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Arthroscopic foveal reattachment of triangular fibrocartilage complex: Inside-out technique at specific ulnocarpal anatomical landmarks

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Abstract

This study evaluates the outcomes of arthroscopic triangular fibrocartilage complex (TFCC) foveal reattachment using an inside-out suture passing through the TFCC at specific ulnocarpal anatomical landmarks to grasp the radioulnar ligaments. Thirty-eight patients with a mean age of 36 years (range 19–54), diagnosed with TFCC injury with distal radioulnar joint (DRUJ) instability, underwent arthroscopic inside-out TFCC foveal reattachment using designated suture sites. At a mean follow-up of 32 months (range 26–44), pain score, range of motion, grip strength, Disabilities of the Arm, Shoulder and Hand (DASH) score, and Modified Mayo Wrist Score all showed significant improvement after surgery. The DRUJ stability was restored and the minimal clinically important difference threshold for the DASH score was achieved in all patients. Arthroscopic TFCC foveal reattachment using the inside-out technique at specific ulnocarpal anatomical landmarks provided reliable outcomes and could be considered as another straightforward procedure for treating TFCC injuries with DRUJ instability.

Level of evidence: IV

Keywords

Wrist arthroscopy, triangular fibrocartilage complex, distal radioulnar joint, inside-out, foveal reattachment, anatomical landmarks

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Introduction

The bony contour between the sigmoid notch and the ulnar head and the integrity of the surrounding soft tissues contribute to the stability of the distal radioulnar joint (DRUJ). The main ligamentous stabilizer of the DRUJ is the triangular fibrocartilage complex (TFCC), which consists of the triangular fibrocartilage (TFC), radioulnar ligaments (RULs), ulnocarpal ligaments (UCLs) and the extensor carpi ulnaris (ECU) subsheath (Nakamura et al.,1996; Palmer and Werner, 1981).

The proximal component of the TFCC is the palmar and dorsal radioulnar ligaments (PRUL and DRUL) (Nakamura and Makita, 2000; Nakamura et al., 2001). This component has the primary role of restraining rotation and translation of the distal radius on the ulnar head (Haugstvedt et al., 2006; Nakamura and Makita, 2000). The UCLs arise from the PURL and the palmar portion of the foveal area and insert into the ulnar carpal bones. They also help to stabilize the ulnar head to constrain the DRUJ

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(Ishii et al., 1998; Nakamura et al., 2001). The most common cause of DRUJ instability is avulsion of the RULs and UCLs from the fovea (Haugstvedt et al., 2006). Therefore, the primary treatment to restore DRUJ stability is reattachment of these vital structures.

Arthroscopic TFCC foveal reattachment is recognized as a surgical restoration of DRUJ stability, allowing accurate intra-articular evaluation and treatment with less soft tissue dissection than open surgery. Many studies have popularized the outside-in TFCC suture technique, in which the TFCC is entered from below the TFCC disc at the base of the ulnar styloid (Atzei et al., 2008; Atzei, 2009; Chen, 2017; Iwasaki and Minami, 2009; Iwasaki et al., 2011; Liu and Arianni, 2020; Liu et al., 2021, Luchetti et al., 2014; Nakamura et al., 2011; Park et al., 2018; Shinohara et al., 2013). The inside-out suture-passing technique, in which the TFCC suture is passed over the designated site in a single pass, is another technical option (Waitayawinyu, 2021). However, few studies have addressed the clinical outcomes of this approach (Fujio, 2017; Tang et al., 2012).

In terms of TFCC suture placement, a recent anatomical study demonstrated the landmarks to navigate the reliable TFCC suture locations for arthroscopic TFCC foveal reattachment. Ninety-seven per cent of RULs located beneath the TFCC disc were secured with the palmar and dorsal TFCC sutures placed at the locations identified in the study (Waitayawinyu et al., 2023).

