Impact of Distal Ulnar Fracture Malunion on Distal Radioulnar Joint Instability: A Biomechanical Study of the Distal Interosseous Membrane Using a Cadaver Model

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Purpose Certain distal ulna fractures may contribute to distal radioulnar joint (DRUJ) instability. We hypothesized that residual distal ulna translation could affect DRUJ stability by slackening the distal interosseous membrane (DIOM). We aimed to test this hypothesis in a cadaver model.

Methods We created an ulnar translated distal ulna fracture model in 6 cadavers. Dorsal and palmar displacements of the ulna relative to the radius were measured and DRUJ instability was staged under the following conditions: (1) 0-, 2-, and 4-mm ulnar translation of the distal ulna with an intact triangular fibrocartilage complex (TFCC) and DIOM; (2) 0-, 2-, and 4-mm translations with TFCC divided and an intact DIOM; and (3) a 0-mm translation with TFCC and DIOM divided.

Results With an intact TFCC, dorsal and palmar displacements were not increased with any amount of distal ulna translation. After TFCC division with 0-mm translation, dorsal displacement increased significantly with DRUJ dislocation, whereas palmar displacement increased to a lesser extent with DRUJ subluxation. Palmar displacement gradually increased as the translation increased, and with 4-mm translation the ulnar head displaced to a perched position off the sigmoid notch. With TFCC and DIOM division, displacements increased markedly with DRUJ dislocation both dorsally and palmarly.

Conclusions Dorsal dislocation occurred when the TFCC was divided regardless of the amount of distal ulna translation. Palmar subluxation occurred when the TFCC alone was divided. Palmar displacement to a perched position occurred because of slackening of the DIOM as a result of translation of the distal ulna. Bidirectional DRUJ instability with dorsal dislocation and palmar displacement to a perched position occurred when the TFCC was divided and the distal ulna was ulnarly translated.

Clinical relevance Bidirectional DRUJ instability might occur when distal ulna translation deformity is associated with TFCC injury because the DIOM loses its function as a secondary stabilizer. *(J Hand Surg Am. 2017;42(3):e185−e191. Copyright © 2017 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Distal interosseous membrane, distal radioulnar joint, instability, isolated distal ulnar fracture, translation.

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Fracture of the distal one-third of the ulna is relatively rare.[1–3] Recent studies indicated that certain fracture patterns of the distal ulna contribute to distal radioulnar joint (DRUJ) instability.[4,5] However, potential complications of this fracture have not yet been fully clarified.

The triangular fibrocartilage complex (TFCC) is widely recognized as the primary stabilizer of the DRUJ. It is thought that the dorsal radioulnar ligament of the TFCC constrains palmar displacement of the ulnar head and the palmar radioulnar ligament constrains dorsal displacement.[6–8] The distal interosseous membrane (DIOM) of the forearm, which is distal to the central band of the interosseous membrane, acts as a secondary soft tissue stabilizer of the DRUJ.[9–12] Recently, it was found that the DIOM, coupled with the TFCC, constrained palmar displacement of the distal ulna at the DRUJ but was less able to constrain dorsal displacement in a distal radius malunion model.[11,13] This unique role of the DIOM is suggested to be related to its attachment from the dorsal rim of the radial sigmoid notch to the radial aspect of the ulnar shaft (Fig. 1).[10,11,14] Because the function of the DIOM has not been widely studied, we sought to clarify its role in DRUJ stability after ulnar neck fractures in cadaver models.

We hypothesized that residual ulnar translation of the distal ulna could affect DRUJ stability because as the ulnar shaft approaches the radius, the DIOM slackens, similar to what occurs after a distal radius malunion. We specifically hypothesized the following: (1) Dorsal DRUJ instability would occur mainly when the TFCC is divided with intact bony alignment of the ulna; and (2) bidirectional (dorsal and palmar) DRUJ instability would occur with the TFCC divided and residual ulnar translation deformity of the distal ulna.

MATERIALS AND METHODS

Specimen preparation

We obtained a convenience sample of 6 fresh-frozen, unpaired cadaveric upper extremities that were amputated at the midhumerus. The 6 extremities were from 1 female and 5 male donors; there were 3 right arms and 3 left arms. At the time of death, specimens were aged 51–79 years (mean age, 66 years). The height of the cadavers ranged from 161 to 168 cm, and the maximum diameter of the ulnar head ranged from 16.3 to 17.2 mm; therefore, data normalization based on the ulnar head size was not performed. In all specimens, the DIOM was distal to the middle ligamentous portion (central and accessory bands) of the interosseous membrane, and we easily identified these structures. The distal oblique bundle (DOB) was identified within the DIOM in 3 of the 6 specimens (50%). The occurrence of DOB was similar to that in previous reports.[13,15,16] There was no degenerative TFCC tear in any of the specimens, and TFCC strength remained as a stabilizer in all specimens, which was confirmed after the experiments.

The soft tissues, including the skin, muscles, tendons, and DRUJ capsule, and the structures of the elbow joint were removed; this preserved the TFCC, interosseous membrane, and DIOM. The DIOM was examined distal to the central and accessory bands, and the distal attachment was confirmed. We made a special effort to avoid damage to the TFCC and DIOM, particularly when resecting the DRUJ capsule. Additional open dissection after the experiment confirmed that no forearm had degenerative or abnormal DRUJ changes.

After the dissection, we performed a transverse osteotomy of the ulnar shaft just distal to the distal origin of the DIOM (Fig. 1). We predrilled a hole for a 3-mm fixation screw before the osteotomy so that the osteotomy site would not rotate during fixation. Four screws and hexagonal nuts with washers and an external fixator apparatus were used to stabilize the osteotomy site. The external fixator apparatus, created by a 3-dimensional printer (Objet30 Prime; Stratasys, Rehovot, Israel), was applied to create varying degrees of ulnar translation deformity at the osteotomy site. After applying another external fixator apparatus to the radius, the specimen was mounted on an experimental frame with the forearm in neutral rotation.

Testing protocol

To evaluate DRUJ instability quantitatively by measuring relative displacement between the radius and ulna, a 20-N load was applied to the radius in a dorsopalmar direction with the forearm in neutral rotation using previously described methods (Fig. 2).[13,17,18] Electromagnetic tracking device sensors (3D Guidance trakSTAR; Northern Digital Inc., Waterloo, Ontario, Canada) were attached to the distal end of the radius and ulnar head through the external fixator apparatus. We measured both dorsal and palmar displacements of the radius relative to the ulna in the transverse plane of the radius using these tracking sensors. In addition, we evaluated DRUJ instability qualitatively by the positional relation between the ulnar head and the radial sigmoid notch when the load was applied. In stage 0 (*Reduced*), the DRUJ is reduced and stable. In stage 1 (*Subluxated*),