Understanding Radiocarpal Rotation Through In Vivo Pronation and Supination of the Hand: A Single Case Study

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Abstract

Background: Studies have not clearly defined the motion of the distal radius in relation to the carpus in vivo. We hypothesized that 1) with the hand fixed by grasping a handle to prevent hand and wrist motion, the resulting load in torsion generated by extrinsic muscle in vivo would create motion at the radiocarpal joint; and 2) the motion measured will be between the distal radius and the proximal row of the carpus.

Methods: The data was acquired from the senior author external to our institution; in the current study, we quantify the resulting radiocarpal motion. A K-wire was placed into the second metacarpal, and a second wire was placed in the distal radius. The shoulder was abducted to 90° and the hand was pronated, held stationary gripping a fixed object. The forearm was pronated and supinated to simulate radiocarpal rotation. Photographs were obtained at three points: 1) initial position showing the wire in vertical alignment; 2) same perspective in maximum internal radiocarpal rotation; and 3) same perspective in maximum external radiocarpal rotation. ImageJ (open source) was used to quantify the angle between the wires.

Results: Superimposition of the three photographs in vivo allowed us to approximate two angle measurements. The measurements with maximal internal and external rotations were 16° and 24°, respectively.

Conclusions: Radiocarpal rotation should be considered in addition to flexion and extension motions and radial ulnar deviations when treating degenerative changes in the wrist.

Introduction

The kinematics of the wrist were first studied in 1896 when MB Bryce used “New Photography” to understand the articulations within the wrist joint.[1] Numerous studies have since investigated the kinematics of the wrist.[2-8] Advancements in technology have also helped quantify wrist motion, and studies have described up to 24 distinct movements of the wrist.[9] Furthermore, findings of dynamic computed tomography (CT) scans have revealed variations in morphological features of the carpal bone, which can affect wrist kinematics.[10] Additionally, the mechanical axis of the wrist has shown to be oriented along the dart-thrower’s plane.[9] The wrist may be predisposed to a dart thrower’s motion owing to the orientation of the muscle insertions.[11] The principal orientation of the circumduction that envelopes at the wrist is along this dart-thrower’s-motion path,[9,12] and the thrower’s motion and circumduction may be associated with performance of functional tasks in healthy patients.[13]

New imaging techniques have increased understanding of the wrist joint. Findings of magnetic resonance imaging (MRI) and CT have shown 6°-of-freedom kinematics in the carpal bones,[4,14-17] and the use of 4D CT and MRI has helped study the dynamic motion of the carpus.[18-21] These imaging techniques have also assessed wrist injury and arthritis.[22] Despite the increasing research into wrist kinematics, more clarification is needed in describing movement of the wrist, particularly in the field of wrist arthroplasty implant design.

The purpose of our study was to further investigate the kinematics of the wrist by describing and quantifying radiocarpal rotation through in vivo experimental testing. Radiocarpal rotation considerably affects the kinematics of the wrist during day-to-day activities. A better understanding of this movement can help improve the treatment, early detection, and prevention of degenerative changes in the wrist.

Methods

The current study was classified as "Non-Human Research" by our Human Research Review Committee (#16-108) because the data came into our acquisition after the study was completed external to our institution. We conducted the analysis to quantify that motion.

To quantify radiocarpal rotation about the long axis of the forearm, K-wires were placed into the wrist of the participant (senior author) who was under regional anesthetic. The first wire was placed into the second metacarpal, in a posterior-to-anterior direction, parallel to the long axis of the forearm. The second wire was placed into the distal radius, parallel to the metacarpal wire, with the hand in the pronated orientation and normal to the long axis of the forearm (Figure 1A). The participant laid in supine position on an operating table. His shoulder was abducted to 90°, and his hand was placed on a table beside the bed. The hand was pronated and held stationary, palm down, on the table by gripping a fixed object. The participant pronated and supinated his forearm to simulate radiocarpal rotation, with the hand in this fixed position. Attempted pronation was defined as internal radiocarpal rotation, whereas attempted supination was defined as external radiocarpal rotation.

Photographs were obtained at three points. The first point showed the wires in vertical alignment, proximal to distal, along the forearm (Figure 1B). The second point showed the same perspective but in maximum internal radiocarpal rotation (Figure 2A). The third point showed the same perspective but in maximum external radiocarpal rotation (Figure 2B). These photographs were overlaid using GIMP (GNU Image Manipulation Program, open source), with the base of the metacarpal wire defined as our reference point and Figure 1B defined as the initial wire position. ImageJ, an open-source image processing software, was used to quantify the angle between the wires, about the long axis of the forearm. The distance from the camera to each wire was held constant. The software was calibrated using the known diameter of the K-wire used for pinning.

