Clinical Outcomes of Arthroscopic One-Tunnel Triangular Fibrocartilage Complex Transosseous Suture Repair Are Not Diminished in Cases of Ulnar Styloid Process Fracture Nonunion

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Purpose: To determine whether clinical outcomes of arthroscopic one-tunnel wrist triangular fibrocartilage complex (TFCC) transosseous suture repair are not diminished in cases of ulnar styloid process fracture nonunion (USPFN). **Methods:** Patients who underwent arthroscopic 1-tunnel transosseous suture repair of Palmer 1B foveal TFCC tear (with/without superficial fiber tear; Atzei class 2 or 3 TFCC tear) from 2015 to 2020 were retrospectively reviewed. Group I was the TFCC foveal tear repair group with USPFN. Group II was the TFCC foveal tear repair group without USPFN. In group I, no additional treatment for USPFN was made. Functional preoperative and postoperative outcomes were compared by Modified Mayo Wrist Score (MMWS); Quick Disabilities of the Arm, Shoulder, and Hand (Quick-DASH) score; grip strength; pain visual analog scale (VAS); and distal radioulnar joint (DRUJ) stability. Wrist posteroanterior, lateral, and both oblique views of the wrist were used to assess the ulnar styloid process before and after operation. **Results:** This study consisted of 66 patients: group I (n = 22) and group II (n = 44). No differences were found between the 2 groups preoperatively in MMWS, Quick-DASH, grip strength, and VAS (MMWS: $P = .94$, Quick-DASH: $P = .23$, grip strength: $P = .69$, VAS: $P = .45$). No differences were found between the 2 groups with respect to outcome measures postoperatively in MMWS, Quick-DASH, grip strength, and VAS (MMWS: $P = .59$, Quick DASH: $P = .82$, grip strength: $P = .15$, VAS: $P = .84$). All of the enrolled patients achieved restored function with negative ballottement test and maintained DRUJ stability on follow-up. Of the 22 USPFN cases in group I, 11 (50%) showed spontaneous union after transosseous TFCC foveal repair without any additional USPFN treatment. The proportion of patients achieving a minimal clinically important difference for the Quick-DASH was similar between the 2 groups. **Conclusions:** Although this current study has insufficient statistical power, the available data suggest that patients with TFCC foveal tear combined with USPFNs treated with arthroscopic transosseous repair surgery could experience similar functional improvement compared with those with TFCC foveal tear without USPFNs. The presence of USPFN accompanied by Palmer 1B type TFCC foveal tear may not affect the clinical results, including MMWS, Quick-DASH, grip strength, VAS, and DRUJ stability of patients who undergo arthroscopic 1-tunnel transosseous suture repair. **Level of Evidence:** Level III, retrospective comparative study.

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The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received January 31, 2022; revised manuscript received July 24, 2022; accepted July 28, 2022.

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0749-8063/2295/$36.00

https://doi.org/10.1016/j.arthro.2022.07.025

Disruption of the foveal attachment of the triangular fibrocartilage complex (TFCC) can cause instability of the distal radioulnar joint (DRUJ) and subsequent arthritis.[1,2] Various techniques have been introduced to repair TFCC foveal tears such as inside-out, outside-in, all-inside, and open repairs; recently, arthroscopic transosseous suture repair has been widely performed.[3-11]

In some cases, traumatic TFCC foveal tears can be combined with ulnar styloid process fracture nonunion (USPFN). Earlier reports described several operative treatments including tension band wiring, plate

osteosynthesis, compression screw fixation, or excision of the ulnar styloid process with TFCC foveal repair.[12-14] However, there is no clear consensus on how to manage USPFNs, despite the advancement of new TFCC foveal repair methods.

This uncertainty concerning the optimal treatment of USPFNs that accompany instability of the distal radioulnar joint due to TFCC foveal tears may originate from the heterogeneity of previous study designs. Those that argue against treatment of USPFNs with concomitant TFCC foveal tears believe that USPFNs do not contribute to ulnar-sided wrist pain.[14-16] We have limited our study to patients with USPFNs that accompany TFCC foveal tears that underwent arthroscopic one-tunnel transosseous suture repair without any treatment for the USPFNs.[10] The purpose of this study was to determine whether clinical outcomes of arthroscopic one-tunnel triangular fibrocartilage complex transosseous suture repair are not diminished in cases of USPFN. Our hypothesis was that the presence of USPFN does not affect postoperative wrist function, postoperative pain, and postoperative DRUJ stabilities in patients who underwent arthroscopic one-tunnel transosseous suture repair of Palmer 1B type peripheral TFCC foveal tear.

