Stability and Clinical Outcome after Reconstruction of Complete Triangular Fibrocartilage Disruption

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Abstract

Purpose Patients with symptomatic instability of the distal radioulnar joint (DRUJ) after traumatic complete disruption of the triangular fibrocartilage complex (TFC) are best treated by anatomic reconstruction of the TFC. Postoperative clinical results from the literature are known but the improvement of DRUJ instability remains still challenging to quantify. We recently published a reliable and validated method to measure the instability of the DRUJ. This sonographic method was used to quantify the pre- and postoperative instability in correlation with clinical outcome in patients with complete TFC disruption.

Methods 11 patients with complete disruption of the TFC resulting in symptomatic instability of the DRUJ underwent open reconstruction of the TFC. The instability was measured with sonography preoperatively and one year postoperatively including the Patient-Rated Wrist Evaluation score (PRWE Score).

Results By subjective measurement, 9 patients showed comparable stability to the contralateral side. By objective measurements, DRUJ stability was completely restored in 6 patients. Seven patients had a very good and good clinical outcome. The dorsovolar shift (preoperative mean 5.2mm, min 2.4, max 7.1; postoperative 3.6mm, min 1.2, max 6.2) was significantly decreased ($p < 0.05$) and was postoperatively not different to the contralateral healthy side ($p > 0.1$). PRWE score in the 1 year follow up was 13.8. Three patients remained with significant pain, sonographically two of them were still more lax and one tighter compared to the contralateral side.

Conclusions The sonographic measurement technique allows evaluation of the stability pre- and postoperatively and does not always correlate with the qualitative clinical assessment. The described operation technique is effective for treatment of irreplaceable TFC ruptures and significantly improves the DRUJ stability and wrist function one year after surgery, which could be quantified objectively by ultrasound.

Keywords

- TFC lesions
- instability
- ultrasound

A stable distal radioulnar joint (DRUJ) is a key requirement for a pain-free movement of the wrist. A variety of contributors to DRUJ stability have been identified: its capsule,¹ the triangular fibrocartilage complex (TFC),^{2,3}

the palmar and dorsal ligaments,^{4–8} the ulnocarpal ligaments,⁷ the interosseous membrane,^{9–11} the extensor carpi ulnaris subsheath,¹² the pronator quadratus muscle,^{10,13,14} and the bony joint configuration.⁷ However, majority of

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these studies conclude that TFC plays a key role in stabilizing the joint.¹⁵ After its traumatic rupture, there often remains an instability of the DRUJ with chronic pain that is resistant to therapy. Surgical options to restore instability are a delayed repair or a reconstruction of the distal radioulnar ligaments.¹⁶ Direct repair of the ligaments presumes a good tissue quality and may usually be performed in acute or subacute trauma. According to our experience, chronic lesions are often associated with a poor ligament quality and reconstruction is required. Numerous nonanatomical^{17–19} and anatomical^{16,20} surgical techniques have been described in the literature to restore DRUJ stability, but very often restricted joint motion and remaining instability after surgery were seen in the former group.

A variety of clinical outcome studies have been published,^{16,21–23} but all of them only reported clinical aspects without assessing objective improvement of stability. “Instability” in the DRUJ is still established as a clinical subjective value, as reliable clinical tests to quantify the dorsovolar shift are missing. The presence of an increased translation in comparison to the contralateral healthy side may be caused by a TFC lesion and indicates DRUJ instability. In patients with a tight contralateral DRUJ, the injured side can easily be recognized as unstable, but in several patients with general laxity and therefore increased translation of the DRUJ on the

control reference side, it might not be clinically possible to assess undue translation.

We recently published the results of a reliable and validated ultrasound-based examination for assessing instability of the DRUJ²⁴ that may be helpful also in the assessment of the postoperative DRUJ. The aim of the present study was to evaluate the improvement of DRUJ stability and the clinical outcome after anatomic reconstruction of the distal radioulnar ligaments.

