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Arthroscopically assisted repair of foveal triangular fibrocartilage complex tear using modified "double loop suture" – a retrospective cohort study

Wen Zheng[1], Ling Long Zhao[1*], Xue Jun Yu[1], Peng Li[1], Sheng Tao Xiang[1] and Wen Liang Cao[1]

Abstract

Background The triangular fibrocartilage complex (TFCC) plays an important role in distal radioulnar joint (DRUJ) stabilization, and is frequently torn. In particular, when conservative treatment fails, surgical treatment is needed.

Methods In this retrospective study, fourteen individuals with TFCC foveal tears and DRUJ instability were admitted to the department and treated with arthroscopic-assisted modified "double loop suture" transosseous repair between January 2021 and 2023. During surgery, an osseous tunnel was established, and two nickel-based alloy loops and a 2–0 polydioxanone II (PDS II) suture were used to achieve anatomic repair of the tear. All patients received supervised rehabilitation exercises after surgery.

Results The patients were followed for an average of 15 months. The mean visual analog scale (VAS) score, which was used to assess the pain intensity experienced by patients using their affected hand, significantly decreased from 5 (95% CI 4–6) points preoperatively to 2 (95% CI 1–3) points at the final follow-up ($p < 0.05$). The grip strength and Disabilities of the Arm, Shoulder, and Hand (DASH) score before surgery were 17 (95% CI 13–22) kg and 35 (95% CI 26–44) points, respectively, compared with 21 (95% CI 16–25) kg and 16 (95% CI 9–22) points at the final follow-up ($p < 0.05$). The median Patient-Rated Wrist Evaluation (PRWE) score was 28 (IQR 21, 48) before surgery, which then significantly decreased to 10 (IQR 6, 15) at the final follow-up. The mean flexion–extension range of the wrist significantly increased from 111 (95% CI 100–122) degrees before surgery to 116 (95% CI 106–126) degrees postsurgery ($p < 0.05$), and the mean pronation–supination range of the forearm significantly improved from 125 (95% CI 110–140) degrees to 135 (95% CI 121–149) degrees at the final follow-up assessment ($p < 0.05$). None of the assessed individuals exhibited DRUJ instability, as evaluated by the ballottement test or developed surgery-related complications such as postoperative infection, injury to the dorsal branch of the ulnar nerve or iatrogenic ulnar styloid fracture caused by the establishment of an osseous tunnel.

Conclusion Arthroscopic-assisted modified "double loop suture" is a secure and efficient approach for achieving anatomic repair of TFCC foveal tears, with satisfactory functional improvement and DRUJ stability restoration.

Keywords Triangular fibrocartilage complex, Wrist, Arthroscopy, Injury, Repair

*Correspondence:
Ling Long Zhao
linglongzhao521@sina.com
[1] Department of Hand Surgery, Norinco General Hospital, Xi'an, China

Background

The triangular fibrocartilage complex (TFCC) is composed of the articular disc, ulnar collateral ligament, meniscus homolog, sheath of the extensor carpi ulnaris

(ECU), and dorsal and volar radioulnar ligaments (d-RUL and v-RUL) [1]. The TFCC is separated into the proximal component (pc-TFCC), which functions as the primary stabilizer for maintaining the distal radioulnar joint (DRUJ) and the distal component (dc-TFCC) [2]. TFCC ulnar tears, classified as Palmer 1B injuries according to Palmer [3], can cause DRUJ instability, especially when such injuries involve pc-TFCC, also known as foveal tears. They are classified as European Wrist Arthroscopy Society (EWAS) II or III injuries, according to Atzei et al. [2].

Given the abundant peripheral blood supply of the TFCC, peripheral tears can potentially heal after repair [4] and DRUJ stability can be restored. Previous studies have demonstrated that transosseous suture repair of TFCC foveal tears using various methods can restore DRUJ stability with satisfactory functional improvement [5–9]. According to Nakamura et al., the TFCC foveal insertion footprint is broad [10]; hence, multiple sutures or ligament-specific repairs are required to achieve anatomical repair of the TFCC foveal tear [11, 12].

Originally proposed by Bonte and Mathoulin, the "double loop suture" is used for treating a large tear located in the dorsal portion of the TFCC, in conjunction with an avulsed radiocarpal capsule [13]. In this study, the "double loop suture" was modified and used to repair TFCC foveal tears. The objective of this study was to investigate the feasibility of using the modified "double loop suture" technique for repairing TFCC foveal tears, while also assessing the short-term efficacy of this technique.

