SCIENTIFIC ARTICLE

Relationship Between Ulnar Variance, Cortical Bone Density, and Load to Failure in the Distal Radius at the Typical Site of Fracture Initiation

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Purpose Increased ulnar variance has been shown to lead to diminished load borne by the distal radius. The purpose of this study was to determine the correlations among ulnar variance, bone mineral density, and load to failure at the distal radius.

Methods Posteroanterior radiographs and computed tomographic scans were taken of 12 cadaveric forearms in neutral rotation. Ulnar variance was measured for each wrist by the method of perpendiculars. Measurements of cortical, trabecular, and combined bone density were made at the distal radius. We performed linear regression analysis and correlation analysis to determine the relationship between bone densities and ulnar variance measurements. Next, we loaded the 12 cadaveric radii to failure under axial compression. Linear regression analysis and correlation analysis were then performed to determine the relationship between load to failure and both ulnar variance and cortical density.

Results Increased ulnar variance was significantly correlated with decreased cortical bone density at the distal radius and both were correlated with decreased load to failure. We found no correlation between ulnar variance and trabecular density or combined trabecular and cortical bone density at the distal radius.

Conclusions Our study found that increased ulnar variance and decreased cortical bone mineral density correlates with decreased load to failure under axial compression.

Clinical relevance Ulnar variance is linked to both bone quality and load to failure at the distal radius. *(J Hand Surg Am. 2016;■(■):■−■. Copyright © 2016 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Bone mechanics, fracture, radius, ulna.

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Received for publication January 21, 2016; accepted in revised form August 28, 2016.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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0363-5023/16/■ ■-0001$36.00/0
http://dx.doi.org/10.1016/j.jhsa.2016.08.021

In postmenopausal women distal radius fractures often occur as a result of low-energy trauma.[1] Although older men may sustain a distal radius fracture at a slightly younger age than women, they have similar mechanisms of injury and medical comorbidities.[2] In the Study of Osteoporotic Fractures,[3] a large prospective cohort study in women over age 65 years, women with wrist fractures were 48% more likely than those without fractures to have a clinically important functional decline, at a mean

TABLE 1. Demographic Data on Cadaveric Specimens

Cadaver	Sex	Race	Age, y	Cause of Death
1	M	Caucasian	75	Acute renal failure, congestive heart failure, colitis
2	M	Caucasian	79	Pneumonia, cardiac arrhythmia, dementia
3	F	Caucasian	90	Coronary artery disease
4	M	Caucasian	74	Atherosclerotic cardiovascular disease
5	M	Caucasian	67	Chronic obstructive pulmonary disease
6	M	Caucasian	58	Fulminant liver failure, alcohol abuse, severe thrombocytopenia, respiratory distress

follow-up of 7.6 years. Because the lifetime risk of sustaining a distal radius fracture in 50-year-old Caucasian women and men is about 16% and 3%, respectively,[4] it would be helpful to describe factors that may affect bone quality at the distal radius. Bone mineral density (BMD), as measured by dual-energy x-ray absorptiometry (DXA) at the forearm, is a good predictor of distal radius fractures.[5] However, it has been shown that a large proportion of patients with low-energy distal radius fractures do not have systemic osteoporosis.[6] Therefore, it seems likely that factors other than systemic osteoporosis affect BMD at the distal radius.

Ulnar variance describes the relationship between the lengths of the distal ends of the radius and ulna and consequently the load borne by each of these bones.[7] The load distribution at the forearm can vary greatly. For example, the load distributed through the radius and ulna in 2- to 3-mm ulnar-plus variance wrists is 69% and 31%, respectively. In contrast, the distribution is 94% and 6%, respectively, in 2-mm ulnar-minus variance wrists.[7] In addition, it has been shown that ulnar-positive variance leads to a relatively unloaded lunate fossa, as determined by diminished subchondral bone mineralization in this area compared with ulnar-negative wrists.[8] Those findings are not surprising because in ulnar-positive wrists the ulna is in greater contact with the carpus, thereby offloading the lunate fossa in the radius. This finding is in accordance with Wolff's law given that increased ulnar variance causes reduced load through the radius.[7]

In a study of 157 dorsally displaced distal radius fractures, Baumbach et al[9] defined the extent of this fracture region as being 15.6 mm from the palmar apex of the lunate fossa and 5.2 mm from the dorsal apex of the lunate fossa on sagittal images. The aim of the current study was to assess this fracture region of interest defined by Baumbach et al. Our first hypothesis was that bone densities in this region would correlate inversely with ulnar variance. Our second hypothesis was that distal radius bone density would correlate directly with load to failure whereas ulnar variance would correlate inversely with load to failure at the distal radius.

MATERIALS AND METHODS

We assessed 12 cadaveric wrists from 6 specimens whose demographic data (sex, age, and race/ethnicity) and clinical data (cause of death and other noteworthy medical conditions at the time of death) are listed in Table 1. Our cadavers were obtained from the willed-body program at our institution. Exclusion criteria included evidence of metabolic bone disease or the likelihood of such disease (ie, lytic or blastic bone lesions, sclerotic bone, osteoporotic bone, subchondral cysts, erosions); bone cancer or cancer with bone metastases; and evidence of current or previous distal radius fracture, as indicated by obvious deformity, decreased radial height, and/or ulnar styloid fractures. We evaluated 14 cadavers; after exclusion criteria were applied, we procured 12 wrists from 6 cadavers.

We cut the upper extremity at the mid-humerus. Posteroanterior radiographs of the wrist specimens were obtained with the forearm in neutral rotation, and ulnar variance was then measured through the method of perpendiculars.[10] Radiographs were viewed using a standard DICOM viewer (Mimics, Materialise, Plymouth, MI) and ulnar variance was measured using the measurement tools of this digital system. Two of the authors made measurements to the nearest 0.1 mm, which were averaged. To determine bone densities, computed tomography (CT) scans of the wrist were obtained, again with the forearm in neutral rotation. The distal radius fracture region of interest was defined on the sagittal images as 15.6 mm from the palmar apex of the lunate fossa and 5.2 mm from the dorsal apex of the lunate fossa, based on previous work.[9] We used MIMICS software (Materialise, Inc, Leuven, Belgium) to analyze the CT scans and isolate