Therefore, the aim of this study was to evaluate the clinical outcomes of the arthroscopic TFCC foveal reattachment using combined approaches of the inside-out TFCC suture-passing technique and the use of designated TFCC suture locations at specific ulnocarpal anatomical landmarks. With the advantages of each approach, we hypothesized that the index procedure would result in favourable clinical outcomes.

Methods

Following institutional review board approval, we retrospectively reviewed data on patients who underwent arthroscopically assisted TFCC foveal reattachment using the inside-out technique at the specific ulnocarpal anatomical landmarks. The criteria for diagnosing TFCC injury with DRUJ instability were as follows: (1) a positive ulnar fovea sign (Tay et al., 2007); (2) a positive DRUJ ballottement test (Kleinman, 2007); and (3) MRI evidence of foveal injury at the distal ulna. The DRUJ instability was graded according to severity as none, mild, moderate or severe (Moritomo et al., 2010). In addition, ligament injury (PRUL, DRUL, or both) was determined based on the direction of laxity found on ballottement testing. Inclusion criteria for the index procedure consisted of: (1) mild to moderate DRUJ instability unresponsive to conservative treatment including 4 to 6 weeks of long arm immobilization or severe DRUJ instability; (2) positive foveal disruption, identified by the hook test during radiocarpal arthroscopy or direct visualization during DRUJ arthroscopy (Atzei et al., 2008; Atzei, 2009; Atzei et al., 2021); and (3) a repairable TFCC foveal disruption. The classification system for peripheral TFCC tears was used in this investigation (Atzei and Luchetti, 2011; Atzei et al., 2017). Class 2 TFCC tears (repairable complete tear) or class 3 TFCC tears (repairable proximal tear) were indicated for this procedure. Patients with wrist deformity, ulnar impaction syndrome, degenerative or irreparable TFCC, local or systemic arthritis involving the DRUJ, and less than 24 months of follow-up were excluded from the study. All procedures were performed by a single highly experienced (level 4) hand surgeon specializing in wrist arthroscopic surgery (Tang and Giddins, 2016).

Surgical technique

Under regional or general anaesthesia and tourniquet control, the patient's wrist was distracted (4.5–6.8 kg) by a wrist traction tower. Standard 3–4, 4–5 and 6R portals were created. The intra-articular pathologies were initially identified using wrist arthroscopy via the 3–4 portal. The tension of the TFCC and the adherence of foveal insertion were evaluated by the trampoline test and hook test, respectively. The DRUJ arthroscopy was also used to directly evaluate the foveal insertion of the RULs. Debridement of the TFCC capsular synovitis or fibrovascular granulation tissue was performed using a small joint shaver (ConMed, Largo, FL, USA) and a radiofrequency probe (Arthrex, Naples, FL, USA) via the 6R portal. The TFCC disc, prestyloid recess, ulnocarpal ligaments and lunotriquetral joint were then clearly delineated.

Foveal preparation

Direct assessment of the RULs and foveal insertion was performed using DRUJ arthroscopy. Foveal footprint preparation with debridement of granulation tissue and ligament remnants was then performed through the prestyloid recess using a small joint shaver and curette via the 6R portal. A small joint burr was used to debride thick granulation tissue.

A radiofrequency probe was used in cases with fraying synovium at the prestyloid recess.

A 1.5–2.0 cm longitudinal incision was made on the ulnar aspect of the wrist. The dorsal sensory branch of the ulnar nerve was identified and protected. The extensor retinaculum and ulnar DRUJ capsule were incised longitudinally. The direct foveal (DF) portal was then used in semisupination of the wrist to access the ulnar fovea (Atzei et al., 2008; Atzei, 2009). The foveal footprint was also prepared using the small joint shaver, curette and burr through the DF portal while inspecting from the DRUJ portal or vice versa (Figure 1).

