Three-Dimensional Strain Analysis of the Forearm Interosseous Membrane through Supination and Pronation

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Disclosures:

Introduction: The interosseous membrane (IOM) is a fibrous structure found deep in the forearm that joins the radius and the ulna. The IOM provides structural support for the forearm through its many bands. The IOM can be distinguished into two layers of fibers: anterior and a posterior division, which travel from the radius to the ulna. Within the layers are several distinct bands composed of thin, fibrous tissue: central band, accessory band, distal oblique band, proximal oblique cord, and dorsal oblique accessory cord. Each band originates and inserts on different spots of the ulna and radius. The structural support of the IOM is evident through injuries like the Essex-Lopresti lesion in which the radial head is sectioned off. The radial head is the primary stabilizer for longitudinal forearm stability, so once it is resected, the IOM retains forearm stability. Additionally, the IOM participates in the transfer of load from radius to the distal ulna when the forearm is faced with compression. It is believed that as the forearm moves from maximum supination to maximum pronation the IOM fibers change from a relaxed state, then become tense in the neutral position, and then once again become relaxed as the forearm enters pronation. 3-D reconstruction analysis of pronation and supination of the human forearm should match those of direct measurements with a human forearm in vivo. The objectives of study were to use CT imaging and 3-D digitization to investigate the normal attachment sites of the interosseous membrane (IOM), to recreate and analyze the relationship of the IOM with the radius and ulna, and to understand the tensile strain of the IOM during supination and pronation.

Methods: A sample size of six human forearms was taken (four right and two left; three female and three male). 3-D models of each bone were generated from CT images using computer software (Mimics and Magics; Materialise). In Magics, the locations of the insertions and origins of the IOM bands were marked and analyzed. Once the 3-D CT models were generated, custom simulation software was used (KinSim) to isolate the upper extremity and create virtual models of the IOM bands between the radius and ulna. Strain and tensile functions for each band of the IOM during supination and pronation were developed by virtually rotating the radius along its axis. During this rotation, the lengths of individual bands were recorded through each degree. A graph was plotted of the strain, with neutral mid-prone normalized to zero strain due to each arm having a varied range of rotation.

Results: The central band (CB) of the middle ligamentous complex originates from the interosseous crest of the radius and inserts into the interosseous border of the ulna. The dorsal oblique accessory cord (DLAB) of the middle ligamentous complex originates in the distal 1/3 of the radius interosseous crest and inserts into the distal one-fifth of the ulna. In the CB and DLAB, five of six specimens experienced increasing strain moving from supination to the neutral position in this band. Moving from the neutral to maximum pronation, all the specimens experienced a decrease in strain, while one specimen decreased in strain throughout the whole motion. The distal oblique band (DOB) of the middle ligamentous complex originates from the distal 1/6 of the ulnar shaft and inserts into the inferior rim of the sigmoid notch of the radius. In the DOB, one specimen increased in strain throughout the full motion, while three specimens saw decreased strain. Two specimens experienced decreasing strain moving from supination to the neutral position and increasing strain moving to pronation. The dorsal oblique accessory cord (DOAC) of the proximal membranous portion of the IOM originates from around the distal 2/3 of the ulnar shaft and inserts into the radial interosseous crest. All six specimens experienced increasing strain moving from supination to the neutral position and decreasing strain towards maximal pronation in the DOAC. Finally, the proximal oblique cord (POC) originates from ulnar tuberosity and inserts just distal to the radial tuberosity. Five specimens experienced a decrease in strain moving from supination to the neutral position. Moving from the neutral to maximum pronation, all the specimens experienced an increase in strain, with one specimen showing an increase in strain earlier and before reaching the neutral position. The DLAB and POC experienced a larger magnitude of strain, 2.081 and 1.979, respectively. The DOB experienced the least, with 0.254. The DOB and POC bands decreased strain then increased after the neutral position towards pronation. The CB, DLAB, and DOAC bands increased in strain as they moved towards the neutral position and decreased in strain towards pronation.

Discussion: Little is known about the function of all five main bands of the IOM. Topical research usually features around the prominent central band, since it is the main stabilizer and largest band of the IOM. The other bands have not been isolated and thoroughly studied in vivo. When Moritomo and colleagues analyzed IOM band lengths in vivo, they stated that the distal bands (CB, DLAB, and DOB) had a minimal change in length in forearm rotation - meaning less strain; and the proximal bands (POC and DOAC) had greater changes in length - meaning more strain. They inferred that this is due to the distal ligaments being the main isometric stabilizers of the forearm. Therefore, they must retain their tensile strength throughout the arm rotation.
However, through this study, it was shown that the DLAB and POC possessed the largest magnitude of strain; and CB, DOB, and DOAC possessed the smallest. This could lead to the possibility that DOAC is actually more of a stabilizer than originally thought and the DLAB is actually less of a stabilizer. The study also shows that the mid prone position is of maximal strain for many bands and the minimal strain for the POC.

**Significance:** Analyses utilizing 3-D reconstructions from CT imaging are important tools for measuring complexity and variance in the human body without sacrificing the stresses provided by the skin and fascia, as would be the case with cadaveric dissection.

**Acknowledgments:**

**References:**

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