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Stabilization for acute distal radioulnar instability: A novel surgical technique

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ABSTRACT

Introduction: Instability of the distal radioulnar joint (DRUJ) commonly results from traumatic disruption of the distal radioulnar ligaments of the triangular fibrocartilage complex (TFCC). Treatment of this rupture typically requires immobilization of the wrist and elbow for a period of 6 to 8 weeks. This study evaluated the hypothesis that treatment of DRUJ instability with dynamic stabilization would allow early mobilization of both the radiocarpal and distal radioulnar joints by the first postoperative week without compromising restoration of TFCC integrity.

Materials and methods: Between September 2017 and January 2019, a retrospective study was conducted on 22 patients presenting with DRUJ instability confirmed by intraoperative Ballottement testing. Once instability was confirmed, dynamic surgical stabilization was performed, followed by one week of short cast immobilization. Arthrographic computed tomography (CT) of each patients' affected wrist was performed 4 months later to evaluate TFCC integrity. The recovery of patients was monitored at 1, 3, 6, and 12 months after surgery using the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire, Ballottement test, and evaluation of radioulnar join range of motion (ROM), pain, and complications.

Results: All patients were followed postoperatively for a mean of 13.5 months. After 1 month, all patients exhibited satisfactory range of motion and DRUJ stability. By 3 months, Ballottement tests were negative in 21 of 22 patients, with instability persisting in only 1 patient. At 4 months, CT arthrography contrast leakage (indicative of a TFCC tear) was observed in 5 of 20 patients. Upon reexamination a mean of 10.5 months later, the TFCC tears of these patients had healed in 2 cases (with foveal tears), while no difference in contrast leakage was observed for the other 3 cases (with horizontal or central tears). Revision surgery for implant related complications was performed in 2 cases.

Conclusion: Acute DRUJ instability treated with dynamic stabilization led to satisfactory clinical outcomes in terms of range of motion, pain relief and joint stability, allowing DRUJ movement from the first postoperative week. This technique represents a simple, reproducible and minimally invasive procedure with a low rate of implant related complications.

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Introduction

Instability of the distal radioulnar joint commonly results from traumatic disruption of the distal radioulnar ligaments of the triangular fibrocartilage complex (TFCC) [1,2]. According to the literature, the incidence of distal radioulnar joint (DRUJ) instability after distal radius fracture ranges from 39% to 84% [3–5]. DRUJ instability may occur after injury to any portion of the radius or ulna, including midshaft radial fractures, ulnar styloid fractures, or injuries to the interosseous membrane. Such instability typically presents as a chronic problem rather than being diagnosed acutely after an injury [6–8]. Therefore, it is important to identify this lesion and treat it suitably.

Some radiological factors associated with DRUJ instability have been found to be useful for diagnosis. In particular, widening of the DRUJ gap has been identified as a pertinent risk factor [9,10]. Kwon et al. [11] reported that an ulnar-positive variance of over 6 mm on radiographs made before the reduction of a distal radial fracture increased the risk of instability by a factor of 1.7. A biomechanical study by Kihara et al. [12] found that 20° of dorsal angulation of the radius markedly increased DRUJ diastasis. Ulnar

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Table 1
Patient demographics.

	Patients with acute DRUJ instability n=22
Age, mean (yr) range	43.4 (17-72)
Gender (n,%) Male Female	13 (59) 9 (41)
Associated fracture to DRUJ instability, n(%) Distal radius fracture Radial shaft fracture No radius fracture associated	16 (73) 4 (18) 2 (9)
Time to surgery, mean (days) range	10.3 (2-42)
Duration of surgery, mean (min) range	63.4 (37-90)
Follow-up, mean (months) range	13.5 (12-20)

Table 2
Clinical outcomes.

	1 months Follow-up n=22	3 months Follow-up n=21	Final Follow-up n= 21
Negative Ballottement test (n, %)	22 (100)	20 (95)	20 (95)
Flexion mean (º) range	26 (5-60)	61 (15-80)	80 (60-90)
Extension mean (º) range	29 (15-60)	60 (20-80)	77 (45-90)
Pronation mean (º) range	57 (20-80)	78 (60-90)	85 (70-90)
Supination mean (º) range	52 (20-60)	75 (45-90)	85 (70-90)

styloid fractures, especially at the base with greater than 2 mm of displacement, have been regarded as the primary risk factor for DRUJ instability in distal radius fractures because of their proximity to the deep triangular fibrocartilage complex [13]. Observation of these radiological signs is highly suggestive of DRUJ instability.

