Assessment of Distal Radioulnar Joint Stability After Reconstruction With the Brachioradialis Wrap

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Abstract

Background: The brachioradialis (BR) wrap technique is an option to restore the stability of the distal radioulnar joint (DRUJ). The technique capitalizes on the BR's advantageous insertion point on the radial styloid and the ability of the BR to be harvested with minimal to no deficit. The tendon can then be wrapped around the radius and ulna, tunneling under the pronator quadratus and extensor compartments and secured back into its insertion to provide stability. In this cadaveric study, we used micro-computed tomography (CT) to assess the stability restored by this procedure. **Methods:** Axial CT scans were taken of cadaveric specimens ($n = 10$) in 3 different positions (neutral, 60° pronation, and 60° supination) to establish the baseline measurements of each DRUJ. Surgical disruption of the dorsal and volar ligaments of each DRUJ then simulated a destabilizing injury and the specimens were scanned again. The specimens then underwent the BR wrap procedure and were scanned once more. Degree of ulnar subluxation with respect to the Sigmoid notch was determined using the modified radioulnar line method. **Results:** The mean percentages of subluxation in the neutral position for the normal, injured, and reconstructed DRUJ were $22.4 \pm 4.9\%$, $56.2 \pm 12.9\%$, and $29.0 \pm 6.5\%$, respectively. In 60° pronation, these values were $15.4 \pm 4.7\%$, $53.5 \pm 15.0\%$, and $36.5 \pm 11.8\%$, respectively. In 60° supination, these values were $18.6 \pm 2.5\%$, $69.7 \pm 20.5\%$, and $31.9 \pm 8.7\%$, respectively. **Conclusions:** Values differed significantly between normal and injured conditions in all positions. No significant difference was noted between normal and reconstructed conditions, suggesting reconstruction improves DRUJ biomechanics and more closely approximates normal stability.

Keywords: distal radioulnar joint, brachioradialis wrap, joint instability, Sigmoid notch, joint reconstruction, wrist instability

Introduction

Destabilization of the distal radioulnar joint (DRUJ) can present as an isolated injury or in association with a fracture of the distal forearm.²⁴ Eleven percent to 19% of all distal forearm fractures are associated with DRUJ instability, a factor widely believed to be associated with poorer outcomes.^{13,16} Significant morbidity is due in part to a limited number of options for DRUJ reconstruction and even less information regarding the biomechanical stability of these reconstructions. Arthroscopic and limited open repair of the triangular fibrocartilage complex (TFCC) have emerged as standard treatment for such instability. A failed repair or circumstance in which the native tissues cannot be repaired may lead to significant morbidity and a decreased quality of life.

First described in 1911, the Darrach procedure can effectively alleviate pain following DRUJ disruption via distal ulna resection-osteotomy but is frequently complicated by convergence, carpal translation, and decreased grip strength.^{5,9} In response to these limitations, a DRUJ

arthrodesis with ulnar pseudarthrosis was described by Berry in 1931, and perhaps more famously by Sauvé and Kapandji in 1936.^{2,19} However, distal ulnar instability, radioulnar impingement, and reactive bone formation at the osteotomy site are still potential complications.²² Stabilization procedures for the ulnar stump such as the extensor carpi ulnaris and flexor carpi ulnaris tenodesis or coverage with an Achilles allograft have all been described to treat these complications with varying success.^{3,23} Distal radioulnar ligament-sparing procedures such as those by Watson, Bowers, and Feldon may be indicated for DRUJ reconstruction; however, these techniques may not allow

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Figure 1. Leaving the insertion at the radial styloid intact, the proximal segment of the brachioradialis tendon is harvested, wrapped around the radius and ulna, tunneled under the pronator quadratus, and fixed back into the insertion.

for shortening of the ulnar head and may be associated with longer postoperative immobilization.¹⁴ Described by Milch in 1941, the ulnar shortening osteotomy has also been investigated as an option for the treatment of DRUJ instability and TFCC injuries but is not a viable option for a patient with ulnar negative variance.⁴ Reconstruction techniques such as those by Adams, which utilizes the palmaris longus tendon, and Eliason procedures retain the distal ulna but are quite invasive and technically demanding.^{1,7} DRUJ arthroplasty solutions such as seen with the APTIS and the STABILITY Sigmoid Notch Total DRUJ systems are promising but, as with other prosthetics in the upper extremity, carry a high complication rate.^{8,20}

The brachioradialis (BR) wrap offers a simple reconstructive option which preserves the distal ulna and offers stabilization.¹⁰ The BR tendon insertion is advantageously located at the radial styloid. Minimal dissection is required to route the tendon around the radius and ulna in a wrist-band fashion and to secure the free end back to the styloid with a suture anchor (Figure 1). The procedure can be tailored to the direction of subluxation, performed on even the most scarred wrist, and even paired with a prosthesis (Figure 2). Maximum pronation and supination was not tested after reconstruction in the cadaveric model, but the senior author has not noted this to be an issue in his clinical experience with this procedure. This study attempts to prove the biomechanical stability of this reconstruction utilizing a cadaveric model of injury and micro-CT.