Material and Method

In the time period from January 2010 to December 2011, a total of 11 patients with complete rupture of the TFC resulting in symptomatic instability of the DRUJ underwent open reconstruction of the TFC. Symptomatic patients with a clear history of trauma, clinically and sonographically increased dorsovolar shift compared with the contralateral side, and a visible complete TFC rupture in magnetic resonance imaging (MRI) that was confirmed intraoperatively were included in the study. Exclusion criteria were any incomplete lesion, such as central lesions without rupture of the dorsal and volar radioulnar ligament, chronic central lesions, patients without clear trauma, previous TFC surgery, and patients with rheumatoid diseases. The indication for operative reconstruction

Table 1 Overview of the patients, procedures, clinical information, and DRUJ stability

	Age (y)	Side	Procedure	Preoperative dorsovolar shift (mm)	Postoperative dorsovolar shift (mm)	Contralateral side (mm)	PRWE	P/S	F/E
Case 1	32	Left	TFCR, USOT	5.5	4.0	0.7	34.5	40–0–70	60–0–70
Case 2	21	Right	TFCR, lunotriquetral reconstruction	6.6	6.2	3	0	90–0–90	80–0–40
Case 3	46	Left	TFCR, scaphoid reconstruction	6.3	2.9	1.9	0	75–0–85	70–0–70
Case 4	42	Left	TFCR, plate removal radius	6.5	2	3.3	0	45–0–20	70–0–15
Case 5	15	Right	TFCR, plate removal radius	6	4.6	1.1	25.5	90–0–85	60–0–50
Case 6	52	Right	TFCR, USOT	3.7	4.2	3.2	0	30–0–30	30–0–40
Case 7	53	Left	TFCR, USOT	5.7	1.1	4.7	0	55–0–60	60–0–55
Case 8	40	Left	TFCR, USOT	3.5	5.9	1.8	5	70–0–85	75–0–75
Case 9	37	Left	TFCR, USOT, lunotriquetral ligament reconstruction (partial ECU tendon)	7.1	1.3	2.7	50	50–0–85	50–0–70
Case 10	41	Left	TFCR, USOT, scapholunar and lunotriquetral reconstruction (partial ECU tendon)	2.4	3.9	2	40.5	80–0–90	50–0–70
Case 11	38	Right	TFCR	4.5	2.8	2.4	10	75–0–65	75–0–80

Abbreviations: ECU, extensor carpi ulnaris; F/E, flexion/extension; PRWE, Patient-Rated Wrist Evaluation; P/S, pronation/supination; TFCR, TFC reconstruction; USOT, ulnar-shortening osteotomy.

Note: List of patients' data and outcome: case number, age, wrist side, and procedure done on the wrist. Data of the preoperative and postoperative dorsovolar shift compared with the contralateral side. The function is expressed by pronation/supination and flexion/extension.

was chronic pain and symptomatic instability in patients with manual jobs.

A lesion was declared as complete when the TFC was fully detached from the fovea or radial sigmoid notch. The diagnosis was established intraoperatively through arthrotomy and the type of rupture was classified using the Palmer classification.²⁵ In nine patients, arthroscopy was first done to confirm the complete disruption. Complete ulnar detachment ($n = 7$) was the most common finding (IB). Complete radial detachment was seen only in two patients (ID) and complex central lesions with complete palmar and dorsal ruptures were also seen in two patients (classified as combination of IA and IB). All patients were treated with reconstruction of the TFC complex. An ulnar-shortening osteotomy was added if a preoperative ulnar plus variance and positive ulnar impaction test was present ($n = 8$).¹⁶ All additional operations are listed in ►Table 1.

Primary reconstruction of the TFC was not feasible in all patients due to the delayed referral to our clinic and therefore quality of tissue was mostly not sufficient for reinsertion. The delay between trauma and operation was 20.8 months (minimum, 2.5; maximum, 129; SD, ± 37.1). One construction worker (case 9) was suffering more than 10 years of pain after a severe direct trauma with ulnar styloid fracture. One patient (case 5) was treated elsewhere due to a distal radial fracture and was finally operated almost 4 years after trauma.