Patients

The criteria for inclusion were as follows: (1) patients with ulnar-sided wrist pain and positivity for foveal signs and DRUJ instability (as confirmed by the ballottement test); (2) negative X-ray findings and positive MRI findings for a TFCC foveal tear; (3) failure of initial conservative treatment, which included long-arm splinting for immobilization and oral nonsteroidal anti-inflammatory therapy for two months; (4) TFCC foveal tears repaired by the modified "double loop suture" and (5) completion of a follow-up duration of > 6 months. The exclusion criteria were as follows: (1) TFCC foveal tear not repaired by the modified "double loop suture"; (2) diagnosis of arthritis involving the wrist, whether inflammatory (i.e., rheumatoid, gout, etc.) or noninflammatory; (3) diagnosis of other wrist disorders, such as ulnar impaction syndrome and carpal bone malalignment/malunion/nonunion; (4) TFCC injury combined with scapholunate and/or lunotriquetral ligament injury and (5) < 6 months of follow-up.

Fourteen individuals with TFCC foveal tear and DRUJ instability were admitted to the department and treated with arthroscopic-assisted modified "double loop suture" transosseous repair between January 2021 and 2023. A senior hand surgeon classified as level III (specialist–experienced) according to Tang's classification conducted all the surgeries [14].

The work was approved by the ethical committee of our department. All the patients provided their consent for the surgery and follow-up, which led to the results of this study. All participants provided informed written consent. The work has been reported in line with the Strengthening the Reporting of Cohort, Cross-Sectional and Case–Control Studies in Surgery (STROCSS) criteria [15]. This study was approved by the Ethical Committee (Department of Medical Affairs) of Norinco General Hospital, Xi′an, China on 30 November 2021(ethics review number: 2021xm007).

Methods of assessment

Outcomes were assessed before surgery and at the final follow-up. These included wrist range of motion (ROM), grip strength measured utilizing a calibrated Jamar hydraulic hand dynamometer (Asimov Engineering, Los Angeles, CA, US), pain during use of the affected hand assessed with a 10-point visual analog scale (VAS), the Patient-Rated Wrist Evaluation (PRWE), and the Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire. DRUJ stability and surgery-related complications were also assessed. The stability of the DRUJ was evaluated using the ballottement test in three different forearm positions: neutral, full supination and pronation. During the execution of the ballottement test, clinically unstable DRUJ is characterized by a "soft" endpoint, whereas uninjured DRUJ is characterized by a firm endpoint [16].

Surgical methods

Each individual was placed in the supine position. Following brachial plexus anesthesia, application of a pneumatic tourniquet, routine disinfection, and laying towel, the affected limb was placed on a hand surgery table adjacent to the operation bed. The shoulder was abducted to 90 degrees, and the elbow was flexed to 90 degrees. The index, middle, and ring fingers were suspended on a vertical traction tower (Linvatec, Largo, FL, USA) by three sterile finger traps. These traps were equipped with a 5 kg traction weight. The standard 3–4 and 6R portals were established for arthroscopic surgery, and the 6U portal was established for excretion. With the arthroscope placed in the 3–4 portal and a shaver or a radiofrequency placed in the 6R portal, a synovectomy was performed. Palmer 1A or 1D injury, if present, was treated by debridement. A foveal tear was indicated by a positive hook test employed during the arthroscopic assessment of TFCC tears. DRUJ arthroscopy was not required to further confirm the tear (Fig. 1) [17].

After the TFCC foveal tear was confirmed arthroscopically, the modified "double loop suture" was performed through the following steps. First, a 2-cm skin incision was made longitudinally on the ulnar side of the wrist, from the tip of the ulnar styloid extending proximally along the ulnar border of the distal ulna. Second, between the ECU and flexor carpi ulnaris, an osseous tunnel was created from the distal ulnar to the fovea using a 1.5-mm K-wire, whose exit point was monitored arthroscopically (Fig. 2a). Third, a needle loaded with a 2–0 polydioxanone (PDS) II suture penetrated through the v-RUL at the volar side of the fovea and was inserted into the joint (Fig. 2b). Fourth, two additional needles were used to introduce two nickel alloy loops into the joint through the osseous tunnel and the d-RUL at the dorsal side of the fovea (Fig. 2c). Fifth, all the needles were withdrawn. Using a suture grasper, the PDS II suture was retrieved from the 6R portal after passing through the two loops (Fig. 2d). Sixth, the two loops were retrieved, with the transosseous loop carrying the middle portion of the 2–0 PDS II suture out through the osseous tunnel to form two strands, and the other loop carrying the end of the PDS II suture out through the d-RUL. Seventh, the middle portion of the PDS II suture was cut using scissors to form two sutures at the fovea, one at the volar side and the other at the dorsal side (Fig. 2e). Finally, the two sutures were tied, and the traction was released (Fig. 2f). All incisions were closed with a 5–0 absorbable suture. The affected limb was immobilized with a long arm cast in a rotational neutral position.