Methods

Patients

Approval for the study was granted by our institutional review board (IRB no. 2021AN0538). In total, 205 patients who underwent arthroscopic one-tunnel transosseous TFCC foveal repair January 2015 and December 2020 were retrospectively enrolled. Inclusion criteria were patients with Palmer 1B foveal TFCC tear (with/without superficial fiber tear; Atzei class 2 or 3 TFCC tear) who underwent primary arthroscopic one-tunnel transosseous suture repair.[17] All included patients had a history of ulnar wrist pain that was aggravated by pronation and ulnar deviation. Patients with positive ulnocarpal stress test,[18] DRUJ instability examined with a ballottement test,[19,20] and TFCC foveal tear on 3.0 T magnetic resonance arthrography (MRA) with confirmation via arthroscopic examination with positive hook test were included.[19,21] Exclusion criteria were (1) patients younger than 18 years; (2) patients with a history of other wrist fractures, including distal radius fractures and various carpal bone fractures; (3) patients who were treated with ulna-shortening osteotomy or debridement of a degenerative TFCC central tear for ulnar impaction syndrome; and (4) patients with a history of wrist surgery, including TFCC repair surgery.

Indications for the surgery were patients who had combinations of ulnar-sided wrist pain that was aggravated by pronation and ulnar deviation, patients with positive ulnocarpal stress test and positive ballottement tests, and highly suspected TFCC foveal tear on 3.0 T MRA.

The patients were divided into 2 groups according to the presence of USPFN. Group I comprised patients diagnosed with TFCC 1B foveal tear with USPFN. The presence of USPFNs was analyzed, and patients were selected according to preoperative plain radiographs of the wrists. Group II comprised patients diagnosed with TFCC 1B foveal tear without USPFN. Patients in group II were matched with group I patients based on age, symptom duration, and sex. Group II was selected as a control group and enrolled twice the number of patients as in group I.

Surgical Technique

All enrolled cases of both groups had their foveal tears repaired by 2 senior hand surgery faculty members (I.C.C. and J.W.P.) according to our arthroscopic one-tunnel transosseous TFCC foveal repair method.[11,22,23]

Briefly, the patient was placed in the supine position, and general orthopaedic preparation for arthroscopic wrist surgery was performed. Before applying wrist traction for the arthroscopic procedure, we rechecked the DRUJ instability under general anesthesia. Using a 2.4-mm small joint arthroscope, we approached the radiocarpal joint through the 3-4 and 6R portals. A Palmer 1B TFCC tear was identified through arthroscopic examination and the hook test with a probe inserted in the prestyloid recess. A foveal tear of the TFCC (pc-TFCC tear) was revealed as loss of tension and displacement both radially and distally. A longitudinal skin incision was made on the lateral aspect of the ulna from the tip of the ulnar styloid process to the proximal region, 2 cm between the extensor carpi ulnaris and flexor carpi ulnaris. To create a transosseous tunnel, a specially designed targeting device (C-Ring Aiming Guide; Arthrex) was placed through the 6R portal with the sharp, pointed tip of the ulnar fovea. The acceptable trajectory point was on the proximal region 1 to 1.5 cm distal to the tip of the ulnar styloid process. When the USPFN was present, the bone tunnel was made proximal to the nonunion site as not to disturb the fracture site. A 1.1-mm K-wire was introduced through the targeting guide to the center of the footprint of the torn fibers of the pc-TFCC. First, a 2.7-mm-diameter cannulated drill was used to make a transosseous tunnel, and the tunnel was enlarged by a 4-mm-diameter cannulated drill to prevent iatrogenic fracture during drilling. Under arthroscopic control, a 2-0 high-tensile strength suture (FiberWire; Arthrex) was passed into the joint with the aid of an 18-gauge needle through the osseous tunnel and TFCC. To retrieve the suture, another 18-gauge needle with a lasso loop was passed through the osseous tunnel. The puncture point of the TFCC by the wired lasso loop was at least 4 mm

from the first suture end. The suture was passed through the lasso loop using a fine-tipped mosquito forceps in the joint, and the lasso loop was pulled back through the transosseous tunnel. The 2 ends of the sutures were stabilized with a suture anchor (2.5-mm PushLock; Arthrex) proximal to the trajectory of the bone tunnel, approximately 5 mm apart. After completion of the first suture, a second suture was added using the same method in a cruciform configuration for additional stability. No additional surgical procedure was performed for the USPFN.