The group included six females and five males with a median age of 37.9 years (range, 15–53; standard deviation, 11.7); all of them were right-handed. The lesion affected the left hand in seven cases. The main reason for TFC rupture was a fall on the extended wrist and wrist sprain ($n = 6$) and distortion ($n = 4$). One patient complained of pain after lifting a heavy object. Five patients had an old concomitant fracture (one Galeazzi fracture, case 4; three distal radius fractures, case 1, 5, and 7; one ulnar styloid fracture, case 9). The patient with the primary Galeazzi fracture was fixed by plating 8 months before TFC reconstruction. In one patient with a distal extra-articular radius fracture (36 months), a secondary corrective osteotomy (15 months) was done due to a malunion (case 5). One patient was suffering from a concomitant scaphoid pseudarthrosis (case 3). All described fractures had been primarily treated in another hospital (see ►Table 1).

All patients were diagnosed preoperatively by MRI with direct intra-articular contrast injection. Patients were evaluated radiologically, sonographically, and clinically before surgery and 1 year after surgery on both wrists. The DRUJ stability was assessed by physical examination (passive anteroposterior translation) and sonographically as described before.²⁴ For this study, the DRUJ was declared as stable if the dorsovolar shift was tighter or did not exceed 1 mm compared with the contralateral healthy side. A dorsovolar shift that exceeded this limit was declared as lax. This definition is not based on previous literature but allows a better evaluation of the success of operation.

Grip strength was measured with a hydraulic hand dynamometer, and the ranges of motion of wrist and forearm were determined with a goniometer. Additionally, the Patient-

Rated Wrist Evaluation score (PRWE score; best 0, worst 100 points) was noted to assess postoperative pain and function.

All ultrasound examinations were performed with a high-resolution linear array transducer with 5–17 MHz frequency range (iU22 Ultrasonography System, Philips Medical Systems, Best, the Netherlands) by the same two independent observers, one experienced musculoskeletal radiologist and one experienced hand surgeon. Subjects sat on a chair beside a mobile measurement table opposite the examiner. Both hands were subsequently positioned in a standardized manner. The shoulder was abducted at 60 degrees and the elbow was placed on a pillow and flexed to 90 degrees. The hand was positioned in pronation of 30 degrees on a square brick such that the forearm was in a horizontal position. The brick was placed so that only the pisiform bone was in contact with it. The transducer was placed dorsally above the DRUJ, perpendicular to the longitudinal axis of the ulna. The dorsal surface of the distal radius at the level of Lister tubercle and the center of the ulnar head were displayed on the screen and the distance between them was measured. To determine the same measurement level in each volunteer, the most prominent aspect of the ulnar head was taken. Measurements were taken without load and under forced volar pressure (see ►Fig. 2). The exact measurement technique has been previously described in detail.²⁴ In addition to the absolute measurement of the dorsovolar shift (given in millimeters), we designed a quotient, Q , to express the relationship between the ulnar head and the dorsal radial surface (Q_h , healthy side; Q_{path} , pathological side). The quotient is calculated from the radioulnar distance in the unloaded (hand lifted up) position and the radioulnar distance during maximal pressure force. If the ulnar head stays above the dorsal radial surface during pressure, Q stays <1 , and if the ulnar head drops below the dorsal radial surface, Q becomes >1 ²⁴ and correlates with DRUJ instability.

Operation Technique

The surgical procedure was done according to the description of Adams and Berger¹⁶ excluding the tendon fixation technique and the surgical approach.

Fig. 1 Location of radial and ulnar drill holes (A). Tendon graft pulled through the radial and ulnar drill holes (B).

