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HANDSURGERY

Distal radioulnar joint instability: current concepts of treatment

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Abstract
Distal radioulnar joint (DRUJ) instability is often an underestimated or missed lesion which may entail fatal consequences. The triangular fibrocartilage complex is a biomechanically very important stabilizer of the DRUJ and guarantees unrestricted range of motion of the forearm. To detect DRUJ instability a systematic examination is of uppermost importance. The contralateral healthy arm will be used for comparison during clinical examination. X-rays are required to exclude osseous lesions or deformities. Computed tomography of both wrists in neutral forearm rotation, supination, and pronation may be necessary to verify DRUJ instability in ambiguous situations. Following a systematic clinical examination wrist and DRUJ arthroscopy detects lesions definitely. Tears of the distal radioulnar ligaments which entail DRUJ instability should be repaired preferably anatomically. Ulnar-sided ligament ruptures which cause instability are detected more often than radial-sided ones. Osseous ligament avulsions are mostly refixated osteosynthetically. Ligamentous tears of the distal radioulnar ligaments may be reconstructed using anchor suture or transosseous refixation. Secondary procedures such as tendon transplants are necessary for anatomical reconstruction in cases of unrepairable ligament tears.

Keywords Ligament reconstruction · Distal radioulnar joint · Instability · Classification · Triangular fibrocartilage complex

Introduction

Distal radius fractures with concomitant distal radioulnar joint (DRUJ) instability are often an underestimated entity which may entail devastating consequences for the complete upper extremity [1]. Bearing the latter in mind focus on distal radius fractures does not suffice at all. The anatomical surroundings are to be examined precisely to cope with the complete extent of the injury and to draw the proper conclusions [2, 3]. This review article focuses on triangular fibrocartilage complex (TFCC) lesions as these injuries are far more common than concomitant lesions to the distal part of the interosseous membrane in the context of distal radius fractures [4, 5].

Anatomy

The TFCC is in combination with the distal part of the interosseus membrane the most important stabilizer of the DRUJ to enable unrestricted range of motion of the forearm [3, 6, 7]. The interaction of the TFCC and the distal part of the interosseous membrane are crucial to guarantee DRUJ stability [6–10]. Osseous structures of DRUJ are of minor significance. Basically, four sigmoid notch configurations are known: C-shaped, slope-shaped, S-shaped, and a flat configuration [11]. The latter one may predipose to greater translation of the joint partners within the DRUJ [11].

The radioulnar ligaments of the DRUJ are attached at the palmar and dorsal rims of the sigmoid notch and enclose the articular disc. The superficial fibers of the former ligaments insert at the base of the styloid process whereas the deep fibers insert at the ulnar fovea instead (Fig. 1; video 1) [7, 12].

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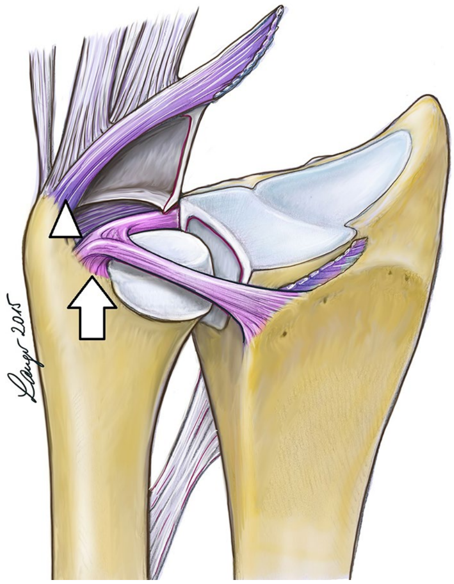


Fig. 1 Palmar view of the distal radioulnar ligaments: superficial fibers with insertion at the base of the ulnar styloid process are detached at the origin (Δ); deep fibers with insertion at the ulnar fovea (→); copyright Springer

The centric insertions of the deep fibers at the ulnar fovea and the epicentric insertions of the superficial fibers at the base of the ulnar styloid process enable smooth tension transition between these structures during pronosupination [13, 14]. These kinematic properties guarantee unrestricted forearm rotation while DRUJ stability is preserved [4, 7, 13]. Furthermore, the biomechanically irrelevant meniscus homologue is part of the TFCC and is located distal to the horizontal articular disc. This former structure is well vascularised and is often located in front of the ulnocarpal recess [15]. The ligg. ulnolunatum et ulnotriquetrum, the floor of the sixth extensor tendon compartment including the tendon sheath, and the lig. collaterale carpi ulnare complete the TFCC [15, 16].