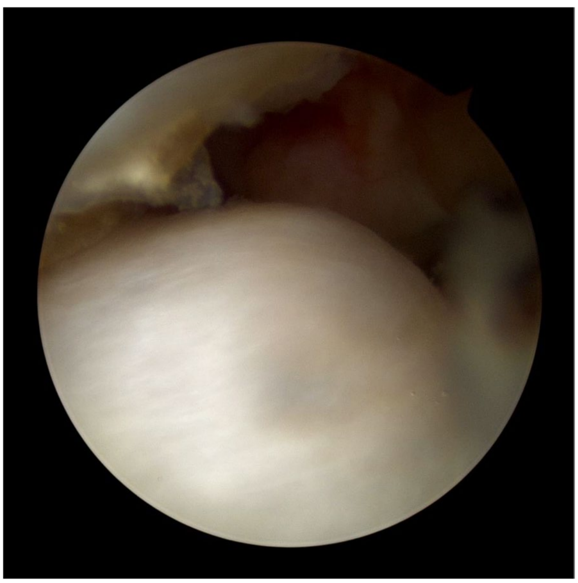

Fig. 1 Intraoperative arthroscopic image showing the elevated ulnar side of the TFCC, indicating a positive hook test and foveal tear diagnosis. TFCC, triangular fibrocartilage complex

Postoperative treatment and rehabilitation

One week after surgery, the patients wore a custom-made brace that allowed flexion and extension of the elbow and wrist but restricted forearm rotation, replacing the original cast. From the fourth week postoperatively, the brace was removed so that the patient could initiate half-range pronation and supination exercises and was replaced after the exercises. From the seventh week postsurgery, a full range of pronation and supination exercises was permitted. The brace was not completely removed until 8 weeks postoperatively. Isometric strengthening exercises were started approximately 3 months after the surgery. The patients were permitted to resume contact sport activities 6 months postoperatively.

Statistics

A normality test was executed for quantitative data using the Shapiro–Wilk test, with significance defined at 0.10. Normally distributed data was presented as the

(See figure on next page.)

Fig. 2 **a** An osseous tunnel was established using a 1.5-mm K-wire. The left image shows the entry point of the K-wire, and the right image shows its exit point, which was monitored arthroscopically using the arthroscope placed in the 3–4 portal. **b** A needle loaded with a 2–0 PDS II suture penetrated through the v-RUL at the volar side of the fovea and was inserted into the joint to introduce the PDS II suture into the joint. The left image shows the arthroscopic conditions, the middle image shows the intraoperative appearance, and the right image shows the schematic diagram. PDS II, polydioxanone II; v-RUL, volar radioulnar ligaments. **c** Two nickel alloy loops were introduced into the joint through the osseous tunnel and d-RUL at the dorsal side of the fovea, using two additional needles. Note that the two loops cannot cross through each other. The left image shows the arthroscopic conditions, the middle image shows the intraoperative appearance, and the right image shows the schematic diagram. d-RUL, dorsal radioulnar ligaments. **d** All needles were withdrawn, and the PDS II suture was retrieved by a grasper from the 6R portal after passing through the two loops. The left image shows the arthroscopic conditions, the middle image shows the intraoperative appearance, and the right image shows the schematic diagram. **e** Both loops were retrieved, carrying the middle and end of the PDS II suture out of the joint through the osseous tunnel and the d-RUL, respectively, with the former forming 2 strands. The volar and dorsal sutures of the fovea were formed after the middle portion of the PDS II suture was cut using scissors. The left image shows the arthroscopic conditions, the middle image shows the intraoperative appearance, and the right image shows the schematic diagram. **f** Repair was completed after the sutures were tied, with the traction released. The left image shows the arthroscopic conditions, and the right image shows the intraoperative appearance

