Effect of Dorsal Capsular Imbrication on Intraoperative DRUJ Instability following Arthroscopic TFCC Repair Surgery

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Research Article

Keywords: distal radioulnar joint, stability, triangular fibrocartilage complex, arthroscopic repair

Posted Date: February 9th, 2024

DOI: https://doi.org/10.21203/rs.3.rs-3919522/v1

Additional Declarations: No competing interests reported.

Abstract

Background

Distal radioulnar joint (DRUJ) stability during unrestricted forearm rotation relies on several factors, including the integrity of the triangular fibrocartilage complex (TFCC), the interosseous membrane, the bony configuration of the sigmoid notch, DRUJ capsule, and the extensor carpi ulnaris tendon with its subsheath. There are currently numerous reported surgical approaches for TFCC repair, however, postoperative DRUJ instability rates are still reported to be around 8 to 12%. As the integrity and strength of the TFCC is crucial for DRUJ stability, it is thus critical to identify if intraoperative dorsal capsular imbrication can further enhance DRUJ stability for improved functional outcomes.

Methods

A retrospective study was performed on patients who underwent arthroscopic TFCC repair between 2016 and 2021. Inclusion criteria comprised a symptomatic ulna fovea sign for over 6 months and dorsal DRUJ subluxation on magnetic resonance imaging. A total of 225 patients were assessed to be suitable and recruited for our study. 135 patients underwent our arthroscopic “cross-form TFCC repair” without dorsal capsular imbrication (CR) and 90 patients underwent our arthroscopic “cross-form TFCC repair” with dorsal capsular imbrication for augmentation of DRUJ stability (DCI). Pain visual analog scale score (VAS), grip strength, modified Mayo Wrist Score (MMWS), wrist range of motion (ROM), and patient-reported outcomes (PRO) were evaluated, and all patients were follow-up for a minimum of 3 years postoperatively.

Results

Both groups showed significant improvements in pain VAS score, grip strength, wrist ROM, MMWS, and PRO between the preoperative and postoperative periods ($p < 0.05$). Significantly lower recurrent DRUJ instability was noted in the DCI group (3.7% vs 1.1%, $p < 0.05$). Re-operative rates were also noted to be lower in the DCI group (2.2% vs 1.1%). However, the DCI group was found to have inferior ROM as compared to the CR group.

Conclusion

Dorsal DRUJ capsular imbrication effectively reduces postoperative DRUJ instability and reoperation rates, enhances grip strength, and maintains wrist ROM in patients with a positive intra-operative ballottement test after arthroscopic TFCC repair.

Introduction

Distal radioulnar joint (DRUJ) stability during unrestricted forearm rotation relies on several factors, including the integrity of the triangular fibrocartilage complex (TFCC), the interosseous membrane, the bony configuration of the sigmoid notch, DRUJ capsule, and the extensor carpi ulnaris tendon with its subsheath [1]. TFCC injury often results from a fall on the outstretched, pronated, and hyperextended wrist, leading to dorsal instability of the DRUJ [2]. Within the anatomical structure of the TFCC, the fovea ulnaris serves as the convergent point of proximal component TFCC (pc-TFCC) insertion, thereby becoming the most indispensable stabilizer for the ulnocarpal joint and DRUJ [3]. Based on the ulnar-side TFCC tear in Palmar type Ib, Atzei et al.[4] classified the treatment-oriented TFCC peripheral tear into five subgroups depending on whether the distal component (dc-TFCC) or the pc-TFCC was involved. Specifically, Atzei class II and III indicate DRUJ instability with complete and pc-TFCC rupture, respectively [5]. Consequently, the current approach for foveal-involved TFCC tear aims at achieving anatomical TFCC foveal reattachment, which can be accomplished through transosseous sutures [6–8] or suture anchor fixation [4, 9, 10] and has shown satisfactory outcomes.

A prior study revealed that even when radiographic findings are negative in patients experiencing post-traumatic wrist pain, 42% of them receive a diagnosis of TFCC injuries [3]. and neglecting severe TFCC tears often leads to chronic DRUJ instability. According to tissue-engineering theory, the interface of bone-to-ligament may not regenerate after injury, resulting in a high rupture recurrence rate [11], and direct bone-to-ligament repair in the chronic stage might exhibit decreased healing potential with the disadvantageous repair margin [12]. Compared with transosseous sutures, transcapsular repair, involving ligament-to-capsular healing, is an alternative method for addressing TFCC fovea tear [13]. Research has supported the notion that transcapsular repair alone can stabilize the DRUJ while achieving anatomical restoration of the dorsal subluxation of the ulna head [13, 14]. However, the integrity of DRUJ surrounding tissues, such as dorsal and volar radioulnar ligaments (DRUL and VRUL) with a superficial and a deep portion attached to the dorsal capsule, needs to be considered after the completion of TFCC repair [15]. For instance, Liu et al.[16] reported post-operative DRUJ instability rates of 12.1% with capsular repair and 10.1% with fovea transosseous repair. Consequently, additional procedures to reinforce DRUJ stability may be necessary.

The dorsal capsular imbrication (DCI) technique has been proposed and reported to yield positive clinical results in chronic DRUJ dislocation cases [17–25]. However, the use of DCI as a reinforcement procedure in TFCC repair operations for chronic DRUJ instability has not been extensively studied. Therefore, the purposes of this study were (1) to identify the indication of positive ballottement test for implementing dorsal capsular imbrication after arthroscopic TFCC repair and (2) for evaluation of the functional and clinical outcomes of dorsal capsular imbrication as compared to non-dorsal capsular imbrication TFCC repair.

Methods

Study Population

This study adhered to the tenets of the Helsinki Declaration and was approved by the Research Ethics Committee of our hospital. We retrospectively reviewed patients with repairable type IB TFCC injuries who underwent arthroscopic “cross-form” trancapsular repair with or without dorsal DRUJ capsular imbrication from January 2016 to January 2021. A minimum follow-up period of 36 months was mandatory for inclusion. The exclusion criteria encompassed patients with non-repairable TFCC (Atzei IV) ulnar and DRUJ osteoarthritis changes (Atzei V). All procedures were performed by an individual senior hand surgeon (Dr. YCC).

Clinical and Image Assessment

Pre-operatively, patients were diagnosed via a series of physical examinations, including ulna fovea sign for TFCC rupture, push-off test, and ballottement test for DRUJ laxity [18]. Wrist X-rays were employed to assess bony structure malalignment, such as ulnar styloid fracture, ulna variance, distal radius fracture or Galeazzi fracture [26]. Additionally, magnetic resonance imaging (MRI) of the wrist was performed to evaluate the condition of articular cartilage wear, detect foveal TFCC tear, and identify ulna head subluxation [27].

Arthroscopic Assessment

Radiocarpal joint arthroscopy was performed using a 3/4 viewing portal (2.7-mm arthroscopy), a 6R working portal (equipped with a synovial shaver and probe), and a 6U portal (utilized as a fluid outflow portal). The 3/4 viewing portal allows the visualization of the dc-TFCC lesion over the ulnar margin of the TFCC. Through the 6R portal, a probe was used to perform a hook test, and a shaver served as a suction test to evaluate the pc-TFCC condition. Notably, in cases whereby diagnosis assessment with pc-TFCC was controversial, a direct foveal (DF) portal was established to further confirm for the diagnosis.