TFCC suture-passing

The outline of the palmar and dorsal suture-passing locations was demonstrated in Figure 2 and 3. Another option for locating the palmar suture-passing location is to use the palmar border of the TFCC disc between the lunate and triquetrum, which was identified distally. These suture-passing locations were also just ulnar to the midpoint between the sigmoid notch and the ulnar capsule (Waitayawinyu et al., 2023). A horizontal mattress suture was created by passing a 70° Micro SutureLasso (Arthrex, Naples, FL, USA) via the 4–5 portal, inserting with inside-out fashion through the palmar TFCC suture location and grasped a 2–0 FiberWire (Arthrex, Naples, FL, USA) from the DF portal and passed the suture from the palmar TFCC suture location out through the dorsal TFCC suture location to the DF portal. For isolated reattachment, a horizontal mattress TFCC suture was placed across the palmar or dorsal TFCC suture locations and halfway between them (Figure 4). The suture was placed parallel to the radial border of the prestyloid recess, allowing for symmetrical grasping of the PRUL and DRUL. The two tails of the TFCC suture were then grabbed from the DF portal.

Foveal reattachment with anchor

To create an insertion hole for the suture anchor, a K-wire was passed through the DF portal and inserted into the prepared foveal insertion site (1.6 mm wire for 2.5 mm anchor and 2.0 mm wire for 2.9 mm anchor). The 1.2 mm K-wire was then inserted in place of the 1.6 or 2.0 mm wire for ease of switching for foveal anchor insertion. Two ends of suture were threaded through the eye of a 2.5 or 2.9 mm knotless suture anchor (Mini PushLock; Arthrex, Naples, FL, USA). After release of wrist traction, the DRUJ was reduced and held steadily in neutral wrist position. The K-wire was removed, and the anchor was inserted at the K-wire hole with the suture tails tightened. Gentle tapping of the tag portion of the anchor was used to secure the suture at the fovea (Figure 5). The ulnar DRUJ capsule and extensor retinaculum were repaired in a vest-over-pants fashion.

Postoperative treatment protocol

A bulky dressing with a slab above the elbow was applied with the wrist in a neutral position for one week. Active finger movement was encouraged. After the swelling had subsided and the skin sutures had been removed, the patient was immobilized in a Muenster-type cast or splint for a further 4–5 weeks. After removal of the splint, active wrist range of motion exercises were started. Resumption of regular activities and rehabilitation protocol with gentle passive range of motion and strengthening

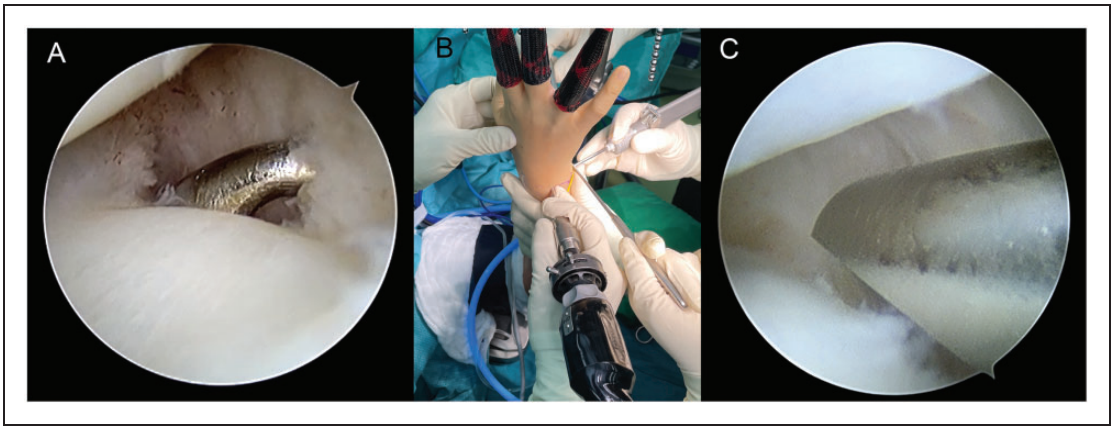

Figure 1. Foveal footprint preparation techniques. (a) Preparation through prestyloid recess using a small joint curette and (b, c) Foveal debridement with a small joint shaver through the direct foveal portal, monitoring from the distal radioulnar joint (DRUJ) portal.