Especially, ulnar-sided TFC tears may cause DRUJ instability with disabling consequences [4, 8, 10, 13, 17, 18]. These kind of lesions are to be detected immediately especially after treatment of distal radius fractures and should be dealt with accordingly.

Etiology

Instabilities of the DRUJ may be caused by osseous or primarily soft tissue lesions. Distal radius fractures with or without avulsion of the ulnar styloid process or forced forearm rotation are responsible for the majority of DRUJ instabilities [19, 20]. Sometimes, Galeazzi type fractures and fractures of the distal ulna may cause instability, as well. Basically, the possibility of instability rises in accordance to the proximal fracture location of the ulnar styloid process and the extent of comminution of the fracture (Fig. 2) [7, 21].

Regarding soft tissue injuries, especially ulnar-sided TFC tears may cause DRUJ instability, as well [18].

Nakamura et al. distinguish between acute (< 6 months) and chronic DRUJ instabilities (> 6 months) whereas the authors do not consider the latter definition as relevant for the below outlined treatment strategy [2, 22].

Symptoms and diagnostics

Evaluation of DRUJ stability is mandatory in case of forearm fractures. The former evaluation is performed during surgery or after completion of conservative fracture treatment.

Isolated soft tissue lesions with instability are often subtle and patients often seek attendance after weeks or even months. Patients suffer typically from ulnocarpal pain with exacerbation during forced forearm rotation. Symptoms may be discreet or more debilitating depending on the extent of instability. Joint laxity and instability ought to be distinguished properly. Therefore, examination in comparison to the contralateral side is advisable. Moreover, static instability with uni- or multi-directional translation of the DRUJ partners and dynamic instability with clicking during

Fig. 2 Dorso-palmar x-ray of the wrist: intra-articular distal comminuted radius fracture with proximal ulnar styloid process avulsion. Dislocation of proximal avulsion of the styloid process is the same as the radial dislocation of the radius fracture. This may correlate with intact superficial fibers. Whereas a flake fracture (Δ) of the ulna head epitomizes the avulsion of the deep fibers of the radioulnar ligaments; copyright Springer

Fig. 3 Lateral x-ray of the wrist: the pisiform is located between the palmar cortex of the capitate (left line) and the palmar cortex of the distal scaphoid (right line); the radial styloid process (outlined) is centrally oriented; lunate, triquetrum, and proximal scaphoid are overlapping each other; copyright Springer

forearm rotation are further crucial parameters to be identified [23].

These parameters ought to be analyzed:

- Direction of instability
- Extent of injury
    - Ligamentous versus osseous
    - Ligamentous: complete or isolated tear of either superficial or deep fibers
    - Quality of the TFCC: un- versus repairable
- Ulna variance

Clinical history

Detailed history taking should include: analysis of trauma; precise topographic pain detection; persistent pain versus pain during load; functional deficits during forearm rotation; prior lesions; functional restrictions regarding recreational or professional activities; prior surgeries; dexterity; patient expectation [2].

Clinical examination

Swelling is often identified ulnarly and the ulna head is often prominent dorsally whereas the carpus is supinated in relation to the forearm [23, 24]. Dorsal subluxation of the ulna head is typically detected with supination loss whereas palmar subluxation of the ulna head may be seen in combination with pronation loss [25, 26].

Pronation and supination may often provoke pain around the distal ulna [23, 24, 27, 28]. "Clicking" or "snapping" sensations of the extensor carpi ulnaris tendon might be observed during forerarm rotation [26–28].