Arthroscopy-assisted “Cross-form” TFCC Capsular Repair With/Without Dorsal DRUJ Capsule Imbrication

The detailed procedure for TFCC repair was described as follows:

Part 1: “Cross-form” TFCC Transcapsular Repair

Using the 3/4 portals, a combination of 2 – 0 ETHIBOND (Johnson & Johnson, Hamburg, Germany) and 2 – 0 prolene (Ethicon Inc., Somerville, NJ, USA) were combined using the inside-out [28] and outside-in [29] TFCC capsular repair techniques, and a 21-gauge spinal needle was employed to perform the two horizontal stitches.

Before suturing, a 2-cm incision was made over the 6U portal. The dorsal cutaneous branch of the ulnar nerve (DCBUN) and flexor carpi ulnaris (FCU) tendon were identified and retracted. The first horizontal mattress suture involved a 2 – 0 ethibond stitch close to the volar-ulnar margin of the TFCC lesion through the 3/4 portal using an inside-out technique (Fig. 2A) and subsequently retracted to avoid DCBUN and FCU involvement (Fig. 3A). The second stitch, a 2 – 0 prolene lasso loop suture, was performed near the dorsal-radial margin of the intact TFCC part through the 6R portal using an outside-in technique. The lasso loop suture carried one end of the 2 – 0 ethibond to form the first horizontal mattress suture (Fig. 2B). For the second horizontal mattress suture, the puncture site of the third stitch was performed close to the volar-radial margin of the TFCC intact part through the 3/4 portal with an inside-out technique (Fig. 2C), and the DCBUN should be protected from being punctured or tied in this step (Fig. 3B). The fourth stitch, a lasso suture, was performed near the dorsal-ulnar margin of the TFCC lesion through the 6R portal using an outside-in technique. The lasso loop suture was then used to carry one end of the third stitch to form the second horizontal mattress suture (Fig. 2D). This “cross-form” TFCC capsular repair created an extensive contact area in the ligament to capsule suture (Fig. 4).

After completing two horizontal mattress sutures, the wrist traction tower device was released and firmly tied in the wrist’s full-pronation position (Fig. 2E). Both sutures were checked to ensure they were tied below the ECU, FCU and DCBUN to avoid neuro-tendon involvement (Fig. 3C), achieved by reducing the ulnar head from dorsal subluxation into a neutral position using thumb compression by an assistant (Fig. 2F).

Part 2: Intra-operative Ballottement Test

We employed the intra-operative ballottement test to assess DRUJ stability after completing the "Cross-form" TFCC transcapsular repair, categorizing it into four grades:

(1) Grade 0: Normal stability (Fig. 5A). In cases where normal stability is detected, the "Cross-form" TFCC transcapsular repair alone is assumed to provide sufficient DRUJ stability.
(2) Grades 1–3: If there is laxity greater than grade 0 in the intraoperative ballottement test after tightening the strings following TFCC repair (Fig. 5B, C, and D), dorsal DRUJ capsular imbrication is performed to stabilize the DRUJ [30].

Part 3. Dorsal DRUJ Capsular Imbrication

A 4-cm curved incision was made along the extensor digiti minimi (EDM) tendon extending proximally to the proximal margin of the DRUJ. Meticulous dissection of subcutaneous tissue was performed, with attention to the dorsal branch of the ulnar nerve. Following the longitudinal incision of the extensor retinaculum, the fourth and fifth extensor compartments were retracted. Subsequently, the dorsal DRUJ capsule was opened and incised longitudinally.

In cases of chronic DRUJ instability, the dorsal capsule often exhibited looseness and weakness due to repetitive dorsal stretching by the ulnar head (Fig. 6A). A rectangular capsule flap, approximately 2 × 2.5 cm^2 and ulnar based, was carefully dissected from the dorsal cortex of radius bone, extending from the radial to ulnar direction, and exposing the radius sigmoid notch and ulnar head (Fig. 6B). To enhance the healing potential of DRUJ capsule-to-bone connection, the dorsal cortex of distal radius was decorticated using a rongeur. Two 1.4 all-suture bone anchors (JuggerKnot; Zimmer Biomet, Warsaw, IN) were individually placed radially over the upper and lower borders of the distal radius sigmoid notch (Fig. 6B).

Subsequently, with the elbow flexed at 90º and the forearm in a straightened position with full pronation, the assistant digitally pressed the dorsally displaced ulnar head, lowering it back into the sigmoid notch. The operator then imbricated the detached radius- and ulnar-based capsule flap by tightening sutures from the bone anchors (Fig. 6C). This maneuver stabilized the ulna head in a secured position (Fig. 6D).

The patient was protected with a long-arm cast, with the forearm in a neutral position, for the first 4 weeks postoperatively. After cast removal, passive three-dimensional (3D) wrist motions were initiated with wrist brace protection from 5 to 8 weeks postoperatively. Low-intensity muscle strengthening exercises were introduced from weeks 9–12 postoperatively.

Clinical Evaluation

The patient’s profile, time interval from injury to surgery, and intra-operative and post-operative complications were documented based on the medical charts. The push-off test and ballottement test were employed to evaluate the ulnar-side pain relief and DRUJ stability, respectively. At postoperative intervals of 3, 6, 9, 12, 24, and 36 months, active motion arcs were measured using a goniometer and grip strength was measured with the Jamar Hydraulic Hand Dynamometer (Jamar Technologies/America, Hatfield, PA).

Additionally, patient-reported outcomes, including MMWS, Patient-Rated Wrist Evaluation (PRWE), and Disabilities of the Arm, Shoulder, and Hand (DASH) were used for clinical results. The proportion of patients meeting the minimal clinically important difference (MCID) of the DASH (MCID: 10–13.5) and PRWE scores (MCID: 14–17) allowed for the quantitative recording of the direct feelings of the patients [31].

Sample Size Calculation

In our prior comparative research [20], the mean ± standard deviation of wrist range of motion (ROM), with respect to pronation and supination, was found to be 161 ± 13.6º, and 156 ± 12.6º in the “dorsal capsular imbrication” group and the “TFCC repair + dorsal capsular imbrication” group, respectively. Based on a statistical power of 80% and a significance level of 5%, we determined that a minimum of 133 cases for group 1 and 90 cases for group 2 were necessary to ascertain whether a true difference in clinical outcomes existed between both groups.

Statistical Analysis

All data were analyzed using SPSS software (version 20.0; IBM Corp., Armonk, NY). The Shapiro–Wilk test showed that the data were not normally distributed; therefore, nonparametric tests were employed for comparison. Categorical variables were presented as frequency (%). The Chi-squared test was used for nonparametric statistical analysis of categorical information, and the Mann–Whitney U test was employed for nonparametric analysis of continuous variables. To compare outcome measurements between two groups (DASH score, PRWE score, grip strength, and ROM), the Wilcoxon rank sum test was used. Statistical significance was set at $p < 0.05$.

Results

From January 2016 to June 2021, a total of 265 patients underwent surgical treatment for post-traumatic chronic DRUJ instability at our hospital. Among them, 40 patients who underwent DRUJ reconstruction were excluded due to 25 patients having Atzei class IV or V TFCC tear, 4 with radioulnar joint arthritis, 7 without adequate follow-up, and 4 with prior wrist surgery. Ultimately, a total of 225 patients were included in our final analysis. Among them, 110 had Atzei class II and 115 had Atzei class III TFCC tears, and all underwent arthroscopy assisted TFCC capsular repair with dorsal DRUJ capsule imbrication (Fig. 1).