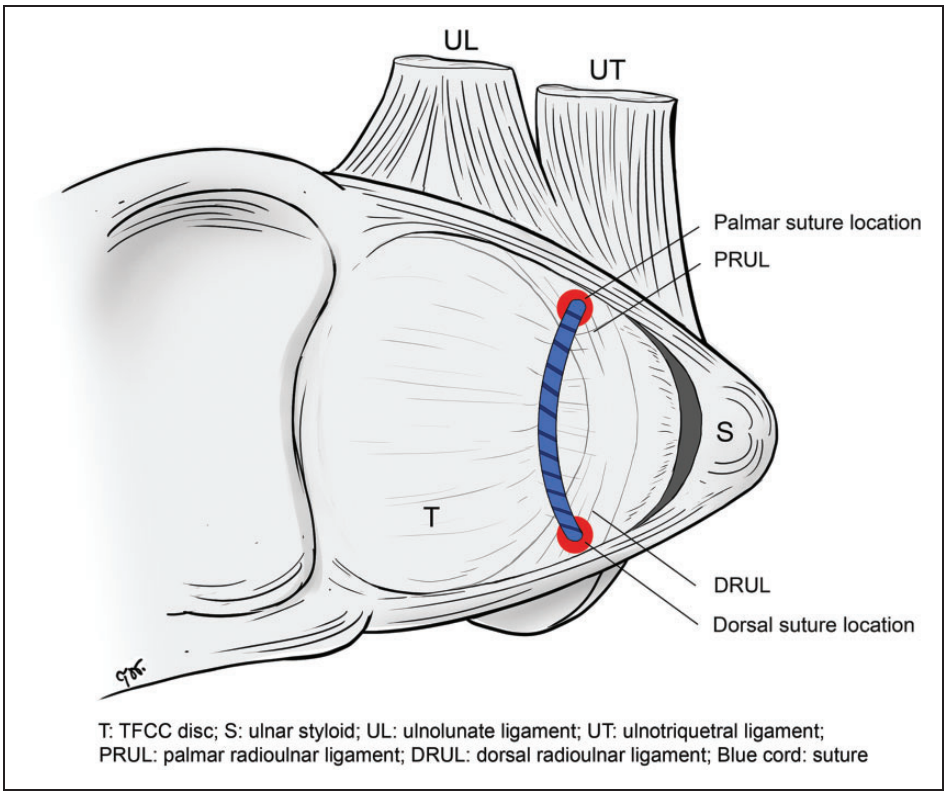

Figure 2. Illustration demonstrates the outline of ulnocarpal anatomical landmarks and triangular fibrocartilage complex (TFCC) suture-passing locations.