Standard clinical diagnosis of acute DRUJ instability relies upon physical examination, although imaging methods and wrist arthroscopy may be used to distinguish structural abnormalities and to assist with surgical planning [14]. Several physical tests have been reported for the evaluation of DRUJ instability [15]; however, it is still unclear whether these tests accurately measure instability due to tears of the triangular ligament. According to the literature, the most reliable of these assessments is the Ballottement test, in which the dorso-palmar stability between the ulna and radius is examined in the neutral, pronated, and supinated positions, respectively [15]. In cases of clinical instability supported by radiographic evidence, a correlation with TFCC injuries has been reported [14]. Specifically, avulsion of the TFCC at the fovea [16], as the TFCC is the primary stabilizer of the DRUJ.

Acute DRUJ instability can be treated conservatively with a cast, without the need for repair, using a long arm cast including immobilization of the wrist and elbow to prevent rotation [17]. The DRUJ should be immobilized in a position of stability. Transosseous Kirschner wires may be used for unstable joints [18]. In the last several years, several open and arthroscopic procedures have been recommended to repair a foveal tear [19]. Regardless of the treatment performed, most authors recommend immobilization of the wrist and elbow for at least 4 to 8 weeks [19]. This period of immobilization may compromise the patient's recovery after radius surgery and limit the radioulnar range of motion. Early functional recovery of postoperative radius fracture requires early mobilization. However, approaches that allow mobilization can also lead to poor TFCC healing.

For cases in which wrist pronation is locked, distal radioulnar joint stability could be achieved by avoiding translation of the radius relative to the stable ulna while maintaining complete flexo-extension of the radiocarpal joint. We therefore hypothesized that an extra-articular system construct using FiberWire and two anchors would restore DRUJ stability in cases of post-traumatic acute unstable DRUJ, by restricting the direction of rotation where the instability occurs and stabilizing dorsopalmar translation movement and joint opening. This stabilization could consequently enable proper healing of the TFCC with mobilization of the wrist after the first postoperative week. Here we report the results of DRUJ instability treatment in a series of cases using this dynamic stabilization approach, allowing early mobilization of both the radiocarpal and DRUJ after the first postoperative week, accompanied by an assessment of TFCC integrity at 4 months after surgery.

Materials and methods

Study cohort and data collection

Between September 2017 and January 2019, a cohort of 23 patients with radiologic evidence of DRUJ instability, and intraoperative instability confirmation by Ballottement test within the previous 6 weeks were retrospectively enrolled in this study. Informed consent was obtained from all participants prior to enrollment. The exclusion criteria were: (1) negative intraoperative manual (Ballottement) stress test findings, (2) a follow-up period of less than 1 year, (3) abnormal wrist function before the injury or a prior history of wrist surgery, (4) chronic lesions (more than 6–8 weeks after the index episode), (5) severe osteoporosis or history of previous pathology in the affected wrist, (6) concomitant tendinous or neovascular lesion, (7) multiple traumatic injuries or open distal radius fracture, (8) and refusal to provide informed consent. One patient was excluded for failure to return for follow-up assessment. Therefore, a total of 22 patients with a mean age at the time of the DRUJ instability was 43 years (sd = 15). The study group included 13 men and 9 women. The mean follow-up period was 13.5 months (sd = 3.7) (Table 1).

DRUJ instability occurred more frequently (20 patients) in conjunction with other fractures of the radial shaft or metaphysis (Galeazzi fracture-dislocations; 4 patients), the distal radius (16 patients), the ulnar process (1 patient), and an isolated lesion (1 patient). Among the patients with distal radius fractures, 15 patients presented with Type VIII fractures and 1 patient presented with a Type V Fracture, according to Frykman Classification. Ulnar styloid fracture was presented in 15 (93.7%) of the cases of DRUJ instability associated to distal radius fracture. In cases of Galeazzi fracture dislocation, a 3-type classification system [20] based on the fracture pattern of the shaft of the radius associated with DRUJ instability after fracture fixation was used. According to this classification scheme, Type I fractures are located at the distal third of the radius (from the point at which the diaphysis begins to straighten to the metaphyseal flare), type II fractures are those of the middle third of the radius (from the beginning of the radial bow to the point at which the diaphysis begins to straighten), and type III fractures occur in the proximal third of the radius (from the radial tuberosity to the beginning of the radial bow. Among patients with

