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CASE REPORT

Treatment of acute distal radioulnar joint instability with distal oblique bundle augmentation of the interosseous membrane by suture-button suspension: A case series

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ABSTRACT

The stability of distal radioulnar joints is afforded by bony radioulnar articulation and peripheral soft-tissue stabilizers. The primary soft-tissue stabilizers are structures that surround the distal radioulnar joint and are collectively referred to as the triangular fibrocartilaginous complex. Among the stabilizers, the volar and dorsal radioulnar ligaments contribute the most to the stability of distal radioulnar joints. For acute traumatic distal radioulnar joint instability accompanied by purely ligamentous injury, traditional surgical treatments involve the repair or reconstruction of the distal radioulnar ligament; however, these intra-articular procedures are highly invasive and difficult. The extra-articular reconstruction of the secondary stabilizer such as the distal oblique bundle of the interosseous membrane has attracted significant attention in recent years; however, most studies have only conducted cadaveric or laboratory model-based investigations. In this article, we present three patients who suffered from acute dorsal wrist pain after a trauma event. Radiographic and physical examinations revealed distal radioulnar joint instability. All patients were treated with minimally invasive suture-button suspension augmentation in the direction of distal oblique bundle of the interosseous membrane. The instability was resolved after the surgical procedure, but two patients developed ulnar wrist pain and one patient underwent implant removal. All patients have been continually followed at our outpatient department and exhibited stable wrists, despite mild limitation in the range of motion after the procedure. In conclusion, acute traumatic distal radioulnar joint instability may be sufficiently treated with suture-button suspension for augmentation of the distal oblique bundle; however, some obstacles impede the *in vivo* adoption of this treatment.

Keywords: Distal oblique bundle, distal radioulnar joint, instability, minimally invasive surgery, suture-button suspension, wrist pain.

The distal radioulnar joint (DRUJ) is a diarthrodial trochoid synovial joint,[1] composed of two parts: bony radioulnar articulation and peripheral soft-tissue stabilizers. The bony articulation accounts for only approximately 20% of the stability of the DRUJ[2] The primary soft-tissue stabilizers are structures surrounding the DRUJ, collectively referred to as the ulnoligamentous complex or more popularly as the triangular fibrocartilaginous complex (TFCC).[3,4] Among the stabilizers, the volar and dorsal radioulnar ligaments contribute the most to the stability of DRUJs.

Injuries of the DRUJ require special consideration due to the complex motion and function of this joint.[5] Acute traumatic DRUJ injuries occur commonly with fractures of the forearm such as ulnar styloid fracture, Essex-Lopresti injury, and distal radius fracture, with 10 to 19% of such incidences being reported.[6-9] In most of these cases, the stability of DRUJ can be restored after the fracture is well reduced.[10] If the instability of the DRUJ persists, direct TFCC repair, temporary radioulnar pining, or wrist immobilization in neutral or supination position for four to six weeks.

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The treatment protocol for DRUJ injuries with purely ligamentous rupture is variable and controversial. Non-operative treatment is typically combined with pain control, brace or splint immobilization, activity modification, and occupational therapy. If all conservative treatments fail to alleviate the symptoms, distal radioulnar ligament repair-either by the open or arthroscopic method-should be considered. In the case when the TFCC is irreparable, reconstruction is recommended.[11] Various reconstruction procedures aim at stabilizing or reinforcing the TFCC, such as extrinsic radioulnar tether, extensor retinaculum capsulorrhaphy, ulnocarpal sling, and the reconstruction of the distal radioulnar ligaments. However, most of these procedures are considerably invasive and difficult; for instance, the Adam procedure requires tendon graft harvesting, opening of the extensor compartment, DRUJ capsulotomy, and bone tunnel drilling in the radius and ulna.[12-14] Therefore, researchers prefer reconstruction or reinforcement of the secondary stabilizer. In particular, the augmentation or reconstruction of the distal oblique bundle (DOB) of the interosseous membrane has attracted significant attention in recent years, and with the introduction and development of suspension system implants, the tendon grafting procedure can be circumvented.[15]

Several researchers have proposed the utilization of a suspension system in cases of DRUJ injury, but most studies have conducted cadaveric or laboratory model-based investigations.[15-17] In this article, we discuss our experience of employing a minimally invasive DOB augmentation technique that utilizes a suture-button suspension system developed by De Vries et al.[15] in three patients with traumatic purely ligamentous DRUJ injuries.