This study comprised 130 (57.8%) men and 95 (42.2%) women, with right-sided DRUJ instability occurring in 142 (63%) and left-sided in 83 (36%) cases. The patients' ages ranged from 22 to 58 years (mean, 41 years). The duration of symptoms before surgery ranged from 6 to 24 months (mean, 12.7 months; range, 6–24 months). The mean follow-up time was 45 months (range: 36–60 months) (Table 1). Table 2 presents the demographic and clinical characteristics of the patients, who were divided into two groups: Group 1, "Cross form" TFCC repair (CR), and Group 2, "Cross form" TFCC repair + DRUJ dorsal capsular imbrication (DCI), with no significant difference in each variable category.

Table 1
Patients Demographic and Clinical Characteristics

Variable	**CR[a]**	**DCI[b]**	**P value***
Number	135	90	
Sex			
Female	55	40	
Male	80	50	
Hand (R/L)	76/59	66/24	
Age	41.5 (25–58)	36.3 (22–55)	> 0.05
Symptoms to surgery (months)	12.2 (6–24)	13.5 (6–24)	> 0.05
Follow-up (months)	30.9 (24–42)	34.7 (24–40)	> 0.05
Atzei classification			
II	82	40	
III	53	50	
P value* significance difference under Chi-squared test			
CR[a]: Cross-form repair			
DCI[b]: Cross-form repair + Dorsal capsular imbrication			

Table 2
Cross-form repair group: 135 cases (Pre-operative vs. Post-operative 3 years)

Variable	Pre-operative	Post-operative	P value*
Grip strength[a]	50% ± 21%	90.1% ± 5%	< 0.05
Wrist ROM[b]			
Flex-extension	52.3% ± 17%	95.4% ± 5%	< 0.05
Supi-pronation	47.3% ± 22%	92.4% ± 2%	< 0.05
Radial-ulnar deviation	57% ± 18%	90.5% ± 5%	< 0.05
DASH[c] score	51.6 ± 14.2	9.9 ± 4.2	< 0.05
PRWE[d]: score	40.7 ± 10.3	10.5 ± 5.7	< 0.05
MMWS[e]	50% ± 21%	95.1% ± 5%	< 0.05
Grip strength[a] (op/non-op) × 100%;			
Wrist range of motion[b] (op/non-op) × 100%			
DASH[c]: Disabilities of the Arm, Shoulder, and Hand			
PRWE[d]: Patient-Rated Wrist Evaluation			
MMWS[e]: Modified Mayo Wrist score			
P value* significance difference under Mann-Whitney test			

The preoperative and 36-month postoperative scores for DASH, PRWE, grip strength, MMWS, and wrist ROM (flexion-extension + pronation-supination + radial-ulnar arcs) are shown in Table 2 (Group 1) and Table 3 (Group 2), and all significant differences were identified with $p < 0.05$. Additionally, patient-reported outcomes scores showed that 95% (214 in 225) of patients achieved the MCID for DASH scores, and 92% (207 in 225) achieved the MCID for PRWE scores.

Table 3
Cross-form repair + Dorsal capsular imbrication group: 90 cases (Pre-operative vs. Post-operative 3 years)

Variable	Pre-operative	Post-operative	P value*
Grip strength[a]	47% ± 17%	95.1% ± 5%	< 0.05
Wrist ROM[b]			
Flex-extension	51.3% ± 20%	92.4% ± 3%	< 0.05
Supi-pronation	49.2% ± 19%	91.1% ± 3%	< 0.05
Radial-ulnar deviation	56% ± 18%	88.2% ± 4%	< 0.05
DASH[c] score	50.1 ± 17.1	10.2 ± 4.2	< 0.05
PRWE[d]: score	41.7 ± 11.4	9.5 ± 5.1	< 0.05
MMWS[e]	44% ± 25%	93.7% ± 5%	< 0.05
Grip strength[a] (op/non-op) × 100%;			
Wrist range of motion[b] (op/non-op) × 100%			
DASH[c]: Disabilities of the Arm, Shoulder, and Hand			
PRWE[d]: Patient-Rated Wrist Evaluation			
MMWS[e]: Modified Mayo Wrist score			
P value* significance difference under Mann-Whitney test			

Comparison of post-operative results between Group 1 and Group 2 are shown in Table 4 and Fig. 7. Our findings revealed that in the short-term (post-operative 3 months to 1 year), even though the DCI group exhibited better grip strengths than the CR group, they had wrist stiffness (Fig. 7). Interestingly, in the mid-term (post-operative 1 year to 3 years), the DCI group continued to demonstrate superior grip strengths compared with the CR group (Table 4). However, no significant difference was observed in all directions of wrist ROM between the two groups at the post-operative 3-year follow-up (Table 4).

Table 4
Cross-form repair group vs. Cross-form repair + Dorsal capsular imbrication group (Post-operative 3 years)

Variable	CR[f]	DCI[g]	P value*
Grip strength[a]	**90.1% ± 5%**	**95.1% ± 5%**	**< 0.05**
Wrist ROM[b]			
Flex-extension	95.4% ± 5%	92.4% ± 3%	> 0.05
Supi-pronation	92.4% ± 2%	91.1% ± 3%	> 0.05
Radial-ulnar deviation	90.5% ± 5%	88.2% ± 4%	> 0.05
DASH[c] score	9.9 ± 4.2	10.2 ± 4.2	> 0.05
PRWE[d]: score	10.5 ± 5.7	9.5 ± 5.1	> 0.05
MMWS[e]	95.1% ± 5%	93.7% ± 5%	> 0.05
Complications			
Reoperation (%)	2.2%	1.1%	> 0.05
Recurrent instability (%)	**3.7%**	**1.1%**	**< 0.05**
Grip strength[a] (op/non-op) × 100%;			
Wrist range of motion[b] (op/non-op) × 100%			
DASH[c]: Disabilities of the Arm, Shoulder, and Hand			
PRWE[d]: Patient-Rated Wrist Evaluation			
MMWS[e]: Modified Mayo Wrist score			
CR[f]: Cross-form repair			
DCI[g]: Cross-form repair + Dorsal capsular imbrication			
P value* significance difference under Mann-Whitney test			

Post-operative complications included: (1) Recurrent DRUJ instability, which occurred in 3.7% (5/135) and 1.1% (1/90) in Group 1 and Group 2, respectively, with a significant difference between the two groups; and (2) Repeated surgery, the re-operative ratio was noted as 2.2% (3/135) and 1.1% (1/90) in Group 1 and Group 2, respectively, with no significance difference observed.

Notably, a total of 95% (214/225) of patients achieved pain relief in the push-off test, 97.3% (219/225) regained DRUJ stability in the ballottement test, and only 1.8% (4/225) required re-operation due to DRUJ osteoarthritis changes after 3 years postoperatively. Moreover, patient-reported outcomes indicated that 91% and 92% of patients achieved the MCID in the DASH and PRWE scores, respectively [31].