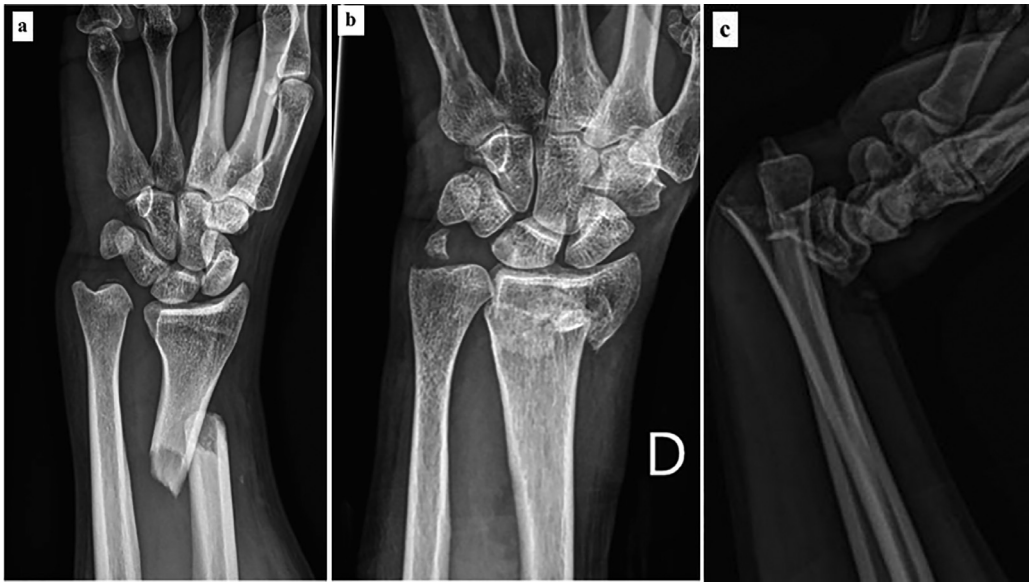


Fig. 1. Postreduction radiographs demonstrating signs of distal radioulnar joint instability. **A)** Ulnar process avulsion, **b)** DRUJ gap widening, **c)** Dorsal Tilt.

DRUJ instability associated a radial shaft fracture, a Type I fracture affecting the distal third of the radius was reported in 2 patients, and a Type II affecting the middle third of the radius was observed in 2 patients.

Instability assessment

Probable preoperative instability was ascertained via radiologic assessments of DRUJ integrity. High risk of DRUJ instability was considered to be present in cases with: (1) fractures at the base of the ulnar styloid with over 2 mm of displacement (Fig. 1a), (2) widening of the DRUJ gap (Fig. 1b), (3) 20° or greater dorsal angulation of the radius (Fig. 1c), and (4) positive ulnar variance of 6 mm or more based upon the prereduction radiograph. Instability was subsequently confirmed by intraoperative Ballottement testing, the results of which were compared with those for the contralateral side after radius fracture fixation in patients with radius fractures. This fixation procedure consisted of stabilizing the ulna with one hand and translating the radius to its volar and dorsal limits with the other, noting both the amplitude and firmness of the end point compared to the contralateral side; this maneuver was performed in neutral rotation, pronation, and supination. Postoperative Ballottement testing was performed on every patient after DRUJ stabilization.

Surgical technique

All surgeries were performed by the same surgeon. A suture tape was placed obliquely between the two bones, from the dorsal surface of the ulna to the volar region of the radius through the interosseous membrane. This tape remained taut as the hand was rotated in pronation, which prevents translation of the ulna dorsally when there is a tear of the TFCC, allowing complete supination. Contrarily, in the presence of volar instability the tape was affixed from the dorsal aspect of the radius to the volar region of the ulna, making it possible to simultaneously and completely mobilized a component of the rotation movement (supination/pronation), partially mobilizing another component (pronation/supination), while the radiocarpal joint enjoys total mobility. This system allowed the TFCC to heal in a position of stability without preventing mobilization.

To perform this technique, only two elements are necessary:

- Suture tape: Polyethylene, high-molecular-weight tape with a braided structure, 2 mm wide, with high resistance to tensile stress. The FiberTape (Arthrex, Naples, FL, USA) suture was used in the cases described here.

- Anchors: A device composed of nonabsorbable thermoplastic material, usually polyetheretherketone (PEEK). It is a solid device that fixes the suture tape with tension, providing high tensile strength. In this study, SwiveLock C Anchor 3.5 mm (Arthrex, Naples, FL, USA) was used.

The steps required vary to some extent with the nature of the injuries.

We chose the metaphyseal-diaphyseal region of the radius as the point of origin of the tenodesis. Using a hemostatic or mosquito clamp, tunneling is performed from the radius to the ulna in the volar to dorsal direction and proximally to distally, crossing the interosseous membrane to the ulnar neck (Fig. 2). This path reproduces the trajectory that the suture tape should follow.

