SCIENTIFIC ARTICLE

Distal Radioulnar Joint Reaction Force Following Ulnar Shortening: Diaphyseal Osteotomy Versus Wafer Resection

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Purpose To compare how ulnar diaphyseal shortening and wafer resection affect distal radioulnar joint (DRUJ) joint reaction force (JRF) using a nondestructive method of measurement. Our hypothesis was that ulnar shortening osteotomy would increase DRUJ JRF more than wafer resection.

Methods Eight fresh-frozen human cadaveric upper limbs were obtained. Under fluoroscopic guidance, a threaded pin was inserted into the lateral radius orthogonal to the DRUJ and a second pin was placed in the medial ulna coaxial to the radial pin. Each limb was mounted onto a mechanical tensile testing machine and a distracting force was applied across the DRUJ while force and displacement were simultaneously measured. Data sets were entered into a computer and a polynomial was generated and solved to determine the JRF. This process was repeated after ulnar diaphyseal osteotomy, ulnar re-lengthening, and ulnar wafer resection. The JRF was compared among the 4 conditions.

Results Average baseline DRUJ JRF for the 8 arms increased significantly after diaphyseal ulnar shortening osteotomy (7.2 vs 10.3 N). Average JRF after re-lengthening the ulna and wafer resection was 6.9 and 6.7 N, respectively. There were no differences in JRF among baseline, re-lengthened, and wafer resection conditions.

Conclusions Distal radioulnar joint JRF increased significantly after ulnar diaphyseal shortening osteotomy and did not increase after ulnar wafer resection.

Clinical relevance Diaphyseal ulnar shortening osteotomy increases DRUJ JRF, which may lead to DRUJ arthrosis. *(J Hand Surg Am. 2015;40(11):2206–2212.*

Key words Ulnar shortening, distal radioulnar joint, joint reaction force, wrist.

Ulnar shortening osteotomy is a common, effective procedure for treating ulnar impaction syndrome.[1,2] Biomechanical studies have demonstrated that surgical shortening of the ulna decreases loads across the ulnocarpal joint[3] and stabilizes the distal radioulnar joint (DRUJ).[4,5] However, biomechanical data also demonstrate that ulnar shortening results in increased DRUJ pressure.[6] Although enhanced DRUJ stability may be desirable in some cases, increased pressure within the DRUJ has the potential to lead to pain and DRUJ arthrosis. Radiographic changes within the DRUJ have been observed after ulnar shortening procedures.[7,8] Such changes may be a result of increased forces across the DRUJ resulting from ulnar shortening.

Ulnar shortening is most commonly accomplished by performing a diaphyseal shortening osteotomy[2,9,10] or a distal ulnar wafer resection.[11] Little is known about how the location of the osteotomy affects DRUJ joint reaction force (JRF). In a biomechanical study comparing ulnar osteotomies proximal and distal to

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the distal interosseous membrane, Arimitsu et al[4] found that proximal osteotomy resulted in significantly greater DRUJ stability. However, the effects on DRUJ JRF were not measured. Because increased JRF across the DRUJ may lead to subsequent arthrosis and pain, it is important to determine how the location of the osteotomy might affect JRF.

Prior biomechanical studies have examined pressure across the DRUJ using pressure-sensitive devices inserted into the joint.[6,12,13] Such techniques require dissection around the joint, removal of stabilizing soft tissue structures, and a capsulotomy for insertion of the pressure sensor. Sectioning of these structures has been shown to alter DRUJ stability,[14] and there are concerns about the reliability of measurements using devices interposed between articular surfaces.[15,16]

The reaction force experienced at a joint is a sum of the forces acting on that joint, including the effect of gravity on the mass of the limb, muscle forces, and tension within the soft tissues across the joint. These forces tend to compress the joint, and in response the articular surfaces experience equal, opposing JRFs that resist this compression. The purpose of the current study was to compare how ulnar diaphyseal shortening and distal ulnar wafer resection affect DRUJ JRF. Our hypothesis was that ulnar shortening would increase DRUJ JRF and diaphyseal shortening osteotomy would increase DRUJ JRF more than wafer resection.

MATERIALS AND METHODS

In prior work, we developed a reliable, nondestructive method of measuring DRUJ JRF that preserves all soft tissues about the DRUJ and does not require insertion of a device into the joint.[18] This method involves distracting the joint to the point where the distraction force is equal and opposite to the baseline compressive force. The details and theory behind this method have been previously described.[18,19] Based on a pilot study measuring DRUJ JRF with this technique in 7 specimens, a power analysis demonstrated a sample size of 7 would have 83% power to detect a 30% increase in JRF with a significance level of .05 using a 2-sided paired *t* test. Therefore, 8 fresh-frozen human cadaveric upper limbs from the shoulder girdle to the hand were obtained. All specimens were physically and radiographically examined to rule out preexisting DRUJ pathology and previous fracture or surgery in the upper extremity. We classified DRUJ orientations according to the Tolat system[20] (type 1, parallel; type 2, oblique; type 3, reverse oblique). Specimens were excluded if they had a Tolat type 3 DRUJ or greater than 1 mm positive or negative ulnar variance.

Under fluoroscopic guidance, a threaded Steinmann pin was placed in the middle of the lateral side of the distal radius transverse to the DRUJ. A second pin was placed in the middle of the medial side of the distal ulna colinear to the radial pin. Pins were placed percutaneously, preserving all soft tissue about the DRUJ.

Specimens were mounted onto a tensile testing machine (MTS Insight 100; MTS Systems, Eden Prairie, MN) using a custom fixture with the elbow fixed at 90° and the forearm in neutral rotation (Fig. 1). An axial extensometer (MTS 634.28; MTS Systems) was placed on each pin to allow for precise measurement of displacement. A uniaxial distracting force was applied across the DRUJ at a rate of 0.4 mm/s while force and displacement were simultaneously and constantly measured. We chose this relatively slow rate of distraction to minimize the viscoelastic effects of the soft tissues. Force−displacement curves were generated for each arm and a best-fit polynomial function was calculated to model the curve. The second derivative of the polynomial was set to 0 and its root was solved to determine the inflection point representing JRF. The details of this method of JRF measurement have been previously described.[18] Each measurement was performed 3 times and the average of the 3 measurements was used.

After we obtained baseline control data, we performed a standard ulnar diaphyseal shortening osteotomy with resection of a 3-mm segment at a location 6 cm proximal to the ulnar styloid. The amount of ulna to be resected was measured with calipers before performing the osteotomy. Osteotomies were fixed with a custom-slotted, 3.5-mm dynamic compression plate to allow subsequent re-lengthening of the ulna (Synthes, West Chester, PA). Joint reaction force was measured as described above. The ulnas were then re-lengthened by 3 mm, measured with precise calipers. The removed segment of bone was reinserted as a supplementary method to confirm that the original length was reestablished. The ulnas were held at their original length using the custom compression plate (Fig. 2). The ulnas were re-lengthened to reestablish normal anatomy and return JRF to baseline before performing wafer resection. This allowed each specimen to serve as its own control and verify that changes in JRF from ulnar shortening could be reversed with re-lengthening. Joint reaction force was calculated in the re-lengthened state to confirm return to baseline. We then performed a distal ulna wafer resection with removal of a 3 mm wafer as described by Feldon et al[11] and again calculated JRF. Care was taken to protect the triangular fibrocartilage complex (TFCC), which was