Assessment of Clinical Outcome

Modified Mayo Wrist Score (MMWS) and Quick Disabilities of the Arm, Shoulder, and Hand (Quick-DASH) questionnaires were obtained preoperatively and at final follow-up at least 12 months postsurgically. Grip strength was assessed using a hydraulic hand dynamometer (Baseline; FEI) and was presented as a percentage of that of the contralateral side. Pain using a 10-point visual analog scale (VAS) on provocative motion was assessed. Pre- and postoperative DRUJ stabilities were assessed using the ballottement test.

Patient-reported outcomes including measurements in MMWS, Quick-DASH, grip strengths, and VAS were performed by a single licensed physical therapist at our institution, and the results were reviewed by an orthopaedic hand surgeon for accuracy. Preoperative and postoperative distal radioulnar stabilities were checked by orthopaedic hand surgeons on visits to the outpatient clinic. All enrolled patients were blinded to whether USPFNs were present. All clinical outcome assessments were collected at 12 months postoperatively and at subsequent annual follow-ups. Wrist PA, lateral, and both oblique views of the wrist were used to assess the ulnar styloid process before and after operation. The differences in preoperative and postoperative Quick-DASH scores were calculated, and clinically important outcome improvement was determined using the minimal clinically important difference (MCID) as described.[24-26] The longitudinal change on the Quick-DASH of 15.91 points was set as a standard.

Statistical Analysis

Descriptive statistics were applied to patient demographics and clinical characteristics. To evaluate statistical significance between the cases and controls, an independent *t* test and Fisher exact test were performed; a paired *t* test was used to assess differences between the preoperative and postoperative results. Post hoc analysis was performed using G power with a confidence interval for power analysis. A χ^2 test for association was performed to determine whether a relationship existed between the 2 groups and the MCID for the Quick-DASH. Statistical analyses were performed using the Statistical Package for the Social Sciences (IBM SPSS Statistics) version 20 software (IBM Corporation). Meaningful statistical significance was set as $P < .05$.

Results

Of the 205 patients who underwent arthroscopic TFCC foveal repair using the one-tunnel transosseous suture technique, 32 patients showed combined USPFNs. According to the exclusion criteria, 10 of 32 patients were excluded, and finally 22 patients comprised group I. To increase statistical power, 44 patients without USPFNs were selected as group II (Fig 1). Baseline demographic data collected can be found in Table 1.

All prior nonoperative treatments have been performed at other institutions prior to patients' visit to our hospital as most of the enrolled patients are referred patients from primary or secondary clinics. Combinations or single treatment of immobilization, physiotherapy, and steroid injection were performed in 33, 24, and 8 patients, respectively. Twenty-five patients had no available records of previous treatments.

All patients had repairable TFCCs via transosseous sutures on the fovea in both groups. The average MMWS, Quick-DASH, grip strength, and VAS pain scores indicated significant improvement at the last follow-up ($P < .001$) in both groups.

No differences were found between group I and group II preoperatively in MMWS, Quick-DASH, grip strength, and VAS (MMWS: 64.3 and 64.6, $P = .94$; Quick-DASH: 20.7 and 22.7, $P = .23$; grip strength: 76.7% and 78.2%, $P = .69$; and VAS: 3.7 and 3.6, $P = .45$). Furthermore, no differences were found between group I and group II with respect to outcome measures postoperatively in MMWS, Quick-DASH, grip strength, and VAS (MMWS: 89.5 and 90.8, $P = .59$; Quick-DASH: 3.6 and 3.9, $P = .82$; grip strength: 99.0% and 95.7%, $P = .15$; and VAS: 0.1 and 0.2, $P = .84$) (Table 2). All of the enrolled patients achieved restored wrist function with negative ballottement test and maintained DRUJ stability on follow-up. The frequency of each group achieving clinically significant outcome improvement as measured by the MCID for the Quick-DASH showed no difference; group I was 13 (59%) and group II was 30 (68%) ($P = .08$).