The tip of the mosquito clamp marks the incision in the ulnar neck (Fig. 3a). A 1 cm incision was made over the ulna in the sheath of the extensor carpi ulnaris (ECU) and continued with sharp dissection to the periosteum, retracting it to the ulna and preserving the trajectory of the dorsal sensory branch of the ulnar nerve (Fig. 3b). The insertion site for the anchor was chosen at approximately 2 cm proximal to the ulnar head (Fig. 3c). A bone tunnel was then drilled in the ulna using 3.5mm cannulated drill without fluoroscopic guidance (Fig. 3d). The SwiveLock anchor device was used to hold the FiberTape approximately at the midpoint to tunnelize a double thread (Fig. 4a-b). From this region, the tape was recovered using a mosquito (Fig. 4c-d) and then pushed back through the path previously made up to the metaphysis of the radius, 5 cm proximal to the articular surface (Fig. 5a).

A second anchoring of the tape was performed through the screw hole of the osteosynthesis plate or in the distal part or radial shaft, depending on the initial osseous injury, applying tension to the tape in the maximum supinated position (Fig. 5b-d). In the case of one patient with DRUJ instability related to ulnar styloid process fracture, a DRUJ stabilization was performed without fixation of ulnar styloid process.

Rehabilitation protocol

After surgery, an antebrachial splint was placed in a functional position using a sling. The patient was subsequently discharged from the hospital and scheduled for a follow-up visit

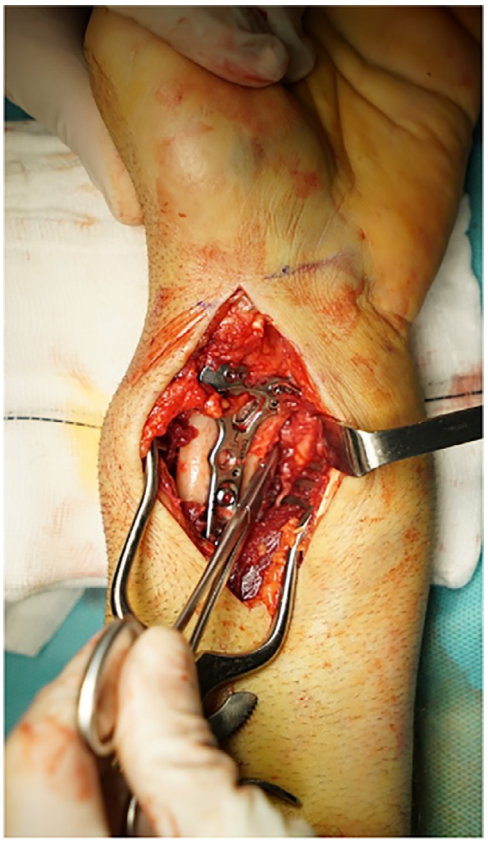


Fig. 2. A tunnel from the radius to the ulna is performed crossing the interosseous membrane.

within the first postoperative week, which consisted of surgical wound care and indication to begin active in-home kinesiotherapy to develop radiocarpal and radioulnar mobility. The patient then wore a removable rigid antebrachial orthesis and was referred to the rehabilitation service after one month postoperatively to begin physiotherapist-directed rehabilitation. Strengthening exercises were permitted to start at postoperative week 12.

Follow-up and outcome measures

Clinical outcomes were assessed based on achieving proper stability (palmar-dorsal translation of the ulna relative to the radius), restoration of wrist function (wrist range of motion [ROM], the Disabilities of the Arm, Shoulder and Hand [DASH] score), time lost from work and any relevant complications. Medical records comprising demographic information, trauma mechanism, surgical time, surgical protocols, and radiographs were also collected in a digital database.

Radiographic evaluation

Anteroposterior, lateral, and oblique view radiographs were taken immediately after surgery, and follow-up radiographs were taken at 1 month, 3 months, 6 months, 12 months, and the last follow-up visit (mean = 13.5 months, sd = 3.7 months) postoperatively. Using these images, the quality of fracture reduction and radius fracture healing was evaluated. The presence or absence of ulnar styloid process fracture healing was also documented.

Wrist arthrographic computed tomography (CT), which allows for diagnosis of ligament and TFCC tears in the wrist, was performed at 4 postoperative months for all patients. The routine CT arthrographic protocol at our institution was used. A 2 ml solution consisting of 50% of iodinated contrast medium (Iomedrol 350), 25% of anesthetic (mepivacain), and 25% of 0.9% saline was injected with a 24-gauge needle into the DRUJ under ultrasound guidance.