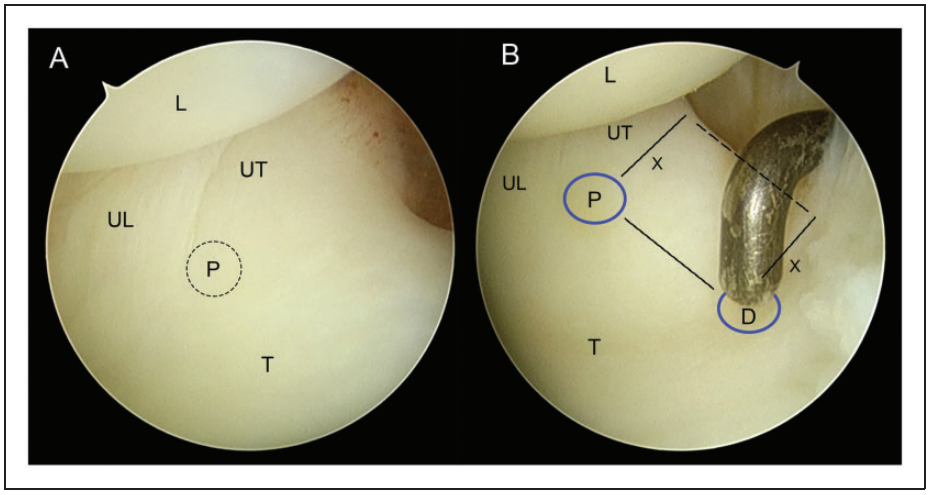

Figure 3. Triangular fibrocartilage complex (TFCC) suture-passing locations. (a) The palmar location (P) is at the intersection of the palmar border of the TFCC disc (T), the ulnolunate (UL), and ulnotriquetral (UT) ligaments and (b) The dorsal location (D) is at the dorsal border of the TFCC disc opposite the palmar location (P) at a point equidistant (X) from the dorsal or palmar location and the radial border of the prestyloid recess (dashed line).

exercises was started 10–12 weeks after surgery. Exercise and partial-weight-bearing weight training was allowed 3 months after surgery. Full-weight training and other high-impact sports involving the wrist were allowed 6–8 months after surgery.

Preoperative and postoperative assessments

Before surgery, wrist pain was assessed using a visual analogue scale pain score ranging from 0

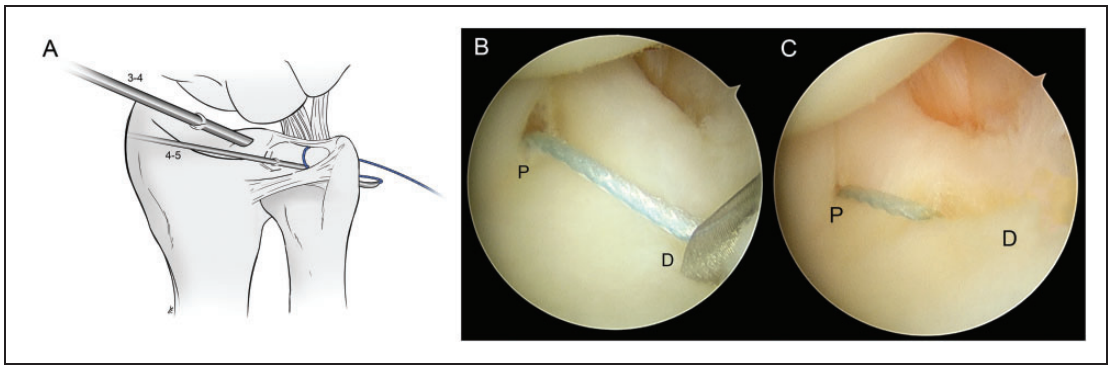

Figure 4. Triangular fibrocartilage complex (TFCC) suture-passing. (a, b) palmar radioulnar ligament (PRUL) and dorsal radioulnar ligament (DRUL) reattachment; a horizontal mattress suture is passed through the palmar (P) and dorsal (D) suture locations and (c) Isolated PRUL reattachment.