In group I, 13 patients had an ulnar styloid process fracture at the base; 9 patients had nonbase fractures. Of the 22 cases of USPFNs, 11 (50%) showed spontaneous union at a mean follow-up of 42 months after operation (range, 12-79). Of the 11 cases that achieved spontaneous union, 9 were base fractures and 2 were nonbase fractures. Spontaneous union of the USPFN after operation and the relationship with the bone tunnel are illustrated in Figure 2. All enrolled patients did not show any complications such as rerupture of the TFCC, infection, or paresthesia at final follow-ups.

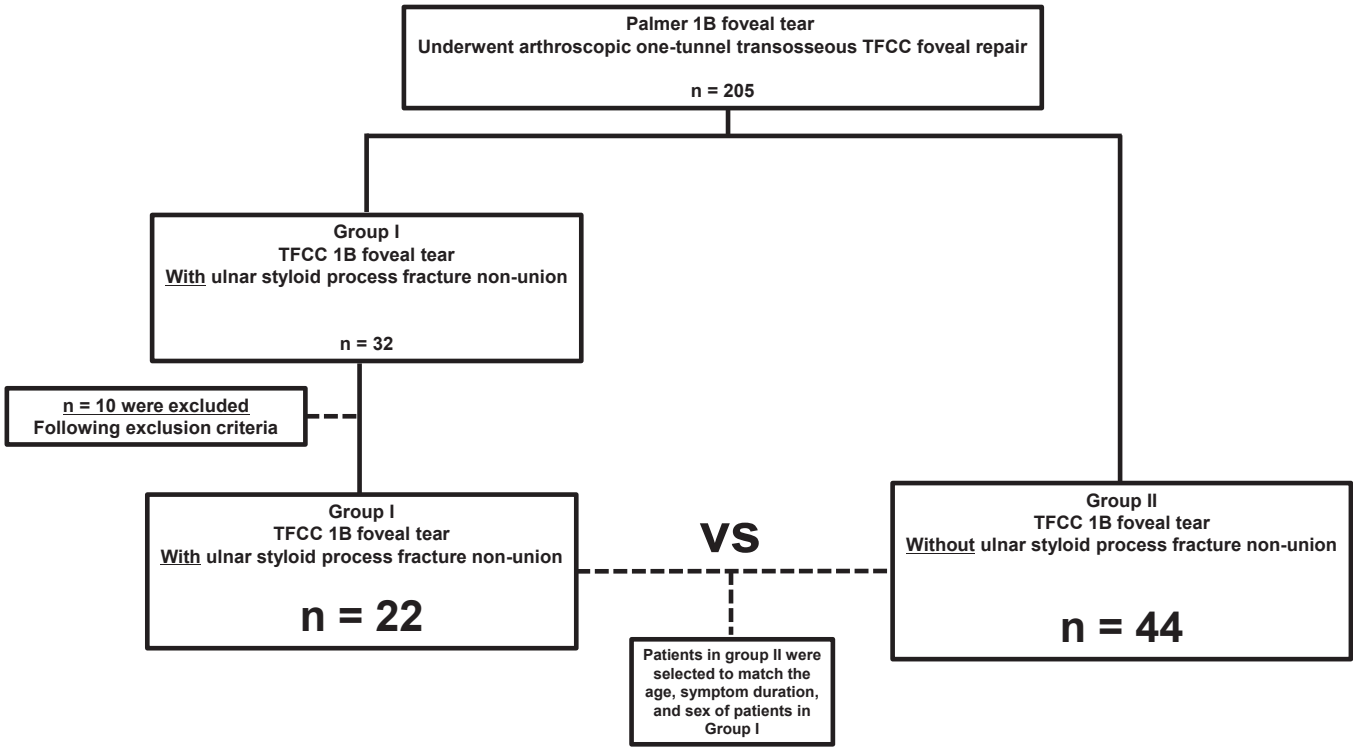

Fig 1. Patient flowchart: A total of 66 patients with TFCC foveal tear combined with (group I) or without USPFNs (group II) who underwent arthroscopic 1-tunnel transosseous TFCC suture repair were included. TFCC, triangular fibrocartilage complex; USPFN, ulnar styloid process fracture nonunion.