Figure 2. In situ example of brachioradialis wrap procedure used to stabilize ulnar prosthesis following distal radioulnar joint reconstruction.

Materials and Methods

Ten lightly embalmed, cadaveric arms (five matching pairs) were obtained through the bequeathal program at the University of Louisville. Informed consent was obtained from all individual participants included in the study. The specimens were amputated from the donor at the level of the distal third of the humerus and stored at 32°F. Each specimen was thawed overnight before testing. Each was carefully loaded onto the jig with the ulna securely bolted to an upright post to allow for rotation of the radius around the ulna. A transfixing pin was placed through the second through fifth metacarpals to control supination and pronation (Figure 3). This pin was then secured to an Ilizarov ring which was positioned atop of the scanning canister. The ring could then be rotated atop the canister to simulate differing positions of pronation and supination (Figure 4).

Each wrist was scanned using a micro-CT system (ACTIS 200/225 FFi-HR CT/DR, BIR Inc, Lincolnshire, Illinois) in 3 anatomic positions: neutral, 60° pronation, and 60° supination in their native, uninjured state. Then, an incision was made over the border of the ulna and dissection was carried both dorsally and volarly to section both the dorsal and volar distal radioulnar ligaments simulating a destabilizing injury to the DRUJ. The wrist was rescanned in the sequence previously described. Finally, the BR wrap procedure was performed on the “injured” specimen and scanned once more.

Figure 3. A transfixing pin was passed through the second and fifth metacarpals and attached to an Ilizarov ring to control degrees of pronation and supination during computer tomographic scanning.

Figure 4. Specimens were fixed onto a rotating canister and computed tomographic scan performed in the positions of neutral, 60° pronation, and 60° supination.

The BR graft was harvested with a 2-incision technique leaving the distal insertion intact on the radial styloid (Figure 5). The free end of the graft was harvested at the musculotendinous junction approximately 13 to 15 cm proximal to the insertion. Care was taken to debride the distal muscle and harvest 1 cm of the tendon within the junction. Then, the tendon was tunneled beneath the extensor tendons on the dorsum of the wrist. The graft was then retrieved into the incision on the ulnar border of the wrist, wrapped just proximal to the ulnar head, tunneled beneath the pronator quadratus, and retrieved in the radial wound. It was then secured back near the area of insertion with a suture anchor (Arthrex, Naples, Florida) and reinforced back to the tendon insertion with non-absorbable suture. It should also be noted that great care be taken when harvesting the graft, making sure to

Figure 5. A 2-incision technique is used to first harvest a proximal portion of the brachioradialis tendon (indicated with instrument), which is subsequently tunneled around the radius and ulna.

protect the superficial radial nerve. The graft should be passed deep to it.

As noted in the technique, the wrap can be modified in its direction wrapping volar first, and then dorsal if desired.¹⁰ The level of tension provided in either the dorsal or volar direction can also be adjusted by adding suture anchors in the distal radius adjacent to the DRUJ to provide another secure fixation point for the tendon graft. Clinically, the direction of the wrap may vary based on the direction of subluxation of the ulnar head. A dedicated study on this topic has not been performed; however, based on anecdotal experience, the senior authors suggest tunneling dorsally in the event of dorsal ulnar subluxation and tunneling volarly the event of volar subluxation. For the sake of standardization in this study, all grafts were wrapped from dorsal to volar and no accessory suture anchors were placed.

Results

The modified radioulnar line method (Figure 6), as described by Nakamura et al was employed to evaluate the subluxation of the ulna with respect to the sigmoid notch for each of the 10 specimens in their normal, injured, and reconstructed conditions.^{15,17} A value of less than or equal to 25% of subluxation is assigned to this system as being normal. One hundred slices at approximately 0.1-mm increments were taken. Slice numbers 25, 50, and 75 were measured and averaged to represent the subluxation through the proximal to distal aspect of the Sigmoid notch. Visual comparison of CT scans following reconstruction demonstrated correction of the distal radius and ulna to near normal relation (Figure 7).

Figure 6. The modified radioulnar line method described by Nakamura et al is a simple and accurate method used to quantify subluxation of the ulna with respect to the Sigmoid notch.

The mean percentages of subluxation ($\pm$ the standard error of the mean) for the normal, injured, and reconstructed DRUJ in the neutral position were $22.4 \pm 4.9\%$, $56.2 \pm 12.9\%$, and $29.0 \pm 6.5\%$. The stability of the DRUJ, although not corrected to the native stability, was much improved from the injured joint. In 60° pronation, the percentages of subluxation were $15.4 \pm 4.7\%$, $53.5 \pm 15.0\%$, and $36.5 \pm 11.8\%$, respectively, for the normal, injured, and reconstructed joints. This again showed a trend toward stability, but not true restoration to preinjury stability. The final position of 60° supination showed a similar trend of $18.6 \pm 2.5\%$, $69.7 \pm 20.5\%$, and $31.9 \pm 8.7\%$.