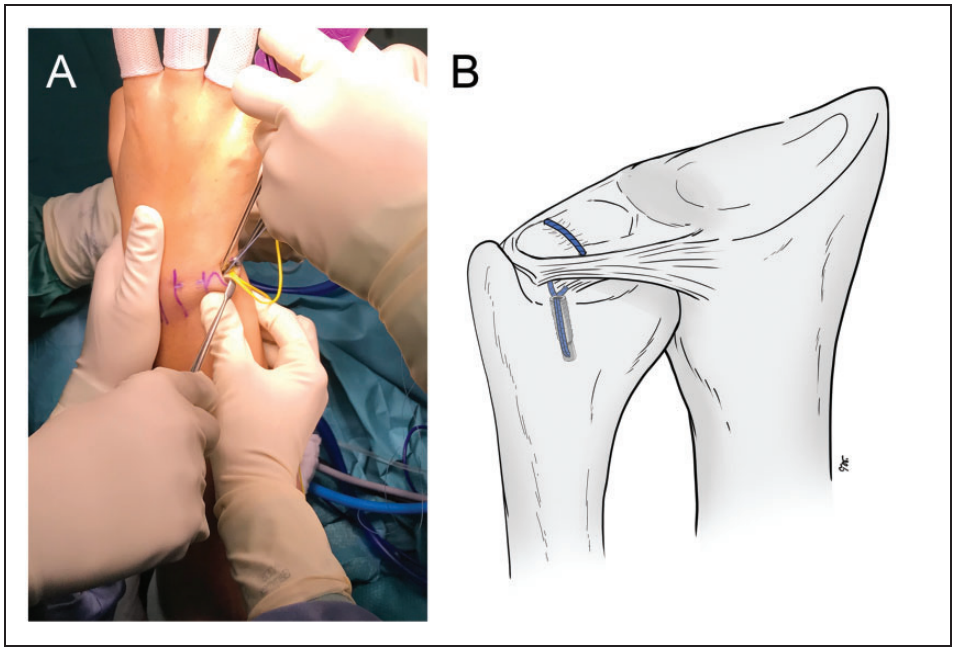

Figure 5. Insertion of the suture anchor. (a) The distal radioulnar joint (DRUJ) is reduced and maintained while tensioning the suture and tapping the anchor and (b) Illustration demonstrates the position of the secured suture with the anchor.

(no pain) to 10 (maximum pain). Wrist symptoms and disability were assessed using the Disabilities of the Arm, Shoulder and Hand (DASH) score (Hudak et al., 1996). For objective assessments, wrist range of motion and grip strength were quantified using a standard goniometer and a Jamar hydraulic hand dynamometer (Asimow Engineering, Los Angeles, CA, USA), respectively (Klum et al., 2012). In addition, the Modified Mayo Wrist Score (MMWS) was used to grade each wrist (Cooney et al., 1987). The contralateral limb was also measured for comparison. All assessments were performed by a hand surgeon who was not involved in the procedure. At the final follow-up, all parameters, including DRUJ stability, were reassessed by the same investigator. Any operative complications were recorded.

Statistical analysis

The normal distribution of the data was assessed using the Shapiro–Wilk test. The paired *t*-test was used to compare the parameters before and after surgery. Outcome data from a group of patients with isolated RUL reattachment and a group of patients with PRUL and DRUL reattachment were compared using paired and independent *t*-tests. For clinical detection, the minimum clinically important difference (MCID) threshold of 13.5 points for

each patient's DASH score was also evaluated (Harris et al., 2017; Kim and Park, 2013). A *p*-value of <0.05 was considered to be statistically significant.

Results

Between September 2017 and July 2020, 52 patients underwent surgery for DRUJ instability at our institution. Six patients with irreparable TFCC tear, two patients with malunited distal radius, one patient with rheumatoid arthritis and five patients with less than 24 months of follow-up were excluded. Thirty-eight patients underwent arthroscopic TFCC foveal reattachment as described. The patients' demographic data are shown in Table 1.

The pre- and postoperative outcome parameters are shown in Table 2. All parameters improved significantly after surgery ($p<0.001$). Comparisons of mean differences in pre- and postoperative parameters between a group of patients who had isolated PRUL reattachment and those who had PRUL and DRUL reattachment are shown in Table 3. Mean grip strength and percentage of contralateral grip strength improved significantly in the PRUL and DRUL reattachment group ($p<0.05$). Pre- to postoperative improvements in pain, range of motion, DASH score and MMWS were not significantly different between these two groups.

At final follow-up, all patients had a stable DRUJ. All patients reached the MCID threshold for the DASH score. According to the MMWS, 22 patients had an excellent outcome, and 16 had a good outcome. Overall, the mean postoperative MMWS was 92.5 (SD 5.54). All patients were able to return to their normal activities without the need for reoperation. At 6 months, 27 patients had fully resumed sports activities, including goalkeeping, yoga, weight training, cycling, tennis and badminton. Two patients returned to full-weight training and tennis competition at 8 months. The remaining nine did not participate in any sports activities. Postoperatively, two patients had hypersensitivity and tingling over the dorsoulnar aspect of the hand. In both patients this symptom resolved within three months.