Fig. 2 Example of a sonographic measurement of one reader in the same patient (case 11). (A) Preoperative unloaded position. (B) Preoperative loaded position, the ulnar head drops down. (C) Postoperative unloaded position. (D) Postoperative loaded position. The ulnar head drops down but the DRUJ is more stable than preoperatively (B). LT, Lister tubercle; UH, ulnar head.

Approximately a 4-cm convex-shaped incision to the radial side was made over the fifth extensor compartment. The retinaculum was cut longitudinally to expose the fourth and the fifth compartment. The compartment of the extensor digiti quinti was opened to retract the tendon. The exposed capsule of the DRUJ may be opened performing a transverse arthrotomy. Alternatively, an L-shaped capsular flap may be created with one limb made along the dorsal rim of the sigmoid notch and the other just proximal and parallel to the dorsal radioulnar ligament.¹⁶ The articular surface of the TFC and its type of disruption were exposed and investigated for potential repair or reconstruction. In all our patients, a direct repair was not possible due to attenuated tissue and/or loss of substance. Functioning cartilage residuals are left and not removed, particularly the radioulnar and ulnocarpal ligaments.¹⁶ Nonunions of ulnar styloid were resected but the sheath of the extensor carpi ulnaris tendon should be preserved and not opened to maintain a stable ulnocarpal joint.

In all patients, we used the palmaris longus tendon from the ipsilateral side; alternatively, a similar-sized autograft may be used for reconstruction (contralateral side, toe extensor). The radial drill hole was made under fluoroscopic control using a guidewire first. The location should be chosen far enough from the sigmoid notch and the radiocarpal joint so as not to penetrate the subchondral bone by the drill. The position of the guidewire was now controlled in true anteroposterior and lateral fluoroscopic views to exclude penetration into the sigmoid notch. Finally, the wire should be placed parallel to the radiocarpal and radioulnar joint. Then, a 2.7- to 3.2-mm cannulated drill was used, depending on the

graft thickness. Care must be taken not to penetrate the palmar soft tissue when drilling (►Fig. 1).

Compared with the technique of Adams and Berger,¹⁶ we did not use a circumferential course of the graft around the ulna. A drill hole (3.2–4.5 mm) was created from the ulnar fovea directly into the medullary canal in the direction of the ulnar bone axis. The diameter must be chosen larger than the radial hole to ensure that both graft legs may be pulled through. Two additional pullout holes (2.5 mm) were created on the dorsal side of the ulna shaft, the first ~2.5 cm and the second 3.5 cm proximal to the ulnocarpal joint. The graft was now pulled through the radial tunnel with a 2 Ethibond thread. On the palmar side, through a separate incision, the graft was pulled back to the fovea of the ulna through the ulnocarpal ligaments, taking care not to entrap neurovascular structures or flexor tendons. The two graft legs were now pulled through the tunnel at the ulnar fovea to exit each one through the two dorsal-sided channels (►Fig. 1). To complete the fixation, both legs were knotted together with two sutures fixed at the end of each leg. They must be tightened and fixed in a pronation-supination neutral forearm position to avoid restriction in pronation or supination.

The extremity was immobilized for 4 weeks in a long arm cast in a slightly supinated position to preserve a good range of supination. After 4 weeks, pronation-supination exercises were started with occupational therapy guidance, and after 6 weeks the long arm cast is substituted by a short arm cast. Muscle strengthening and force exercises were allowed 3 months postoperatively, and full weight bearing was

allowed after 6 months. If necessary, a dynamic supination splint is applied after 6 to 8 weeks. The scaphoid pseudarthrosis (case 3) was reconstructed with an iliac crest bone block and was immobilized for a total of 8 weeks.

Results

Clinical Data

The overall PRWE score at the 1-year follow-up was 15.0 points (minimum, 0; maximum, 50; SD, ± 19.1). Five of 11 patients were completely pain free (PRWE score, 0). Two patients had residual pain while heavy weight bearing and forced torque motion (PRWE score, 5 and 10, respectively), one patient had improved subjectively (PRWE score, 25.5) but still suffered low pain during daily activities, and three patients improved but still complained of significant pain during daily activities (PRWE score, 34.5, 40.5, and 50, respectively) with a poor result. Two of the patients with poor clinical outcome ($n = 3$) were sonographically more lax (case 1 and 10) and one was tighter than the contralateral side (case 9).