The following clinical test are evaluated scientifically [3].

Ulna fovea sign

Ulna fovea sign is positive whenever pain is provoked within the "soft spot" between the flexor carpi ulnaris tendon, styloid process, pisiform, and ulna head. A positive sign hints at ulnar-sided tears of the radioulnar ligaments [29].

Dorso-palmar stress test

The forearm is in neutral rotation and the examiner holds the distal radius firmly. Dorsal and palmar translation of

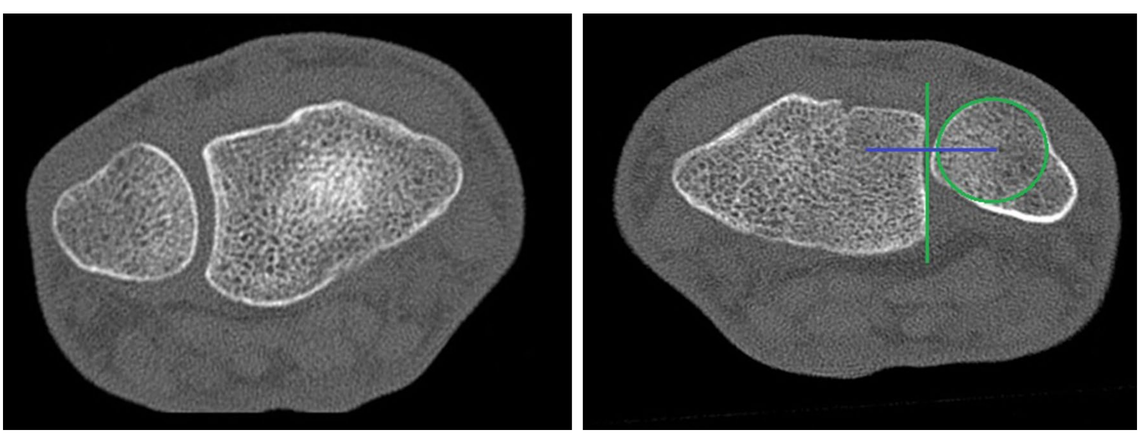


Fig. 4 CT of both wrists with dorsal subluxation of the left ulna head; radioulnar ratio method is outlined; the flat configuration of the sigmoid notch is evident, copyright Springer

Table 1 Radioulnar ratio method

Lo et al. [42]			Park and Kim [45]			Kim and Park [40]		
Forearm rotation	Ratio	Twofold SD	Forearm rotation	Ratio	95%-CI	Forearm rotation	Ratio	95%-CI
Neutral rotation	0.5	0.08	Neutral rotation	0.51	0.32–0.69	Neutral rotation	0.48	0.22–0.76
90°-pronation	0.6	0.1	70°-pronation	0.66	0.48–0.86	70°-pronation	0.63	0.35–0.88
90°-supination	0.37	0.18	70°-supination	0.42	0.28–0.52	70°-supination	0.43	0.22–0.6

95%-CI 95%-confidence interval, *SD* standard deviation

the ulna head is applied at the same time with the second hand. Extent of translation is graded: grade 0 defines physiological articulation, grade 1 defines ligament laxity without loss of function and firm endpoint, grade 2 defines dynamic instability with loss of function without firm endpoint, and grade 3 defines spontaneous subluxation with reduction during active forearm rotation (video 2) [3, 30].

Press test

The patient pushes his hands from an armchair to stand up. If a reproducible ulnocarpal pain is provoked, this test is positive [31]. Lester et al. examined 27 patients with suspected TFCC lesions and 14 patients underwent arthroscopy because of persistent pain. TFCC lesions could be detected in all patients. The authors concluded that a 100% sensitivity regarding TFCC lesions is present. A 100% specificity was declared since a control group of 100 patients with other complaints excluding TFCC lesions were examined. In all cases a negative test was found [31].

Radiological examination

Two perpendicular oriented x-ray projections of the wrist are mandatory. Specific projections and/or projections of the contralateral side may be added. Osseous or ligamentous malformations can prevent properly performed x-rays [32]. Therefore, computed tomography may be useful in these cases.