Table 1. Patients' demographic data

Age (years) (mean, range)	36, 19–54
Time from injury to surgery (months) (mean, range)	12, 4–22
Follow-up time (months) (mean, range)	32, 26–44
	No. of patients
Male:female	28:10
Side (right:left)	26:12
Dominant hand injury	29
Atzei and Luchetti classification (class 2:class 3)	6:32
Severity of DRUJ instability (moderate:severe)	9:29
Both PRUL and DRUL tears:isolated PRUL tears	33:5

DRUJ, Distal radioulnar joint; DRUL, dorsal radioulnar ligament; PRUL, palmar radioulnar ligament.

Discussion

The arthroscopic inside-out foveal reattachment technique using TFCC suture locations at designated ulnocarpal anatomical landmarks provided significant improvements in pain, grip strength, functional outcomes and restoration of DRUJ stability in all patients.

Regarding the TFCC suture-passing, few studies have proposed the inside-out technique for TFCC foveal reattachment. Tang et al. (2012) reported an

Table 2. Preoperative and postoperative outcome parameters

Outcome measures	Preoperative	Postoperative	Mean difference (95% CI)	*p*-Value
VAS pain score	6 (1)	1 (1)	−4.5 (−4.9 to −4.0)	<0.001*
Wrist range-of-motion				
Flexion-extension	118° (12)	125° (8)	6.8 (3.5–10.2)	<0.001*
Percentage of contralateral flexion-extension	91 (8)	96 (7)	5.4 (2.7–8.0)	<0.001*
Pronation-supination	154° (15)	167° (8)	12.6 (8.5–16.8)	<0.001*
Percentage of contralateral pronation-supination	89 (8)	97 (5)	7.3 (4.9–9.8)	<0.001*
Grip strength (kg)	23 (5)	31 (5)	7.8 (6.4–9.3)	<0.001*
Percentage of contralateral grip strength	71 (13)	96 (9)	24.4 (20.7–28.2)	<0.001*
DASH	43 (10)	9 (5)	−34 (−37.1 to −31.0)	<0.001*
Modified Mayo Wrist Score	71 (8)	93 (6)	22 (19.1–24.9)	<0.001*

Data are presented as mean (standard deviation).
*Paired *t*-test.
CI, Confidence interval; VAS, visual analogue scale; DASH, Disabilities of the Arm, Shoulder and Hand.

Table 3. Outcome analysis between groups with different RUL reattachment

Outcome measures	Isolated palmar RUL reattachment ($n=5$)		Palmar and dorsal RULs reattachment ($n=33$)		
	Mean difference (95% CI)	*p*-Value	Mean difference (95% CI)	*p*-Value	*p*-Value
VAS pain score	−4 (−6.2 to −2.2)	0.005*	−4 (−5.0 to −4.0)	<0.001*	0.67
Wrist range-of-motion					
Flexion-extension	6° (−5.1–17.1)	0.21	7° (3.3–10.7)	0.001*	0.85
Percentage of contralateral flexion-extension	5 (−4.0–13.0)	0.21	6 (2.6–8.5)	0.001*	0.80
Pronation-supination	12° (−10.2–34.2)	0.21	13° (8.5–17.0)	<0.001*	0.91
Percentage of contralateral pronation-supination	7 (−5.8–19.6)	0.21	7 (4.9–9.9)	<0.001*	0.88
Grip strength (kg)	4 (2.5–5.5)	0.002*	8 (6.9–9.9)	<0.001*	<0.001*
Percentage of contralateral grip strength	13 (5.5–21.3)	0.009*	26 (22.2–30.0)	<0.001*	0.017*
DASH	−36 (−49.4 to −22.3)	0.002*	−34 (−37.0 to −30.5)	<0.001*	0.64
Modified Mayo Wrist Score	16 (5.8–26.2)	0.012*	23 (19.8–25.9)	<0.001*	0.10

p-Values were calculated using a paired *t*-test and an independent *t*-test.
RUL, Radioulnar ligament; VAS, visual analogue scale; CI, confidence interval; DASH, Disabilities of the Arm, Shoulder and Hand.

