SCIENTIFIC ARTICLE

Force Variations in the Distal Radius and Ulna: Effect of Ulnar Variance and Forearm Motion

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Purpose To better define normal wrist joint forces during wrist motion and forearm motion at specific wrist and forearm positions and to see if there is a relationship between these forces and the amount of ulnar variance. A secondary purpose was to determine the relationship between the thickness of the articular disk of the triangular fibrocartilage complex and the amount of force transmitted through the distal ulna.

Methods Multi-axis load cells were attached to the distal radius and ulna of 9 fresh cadaver forearms. The axial radial and ulnar compressive forces were recorded while each wrist was moved through wrist and forearm motions using a modified wrist joint simulator. During each motion, the tendon forces required to cause each motion were recorded. The ulnar variance and triangular fibrocartilage complex articular disc thickness were measured.

Results The axial force through the distal ulna and the wrist extensor forces were greatest with the forearm in pronation. No relationship was found between the amount of force through the distal ulna and the amount of ulnar variance. A strong inverse relationship was found between the triangular fibrocartilage complex thickness and the ulnar variance.

Conclusions Wrists with positive ulnar variance have generally been thought to transmit greater loads across the distal ulna, which has been felt to predispose these wrists to the development of ulnar impaction. The results of this study appear to show that all wrists have similar loading across the distal ulna regardless of ulnar variance. By comparison, pronation relatively increases loading across the distal ulna.

Clinical relevance Because these results suggest that within reasonable ranges of ulnar variance loading across the distal ulna is independent of ulnar variance, the clinically observed incidence of ulnar impaction is more likely the result of increased wear on a thinner and less durable triangular fibrocartilage complex than due to increased distal ulna loading in ulnar positive variant wrists. *(J Hand Surg Am. 2015;40(2):211−216. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Radioulnar carpal joint, ulnar variance.

ULNAR IMPACTION SYNDROME is the impaction of the ulnar head against the triangular fibrocartilage complex (TFCC) and ulnar carpus.[1] Several early studies examined questions related to this topic, ranging from how to best measure ulnar variance[2] to the distribution of loading of the carpus against the distal radius and ulna under static wrist tendon loading.[3] Others have looked at loading across the distal radius and ulna following surgical treatment[4] as related to the role of the interosseous membrane,[5] as related to the repair of the interosseous membrane,[6] or

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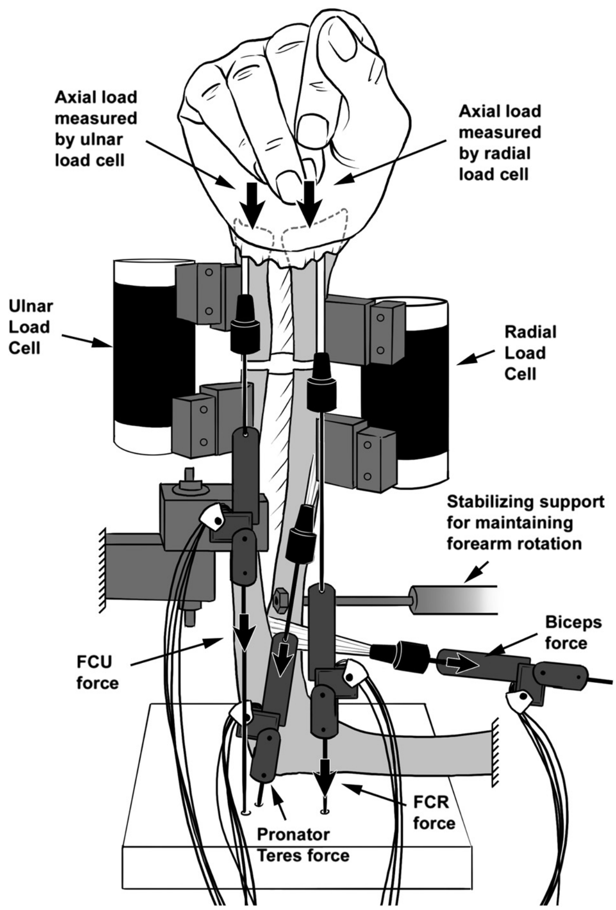

FIGURE 1: Illustration of the combined wrist and forearm simulator. A stabilizing support was used, when appropriate, to keep the radius in neutral, 45° supination, or 45° pronation. The support allowed free axial motion of the radius and limited transverse motion but prevented forearm rotation.