CASE REPORT

Case 1- A 26-year-old female patient presented to the emergency department after a traffic accident. She was hit by a car while she was on a scooter and fell onto an outstretched hand and injured her right wrist. Tenderness was noted on the dorsal side of the wrist. Ulnar head dislocation was observed during forearm pronation. The dorsopalmar stress test and Ballottement test were positive (Video 1). X-ray images revealed widening of the right DRUJ and posterior dislocation of the ulnar head (Figure 1). After discussions regarding her treatment options, the patient was recommended surgical treatment.

For Case 1, pain management notably improved from Visual Analog Scale (VAS) score 5 to none after the surgery. The stability of the wrist considerably improved, but mild laxity was indicated by the dorsopalmar stress test result, unlike on the contralateral side. The range of motion (ROM) was nearly complete with 70° during pronation and

VIDEO 1. Significant ulnar head dislocation was observed in dorsopalmar stress test in Case 1.

FIGURE 1. X-ray images showing widening of the right DRUJ up to 3mm and posterior dislocation of the ulnar head.
DRUJ: Distal radioulnar joint.

80° during supination, and no discomfort was presented in the latest follow-up. X-ray images revealed residual widening of DRUJ, but well reduced ulnar head without dislocation compared to the preoperative X-ray (Figure 2). The patient was highly satisfied with surgery.

Case 2- A 35-year-old female patient presented to our outpatient department with a forceful twist of the right wrist that occurred during work. The wrist pain worsened notably, while the patient was performing forearm pronation and supination. On physical examination, tenderness and swelling were noted on the dorsal side of the wrist. Ballottement test results were positive. The X-ray images indicated considerable widening of the right DRUJ (Figure 3). A thermoplastic splint was used to immobilize the wrist and set it in a neutral position for one month. However, the pain recurred one week after the splint was removed. Therefore, surgical treatment was arranged for the patient.

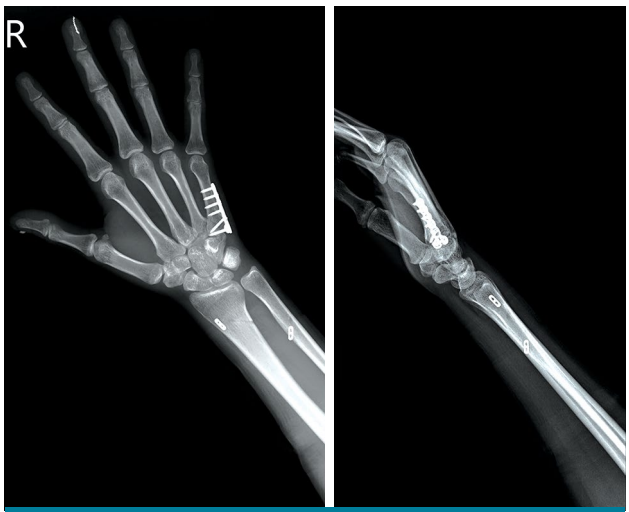

FIGURE 2. X-ray images showing residual widening of DRUJ but well reduced ulnar head without dislocation compared to the preoperative X-ray.
DRUJ: Distal radioulnar joint.