On average, wrist flexion recovered to 62 degrees (minimum, 30; maximum, 80; SD, ± 14 ; 94% of preoperative status) and wrist extension recovered to 58 degrees (minimum, 15; maximum, 80; SD, ± 20 ; 94% of the preoperative status). Supination recovered to 70 degrees (minimum, 20; maximum, 90; SD, ± 24 ; 91% of preoperative status) and pronation recovered to 60 degrees (minimum, 30; maximum, 80; SD, ± 16 ; 96% of the preoperative status). Grip strength improved to 34.7 kg (minimum, 30; maximum, 80; SD, ± 13 ; 122% of the preoperative status and 82.3% of the contralateral strength).

Preoperative Instability

Clinically evaluated, all patients had an increased dorsovolar shift on the pathological side compared with the healthy wrist. Sonographically, the mean preoperative dorsovolar translation of the pathological wrist was 5.2 mm (minimum, 2.40; maximum, 7.10; SD, ± 1.5), whereas the measurement of the contralateral side was 2.4 mm (minimum, 0.7; maximum, 4.7; SD, ± 1.1), which was significantly different ($p < 0.05$). The quotient Q on the pathological side (Q_{path}) was 1.4 (minimum, 0.82; maximum, 2.41; SD, ± 0.46), whereas the quotient Q on the healthy side (Q_{h}) was 0.59 (minimum, 0.19; maximum, 1.0; SD, ± 0.25). Q_{h} and Q_{path} as well as the dorsovolar shift measured in millimeters were significantly different ($p < 0.05$).

Postoperative Stability

By subjective evaluation, the stability was restored and comparable in seven patients (case 3, 4, 6, 7, 9, 10, and 11). By sonographic measurements, DRUJ stability was tighter (the healthy side shows a dorsovolar translation that is at least 1 mm larger than the operated side) in three patients (case 4, 7, and 9), comparable to the healthy wrist (the operated side does not exceed ± 1 mm compared with the healthy side) in three patients (case 3, 6, and 11), and still more lax than the contralateral side (the operated side shows

a dorsovolar translation that is at least 1 mm larger than the healthy side) in five patients (case 1, 2, 5, 8, and 10). The postoperative dorsovolar translation of the pathological wrist was 3.5 mm (minimum, 1.1; maximum, 6.2; SD, ± 1.7). The quotient Q on the pathological side (Q_{path}) was 0.93 (minimum, 0.40; maximum, 1.89; SD, ± 0.55) 1 year postoperatively. There was no significant difference between the postoperative Q_{path} and Q_{h} ($p > 0.05$) and the dorsovolar shift measured in millimeters ($p > 0.05$). A sonographic example of the preoperative and postoperative measurement is given in **Fig. 2**.

Complications

Three patients showed a poor outcome with persistent wrist pain; two of them (case 1 and 10) had a recurrent laxity and one (case 9) had a tighter DRUJ compared with the healthy side. A complex regional pain syndrome and symptomatic DRUJ arthritis could be excluded in all three patients. One patient (case 6) showed a poor range of motion but was free of pain and not limited during daily activities. There was no wound healing disorder, infection, or nerve lesion recorded.

Discussion

A stable DRUJ is an important element for the wrist function, not only for forearm rotations but also for load and force transmission.²⁶ The surrounding soft tissues of the DRUJ are considered to be the most important stabilizers because the bony joint configuration of the joint does not allow a significant inheritance.² Many stabilizers of the DRUJ have been identified¹⁻¹⁴ but the majority of these studies conclude that particularly the TFC plays the key role in stabilizing the joint.