Discussion

The results of this study demonstrated favorable clinical outcomes in patients who underwent arthroscopic one-tunnel transosseous suture repair of the TFCC foveal detachment regardless of the presence of USPFNs. Although the combination of the TFCC foveal tear and presence of USPFNs is rare, the available data suggest that surgical repair using the one-tunnel transosseous repair method may be sufficient in treating patients with TFCC who have concomitant USPFNs without additional treatment for the USPFN. Postoperative pain and DRUJ stability were not influenced by the presence of USPFNs.

Although many studies have investigated surgical treatment of USPFNs, limited information is available with respect to treatment of TFCC 1B foveal tear with concomitant USPFN. In one study, TFCC tears associated with symptomatic ulnar styloid nonunions were treated by open ulnar styloid excision and outside-in TFCC repair with good clinical outcome measures, including DASH and VAS pain scores.[14] However, other clinical results were unaffected by the presence of ulnar styloid process fracture unions.[27,28] Simple excision of a USPFN can disturb the anatomic relationship among the extensor carpi ulnaris, fovea, and styloid insertion of the TFCC. Therefore, excision of a USPFN should be carefully considered when the USPFN is the most evident source of pain.

The USPFNs usually do not affect the stability of the DRUJ, as evidenced by the anatomy of the TFCC with its foveal insertion site as the most significant factor in maintaining stability. Radioulnar ligaments attach to the ulnar styloid, radius, and ulna fovea. These include ulnotriquetral and lunotriquetral ligaments and the subsheath of the extensor carpi ulnaris, all of which contribute to the integrity of the TFCC in varying degrees.[29]

According to a topographical anatomy study of the distal ulnar attachment of the radioulnar ligament, the deep limbs of the TFCC that attach to the fovea have broad marginal insertions. However, the superficial limbs have condensed and circular insertions to the ulnar styloid.[30] Maximal width, height, area, perimeter, and circulatory ratio of the footprint of the deep limb of the TFCC are 12.68 mm, 3.10 mm, 29.67 mm^2, 27.44 mm, and 2.86, respectively.[30] Such wide insertion of the deep limb is comparably larger than that of the superficial limb where the footprint parameters of the maximum width, height, area, perimeter, and circulatory ratio are 4.11 mm, 5.25 mm, 18.36 mm^2, 14.69 mm, and 1.06, respectively.[30] These findings suggest that superficial fibers attached to the USPFNs do not contribute much to the stability of the DRUJ, and avulsion of the whole footprint of the TFCC foveal region is rare. Earlier biomechanical studies have also shown that the deep component of the TFCC is more

Table 1. Demographic Characteristics

Characteristic	Group I, TFCC With USPFN (n = 22)	Group II, TFCC Without USPFN (n = 44)
Age at operation, y*	24.3 (18-33)	24.9 (18-38)
Male/female	21/1	34/10
Symptom duration, y*	1.2 (0.5-2)	1.2 (0.5-2)
Follow-up, mo*	34.8 (12-101)	22.9 (12-67)
With TFCC distal component tear	5	6

Note: Unless otherwise indicated, data are number of patients
TFCC, triangular fibrocartilage complex; USPFN, ulnar styloid process fracture nonunion.
*Data are average with range in parentheses.

important in providing stability than is the superficial component.[31-33] In our study, arthroscopic findings of TFCC foveal tear with USPFNs were not significantly different from those with TFCC foveal tears only.

Fifty percent (11 of 22) of USPFNs had spontaneous union after transosseous suture repair of TFCCs in this study. Although we could not reveal the reasons for these findings, the findings might be explained by increased blood flow and regenerative potential through the bone tunnel preparation adjacent to the nonunion sites. Of the 13 base fractures, 9 cases of spontaneous unions occurred (69%), whereas only 2 of 9 nonbase cases (22%) showed spontaneous unions. This finding may be due to the greater contact area for the bone to heal in base fracture cases. Furthermore, we think that fractures at the base are closer to the bone tunnel for transosseous suture repair; therefore, increased healing potential through the bone tunnel affected the increased union rate. Studies by Iwasaki et al.[34] and Abe et al.[35] suggest that bone bleeding from bone preparation can induce osteoinductivity and healing of the distal radioulnar structures. The enhanced regenerative potential with bone tunneling is evident by a higher percentage of spontaneous unions of base, rather than nonbase, USPFNs.

