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ORIGINAL ARTICLE

Variation in stress distribution patterns across the radial head fovea in osteochondritis dissecans: predictive factors in radiographic findings

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Background: Predictive factors for the development of osteoarthritis in adolescent osteochondritis dissecans (OCD) of the humeral capitellum remain unclear. The objectives of this study were to assess subchondral bone density in the radial head fovea of patients with OCD and to evaluate stress distribution in the radiocapitellar joint. The relationship between radiologic classification and stress distribution, according to multivariate ordinal regression analysis, was also investigated.
Methods: Computed tomography (CT) imaging data from 54 male patients with OCD (mean age, 13.1 years) were collected. Stress in the radial head fovea was measured using CT osteoabsorptiometry. A stress map was constructed and divided into 4 sections, and percentages of high-density regions in each section were quantitatively analyzed. Multivariate ordinal regression analyses were performed of bone density, incorporating the stage, location, and size of the OCD lesion and the presence of medial elbow disturbance in the radiographic images.
Results: The percentage of high-density area in the anteromedial, posteromedial, and the anterolateral sections of the radial head fovea were significantly increased compared with the posterolateral section. Multivariate ordinal regression analysis revealed that the location and size of the lesion and a history of excessive valgus stress were associated with imbalances in the radial head fovea.
Conclusions: When the OCD lesion is large and located laterally and a medial epicondyle disturbance is apparent on radiographs, the risk for developing advanced radiocapitellar osteoarthritis should be considered. These findings can be useful in the decision-making process for treating OCD.
Level of evidence: Anatomy Study; Imaging
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Keywords: adolescent; baseball; computed tomography; elbow; osteochondritis dissecans; stress distribution

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Elbow disorders related to throwing motion have been recognized in adolescents, which include osteochondritis dissecans of the humeral capitellum (capitellar OCD).[15,32] Recent studies have demonstrated that young patients with capitellar OCD have the potential to spontaneously heal without surgical treatment.[19,33] More recent studies have reported excellent or satisfactory results after various surgical treatments, including arthroscopic débridement or an osteochondral graft for capitellar OCD.[12,28,31] In contrast, we found that severe osteoarthritis had already developed in some patients despite their very young age.[25] Although several factors related to unacceptable treatment outcomes have been identified,[17,20] predictive factors for severe osteoarthritis in adolescent capitellar OCD have not yet been elucidated.

Assessing radiocapitellar joint stress under actual loading conditions during the pitching motion remains challenging. Several studies have reported that excessive stress on the elbow leads to various disorders, including capitellar OCD, ulnar collateral ligament injury, or olecranon stress fracture.[8,9] The patterns of subchondral bone density are believed to reflect the distribution of stress on the joint surface during actual loading conditions.[24] Previous studies have demonstrated that computed tomography (CT) osteoabsorptiometry can potentially be used to evaluate long-term stress distribution patterns in various joints.[4,8,14,23,30]

Although evaluating subchondral bone density of the capitellum in patients with capitellar OCD is difficult, we contemplated whether radial head stress distribution patterns would be useful in assessing radiocapitellar stress patterns. We hypothesized that several radiographic factors in patients with capitellar OCD would reflect changes in stress acting on the radiocapitellar joint and subchondral bone mineral density of the radial head fovea. The objectives of this study were to examine subchondral bone density in the radial head fovea of patients with capitellar OCD and assess the stress distribution patterns in the radiocapitellar joint. A secondary objective was to investigate the relationship between radiologic classification and stress distribution across the radial head fovea by using multivariate ordinal regression analysis.

Materials and methods

Data collection

In this case-control study, data from consecutive patients who were treated at our hospitals were retrospectively reviewed. Between 2010 and 2016, imaging data from radiographs and CTs were obtained from the throwing-side elbows of 54 male patients with capitellar OCD (mean age, 13 years; range, 10-17 years). All participants were baseball players, and none had undergone previous elbow surgery.

Inclusion criteria were individuals with asymptomatic and symptomatic capitellar OCD diagnosed using anteroposterior plain radiography with the elbow in 45° flexion. Data were included regardless of the treatment method used; conservatively or surgically treated patients were both included.

Exclusion criteria were a history of traumatic injury, the presence of severe osteoarthritis, or symptomatic valgus instability. Symptomatic valgus instability was defined as positive history, painful patterns during pitching motion, tenderness in the ulnar collateral ligament, positive stress maneuver, and plain radiograph under the gravity stress condition. The current study focused on advanced lesions of the capitellum; therefore, individuals with early-stage capitellar OCD were excluded.

Imaging classification

Anteroposterior plain radiographs, acquired with the elbow positioned at 45° flexion, were used to classify the lesions. Advanced lesions were divided into 2 groups according to the stage: the nondisplaced fragment stage (nondisplaced group) and the displaced or detached fragment stage (detached group). This excluded the early (ie, lucent) stage, according to the modified Minami classification.[12,22,32] As indicated in previous reports,[10,17] lesions were also categorized according to their locations: central, lateral, and lateral extended. The lateral location was defined as <33% of the width of the capitellum, and the lateral extended location was defined as ≥33% of the width of the capitellum. The size of the capitellar lesion was calculated using the short and long axis of an oval shape placed in a 3-dimensional reconstructed CT image. A history of excess valgus stress was defined as the medial epicondyle fragment from an anteroposterior plain radiograph acquired with the elbow in 45° flexion or ulnar collateral ligament (UCL) injury revealed on magnetic resonance imaging (MRI) in 44 patients.

CT osteoabsorptiometry

CT imaging data were transferred to the Aquilion One image analysis system (Toshiba Medical Systems, Otawara, Japan) for further evaluation. A 3-dimensional bone model was created from the axial image stack. Sagittal views at intervals of 1 mm were acquired from the multiplanar reconstruction model.

A customized software program was used for further evaluation. The region of interest in the sagittal images was selected so that it included the entire subchondral bone layer of the articular surface of the radial head fovea. After the region of interest was established, Hounsfield units (HU), defined as x-ray attenuation in which water is considered 0 HU and compact bone 1000 HU, were automatically measured at each coordinate point within each 1-mm interval. The density range (in HU) from minimum to maximum in each elbow was divided into 8 equal intervals, and the densities measured at each coordinate point were mapped using an 8-grade color scale in which red indicated the highest bone density. The measurements and mapping were repeated for each slice, and by stacking these data, a 2-dimensional mapping image was obtained on which the distribution of subchondral bone density was projected. Quantitative analysis of the mapping data was focused on the location of the high-density area (HDA) across the radial head fovea. The HDA was defined as the greatest interval in the entire threshold—from minimum to the maximum HU—for each elbow.

For analysis of stress-distribution patterns, the articular surface of the radial head fovea was divided into 4 sections: anterolateral, anteromedial, posterolateral, and posteromedial (Fig. 1). Because the bone density in each patient or the CT program may have affected the results, the percentage of HDA (%HDA) for each section of the radial head fovea was calculated.

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