Prerequisites for a proper lateral x-ray projection of the wrist

- Ulnar styloid process is projected centrally to the ulna [13, 33, 34].
- The pisiform is projected between the interval of the palmar cortex of the capitate and the palmar cortex of the distal scaphoid (Fig. 3) [35, 36].
- Overlapping of proximal scaphoid, lunate, and triquetrum [32, 37].
- Radial styloid process is projected centrally to the proximal carpal row.

Distances of greater than 6 mm between the dorsal cortex of the distal radius and distal ulna are very suspicious regarding DRUJ instability. Distances of 4–5 mm are ambiguous whereas distances of less than 3 mm are not indicative for DRUJ instability [38]. X-ray projections which are angled at least 10° from standard prevent correct interpretation of the films [37].

Prerequisites for a proper dorso-palmar x-ray projection of the wrist

- Both radial and ulnar styloid processes are contouring the wrist [13, 33].
- The lunate lies completely within the lunate facet [33].

Flake fractures at the ulna head (Fig. 2), proximal ulnar styloid process fractures, DRUJ gap, sagittal dislocation of distal radius fractures greater than 20°, and shortening of the radius greater than 5 mm are indicative for DRUJ instability [25, 39]. Overlapping of radius and ulna hints at a palmar luxation of the ulna whereas a wider gap may be suspicious for a dorsal luxation of the ulna [25].

Computed tomography

This technique enables the best visualization to diagnose DRUJ instability since anatomic structures do not overlap each other [40, 41]. Both wrists should be examined in neutral forearm rotation, pronation, and supination [26, 41].

Several assessment methods have been published so far [26, 32, 37, 41–44]. The radioulnar ratio method proved to be reliable and feasible during daily routine [3, 42]. A transparent template with marked concentric circles with increasing radii is put at the ulna head to determine the center of the ulna head. Then a line connecting the palmar and dorsal rims of the sigmoid notch is drawn. A line perpendicular to the latter line is then drawn through the center of the ulnar head. The distance between the dorsal and palmar rims of the sigmoid notch is measured along the line. The ratio of the latter length to the distance of both rims is finally calculated (Fig. 4) [42].

Studies which have determined physiological ratios are listed in Table 1 [40, 42, 45].

Fig. 5 Classification of TFCC lesions according to Palmer [15]; copyright Springer

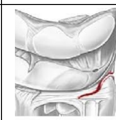
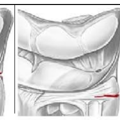
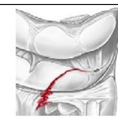
Classification	Pathology	Illustration
1A	traumatic central tear	
1B	traumatic ulnar-sided tear (left illustration), somtimes with concomitant avulsion of the styloid process (right illustration)	 
1C	traumatic peripheral tear incorporating the ligg. ulnolunatum et ulnotriquetrum	
1D	traumatic radial-sided tear, somtimes with concomitant fracture of the sigmoid notch	
2A	degenerative lesion with thinning of the articular disc	
2B	degenerative lesion with thinning of the articular disc and cartilage lesions at the lunate and/or ulna head	
2C	degenerative lesion with perforation of the articular disc and cartilage lesion at the lunate and/or ulna head	
2D	degenerative lesion with perforation of the articular disc and cartilage lesion at the lunate and/or ulna head and tear of the lig. lunotriquetrum	
2E	degenerative lesion with perforation of the articular disc and cartilage lesion at the lunate and/or ulna head and tear of the lig. lunotriquetrum with ulnocarpal osteoarthritis	

Fig. 6 Atzei classification regarding ulnar-sided TFCC lesions [48]; copyright Springer

Classification	Pathology	Illustration
1	tear of the superficial fibers of the radioulnar ligaments	
2	tear of the superficial and deep fibers of the radioulnar ligaments	
3	tear of the deep fibers of the radioulnar ligaments	
4	unrepairable, complete, ulnar-sided tear of the radioulnar ligaments	
5	ulnar-sided tear of the radioulnar ligaments and DRUJ osteoarthritis	