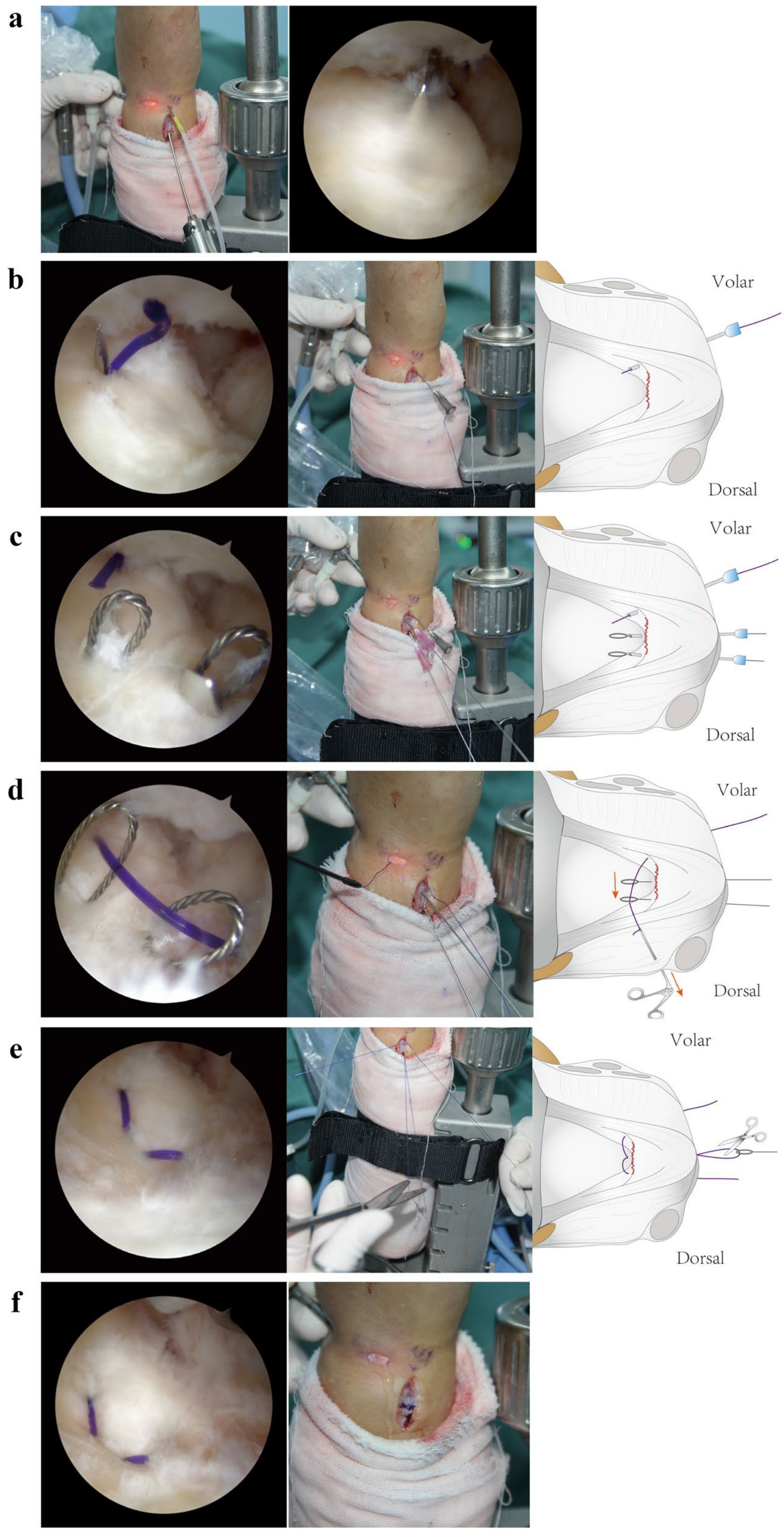

Fig. 2 (See legend on previous page.)

means with 95% confidence intervals (CI), and non-normally distributed data as medians with interquartile range (IQR). The variations between preoperative and postoperative data were assessed using paired t-tests in cases where the data conformed to a normal distribution. Alternatively, the Wilcoxon signed-rank test was employed for non-normally distributed data. Two-tailed tests were employed throughout the analysis, and the significance level was defined at 0.05.

Results

Among the 14 patients included in this study, six were male, whereas eight were female, with a mean age of 40 years (ranging from 20 to 60 years) and a mean follow-up duration of 15 months (ranging from 7 to 24 months). On the basis of the findings of arthroscopy, in addition to foveal tears, 3 patients had additional Palmer type 1D TFCC tears (numbers 1, 3, and 7), and 2 patients had additional Palmer type 1A TFCC tears (numbers 5 and 11). Both Palmer type 1A tears and type 1D tears were managed by arthroscopic debridement, whereas foveal tears were repaired using the techniques described in this study.