Discussion

Our study showed that incorporating augmented DCI in TFCC repair for patients with an intraoperative positive intraoperative ballottement led to satisfactory postoperative clinical and functional results and could be considered as an indication for DCI augmentation. Such an augmentation led to significantly lower reoperation rates with patients having significantly higher grip strength. However, patients undergoing DCI might experience a brief period of decreased wrist ROM. According to the Atzei classification, TFCC fovea tear (class II, III) required foveal TFCC repair [4, 32]. The neglected TFCC fovea tear might contribute to chronic DRUJ instability [5] resulting in decreased grip strength or limited wrist ROM [33]. Despite the favorable outcomes reported for “transosseous repair [6–8]” “fovea repair with suture anchors [4, 9, 10]”, re-operation rates have been documented in the range of 6.7–30% [8, 34–37]. Discrepancies in clinical results and reduced efficacy of fovea repair may be attributed to (1) the poor quality or irreparable remnants of TFCC fovea tears that cannot stabilize DRUJ, (2) insufficient coverage area for sutures or knots, increasing the risk of TFCC cut-through during knot tying, and (3) inadequate foveal debridement or improper positioning of bony tunnels, leading to limited bone-to-ligament regeneration capacity.

Recent studies comparing DRUJ stability after capsular repair and transosseous repair have produced varying results: Ruch et al. [38] demonstrated no significant difference, while Johnson et al.[39] indicated greater stability with transosseous repair. However, the critical factor for successful TFCC repair lies in the healing potential of the contact surface, which is notably poor in ligament-to-bone repair (fovea repair): 1. Ulna fovea has a “band shaped”-like footprint [40], whereas “suture anchor repair” and “transosseous tunnel repair” only provide a point contact area between the TFCC remnant and the ulna fovea; 2. “ Enthesis” refers to the insertion site of a tendon, ligament or joint capsule into bone [41]. Fovea repair, “transooseous repair” or “suture anchor repair,” requires the reattachment of TFCC remnant parts into the ulna fovea. Few vessels penetrate the enthesis due to a calcified barrier [42]. In contrast, capsular repair may be more effective in enhancing the healing potential of the TFCC through ligament-to-capsule repair compared to [43] ligament-to-bone repair. However, a comprehensive review involving 825 cases across 30 studies revealed post-operative distal radioulnar joint (DRUJ) instability rates of 12.1% for capsular repair and 10.1% for fovea transosseous repair. Regarding re-operation rates, they were 7.9% for capsular repair and 5.5% for fovea transosseous repair [16]. These results indicate that intraoperative instability of the DRUJ can be a concern in both primary methods of TFCC repair. Therefore, employing an intraoperative DRUJ stability test could be essential for identifying potential postoperative instability and the failure of TFCC repair. Augmentation with DCI can help prevent postoperative DRUJ instability and the need for subsequent reoperation.

The intra-operative ballottement test is a simple method for evaluating DRUJ stability after arthroscopic TFCC repair. A positive result suggests that the strength of the repaired TFCC alone may be insufficient to maintain DRUJ stability. DCI can be employed as a supplementary method to enhance DRUJ stability. Using DCI as a sole treatment for patients with DRUJ instability has been successful in restoring DRUJ stability in 97.8% of cases, with 93.6% of patients experiencing pain relief through this approach [17–25]. In a long-term study spanning 10 years, it was observed that DCI effectively restored wrist function to levels comparable to the contralateral hand. DCI can also function as a secondary stabilizer, following a similar bridging concept to that of the internal brace used in anterior talofibular ligament [44] or knee medial collateral ligament repair [45]. When combined with the suture tap and bone anchors, it can reinforce ligament strength and prevent injury recurrence during the rehabilitation process [44]. Similarly, DCI can restore intact DRUJ kinematics and radioulnar ligament reconstructions in chronic DRUJ instability [46]. In the present study, recurrent DRUJ instability was found to be significantly lower in patients with the augmentation of DCI, compared to 3.7% and 1.1% in CR group 1 and "DCI group 2, with a significant difference. Thus, we believe that DCI could be an effective method for addressing intraoperative DRUJ instability following TFCC capsular repair.

In this treatment protocol, we aim to outline the procedures necessary to restore the integrity of TFCC and DRUJ capsules: (1) "TFCC capsular repair" combines the benefits of the inside-out and outside-in techniques, reducing the cut-through rate, purchasing the wide contact area between the ulna fovea and adhering TFCC remnant part with the surrounding tissue to reinforce the DRUJ stability. The crux of transcapsular repair is the ligament-to-soft tissue healing process. Therefore, non-absorbable suture 2 − 0 ethibond was selected to provide reliable tension support. (2) Intraoperative ballottement test could be used to check for integrity of the DRUJ stability, grade 0 indicates that "TFCC transcapsular repair" was sufficient to maintain DRUJ stability, while grade I, II or III suggests that DRUJ laxity or subluxation existed after transcapsular repair, and the subsequent augmentation for DRUJ stability was needed. (3) Dorsal DRUJ capsular imbrication worked by tightening the redundant laxity of dorsal DRUJ capsule, thereby reducing the subluxation of ulna head and reattaching the DRUL to the tightened DRUJ capsule under wrist full-pronation position. Tension of the imbricated capsule can be optimized to stabilize DRUJ with the utilization of two suture anchors over the dorsal cortex of the radius sigmoid notch. Our results indicated a slightly higher rate of postoperative distal radioulnar joint (DRUJ) instability in Group 1, which underwent only TFCC capsular repair, compared to Group 2, which received both TFCC capsular repair and dorsal DRUJ capsular imbrication. This implies that late DRUJ instability may manifest in patients who initially tested negative in the intraoperative ballottement test but only underwent TFCC repair. It also implies that DCI is a reliable procedure to build up the DRUJ stability.

A major concern about our methods was that wrist stiffness was found approximately postoperative 6 months in the DCI group. However, wrist ROM were comparable to the CR group after midterm follow-ups. Furthermore, grip strength of DCI was not affected even with decreased wrist ROM. Another issue to consider was that tying knots during the transcapsular repair may lead to transient dorsal ulnar sensory nerve irritation due to intra-operative retraction; however, symptoms were noted to subside within 2 weeks postoperatively. This study has its own limitations. Firstly, it focused solely on surgical outcomes and functional measures, lacking postoperative axial MRI to verify the repositioned DRUJ. Secondly, being a retrospective comparative study with midterm follow-up, a longer-term investigation is needed to validate the observed clinical outcomes. Third, the intraoperative ballottement test employed in this study remains subjective. Future studies should consider standardizing pull strength and translation distance measurements to enhance the accuracy of identifying subtle cases of DRUJ instability following TFCC repair. Finally, we did not include a control group comprising patients with persistent instability after TFCC repair who did not receive additional augmentation treatment to enhance DRUJ stability. However, establishing such a control group presented ethical and clinical challenges, as leaving untreated cases of persistent DRUJ instability were not considered feasible.

Conclusions

Our findings revealed that in chronic cases of DRUJ instability with ulna fovea tear, “Cross form” TFCC repair may be employed to restore DRUJ stability. Specifically, if the intra-operative ballottement test indicates residual DRUJ instability following TFCC capsular repair, “Dorsal capsular imbrication” can be applied to augment DRUJ stability. This procedural protocol serves as a viable treatment option for patients experiencing chronic DRUJ instability.

Declarations

Author contributions:

Chen-Wei Yeh and Cheng-En Hsu designed the concept. Wei-Chih Wang, Tsung-Yu Ho and Bor-han Wei were the attending doctor and treated the patient. Chen-Wei Yeh and Cheng-En Hsu contributed to literature review and manuscript drafting. Yung- Cheng Chiu revised the manuscript.

