SCIENTIFIC ARTICLE

Effect of Volarly Angulated Distal Radius Fractures on Forearm Rotation and Distal Radioulnar Joint Kinematics

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Purpose To examine the effect of volar angulation deformities of the distal radius with and without triangular fibrocartilage complex (TFCC) rupture on forearm range of motion and the kinematics of the ulnar head at the distal radioulnar joint (DRUJ) during simulated active forearm rotation.

Methods Volar angulation deformities of the distal radius with 10° and 20° angulation from the native orientation were created in 8 cadaveric specimens using an adjustable apparatus. Active supination and pronation were performed using a forearm motion simulator. Pronation and supination range of motion was quantified with each deformity. In addition, changes in the dorsovolar position of the ulnar head relative to the radius were calculated after simulating each distal radial deformity. Testing was performed with the TFCC intact and sectioned.

Results Volar angulation deformities of 20° decreased the supination range with preservation of pronation. There was no effect of TFCC status on the range of forearm rotation. With the TFCC intact, volar angulation deformities translated the ulna slightly dorsally in pronation and volarly in supination. After sectioning the TFCC, volar angulation deformities of 10° and 20° translated the ulna dorsally throughout forearm rotation.

Conclusions Volar angulation deformities reduce supination range and alter the DRUJ kinematics. The increased tension in the intact TFCC caused by volar angulation deformities likely prevented the expected dorsovolar displacement at the DRUJ and restricted supination. Dividing the TFCC released the constraining effect on the DRUJ and allowed the ulna to translate dorsally. However, supination remained limited, presumably because of impediment from the dorsally subluxated ulna.

Clinical relevance This study demonstrated the importance of correcting volar angulation deformities of the distal radius to less than 20° in order to maintain normal range of forearm rotation and to less than 10° to maintain normal DRUJ kinematics when the TFCC is ruptured. *(J Hand Surg Am. 2015;40(11):2236−2242. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Key words Distal radioulnar joint, distal radius fracture, kinematics, triangular fibrocartilage complex, volar angulation.

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ALTHOUGH VOLARLY ANGULATED fractures of the distal radius are less common than dorsally angulated fractures, they are often unstable and have a high incidence of malunion when treated nonsurgically.[1] Distal radial malunion with volar angulation often results in a deformity, wrist pain, and functional deficits.[2–4] These include the loss of grip strength, loss of wrist extension, and painful or limited supination of the forearm. Restriction of forearm supination is often disabling because compensation cannot be provided via the shoulder.[4] Surgical treatment is, therefore, usually recommended for patients with acute displaced or malunited distal radius fractures with volar angulation.[1–4] However, the magnitude of volar angulation that could cause these findings is unclear.

Previous biomechanical studies have examined the effects of dorsal angulation deformities of the distal radius.[5–7] However, there have been few studies that examined the effects of volar angulation deformities. Pogue et al[5] examined the effects of volar angulation deformity on pressure distributions and contact areas in the wrist joint and reported volar angulation of 30° displayed a more concentrated load dorsally in the lunate fossa than the normal state. Bessho et al[8] examined the relationship between increased volar angulation and distal radioulnar joint (DRUJ) stability and showed that volar angulation deformities increased the DRUJ stiffness.

The purpose of this *in vitro* biomechanical study was to examine the effects of volar angulation deformities of the distal radius with and without triangular fibrocartilage complex (TFCC) transection on the range of forearm rotation and the kinematics of the ulnar head relative to the sigmoid notch at the DRUJ using an active motion simulator. Our hypotheses were that volar angulation deformities of the distal radius would decrease the range of forearm rotation and alter the kinematics of the DRUJ. We also hypothesized that sectioning of the TFCC would restore the range of forearm rotation and magnify the changes in DRUJ kinematics caused by volar angulation.

MATERIALS AND METHODS

Specimen preparation

Eight fresh-frozen left cadaver upper limbs, from donors with a mean age of 60 years (range, 29–75 years; 6 males), were amputated at the midhumeral level and stored at −20°C. The limbs were thawed at room temperature (22°C) for 18 hours and then prepared for testing. The fingers were disarticulated at the metacarpophalangeal joints. Sutures were secured to the tendons of the biceps, pronator teres, flexor carpi ulnaris, flexor carpi radialis, extensor carpi ulnaris, and extensor carpi radialis longus. The extensor carpi radialis brevis was excluded because it was not needed to balance the wrist. Sutures were then passed through alignment guides placed at the medial epicondyle for the pronator teres and wrist flexors and at the lateral epicondyle for the wrist extensors to replicate the physiological direction of muscle action. To simulate the function of the supinator, a suture anchor was inserted into the radial tuberosity, and the suture was passed via a plastic sleeve through its ulnar attachment. The action of the pronator quadratus was simulated using a screw hole on the radius implant as the suture's insertion, which was then passed through a plastic sleeve in the ulnar origin. An adjustable implant described previously[7] was secured to the distal radius using bone screws augmented with polymethylmethacrylate to create volar angulation deformities of the distal radius (Fig. 1). To insert the implant, a 20-mm segment of the volar radius was removed 2 mm proximal to the DRUJ leaving the dorsal cortex intact. The dorsal bone bridge was removed after implant insertion to maintain the original alignment of the radius.

An *in vitro* forearm motion simulator described previously,[6] using computer-controlled servo motor and pneumatic actuators attached to tendons, was used to simulate active supination and pronation (Fig. 2). The humerus was rigidly secured to the simulator via a clamp. The ulna was secured with 2 threaded pins to the simulator with the elbow in 90° flexion to allow the forearm to rotate freely. A rod was inserted longitudinally into the third metacarpal shaft and placed through a ring mounted on the motion simulator to maintain the wrist in neutral flexion-extension and radioulnar deviation. To simulate active supination, the biceps suture was attached to a servo motor (SM2315D; Animatic, Santa Clara, CA) while the pronator teres suture was attached to a pneumatic actuator (Airpot Corporation, Norwalk, CT). Conversely, for simulated active pronation, the pronator teres was attached to the servomotor while the biceps suture was attached to the pneumatic actuator. The sutures to the other tendons were routed through an alignment system mounted on the testing apparatus and were attached to individual pneumatic actuators. In order to accurately quantify continuous forearm motion, optical tracking markers (Optotrak Certus; Northern Digital, Waterloo, Ontario, Canada) were attached to pedestals mounted on the shaft of the radius and ulna.

Experimental protocol

Active supination was simulated by displacing the biceps tendon at a constant velocity of 5 mm/s using a