In terms of functional assessment, the mean VAS-based pain scores, grip strength, and DASH scores before surgery were 5 (95% CI: 4–6) points, 17 (95% CI: 13–22) kg, and 35 (95% CI: 26–44) points, respectively. At the final follow-up, these values changed to 2 (95% CI 1–3) points, 21 (95% CI 16–25) kg, and 16 (95% CI 9–22) points, respectively, with significant differences. The median PRWE score was 28 (IQR 21, 48) before surgery and 10 (IQR 6, 15) at the final follow-up, and the difference was significant. In terms of ROM, the mean flexion–extension range of the wrist significantly increased from 111 (95% CI 100–122) degrees before surgery to 116 (95% CI 106–126) degrees at the final follow-up ($p < 0.05$), and the mean pronation–supination range of the forearm significantly increased from 125 (95% CI 110–140) degrees before surgery to 135 (95% CI 121–149) degrees at the final follow-up ($p < 0.05$). During the final follow-up, none of the patients developed DRUJ instability, as evaluated using the ballottement test, and no patients experienced surgery-related complications. The demographic data and assessments at the preoperative and final follow-ups are presented in Tables 1 and 2, respectively.

Discussion

The TFCC plays an important role in DRUJ stabilization [18, 19]. According to previous studies, TFCC transosseous repair is more effective in restoring DRUJ stability than in capsular repair is [19]. A systematic review of cadaver studies by Koeyvoets et al. revealed that, compared with suture anchor repair and peripheral capsular repair, transosseous tunnel repair yielded greater stability for the DRUJ and stronger TFCC repair [20]. Gietzen et al. studied the morphology of the ulna fovea using wrist computed tomography arthrography and reported that the mean length and anterior–posterior diameter was 6.89 ± 2.36 and 5.05 ± 1.97 mm, respectively [21]. They reported that the v-RUL and d-RUL possess wide

Table 1 Demographic data of the patients

No	Sex	Age (years)	Follow-up (months)	L/R	VAS		Grip (kg)		PRWE		DASH		Flexion-Extension (°)		Pronation—supination (°)	
					Preop	Final	Preop	Final	Preop	Final	Preop	Final	Preop	Final	Preop	Final
1	F	32	13	R	6	4	8.4	8.2	73	19	65	33	82	90	86	96
2	F	30	11	L	5	2	9.2	14.6	42	10	36	9	96	105	89	121
3	F	57	16	R	5	2	7.3	12.2	70	45	55	36	79	83	133	148
4	M	32	20	R	3	0	10.0	9.8	19	7	16	0	124	133	156	150
5	M	28	9	R	4	1	26.2	25.7	60	34	38	21	117	128	124	139
6	M	52	22	L	4	0	12.4	18.9	25	8	32	15	105	108	165	172
7	F	46	13	L	7	3	10.0	15.8	25	11	61	33	93	97	146	139
8	F	54	15	R	2	2	13.1	22.3	30	13	37	18	112	121	118	145
9	M	51	24	R	5	3	34.9	33.0	19	5	35	4	135	130	110	131
10	F	24	7	R	6	0	21.0	27.7	21	4	26	15	118	118	128	125
11	F	60	15	R	2	2	20.0	23.1	23	10	16	2	106	115	152	150
12	M	34	12	R	5	0	23.6	19.7	32	6	24	17	122	116	146	170
13	F	20	17	L	9	5	24.0	30.6	44	12	27	8	142	137	96	104
14	M	34	20	R	3	2	22.4	28.4	20	5	25	6	122	141	99	95

F Female, *M* Male, *L* Left, *R* Right, *Preop* Preoperation, *VAS* Visual Analog Scale, *PRWE* Patient-Rated Wrist Evaluation, *DASH* Disabilities of the Arm, Shoulder, and Hand questionnaire

Table 2 Assessments before surgery and at the final follow-up

Assessment	Preoperation	Final follow-up	*p* value
VAS$^{\Delta}$	5 ± 2	2 ± 2	0.000*
Grip Strength$^{\Delta}$ (kg)	17 ± 8	21 ± 8	0.007*
PRWE ▫	28 (21, 48)	10 (6, 15)	0.001*
DASH$^{\Delta}$	35 ± 15	16 ± 12	0.000*
Flexion- Extension$^{\Delta}$ (°)	111 ± 19	116 ± 18	0.022*
Pronation—supination$^{\Delta}$ (°)	125 ± 26	135 ± 24	0.015*