Informed consent statement:

The patient provided consent for the use of his medical documentation and information for the present article.

Consent for publication & Availability of data and materials:

The authors agreed for the publication and data usage.

Conflict-of-interest statement:

The authors declared that they have no conflict of interest. The authors did not receive any financial support or fundings for this manuscript.

Acknowledgements & Disclosure of interest:

The authors declared that they have no competing interests.

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Figures

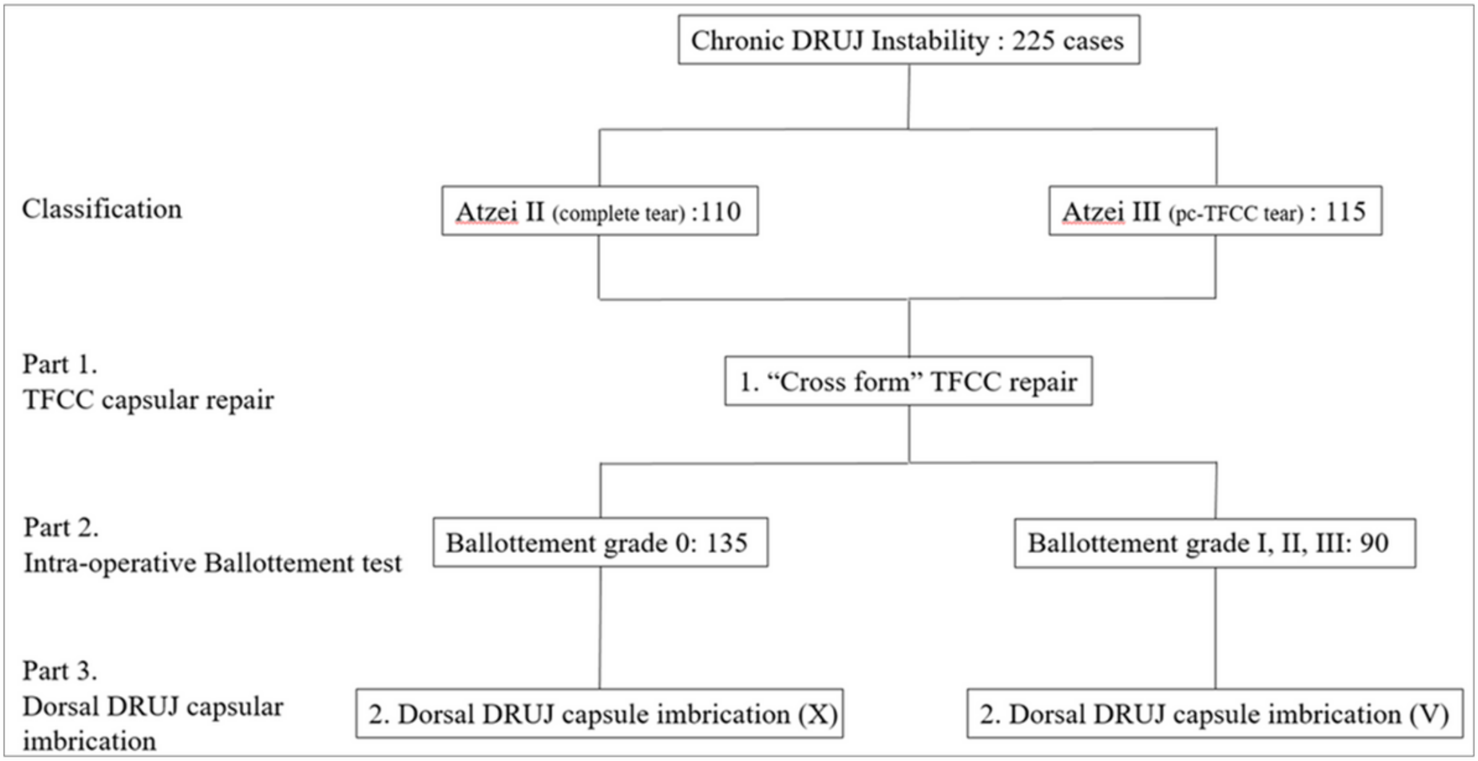

Figure 1

Treatment protocol of patients with chronic DRUJ instability

TFCC, triangular fibrocartilage complex; DRUJ, distal radioulnar joint

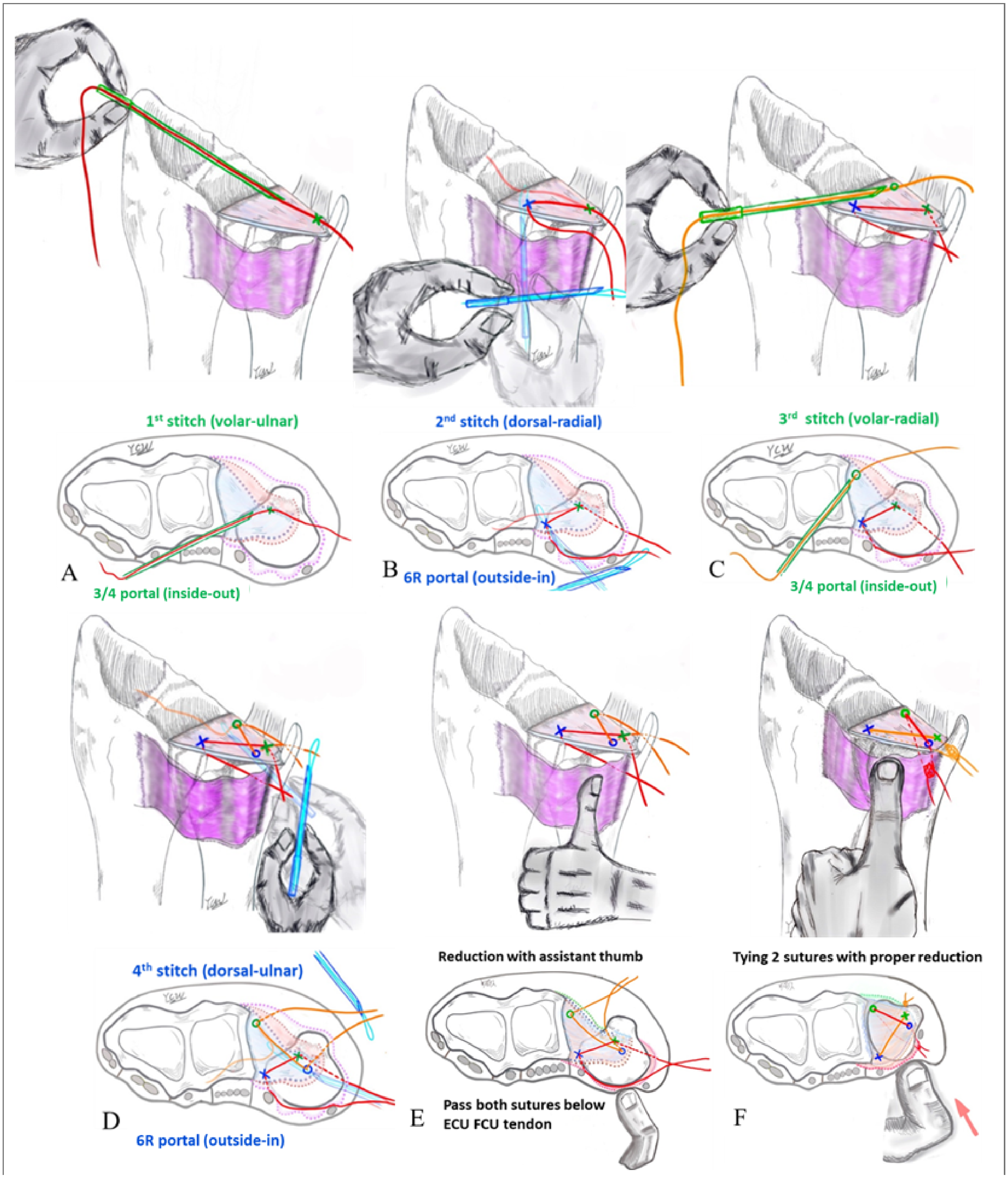

Figure 2

Part 1. "Cross-form" TFCC transcapsular repair (Green color: 3/4 portal, inside-out technique) (Blue color: 6R portal, outside-in technique)