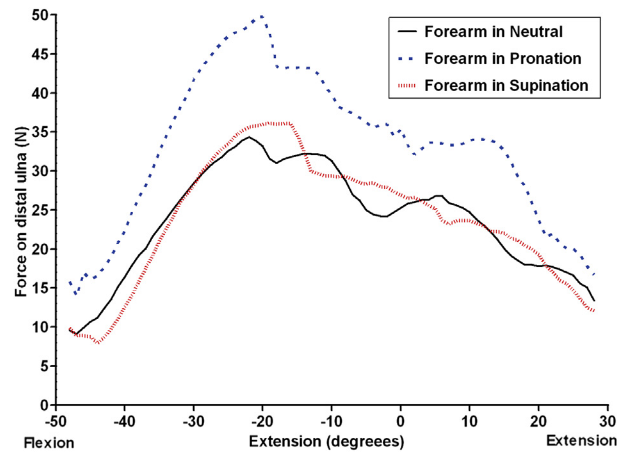

FIGURE 2: Average change in force on the distal ulna during wrist flexion-extension with the forearm positioned in neutral, 45° pronation, or 45° supination. Average of 8 limbs because one wrist could not flex to 50°. Data are with the wrist moving from 50° flexion to 30° extension with the interosseous membrane distal to the load cells sectioned.

due to changes in shortening or lengthening of the ulna.[3] These studies were limited because they did not include dynamic wrist motion and therefore did not simulate normal wrist kinematics. Although surgical lengthening of the ulna clearly causes an increase in the load on the ulna,[3] some[7,8] have interpreted these results to mean that a naturally longer ulna (having a greater positive ulnar variance) will have increased ulnar carpal loading compared with a shorter ulna. The current study investigates this perception of how the native ulnar variance affects the force on the distal ulna, and expands on previous studies by studying the forces across the distal radius and ulna while the wrist was loaded through a range of wrist and forearm positions and motions.

Axial forces across the wrist have been only weakly correlated with ulnar variance,[9] and direct relationships with forearm or wrist position have not been well characterized. When faced with the common clinical scenarios of distal radius fractures, ulnar impaction, distal radioulnar joint instability, and even distal radioulnar joint arthroplasty, the hand surgeon needs to have a greater knowledge of the normal forces across the distal radius and ulna and changes that may have occurred to the triangular fibrocartilage complex. As such, clinical decisions such as surgical indications, splinting positions, and therapy protocols are developed with an incomplete understanding that could negatively affect clinical outcomes.

The primary purpose of this study was to better define wrist joint forces during wrist and forearm motion at specific wrist and forearm positions and to see if there was a relationship between these forces and the amount of wrist ulnar variance. A secondary purpose was to determine the relationship between the thickness of the articular disk of the TFCC and the amount of force transmitted through the distal ulna.

METHODS

Nine fresh cadaver forearms (average age, 75 y; 4 female, 5 male) were tested in a combined wrist and forearm joint simulator.[10] Prior to testing, anteroposterior and lateral radiographs of each wrist were obtained in a standard neutral wrist position with the elbow at 90° of flexion and the forearm in neutral rotation. A wrist joint motion simulator[11] was modified to also cause forearm supination and pronation (Fig. 1). Wrist motion was caused by applying physiological forces to the tendons of the extensor carpi ulnaris, extensor carpi radialis brevis, extensor

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