Patients were transferred to the CT in a prone position with the injured wrist laid in pronation overhead. High-resolution acquisition was performed over 10 to 20 minutes (mean = 15 minutes) with a 256- MDCT Dual Flash (Siemens) at 120 kV, 100 mAs, and 0.6 mm of collimation. Reconstructions were performed in sections 0.6 mm thick with 50% overlap in sagittal and coronal planes.

An observer with 2 years of experience in musculoskeletal radiology reviewed MDCT arthrographic images for tears of the TFCC. The presence or absence of communicating and noncommunicating triangular fibrocartilage tears was recorded. A communicating tear was defined as a tear in the triangular fibrocartilage that allowed passage of contrast material from the DRUJ into the radiocarpal compartment. A noncommunicating tear was defined as localized leakage of contrast material within the triangular fibrocartilage without communication to the adjacent compartment. The

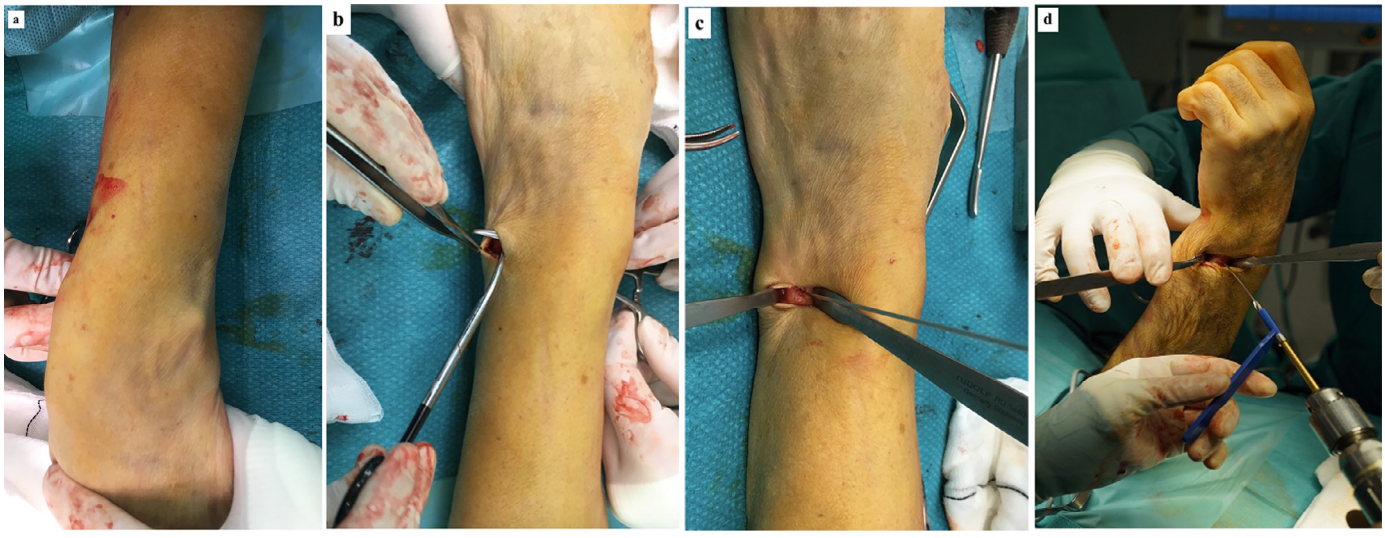


Fig. 3. (a). The tip of the mosquito clamp marks the incision in the ulnar neck. (b) A 1 cm incision was made over the ulna in the sheath of the extensor carpi ulnaris. (c) The insertion site for the anchor was chosen at approximately 2 cm proximal to the ulnar head. (d) Tunnel drilling into the ulna using 3.5mm cannulated drill.