inside-out TFCC repair in five patients with a short follow-up period of 8 months. This technique necessitates the use of a meniscal double-barrel cannula for suture-passing. Insertion of the cannula, which is relatively large, is associated with the risk of cartilage injury, especially to the lunate cartilage. Furthermore, the fixed curve and fixed distance between the two holes of the cannula limit the locations and direction of suture-passing. Fujio (2017) used an innovative single-lumen curved guide for drilling with a stitcher needle through the TFCC, fovea, and the ulnar cortex. This procedure involved a technical complexity of drilling and passing the suture using the surgeon's special instrument.

The advantages of the inside-out TFCC suture-passing technique used in the current study include the ability to simply locate the suture-passing location and pass the suture in one attempt. The straightforward and precise suture-passing can lessen soft tissue injury, particularly to the TFCC disc. This technique is also more efficient for passing the suture over the floppy or floating TFCC disc and RULs in cases of DRUJ instability, which can be difficult when using the outside-in method (Luchetti et al. 2014; Nakamura et al., 2011; Park et al. 2018; Shinohara et al., 2013). Another advantage is using the 70° Micro SutureLasso through the 4–5 portal while the arthroscope is at the 3–4 portal. This can reduce the risk of lunate cartilage injury and provide a wide angle for suture insertion without obstruction from the arthroscope at the 3–4 portal. Moreover, the technique allows grasping the TFCC and RULs to the foveal area without exposure of the extensor carpi ulnaris tendon sheath floor or 6U portal area, as required in previously described techniques (Chen, 2017; Luchetti et al. 2014).

Viewing from the standard radiocarpal arthroscopy, passing the inside-out suture through these TFCC suture locations obviates the necessity for the technically demanding DRUJ arthroscopy to monitor the RUL suture-passing. Sutures passed through these reliable locations can secure the RULs to the broad foveal footprint over the ulnar head (Shin et al., 2017). Moreover, the suture through the palmar suture location can grasp the PRUL and the UCLs simultaneously. Therefore, this perpendicular structure which aids in stabilizing the ulnar head can be secured.

In our study, postoperative improvement in pain, range of motion, DASH score and MMWS did not significantly differ between the group of patients having isolated PRUL reattachment and the group with PRUL and DRUL reattachment; however, grip strength improvement was significantly greater in the latter. Accordingly, DRUJ stability can be achieved with selective reattachment of an isolated dorsal or palmar RUL tear. Our findings regarding the ligament-specific repair for TFCC foveal avulsions correspond with the study proposed by Liu et al. (2021).

Suturing to a bone anchor that is inserted directly into the fovea through the DF portal is technically easy and requires only minimal dissection over the ulnar aspect of the wrist. In addition, no targeting device placement over the TFCC disc is required. This procedure also avoids drilling through the distal ulna and the use of fluoroscopy as opposed to the transosseous/bone tunnel technique. Nonetheless, TFCC suture-passing using the

inside-out technique through the designated location in this study can also be used in conjunction with transosseous/bone tunnel technique. Although securing a horizontal mattress suture with an anchor has the disadvantage of squeezing the surface of the articular disc, the thickness of the articular disc's border and the RULs beneath can withstand the pulling force from the suture anchor and retain the grasping suture in place.

Two patients reported transient numbness in the region of the dorsal branch of the ulnar nerve, which was also reported in previous studies (Afifi et al., 2022; Atzei et al., 2008; Atzei, 2009; Nakamura et al., 2011; Shinohara et al., 2013; Tang et al., 2012).

This study has limitations. First, this was a retrospective study and examined a single surgical technique without a control group. Second, the small number of patients in the isolated PRUL reattachment group may have affected the evaluation of differences between groups. However, the mean difference in grip strength between groups was proportionately large with no overlap of 95% confidence interval. Further large-scale comparative study including the patients with isolated DRUL reattachment is recommended.

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Supplementary material Supplemental material for this article is available online.

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