Fig. 7 Dorsal-palmar x-ray of the wrist: comminuted distal radius fracture with proximal avulsion the ulnar styloid process

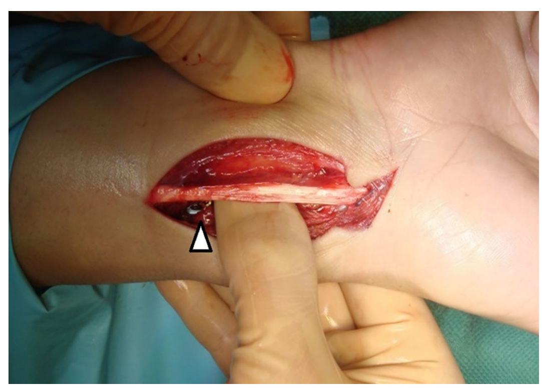


Fig. 8 Intraoperative ballottement test to examine DRUJ stability after internal fixation of a distal radius fracture using a fixed angle plate system (Δ); radius and ulna are held between thumb and fingers of each hand and translation between both bones is provoked; copyright Springer

Wrist arthroscopy

Wrist arthroscopy is still the reference standard to diagnose TFCC lesions precisely (video 1 and 3, copyright Springer) [46]. Arthroscopic visualization facilitating the 3/4 portal enables direct detection of lesions regarding the superficial

Fig. 9 Dorsal-palmar x-ray of the wrist 5 weeks after surgery: refixation of the ulnar styloid process using a self taping screw and a fixed angle plate system for the distal radius fracture

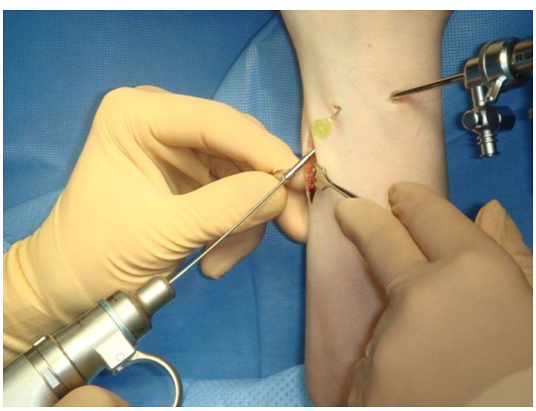


Fig. 10 Drilling of the bone tunnels; visualisation via the 3/4 portal; copyright Springer

part and/or complete ruptures of the TFCC. A positive "Hook" test (video 3) may indirectly hint at a tear of the deep part of the TFCC whereas DRUJ arthroscopy enables direct identification of such lesions [22]. Precise classification of TFCC lesions is only possible if wrist arthroscopy is applied to initiate adequate therapy (Fig. 5, 6).

Therapy

The following treatment concept is a current strategy which proved to be reliable in our hands even with concomitant distal radius fractures [2].

Osseous avulsions of the TFCC

Examination of the DRUJ stability is mandatory intra-operatively after fixation of distal radius fractures. Especially, avulsions of the ulnar styloid process are suspicious of DRUJ instability and should be dealt with accordingly (Fig. 7). After reduction and internal fixation of the fracture the "Ballottement" test as a modified dorso-palmar stress test is performed dynamically in different rotational positions of the forearm (Fig. 8) [3, 30, 47]. Reference for the latter test is the contralateral side. Refixation of the ulnar styloid process is mandatory in case of instability (Fig. 9). Afterwards immobilization in neutral forearm rotation is recommended in a long arm cast for 2–3 weeks.

Tears of the superficial part of the TFCC (Atzei 1)

Tears of the superficial part of the TFCC may cause both pain and instability. These symptoms are often less evident than tears of the deep part of the TFCC (Atzei 3) or complete ulnar-sided lesions (Atzei 2). Arthroscopic fixation of the superficial part to the capsule may suffice in most cases [48].