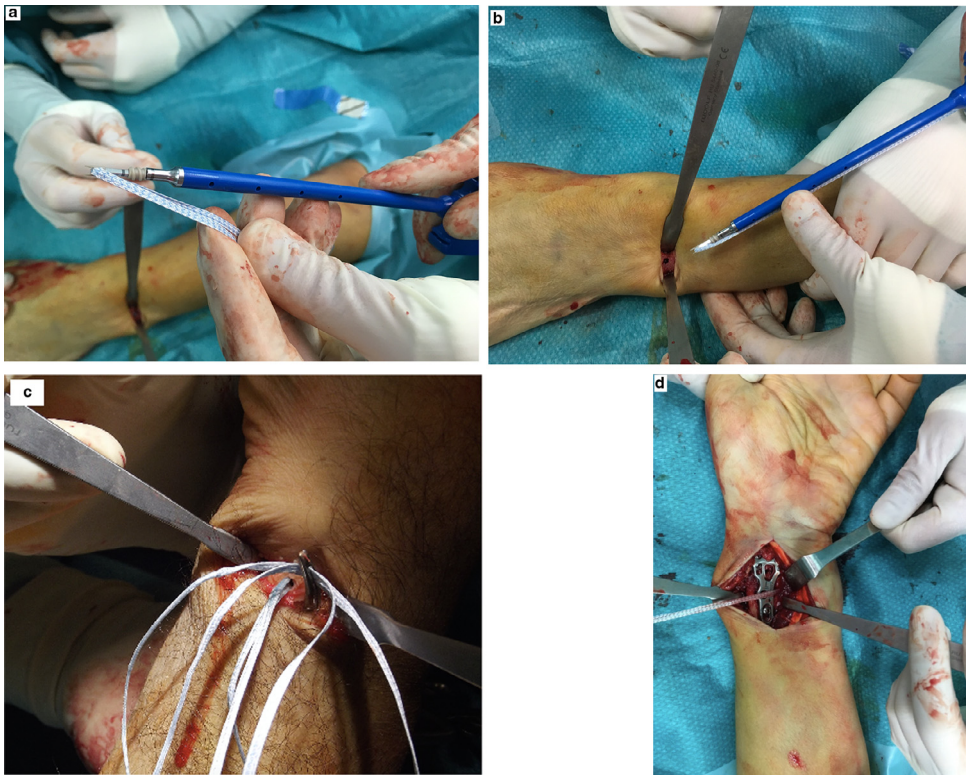


Fig. 4. a). The FiberTape is holded into the SwiveLock anchor. b) The anchor is introduced into the ulna. c-d) FiberTape is recovered with Mosquito Clamp.

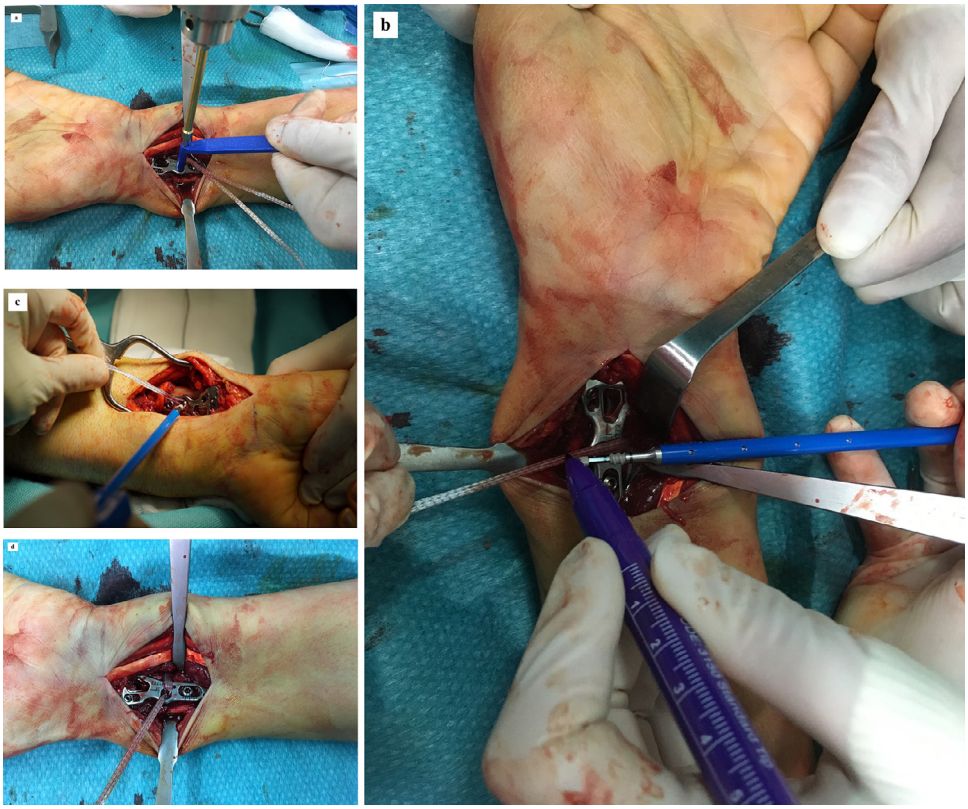


Fig. 5. a). A second anchor is drilled approximately 5cm proximal of the articular surface b) The length of the anchor is delimited in the FiberTape applying tension to the tape in the maximum supinated position. C) The FiberTape is holded into the SwiveLock anchor at the mark that has been previous delimited. D) After the FiberTape is introduced into the tunnel, distal radioulnar pronation is limited by the tension of the tape.

