for the consideration of active treatment for osteoporosis to prevent subsequent femoral neck fracture in elderly patients. In the future, we will increase the number of cases to clarify the different mechanisms of USF between the tip and base in ulnar styloid.

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Compliance with ethical standards

Conflict of interest None.

Ethical approval "All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."

Informed consent "Informed consent was obtained from all individual participants included in the study."

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