VAS visual analog scale for pain during activities of daily living (e.g., wringing out towels, unscrewing caps from unopened bottles, using a knife to cut vegetables, and lifting heavy objects), an instrument employed to quantify the pain intensity experienced by patients using their affected hand

PRWE Patient-Rated Wrist Evaluation

DASH Disabilities of the Arm, Shoulder, and Hand Questionnaire

$^{\Delta}$ Normally distributed data are presented as the means ± standard deviations

▫ Nonnormally distributed data are presented as IQRs (25th percentile, 75th percentile)

* $p < 0.05$

[a] Paired *t*-test

[b] Wilcoxon signed rank test

and distinct individual insertion areas. An anatomical study by Shin indicated that the deep limbs (i.e., pc-TFCC) have broad marginal insertions at the fovea [22], which was consistent with the findings of the study by Liu et al. [12].

Overall, all these studies suggest that multiple-loop times sutures rather than a single-loop suture are needed for the anatomical repair of complete TFCC foveal tears. The modified "double-loop suture" utilized in this study uses two sutures to achieve anatomic repair. Several reports on the repair of TFCC tears using multiple sutures have been published previously. Notably, Soliman et al. introduced a modified technique for repairing the EWAS I lesion of the TFCC using a single strand to achieve two sutures [23]. Nakamura et al. reported an arthroscopically assisted transosseous outside-in approach for TFCC reattachment. This approach involved the use of two separate 1.2-mm osseous tunnels with two sutures [10].

Compared with the previous "double-loop suture," the present method has the following advantages. First, it could be implemented in the transosseous repair of TFCC foveal tears, whereas the original method was only applicable to the capsular repair of TFCC dorsal tears. Second, 1 suture and 2 loops were used in the current method, whereas 2 sutures and 1 loop were used in the original method. It is believed that when the loop, which is formed by a single wire and carries two PDS II sutures (four strands), passes through the TFCC, it has the risk of breaking. However, in this technique, each loop carries only two strands of the PDS II suture when passing through the TFCC, resulting in a reduced risk of loop breakage. In addition, compared with the wire loop, the nickel alloy loop is less likely to break when it passes through the TFCC with a PDS II suture. The two loops do not cross each other in the joint, preventing the PDS II suture from winding itself while being retrieved, which is one of the key points of this technique. Nonetheless, this study has several limitations, including its small sample size, short follow-up time, and lack of comparison.

In this study, the mean preoperative pain score of the patients was 5 points, which decreased to 2 points at the last follow-up, representing a 3-point reduction. This decrease surpassed the minimum clinically important difference (MCID) of 2 points proposed by Farrar and Salaffi for pain evaluation using the Numeric Rating Scale (NRS) score [24, 25]. Additionally, the DASH score at the last follow-up was 16 points, a significant reduction of 19 points from the preoperative score of 35 points. This improvement met Franchignoni's reported MCID for DASH, which was 18 points [26]. It is important to note that these MCID criteria are not specifically tailored for joints with TFCC injuries but are currently the best available reference standards. Regarding other outcome indicators, including grip strength, PRWE score, wrist flexion–extension range, and forearm pronation-supination range, no prior studies have provided reference data.

Conclusion

This modified "double- loop suture" is a secure and efficient technique for achieving anatomical repair of TFCC foveal tears with satisfactory functional improvement and restoration of DRUJ stability.

Abbreviations

TFCC	Triangular fibrocartilage complex
DRUJ	Distal radioulnar joint
PDS II	Polydioxanone II
VAS	Visual Analog Scale
DASH	Disabilities of the Arm, Shoulder, and Hand
ECU	Extensor carpi ulnaris
EWAS	European Wrist Arthroscopy Society

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Authors' contributions

Material preparation, data collection and analysis were performed by P Li; S T Xiang; W L Cao. The first draft of the manuscript was written by W Z; L L Zhao; X J Yu, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets used and/or analysis during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
All procedures performed in research involving human participants are in accordance with the ethical standards of the institutional and/or National Research Councils and the 1964 Declaration of Helsinki and its later amendments or similar ethical standards. This study was provided by the Ethical Committee (Department of Medical Affairs) of Norinco Gerenal Hospital, Xi´an, China on 30 November 2021.Ethics Review number: 2021xm007. Confirm that informed consent has been obtained from all subjects and/or their legal guardians.

Consent for publication
Written informed consent was obtained from the patient for publication of this case report and accompanying images.

Competing interests
The authors declare no competing interests.

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