First suture (Red color) (A) 1st stitch [volar-ulnar]: inside-out technique from the 3/4 portal (B) 2nd stitch [dorsal-radial]: outside-in technique from the 6R portal; 2nd suture (Orange color)

(C) 3rd stitch [volar-radial]: inside-out technique from 3/4 portal

(D) 4th stitch [dorsal-ulnar]: outside-in technique from 6R portal

(E and F) reduction of the ulna head into the radius sigmoid notch with the assistant’s thumb and tying both sutures.

**TFCC, triangular fibrocartilage complex **

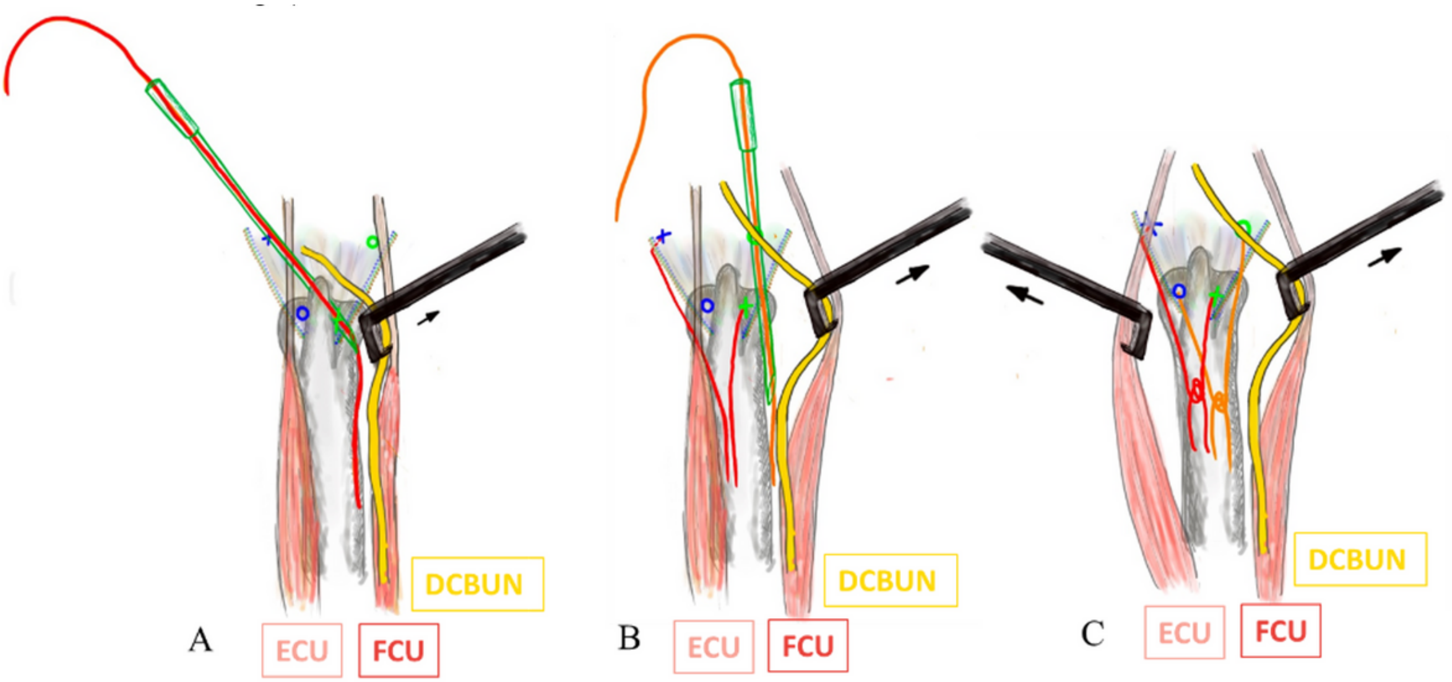

Figure 3

Identified DCBUN and FCU (Green color: 3/4 portal, inside-out technique) (Blue color: 6R portal, outside-in technique, 1st suture: Red color, 2nd suture: Orange color)