The patient in Case 2 exhibited restored wrist stability, but had mild laxity during pronation after the surgery. The ROM was 50° during pronation and 80° during supination, with no pain during movement. The originally reported dorsal wrist pain during pronation diminished and was reported to be VAS 1, which was an improvement compared to VAS 6 pre-operation. X-ray images revealed well reduced DRUJ and good implant position (Figure 4). However, two months after surgery, the patient presented with ulnar wrist pain accompanied by hypersensitivity around the surgical incision, particularly while coming into contact with another object, for instance, while placing her wrist on the table. The pain occurred at the insertion site

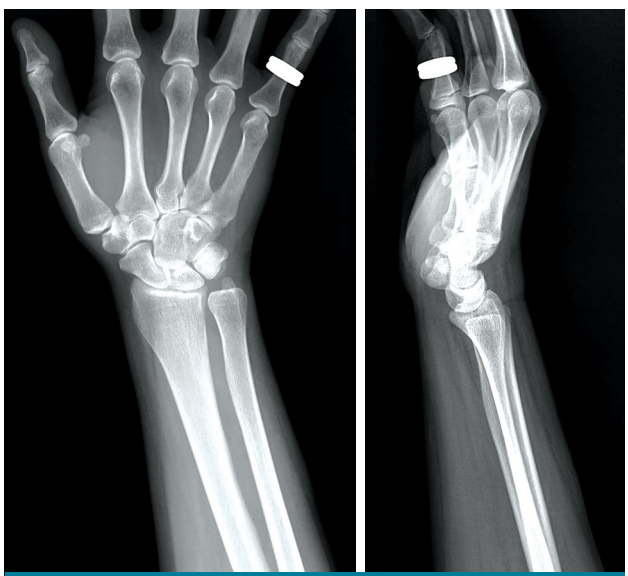

FIGURE 3. X-ray images showing widening of the right DRUJ up to 2 mm.
DRUJ: Distal radioulnar joint.

FIGURE 4. X-ray images showing well reduced DRUJ and good implant position.
DRUJ: Distal radioulnar joint.

of the Dogbone plate of the suspension system. An appropriate amount of pain control and rehabilitation protocol for stretching the peripheral muscle were applied to alleviate the pain, but were ineffective. The newly developed pain was reported to be VAS 3, but occurred constantly during normal life activities. After another two months of conservative management, the discomfort persisted, and the patient, thus, requested for the removal of the implant. During the operation, the surroundings of the Dogbone plate were examined; no tethering of soft tissue was noted. The periosteum under the implant was also examined; it appeared to be intact without significant inflammatory changes. However, the discomfort was immediately alleviated after implant retrieval, and the original dorsal wrist pain has not recurred thus far (Figure 5).

Case 3- A 39-year-old female patient presented herself to our outpatient department with wrist pain after a traffic accident that occurred two months ago. She was admitted to the emergency department earlier and was diagnosed with a wrist sprain. After months of medication, the pain persisted and even increased while performing forearm pronation. On physical examination, tenderness was noted in the dorsal DRUJ. Ballottement test and dorsopalmar stress test results were positive (Video 2). X-ray images indicated widening of the right DRUJ (Figure 6). A sugar tong splint was applied for one month, but the discomfort recurred and significantly interfered with her daily work after the splint was removed. Due to the refractory pain and occupational requirement, surgical treatment was arranged three months after the injury.

The patient in Case 3 with a delayed diagnosis of DRUJ dissociation exhibited a stable wrist without pain after surgery (Video 3). She immediately resumed work within one month owing to the drastic reduction in pain from VAS 6 to 1. However, two months after surgery, ulnar wrist pain, which also occurred in Case 2, developed at the Dogbone plate insertion site with a VAS score of 2. Pain medication such as non-steroidal anti-inflammatory drugs were prescribed, and the patient was advised to stretch to strengthen the forearm muscle. After two months of rehabilitation, the pain gradually improved. In the latest follow-up, the patient exhibited a stable wrist with ROM of 50° during pronation and 70° during supination, with no dorsal wrist pain. The ulnar wrist pain improved to VAS 1 and was reported to occur occasionally while contacting an object. All patients have been continually followed at our outpatient department for more than an year. The outcomes of VAS score and ROM are listed in Table 1.

Surgical methods

For each case, we employed the DOB augmentation technique developed by

FIGURE 5. X-ray images showing well reduced DRUJ without recurrent dislocation or subluxation even after implant retrieval.
DRUJ: Distal radioulnar joint.

FIGURE 6. X-ray images showing widening of the right DRUJ.
DRUJ: Distal radioulnar joint.

