

The Parallelogram Effect: The Association Between Central Band and Positive Ulnar Variance

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Purpose Ulnar impaction syndrome is a poorly understood degenerative wrist condition characterized by symptoms of pain thought to be caused by increased loads between the ulnar head and the carpals. Radiographic evaluation often reveals an ulnar-positive wrist. We hypothesize that progressive elongation of the central band of the forearm interosseous ligaments changes the longitudinal radial–ulnar relationships, resulting in an ulnar-positive wrist. The objective of the study was to identify a relationship between the loss of integrity of the forearm interosseous ligaments and increased ulnar variance.

Methods Six cadaveric human forearms were used to measure displacement of the radius relative to the ulna during axial loading of the lunate fossa of the radius. Radial heights were measured in supination and pronation under a 5-lbF (22-N) preload. Gradual axial loads were applied up to 50 lbF (222N); the resultant axial displacement was measured in supination and pronation. All measurements were evaluated with the interosseous ligament intact and repeated with the central band cut.

Results With an applied 5-lbF preload, cutting the central band increased ulnar variance by 3.02 ± 0.80 mm in supination and by 2.15 ± 0.79 mm in pronation. In supination, when the loads were increased from the 5-lbF preload to 50 lbF, the radius displaced 2.1 times further after the central band was cut (3.00 mm) compared with the group with the intact forearm construct (1.41 mm). In pronation, when the loads were increased from the 5-lbF preload to 50 lbF, the radius displaced 1.8 times further when the central band was cut (2.84 mm) than with the intact forearm construct (1.57 mm).

Conclusions Because of a parallelogram effect, the radius shifted proximally under a 5-lbF preload, creating an ulnar-positive wrist relationship. Dynamic loading of the forearm after ligament excision resulted in significant additional radial displacement relative to the intact forearm.

Clinical relevance Deficiency in the ligamentous restraints of the central band leads to positive ulnar variance, which could be a factor (among others) that contributes to idiopathic ulnar impaction syndrome. (*J Hand Surg Am.* 2018;■(■):1.e1-e6. Copyright © 2018 by the American Society for Surgery of the Hand. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Key words Central band failure, parallelogram effect, ulnar impaction syndrome, ulnar variance.



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POSITIVE ULNAR VARIANCE CAN BE associated with ulnar-sided wrist pain, lunate erosion, or both. The radiographic appearance of ulnar variance depends on the degree of forearm rotation; variance increases in forearm pronation and decreases in forearm supination (relative to neutral forearm rotation).¹⁻⁴ In addition, ulnar variance has been shown to increase significantly during grip.^{5,6} Notably, previous cross-sectional studies showed an association between positive ulnar variance and age, with positive ulnar variance being associated with increasing age;^{7,8} this is an unexpected finding because the bones should not change in length after the growth plates have closed.

Alignment of the upper-extremity skeleton is maintained by ligamentous structures stabilizing the joints among the humerus, radius, and ulna;⁹ these form a closed kinetic chain. The longitudinal axis of the arm and forearm form a small valgus angle. In supination, this angle is defined as the carrying angle, which normally varies between 5° and 15° and is slightly larger in women than in men. Longitudinal stability between the radius and ulna is provided by the forearm interosseous ligament system (Fig. 1). This ligamentous system consists of 3 parts: the proximal and distal oblique ligaments, which prevent distal displacement of the radius relative to the ulna, and the central band, which prevents proximal displacement of the radius relative to the ulna. The central band originates distally from the ulna and inserts proximally on the radius. It is aligned approximately 21° to the longitudinal axis of the forearm.^{10,11} This arrangement allows the central band to transfer axial loads from the radius to the ulna.^{12,13}

The objective of this study was to evaluate the relationship between a loss of integrity of the forearm interosseous ligaments and ulnar variance. We hypothesized that loss of integrity of the central band of the forearm interosseous ligaments may result in ulnar-positive variance. We also hypothesized that failure of the central band would result in proximal displacement of the radius with respect to the ulna and that both bones would progressively shift into a less valgus alignment simultaneously until a new position of stability was reached.

MATERIALS AND METHODS

Specimen preparation

A sample of convenience composed of 6 cadaveric human forearms (average age, 52.6 years; 3 males and 3 females) was used to measure displacement

experienced by the radius relative to the ulna during axial loading of the radius. Specimens were evaluated radiographically with the wrist in neutral forearm rotation and the elbow flexed 90° (positioned in neutral with an unloaded wrist) for signs of wrist pathology. None of the specimens showed signs of wrist pathology or ulnar-positive alignment in the neutral position.

The skin, muscles, tendons, vasculature, and nerves were discarded. The interosseous ligament complex, triangular fibrocartilage complex, distal and proximal radioulnar joint ligaments, and elbow collateral ligaments were preserved. The humerus was cut midshaft and the carpals were removed. The ulnar shaft was oriented vertically and rigidly fixed to an adjacent vertical beam with 2 screws. The forearm construct was then statically positioned in a Mark-10 test stand (version ESM301L, Copiague, NY) in both supination and pronation for testing (Fig. 2).

Ulnar variance caused by physiological loading

The Mark-10 test stand was used to apply axial loads to the articular surface of the lunate fossa of the distal radius (25.4 mm/min). As the radius displaced, the resistive loads increased. A 5-lbF preload was applied to simulate baseline muscle tone. The position of the distal edge of the radius (radial position within the test stand) was noted under a 5-lbF preload in supination and pronation.

For the purposes of this study, the radial position noted under a 5-lbF preload with intact interosseous ligaments was defined as the specimen's baseline position (physiological position). Clinically, ulnar variance refers to the height difference between the distal articular surfaces of the radius and ulna. For the purposes of this study, change in ulnar variance refers to the axial displacement of the radius relative to the specimen's baseline position.

Ulnar variance caused by grip loading

The Mark-10 test stand was used to apply axial loads gradually (25.4 mm/min) from the 5-lbF preload up to 50 lbF, and the resultant axial displacement (change in ulnar variance) was measured in supination and pronation. The 50 lbF measurement was intended to simulate active power grip. All measurements were evaluated with the interosseous ligament intact and repeated with the central band of the interosseous ligament cut and completely excised. Cutting the central band of the interosseous ligament represented acute failure of the central band. Loading and measurements were repeated 5 times for each specimen in each of the 4 loading configurations.

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