One-way analysis of variance and Fisher post hoc tests with $\alpha < 0.05$ were performed using Minitab (Minitab Inc, State College, Pennsylvania). In the neutral, pronated, and supinated positions, there was a significant difference in percent subluxation between the normal and injured specimens ($P < .05$). No significant difference between the normal and reconstructed specimens was detected in any position ($P < .05$). A significant difference was detected between the reconstructed and injured specimens in supination ($P < .05$). These results may suggest improved DRUJ biomechanics and normal stability more closely approximated following reconstruction with the BR wrap technique, particularly in supination (Figure 8).

Discussion

Distal radioulnar joint instability is an unsolved mystery in the world of orthopedic and hand surgery. Over the past 30 years, the biomechanical properties of the DRUJ and TFCC have been described in works by Ekenstam and Hagert,⁶ Schuind et al,²¹ and Kleinman.¹² With this fresh knowledge, there is still a void in the effective options for treating the

problem of instability, especially if primary repair of the native TFCC fails.

To objectively study this joint is a challenge. There is no accepted gold standard test to make the definitive diagnosis of DRUJ instability. Computed tomography has been described by Nakamura et al,¹⁷ Wechsler et al,²⁵ and Lo¹⁵ for use as a diagnostic indicator of instability. These different measurements have been shown to have differing correlations with physical exam findings, as discovered by Kim and Park in 2007.¹¹ The modified radioulnar line is the easiest to construct and visualize when assessing an axial slice of the DRUJ. In Kim and Park's study, the modified radioulnar line also diagnosed the highest number of subluxations at the DRUJ, although some of these were believed to be false positives by the investigators.¹¹ The use of CT scans to evaluate the DRUJ, while still evolving, holds promise as an affordable, convenient modality.

Triangular fibrocartilage repair, the Darrach procedure, the Sauvé-Kapandji, and Adams reconstruction are among the most well-known treatment options for DRUJ instability, but there have been no prospective randomized studies to compare their biomechanical properties or their outcomes. Using an MTS universal testing machine, Petersen and Adams systematically tested the Eliason, Fulkerson-Watson, Boyes-Bunnell, and Hui-Linschield reconstructions with the wrist held in positions of neutral, supination, and pronation.¹⁸ This study found that none of the reconstructions restored the joint to its native stability and the Hui-Linschield actually increased the instability. Utilizing the idea of testing the native joint in multiple positions, creating an injury model, and then testing the reconstruction were employed to test the novel BR wrap. Instead of MTS testing, CT was used to assess stability in each condition as it can be more easily extrapolated to a clinical setting.

A significant limitation of this study is the use of cadaveric specimens and the assumption that living tissue with normal blood flow and turgor will behave similarly when characterizing a soft tissue repair. Scar tissue would also be expected to form postoperatively; however, it is expected that this would actually increase stability. Also, the wrists were not loaded during testing, and testing could only occur in limited positions. This study was also done at one point in time and does not test the wear characteristics of the reconstruction. Tailoring the wrap to the direction of the instability and further securing the wrap closer to the DRUJ with a suture anchor are further options likely to improve the stability of the reconstruction. However, these technique variations were not evaluated in this study.

Petersen and Adams's evaluation of multiple distal radioulnar reconstructions using MTS testing lead him to the conclusion that "abnormal laxity should be anticipated, in at least some positions of rotation, after these

Figure 7. Subluxation of the ulna with respect to the Sigmoid notch was accessed using the modified radioulnar line method (Nakamura et al) using axial computer tomographic scans of specimens in (a) normal, (b) injured, and (c) reconstructed configurations.

Figure 8. Mean percent subluxation of the radioulnar joint for normal, injured, and reconstructed configurations in the positions of neutral, 60° pronation, and 60° supination. Note. Values were significantly different for the normal and injured configurations, validating our model of injury. No significant difference was noted between the uninjured and reconstructed configurations, suggesting an improvement in stability.

procedures.” This statement holds true also for the BR Wrap, but it is yet to be seen if this slight increase is clinically significant.

The BR wrap adds another option to the armamentarium for treating the unstable DRUJ. This biomechanical study demonstrates significant improvement in stability of the injured DRUJ reconstructed using the BR wrap technique. Because no other reconstruction has been proven to completely re-stabilize the DRUJ, the BR wrap offers a viable, low-morbidity, and simple option that can be performed on extremely challenging wrists, including those undergoing revision surgeries or involving a prosthesis.

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Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

This article does not contain any studies with human or animal subjects.

Statement of Informed Consent

There are no human subjects in this article and informed consent is not applicable.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: A.G. has received royalties and honoraria from Stryker Corporation (Kalamazoo, Michigan). The other authors declare that they have no conflict of interest.

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