VIDEO 2. The dorsopalmar stress test result was positive in Case 3.

VIDEO 3. Stable wrist was exhibited immediately after surgery in Case 3.

De Vries et al.[15] The patient was positioned supine on the operating table, with the affected extremity placed on a radiolucent hand table. A tourniquet was applied around the upper arm. After sterile preparation, draping, and tourniquet inflation, a 1-cm longitudinal incision was made at approximately 5 cm proximal to the ulnar head. A gentle dissection was performed to the distal ulna shaft. Under fluoroscopic guidance, a bone tunnel was drilled at a 45° angle to the radius using a 1.2-mm guide pin. To prevent implant tethering with the first extensor compartment, the entry point of the pin was selected at one-third dorsal of the ulnar cortex, with the trajectory directed toward the volar side of the lateral radial cortex. Before perforating the lateral radial cortex, a 1.5-cm longitudinal incision was made above the pin exit point under fluoroscopic guidance. A gentle dissection of the soft tissue was performed using Metzenbaum scissors to prevent damage of the radial artery. The suture-button construct was, then, carefully passed using the guide pin through both tunnels to the far surface of the radius. Once the button on the ulnar side engaged with the bone cortex, the radial side button was applied to the suture and placed cautiously on the radial cortex without kinking the underlying soft tissue. As both buttons were securely placed on the cortex, the sutures were gradually tightened by hand on the radial side with the forearm placed in a neutral position. The suture-button construct was, then, secured with at least four-square knots. The pronation

TABLE I
Outcomes based on improvement in wrist pain and forearm range of motion

	Visual Analog Scale		Pronation		Supination	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
Case 1	5	0	70°	70°	85°	80°
Case 2	6	1	70°	50°	85°	80°
Case 3	6	1	70°	50°	85°	70°

and supination of the forearm were performed multiple times to ensure the ROM and stability of the DRUJ. If the sutures are not sufficiently tightened, the DRUJ may experience subluxation or even dislocation under the intraoperative fluoroscopic stress test. On the other hand, if the sutures are overtightened, the ROM of forearm would be significantly compromised. We do not recommend forceful compression of the DRUJ with clamp. After the procedure was performed, the wrist was immobilized using a forearm brace and set at a neutral position for two weeks, with the elbow allowed to move freely. After two weeks, the forearm brace was removed, and the wrist was allowed to move freely without restrictions.

DISCUSSION

The DOB holds the head of the ulna in the sigmoid notch and can be loosened, when the insertion site at the radius is displaced due to the fracture. Under normal circumstances, the DOB is a secondary stabilizer of the DRUJ; however, when the TFCC is injured, the DOB becomes a key joint stabilizer in cases of both palmar and dorsal deviations.[18-21] In addition, Kihara et al.[22] reported no significant differences in the stability of the DRUJ after the resection of only the distal radioulnar ligaments of the TFCC, leaving the DOB intact. A complete radioulnar dissociation cannot occur at the DRUJ, unless the DOB is compromised. Previous studies have argued for the reconstruction of the DOB instead of that of the distal radioulnar ligament. A biomechanical study demonstrated that, in terms of translation, cyclical loading, and maximal load to failure, the DOB reconstruction performed to resolve DURJ instability was similar to the Adams reconstruction method.[23] A cadaveric study showed that DOB reconstruction by extensor indicis proprius tendon grafting could improve the stability of the DRUJ.[24] Another cadaveric study utilized a suture-button construct, placing it approximately in the direction of the DOB; therefore, DRUJ instability decreased considerably.[15]

The suture-button construct merely requires two small incisions in the distal forearm and bone tunnel drilling in the radius and ulna, aligned with the DOB. There is no need of graft harvesting, less peripheral soft tissue damaging, and less operation time, less anesthesia period. Thanks to its simplicity, the suture-button construct is theoretically less prone to complications. Moreover, the DOB suture-button construct is placed extra-articularly. Suture button construct is an implant with two metallic buttons surrounded with thick fiber wire sutures. In case of system failure, such as broken metallic button or rupture of fiber wire, no implant is left in the DRUJ or wrist joint, and the risk of developing foreign-body synovitis is, thus, low.[15]