Table 3
Complications and revision surgery.

	Complication N=22	Revision Surgery N=22
Related to surgical technique n (%)	3 (13.6)	
Pronation limitation	1	percutaneuos fibertape rupture
Stiffness	1	plate removal associated to arthrolysis
Instability recurrence	1	
No related to surgical technique n(%)	2 (9)	
Postraumatic fracture around plate	1	Open reduction and internal fixation
Flexor tendon synovitis	1	Plate removal

location of a tear was characterized either as a central tear including the radial attachment or as a tear at the ulnar attachment. The integrity of TFCC was considered in cases without contrast leakage.

Statistical evaluation

Statistical analysis was performed using R software [21]. Demographic data and functional outcomes were described by means and standard deviations (sd). 95% confidence intervals for the mean postoperative change in range of motion were calculated to evaluate the significance and magnitude of functional recovery after surgery.

Results

Ballottement tests were negative for all patients 1 month following surgery (Table 2). At 2 months follow-up, one patient suffered a re-fracture after falling down and required open reduction and internal fixation, therefore, this patient was excluded from subsequent analyses. After 3 months postoperatively, Ballottement tests were negative in 20 cases and 1 one case of instability recurrence was reported for a 72-year-old patient with osteoporotic bone.

In the final follow-up assessment, mean range of motion was 80 (60-90) of flexion, 77 (45-90) of extension, 85 (70-90) of pronation, and 85 (70-90) supination (Table 4). In each case this represented a significant improvement from the initial follow-up visit at 1 month postoperatively (95% confidence intervals for the mean change: $\Delta_{flexion} = 41.5º - 64.8º$, $\Delta_{extension} = 35.3º - 54.7º$, $\Delta_{pronation} = 18.5º - 35.3º$, $\Delta_{supination} = 15.5º - 36.3º$).

Table 4

Anatomic reduction and fracture healing was reported in all patients. The union rate for radial fracture was 100%. A total of 18 of 22 patients exhibited associated ulnar styloid process styloid fractures, of which 12 were displaced and 6 non-displaced. Healing of these fractures was observed in 6 patients, all of them with non-displaced ulnar styloid fracture. Therefore, the ulnar styloid process non-union rate was 66.7%.

A total of 5 postoperative complications were reported (Table 3) including 1 case each of: persistent DRUJ instability and implant failure in a 72-year-old patient with osteoporotic bone, flexor tendons synovitis, stiffness of radiocarpal joint, pronation limitation, and a new fracture in a patient with previous type 2 Galeazzi fracture dislocation.

Revision surgery was necessary in 4 patients, including open reduction and internal fixation in a patient with new radial shaft diaphysis, percutaneuos fibertape rupture in one case of pronation limitation, plate removal in one case of flexor tendons synovitis and plate removal associated to arthrolysis in one case of stiffness (Table 3).

Computed tomography (CT) arthrography was performed in 20 patients a mean of 4.1 (sd = 0.9) months after surgery. Two patients were excluded: one because they showed clinical and radiologic signs of instability 2 months after surgery, and the other because they suffered a new fracture after falling down.

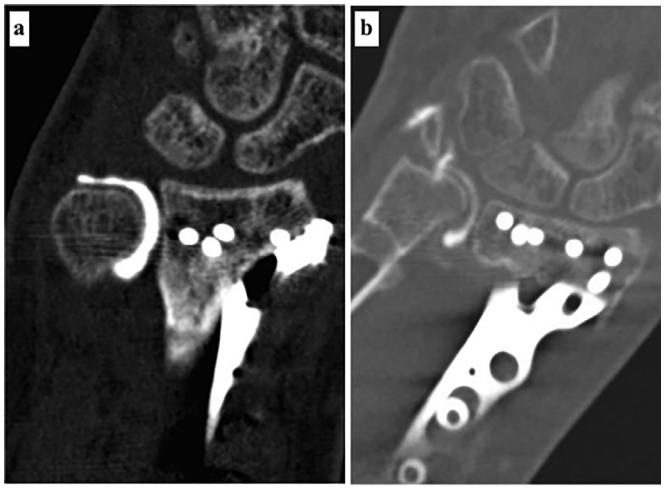


Fig. 6. a). CT arthrogram showing TFFC healing. b) CT arthrogram showing foveal tear.