The presence of increased translation in comparison to the contralateral healthy side is consistent with instability and mostly associated with a complete acute or chronic rupture of the TFC. A symptomatic instability especially in manually active workers is a possible indication for ligament reconstruction. The primary goal of treatment is to achieve a pain-free movement of the wrist during daily activities and work, and restoration of a stable DRUJ and the full range of motion. The clinical preoperative assessment of the instability compared with the contralateral side is often limited because of pain or the difference of the dorsovolar shift is too small to be recognized qualitatively. Furthermore, in patients with generalized ligamentous laxity, it is more challenging to determine if this degree of laxity is pathological. Several methods have been described to quantify the amount of dorsovolar translation based on computed tomography, such as the radioulnar line method,²⁷ the congruity and epicenter methods,²⁸ and the radioulnar ratio method.²⁹ The advantages of sonography, such as rapid availability and low costs, are well known, and sonography of the musculoskeletal system is widely available and performed by radiologists, hand surgeons, and rheumatologists. All these previously described methods are not suitable for clinical daily practice and are time-consuming and cost-intensive. The settings of our measurement technique are simple, and the interobserver

agreement was proven and published recently.²⁴ The method seems to be applicable as well postoperatively in patients after TFC reconstruction; in all 11 patients, the measurement could be done properly without restrictions, even in those patients with persistent pain.

If surgical treatment is indicated, the TFC itself is often not repairable; in our experience, intraoperative findings show poor soft tissue quality. In the present study, all patients had a chronic TFC rupture with a mean delay between trauma and surgery of 20.8 months (minimum, 2.5; maximum, 129; SD, ± 37.1) and did not qualify for a direct TFC repair. Reconstructions were performed in a modified technique according to Adams and Berger.¹⁶ In the method of Adams and Berger,¹⁶ the two graft limbs are tightened circumferentially around the ulnar neck and connected on the dorsal side with a half hitch and securing nonabsorbable sutures. In our technique, both limbs are passed intramedullary through the distal ulna and pulled out through separate holes. With the forearm in neutral position, both limbs are tightened and secured again with nonabsorbable sutures. Previously published reconstruction techniques^{20,30} require a more extensive dissection.

By clinical measurements, seven patients had a comparable postoperative laxity to the healthy side. By sonographical measurement, DRUJ stability was tighter in three patients, comparable to the healthy wrist in three patients, and still more lax than the contralateral side in five patients. Even if the DRUJ instability may be assessed clinically and the method is widely used in publications, the clinical evaluation is severely limited. We believe that assessing the instability clinically by comparing with the contralateral side is a reliable method for follow-ups, but in line with pre- or postoperative evaluation and publication of results, a qualitative assessment should be used to evaluate the results. Unfortunately, our results are not comparable yet to other studies.

Five patients were still more lax compared with the contralateral side but improved function and pain compared with the preoperative situation. Two of them (case 1 and 10) had a poor clinical result and complained of significant persistent pain during daily activity. We see persistent laxity as the main reason for persistent pain but the present series is too small to quantify the correlation between clinical outcome and persistent laxity. In addition, a very tense tendon graft may lead to a very tight DRUJ that could be responsible for a poor functional outcome and persistent pain (case 9). We believe therefore that the TFC reconstruction should be done in a manner that the stability is restored comparable to the healthy side to achieve good clinical results. Also, concomitant lesions that require additional reconstruction may compromise the clinical outcome. In case 9 and 10 with persistent pain and poor clinical result, a lunotriquetral and both lunotriquetral and scapholunar reconstruction, respectively, were performed.

The limitations of this study include small number of patients and examination of only one type of destabilizing wrist pathology. Because of the retrospective design, we did not record the preoperative PRWE score. Furthermore, instability in supination was not tested.

In conclusion, the results of this study show that the described ultrasound technique to measure the quantitative laxity of the DRUJ is a practicable method in clinical daily practice, even for postoperative quantification. The stability of the DRUJ may be assessed quantitatively and makes the results comparable. The clinical results of the published series are similar to those of the literature.

Conflict of Interest

None.

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