EDITOR'S CHOICE

Topographical Anatomy of the Distal Ulna Attachment of the Radioulnar Ligament

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Purpose The deep component of the distal radioulnar ligament provides translational stability and rotational guidance to the forearm. However, controversy exists regarding the importance of this structure as well as the nature of its attachment to the distal ulna. We aimed to evaluate the topographic anatomy of the distal ulna attachment of both the superficial and the deep components of the radioulnar ligament and to assess the relationship between its internal and its external morphometry.

Methods Thirteen human distal ulnae attached by ulnar part of the distal radioulnar ligament were scanned using micro−computed tomography and reconstructed in 3 dimensions. In addition, the distal radioulnar ligaments were examined under polarized light microscopy to determine the histological characteristics of collagen contained within the ligaments.

Results The deep limbs have broad marginal insertions at the fovea, whereas the superficial limbs have a circular and condensed insertion to the ulnar styloid. The center of the deep limb was separated from the base of the ulnar styloid by a mean of 2.0 ± 0.76 mm, and this distance was positively correlated with the width of the ulnar styloid. The mean distance between the center of the ulnar head and the center of the fovea was 2.4 ± 0.58 mm. The proportion of collagen type I was lower in the deep limb than in the superficial limb.

Conclusions This new observation of the footprint of the radioulnar ligament in the distal ulna indicates that the deep limb may serve as an internal capsular ligament of the distal radioulnar joint, whereas the superficial limb as the external ligament.

Clinical relevance Knowledge of the topographic anatomy of the radioulnar ligament's attachment to the distal ulna may provide a better understanding of distal radioulnar ligament−related pathologies. *(J Hand Surg Am. 2017;■(■):1.e1-e8. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Micro-CT, triangular fibrocartilage complex, distal radioulnar ligament, footprint, fovea.

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THE DORSAL AND PALMAR RADIOULNAR ligaments, which are the primary stabilizers of the distal radioulnar joint (DRUJ), converge from their origins at the sigmoid notch of the radius, into both the ulnar styloid (superficial limb) and the ulnar styloid base or fovea of the ulnar head (deep limb), blending with the fibrocartilage structure to form the triangular fibrocartilage complex (TFCC).[1,2]

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Avulsion fractures involving the ulnar styloid base or fovea, where the distal radioulnar ligaments insert, have the potential risk to destabilize the DRUJ, but this remains controversial.[3,4] In fact, several studies have reported neither the fracture size nor the degree of displacement of the ulnar styloid affects objective or subjective clinical outcomes or is a predictor of DRUJ instability.[5–7] Furthermore, it has also been suggested that ulnar styloid fixation may not be necessary if the distal radius is treated with rigid internal fixation. However, few studies have described the detailed topographic anatomy of the distal ulna and its ligamentous attachments, knowledge of which may provide a better understanding of the biomechanical role of the distal radioulnar ligaments and their relationship to DRUJ stability.

Studies utilizing micro-imaging techniques, such as micro−computed tomography (CT), have demonstrated detailed bone morphology and microarchitecture.[8–12] Microimaging can provide the detailed anatomy of the distal radioulnar ligament footprints on the distal ulna head and styloid.

The purpose of this study was to evaluate the topographic anatomy of the distal ulna and the insertions of both the superficial and the deep components of the distal radioulnar ligaments and to assess the relationships between their internal and their external morphometry using micro-CT scans of cadaveric ulnar heads. We also investigated the ratios of type I/III collagen at different locations of the distal radioulnar ligament in order to study the histological characteristics of the ligament.

MATERIALS AND METHODS

Specimen preparation

A sample of convenience comprising 13 human cadaver wrists (7 right and 6 left wrists from 8 males and 5 females; mean age at death, 65 years [range, 54−75 years]) were inspected. All wrists were radiographically imaged and demonstrated normal osseous anatomy. Exclusion criteria were a degenerative or traumatic tear of the TFCC, a known history of previous trauma, infection, or surgical trauma affecting the wrist. However, specimens with evidence of an age-related change on the TFCC were included if both of the superficial and deep components of the distal radioulnar ligaments were intact.

The entire distal ulna was harvested from the wrist, leaving the ulnar part of the TFCC and DRUJ capsule intact through meticulous dissection of all periarticular skin and musculature. Each component of the distal radioulnar ligament complex was carefully dissected from nonligamentous soft tissue (Fig. 1A). The exact origin, insertion, and course of the ligamentous complex were examined under a dissecting microscope (HSZ-600; HUVITZ Inc., Seoul, Korea).

Both the superficial and the deep components of the ligament were cut near their insertions to identify the footprint. The 2 components of the ligament were easily separated by loose connective tissue from the more distal fibers (Fig. 1B).[13] The ligament remnants were marked and painted with Telebrix (Meglumine ioxithalamate; Gubebet, Aulnay-sous-Bois, France) contrast media solution, which is commonly used for enhanced CT.

Micro-CT imaging

Three-dimensional micro-CT renderings of the distal ulna were used to examine external and internal bony architecture. A scan was performed on all specimens using a micro-CT scanner (1076; SkyScan, Antwerp, Belgium). This system comprised an x-ray microscope with a high-definition x-ray microfocus tube, focal spot diameter of 10 μm; a 1.0-mm-thick aluminum filter to remove noise during x-ray scanning; a precision-controlled specimen holder; a 2-dimensional x-ray charge coupled device camera connected to a frame grabber; and a workstation running tomography reconstruction software (NRecon, ver. 1.6.3.3; SkyScan). A 3-dimensional structural image of the distal ulna with voxels $35 \times 35 \times 35$ μm in size was reconstructed from 2-dimensional cross-sectional images in bitmap format with a 35-μm slice thickness (pixel, 35×35 μm).

Topographic parameters

After reconstructing the 3-dimensional image of the distal ulna, the footprints of the 2 components were separated from the cortical surface of the distal ulna and reconstructed using an appropriate threshold, which isolates tissue dyed with the contrast media solution from bone in the software (Fig. 2A). The footprint sizes, including the maximal width and height and an area of each limb to their insertions, were measured using a reverse-engineering software system (Rapidfom 2006; Inus Technology, Seoul, Korea). The accuracy of the measurements was 0.01 mm or mm^2 or less. Circularity was measured from the data by calculating the ratio of the area of the shape to the area of a perfect circle which has the same perimeter.[14] A perfect circle would have a circularity ratio equal to 1; a value less than 1 indicates a deviation from the outline of a circle. In addition, the center of the ulnar head contour was

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