Limitations

Our study had a number of limitations, First, a post hoc power analysis using the difference in postoperative Quick-DASH score between the 2 groups using G power with a confidence interval of 95% showed that the study is underpowered. The observed effect size was calculated to be 0.062, and with the study's sample size, the observed power was calculated to be 0.056. Although this study is underpowered, we could not find any other study reporting outcomes of TFCC tear with concomitant USPFNs treated with arthroscopic transosseous suture repair as the combination of the disease is rare. Second, we did not compare the clinical outcome and the fate of the USPFNs when repairing the TFCC by procedures other than our one large bone tunnel technique. Last, although we found that 50% of the USPFNs were united during the follow-up period, we were not able to elucidate the direct mechanisms for this phenomenon.

Conclusions

Although this current study has insufficient statistical power, the available data suggest that patients with a TFCC foveal tear combined with USPFNs treated with arthroscopic transosseous repair surgery could experience similar functional improvement compared with those with a TFCC foveal tear without USPFNs. The presence of USPFN accompanied by a Palmer 1B type TFCC foveal tear may not affect the clinical results, including MMWS, Quick-DASH, grip strength, VAS, and DRUJ stability of patients who undergo arthroscopic one-tunnel transosseous suture repair.

Table 2. Functional Results Preoperatively and at Final Follow-up

Characteristic	Group I, TFCC With USPFN (n = 22)	Group II, TFCC Without USPFN (n = 44)	*P* Value
Preoperative			
MMWS	64.3 (50-80)	64.6 (40-95)	.94
Quick-DASH	20.7 (11.4-29.5)	22.7 (2.3-36.4)	.23
Grip strength (% of contralateral)	76.7 (42.3-100)	78.2 (34-100)	.69
VAS pain score	3.7 (3-5)	3.6 (2-5)	.45
Postoperative			
MMWS	89.5 (75-100)	90.8 (75-100)	.59
Quick-DASH	3.6 (0-22.7)	3.9 (0-20.5)	.82
Grip strength (% of contralateral)	99.0 (75-120)	95.7 (57.1-100)	.15
VAS pain score	0.1 (0-1)	0.2 (0-2)	.84

Note: Unless otherwise indicated, data are average with range in parentheses.
MMWS, Modified Mayo Wrist Score; QuickDASH, Quick Disability of the Arm, Shoulder, and Hand; VAS, visual analog scale.

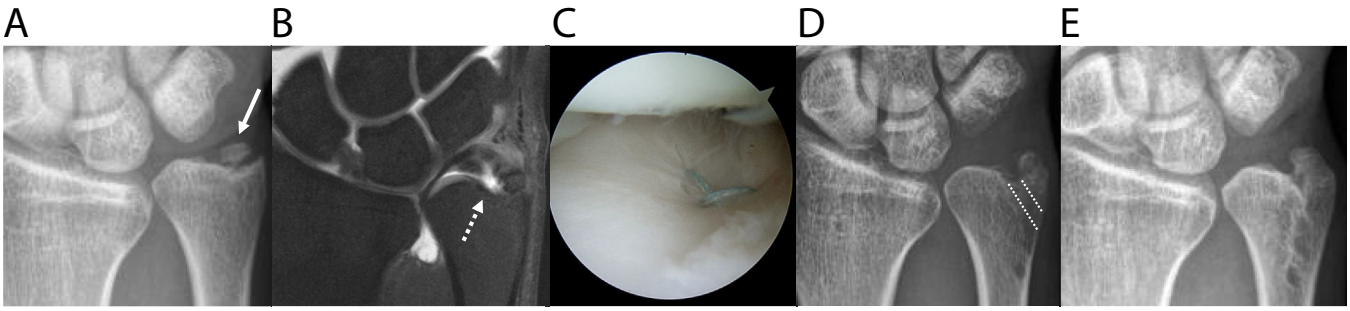

Fig 2. A 31-year-old male patient with TFCC 1B foveal tear and USPFN who underwent arthroscopic transosseous suture repair of the TFCC. (a) Preoperative posteroanterior radiograph with a displaced USPFN (arrow). (b) Magnetic resonance arthrography shows TFCC 1B foveal tear (dotted arrow). (c) Arthroscopic findings after TFCC transosseous suture repair of the TFCC foveal tear. (d) Postoperative posteroanterior radiograph of the wrist with a bone tunnel (dashed line). (e) Postoperative posteroanterior radiograph of the wrist with spontaneous union of the ulnar styloid process. TFCC, triangular fibrocartilage complex; USPFN, ulnar styloid process fracture nonunion.

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