To the best of our knowledge, this is the first study to report the outcome of *in vivo* DOB augmentation using a suture-button suspension system for treating acute traumatic DRUJ injury.[25] The employed technique was developed by De Vries et al.[15] and was slightly modified to fit the patients involved in this study. The surgical procedure was simpler than reconstruction surgery using tendon graft. The suture-button suspension system was minimally invasive, required less time for surgery, and did not present any graft harvest site-related comorbidities. In our case series, surgeries were all accomplished in less than 40 min, and the surgical wounds were all less than 1.5 cm and healed by the first intention, with sufficient restoration of stability. However, among the three patients, two patients developed ulnar wrist pain two months after the operation. This can be attributed to the irritation of the dorsal cutaneous branch of the ulnar nerve, which was approximately 5.1 cm proximal to the ulnar styloid process and 1.9 cm palmar and radial to the subcutaneous border of the ulna.[26] The ulnar nerve can shift even distally in the wrist during full pronation. The anatomic characteristics of the dorsal cutaneous branch of the ulnar nerve were compatible with the patients' complaints. The Dogbone plate of the suture-button suspension system or the four squared suture knot may be exceedingly prominent and cause implant irritation. De Vries et al.[15] reported this potential complication in a technical note and, based on our experience, we believe that this phenomenon can be more serious than expected. We attempted to avoid soft tissue irritation by performing a gentle dissection and placing the implant underneath the muscle to mitigate the sensation of a foreign body, but discomfort still developed. This problem may be addressed by using a knotless suture-button suspension system or a soft tissue implant without plate insertion, for instance, a tendon allograft. Martínez-Martínez et al.[27] developed a minimally invasive DOB reconstruction technique by utilizing an extensor carpi radialis longus (ECRL) hemi-tendon autograft and employed it to treat two patients who exhibited highly satisfactory functional outcomes. The ECRL hemi-tendon was harvested in an antegrade manner by making a proximal incision using a retriever, until the distal

tendon insertion site was reached; the tendon was then reintroduced through the radius-ulna tunnel formed using a C-guide in the direction of the DOB. However, in addition to implant irritation, several other complications may occur while employing this technique to treat an actual patient. First, fastening the suture-button extremely tightly can cause decreased mobility in the wrist, which may be accompanied by pain and discomfort due to increased pressure at the sigmoid notch. This may occur while engaging excessive tension to reduce the joint that the inadequate reduction is actually caused by interposed tendons or other soft tissue in the sigmoid notch that blocks the reduction. In such scenarios, open reduction under direct visualization should be performed instead of repetitive trials or uncontrolled overtightening of the joint. In our case series, we did not encounter difficulties during joint reduction, but identification of the appropriate tightness of the suspension system was challenging. Some residual laxity may be observed, particularly when extreme pronation is performed, if the joint is stabilized in a neutral position without the application of additional compression force. However, postoperative wrist pain may occur due to the increased sigmoid notch pressure, if excessive force is exerted on the DRUJ while applying the suture. Finally, the patient's position should be consistent throughout the preparation of the bone tunnel and application of the suspension system. Any change in position during the procedure may result in tunnel mismatch between the radius and ulna, thereby compromising the tension in the suspension system.

In conclusion, the augmentation of the suture-button suspension system placed in the direction of DOB to treat DRUJ dislocation may provide sufficient stability; however, the *in vivo* implementation of this technique is still limited by a few factors: irritation due to the knot or Dogbone plate and inability to obtain ideal tension in the suspension system. To achieve a better clinical outcome with minimally invasive DOB augmentation procedure, we propose the utilization of a tendon allograft or knotless suspension system. Future studies are warranted to prove the hypothesis proposed in this study.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Conception of the work and drafted the manuscript: Y.N.H.; Gathered the needed information for the manuscript; Provided the first author with academic experiences: C.S.C.; Supervised the direction of manuscript; Revision of the manuscript; Final approval of the version to be published: T.M.W.; All authors have read and approved the final manuscript.

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