(A) Applied the first stitch after retracting DCBUN & FCU

(B) Applied the third stitch after retracting DCBUN & FCU

(C) Retracting the ECU and DCBUN and FCU, and tying both sutures below them

** DCBUN: dorsal cutaneous branch ulna nerve; ECU: Extensor carpi ulnaris; FCU: Flexor carpi ulnaris **

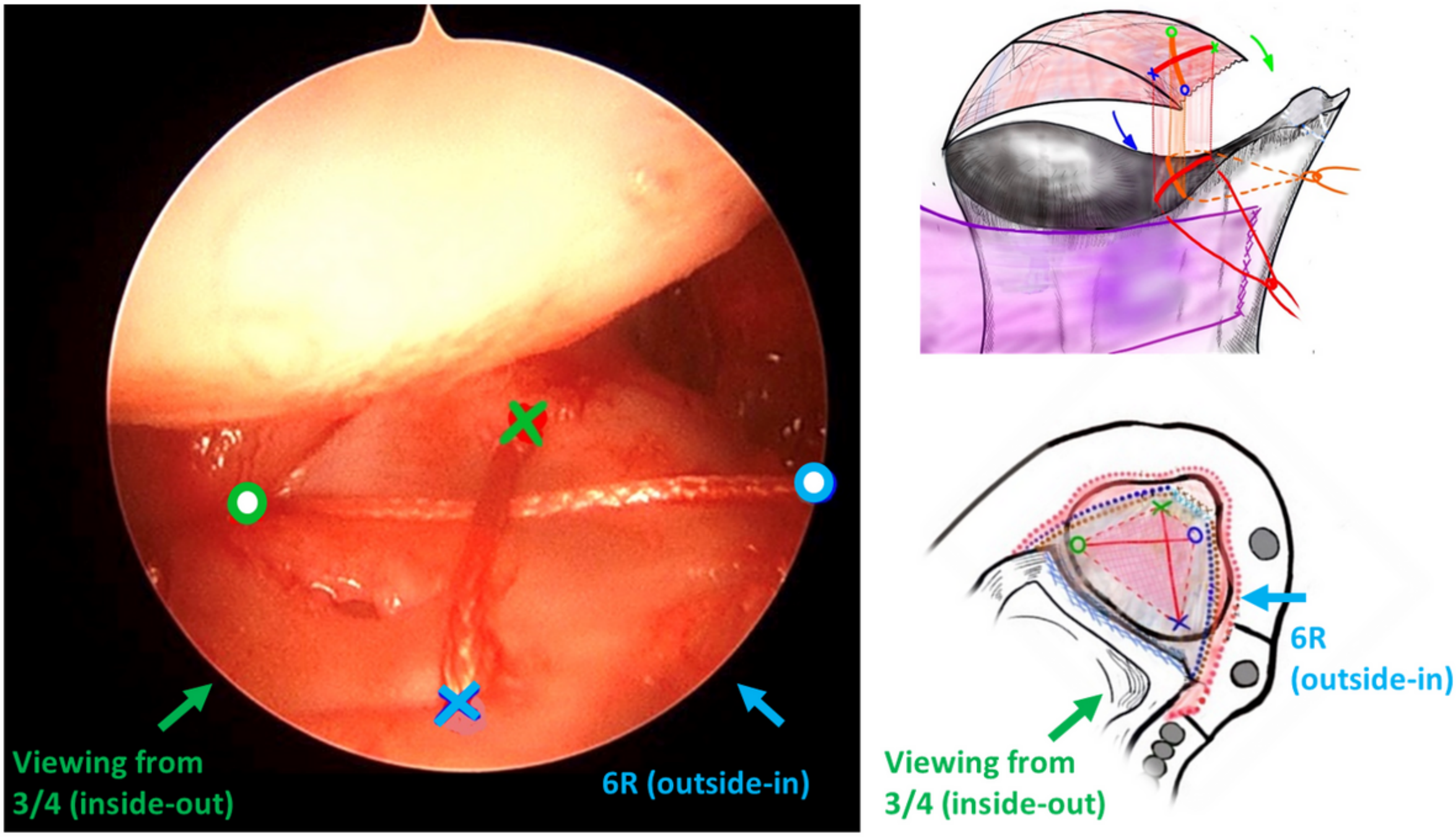

Figure 4

Creating a maximum area of “Cross-form” TFCC transcapsular repair under arthroscope (Viewing from 3/4 portal)

(Green color: 3/4 portal, inside-out technique) (Blue color: 6R portal, outside-in technique, 1st suture: Red color, 2nd suture: Orange color)

**TFCC, triangular fibrocartilage complex **

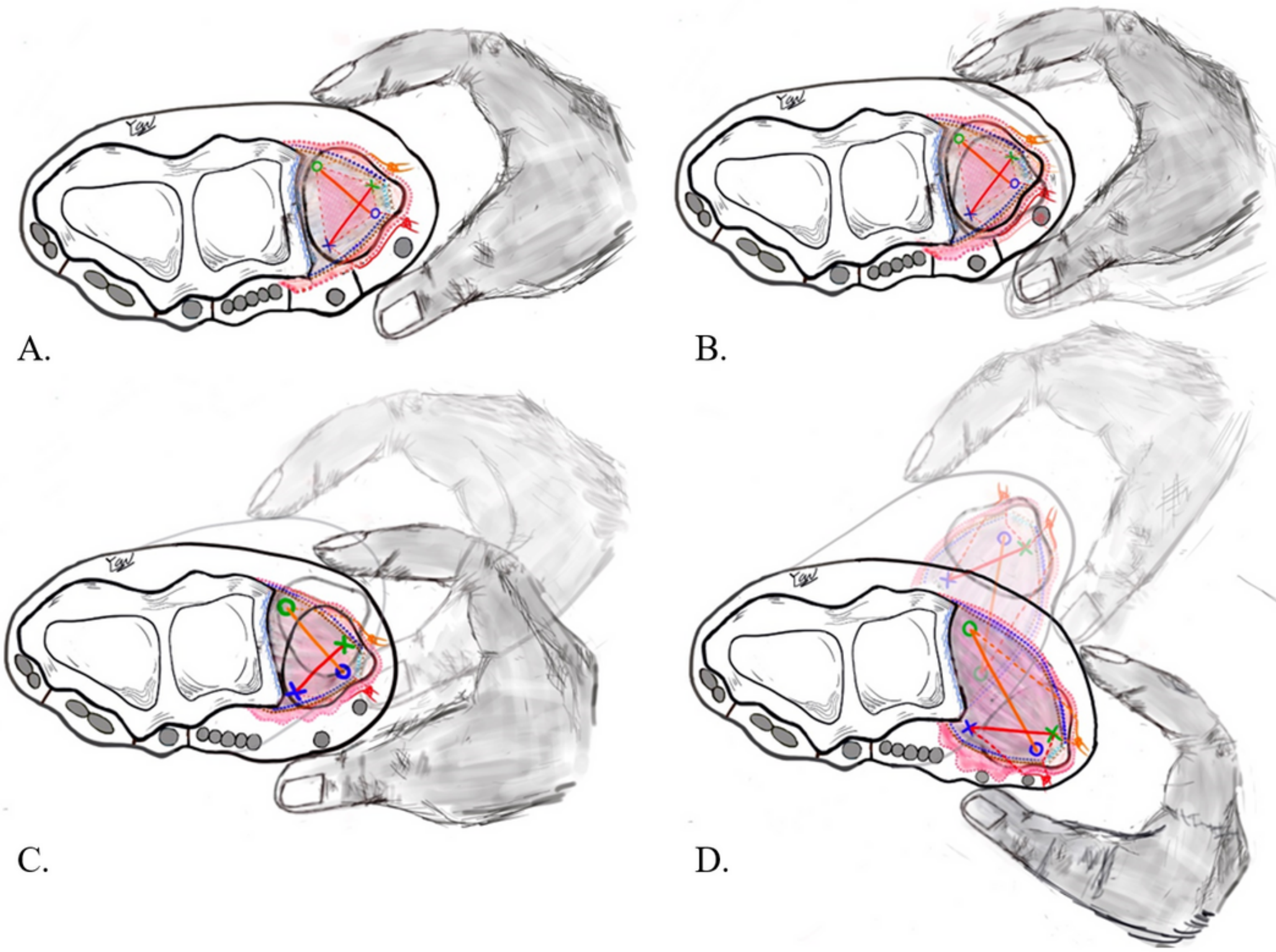

Figure 5

Part II. Intra-operative Ballottement test

(A) Grade 1: Normal stability (relative displacement 0%)

(B) Grade 2: Increase laxity with firm endpoint response to stress (relative displacement 0–25%)

(C) Grade 3: Increase laxity without firm endpoint response to stress (relative displacement 25–50%)

(D) Grade 4: Subluxation with passive range of motion (relative displacement >50%)