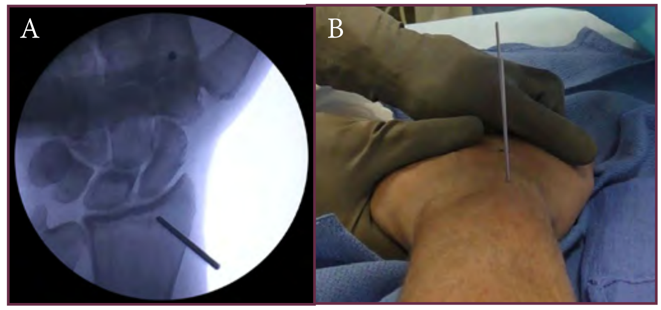

Figure 1. (A) Radiograph of the hand, showing wire placement in the distal radius. (B) Coronal view along the long axis of the forearm, showing the K-wires placed in the distal radius and second metacarpal. Notably, the wires are placed parallel to one another; thus, the second metacarpal wire is blocked from view by the distal radius wire.

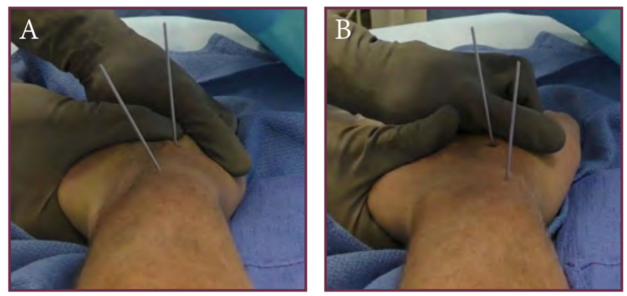

Figure 2. Coronal view along the long axis of the forearm, showing the K-wires placed in the distal radius and second metacarpal. (A) Maximum internal radiocarpal rotation. (B) Maximum external radiocarpal rotation.

Results

Superimposition of the three photographs in vivo allowed us to approximate two angle measurements which correspond to the degree of radiocarpal motion with internal and external rotations about the long axis of the forearm (Figures 3A and 3B). With maximum internal rotation, the measured radiocarpal rotation was 16°. With maximum external rotation, the radiocarpal rotation was 24°.

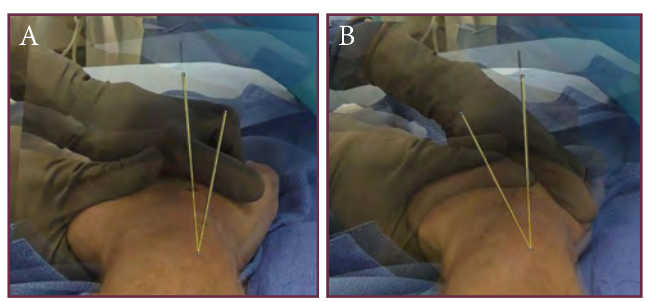

Figure 3. Superimposed images showing maximum rotations of the forearm, with the hand fixed to allow radiocarpal motion only and to negate forearm rotation. (A) Internal rotation (pronation) of the forearm. (B) External rotation (supination) of the forearm.

Discussion

Our study has allowed us to quantify radiocarpal rotation in vivo. We demonstrated this motion by quantifying the degree of radiocarpal rotation with internal and external rotations using images taken from an awake patient with wires inserted into the base of the second metacarpal and the distal radius. This radiocarpal motion was notable and ranged between 16° and 24°. In replicating wrist kinematics, which can be observed in radiocarpal implant designs used in arthroplasty, this motion must be considered to ensure a stable implant that does not loosen and fail postoperatively.

The contribution of carpal motion at the midcarpal and radiocarpal joint has been previously measured during extension and flexion of the wrist and radial and ulnar deviation. The potential effects of ligament laxity on these movements have been described.[4,6,8,16,22-24] Our study provided quantification of in vivo radiocarpal motion when native muscles are loaded with the hand in a fixed position. This motion is observable when turning a screw driver or a door knob forcibly.

Further, cohort studies that considered variation in different patient demographics would better quantify radiocarpal rotation and assess the range of radiocarpal motion. Results of the current study revealed a range of degrees of motion in vivo, which can help investigate this concept using less invasive techniques such as imaging modalities (eg, 4D CT or MRI). Findings of 4D CT and MRI have been used in previous studies to investigate wrist kinematics and offer precise analysis of carpal-bone motion during movements of the wrist.[8]

We acknowledge that the implications of our study are limited. The current study included one patient and therefore did not offer a large sample size from which sufficient data can be extrapolated and applied to the general population. Our angle generation relied on the superimposition of three images, which has the potential for measurement error of angle estimation. However, we expected a range of motion and not an absolute number.

Findings of our study suggest that radiocarpal rotation does occur. Subsequently, this motion should be considered in addition to the better understood flexion, extension, radial, and ulnar deviations. We plan to further study and quantify this motion for consideration during wrist arthroplasty and design of wrist implants.

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Conflict of Interest

The authors report no conflicts of interest.

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