No contrast leakage was observed in 15 of 20 cases (75%) where computed tomography (CT) arthrography was performed (Fig. 6a). TFCC tears were reported for the other 5 patients, including horizontal tearing (2 patients), central tearing (1 patient), central tearing associated to foveal insertion (1 patient), and isolated foveal insertion of the TFCC (1 patient) (Fig. 6b). Ballottement tests were negative in all patients. In the group of 5 patients for whom TFCC healing was not observed, 4 patients had previous distal radius fracture, and 1 patient a Galeazzi fracture-dislocation.

Additional CT arthrograpy was performed for these 5 patients at a mean of 10.5 (sd = 1.9) months after surgery (Table 4). In the two patients with prior foveal tears, no contrast leakage was observed in these follow-up scans. In 3 patients with horizontal or central tears, no changes were observed in the new CT arthrograms.

Discussion

It has been previously described in the literature that indirect radioulnar linkage through an ulnocarpal sling or a tenodesis for DRUJ instability enables stabilization of the joint with good clinical outcomes, although prior applications of these techniques were focused on the treatment of chronic DRUJ instability [22–24] by reconstruction of the distal oblique bundle (DOB) [25–27]. One of these techniques is based upon dynamic stabilization of DRUJ (similarly to our technique), but instead uses a suture-button construct placed percutaneously in the direction of the DOB membrane [27]. This prior application of the technique to five cadaveric specimens with acute DRU joint instability led to a reduction in the degree of dorsal displacement of the radius to baseline values, in a neutral position as well as in pronation and supination.

Our technique does not try to reconstruct the DOB. Instead, it focuses on avoiding rotation of the radius relative to the ulna, ef-

Table 4
TFCC healing.

	CT arthrography n=20	Second CT arthrograpgy n=5
Time to CT arthrography, mean months (range)	4 (2.7 - 5.9)	10.5 (8.3-11.9)
CT arthrography outcomes, n (%) TFCC integrity Horizontal Tear/ Central Tear Ulnar TFCC insertion Tear	15 (75) 3 (15) 2 (10)	17 (85) 3 (15) 0

fectively stabilizing the DRUJ to promote TFCC healing. This is the basis of conservative treatment [28] involving temporary pinning with a K-wire placed transversely proximal to the sigmoid notch. [29]. The most common pattern DRUJ instability in our study, tested by Ballottement testing, was volar radius displacement relative to the ulna, caused by TFCC volar radioulnar ligament disruption. Because of this, DRUJ has been secured in a supine position, avoiding pronation and allowing joint flexo-extension movement. In 22 patients treated with this technique, stabilization of DRUJ was achieved in all patients and persisted at 1 month follow-up. After an additional 2 postoperative months, 2 patients presented with DRUJ instability: one due to implant failure in a patient with osteoporotic bone and the other after re-fracture.

Integrity of the TFCC was observed in 75% of patients via CT arthrography performed at 4 months following surgery. In 5 patients with TFCC disruption, the foveal TFCC tears initially reported in 2 patients were found to be healed in posterior CT arthrography performed at 10 months follow-up. Horizontal tears of the TFCC seen in 3 patients persisted in follow-up CT arthrograms, but without associated DRUJ instability. It is entirely possible that these tears were present before the injury irrespective of any DRUJ instability. Although no arthroscopy or imaging method were used to confirmed TFCC disruption prior to surgery, radiologic signs described in the literature as risk factors for DRUJ instability are consistent with our Ballottement test results, suggesting that our technique stabilized the DRUJ, favored TFCC healing, and allowed DRUJ movement from the first week postoperatively.

It has been previously reported [22–27] that indirect radioulnar linkage techniques may restore stability at the expense of restricting forearm rotation. With our technique, fastening the suture too tightly could also lead to reduced mobility in the wrist. In our study, 2 cases of DRUJ joint stiffness were reported, and for one of these only pronation was limited. In those cases, because tight rope is placed extra-articularly, there will be no intra-articular material and minimal incisions can be made to remove the suture and restore pronation.

This study has several limitations. First, since this was a retrospective cohort study, there was no randomization or control group. Second, the cohort size and follow-up were fairly short. Third, no arthroscopy or imaging methods were used to confirmed TFCC disruption prior to surgical treatment. Considering these limitations, futures studies using this technique could benefit from comparing it to other techniques after a previous diagnosis supported by imaging evidence to conclusively confirm TFCC healing related to surgical intervention using CT arthrography.

In conclusion, acute distal radioulnar joint instability treated with dynamic stabilization of the DRUJ resulted in satisfactory clinical outcomes in terms of range of motion, pain relief, and joint stability. This technique represents a simple, reproducible, and minimally invasive procedure with a low rate of implant related complications.

Declaration of Competing Interest

None.

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