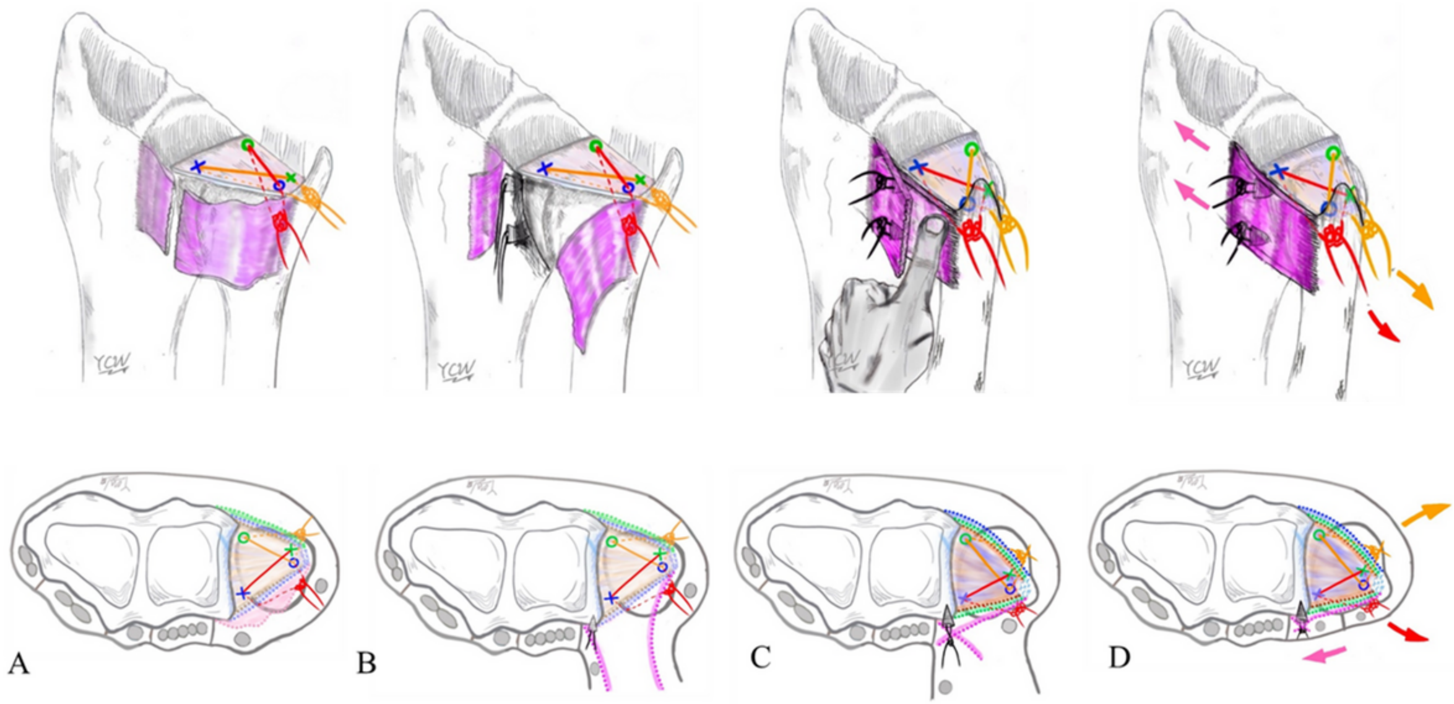

Figure 6

Part III. Dorsal capsular imbrication

(A) Chronic DRUJ instability s/p part 1. "Cross-form" TFCC transcapsular repair, the dorsal capsule remains loose.

(B) Incision of the dorsal capsule into ulnar-based flap and applying two suture anchors over the dorsal cortex near the sigmoid notch.

(C) Reduction of ulna head with assistant's thumb in full forearm pronation.

(D) Operator tightened the knots to maintain the DRUJ's reduction after restoring the normal alignment of the DRUJ.

TFCC, triangular fibrocartilage complex; DRUJ, distal radioulnar joint

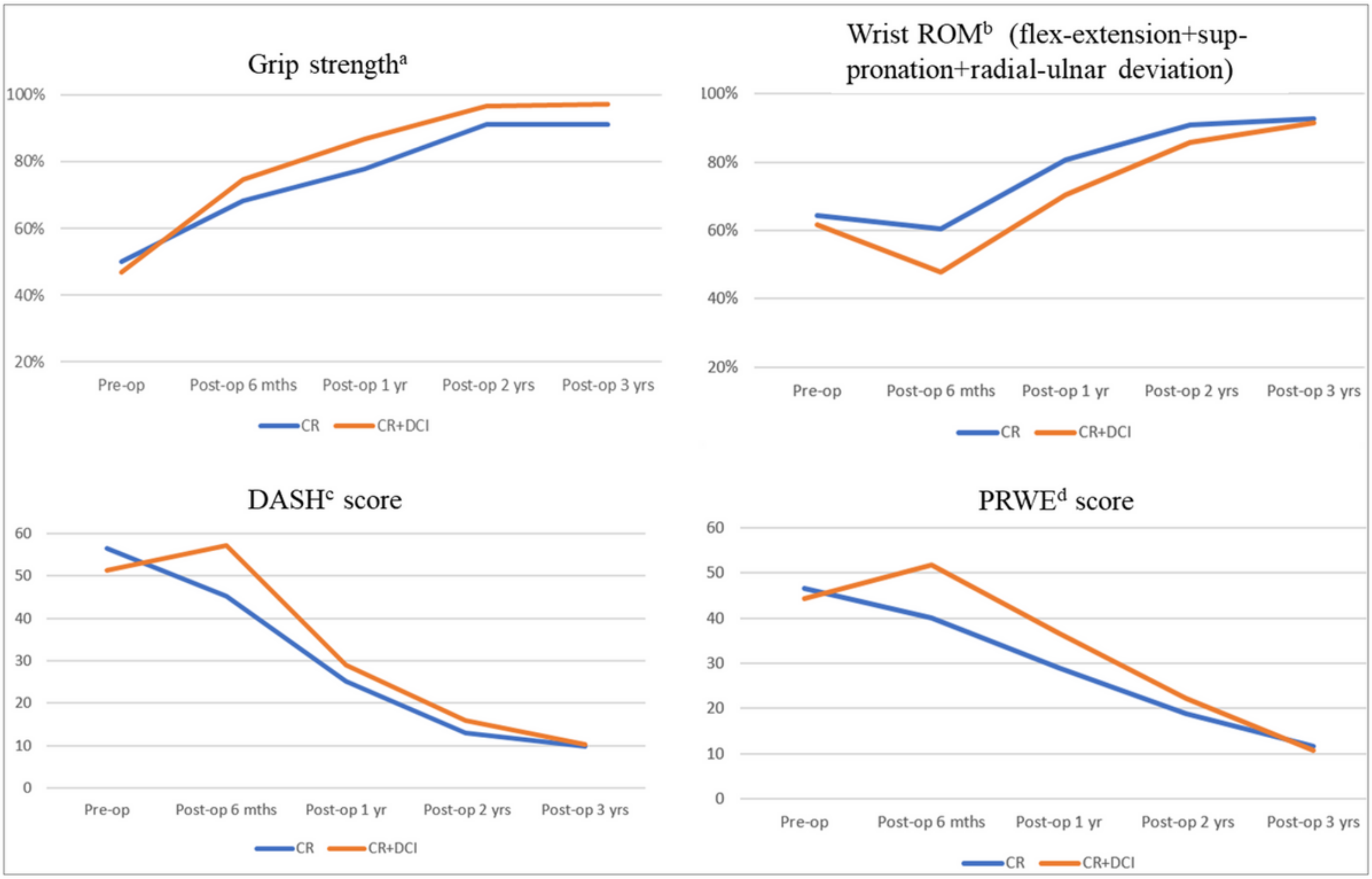

Figure 7

CR[d] group 1 (blue color) vs. DCI[e] (orange color)

(A) Short-term following: post-operative 6 months to 1 year

(B) Mid-term following: post-operative 2 to 3 year

** Grip strength[a] (op/non-op) × 100%; Wrist range of motion[b] (op/non-op) × 100%; DASH[c]: Disabilities of the Arm, Shoulder, and Hand; PRWE[d]: Patient-Rated Wrist Evaluation sc**