Tears of the deep part of the TFCC (Atzei 3)

Anatomic refixation of the deep fibers of the radioulnar ligaments are necessary [49].

This can be achieved either arthroscopically or conventionally. The deep fibers ought to be attached at the ulnar fovea. Arthroscopic assisted transosseous refixation is done facilitating the 3/4 portal. An incision between the flexor carpi ulnaris and extensor carpi ulnaris tendons at the distal ulna reveals the base of styloid process to drill two parallel tunnels aiming at the ulnar fovea for suture fixation (Fig. 10) [50].

The mattress suture is facilitated through both tunnels (Fig. 11).

The refixation of the deep fibers can also be performed conventionally using transosseous technique or anchor suture (Fig. 12). The approach described by Garcia-Elias may be applied for both procedures (Fig. 13) [51].

It is crucial to flex the elbow, elevate the forearm, and reduce the ulnar head in neutral rotation of the forearm before the suture is tightened firmly at the ulnar entrance of the tunnels. Contraindications are DRUJ osteoarthritis. A long arm cast in neutral forearm rotation is applied.

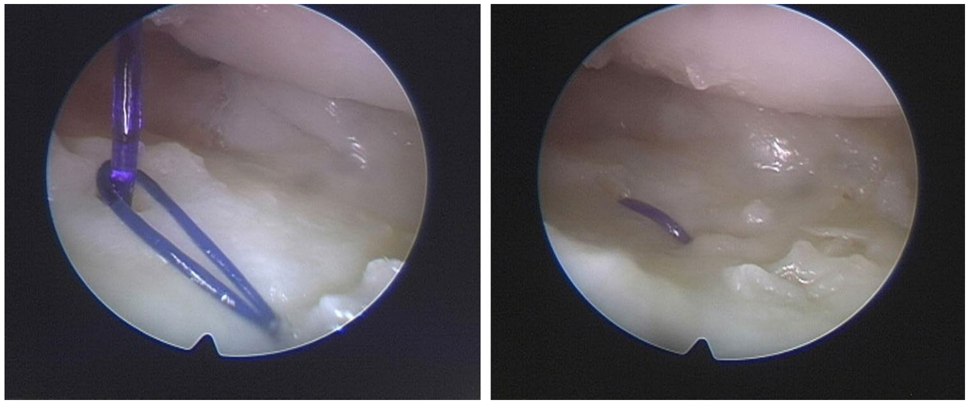


Fig. 11 Arthroscopic view facilitating the 3/4 portal: suture management to refixate ulnar-sided TFCC lesions using a lasso loop (left); completed transosseous mattress suture (right); copyright Springer

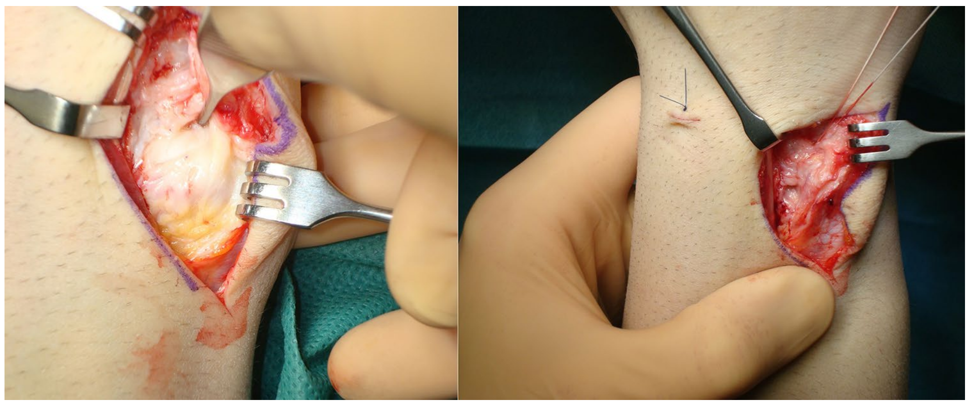


Fig. 12 Approach through the fifth extensor compartment, pincers identify the tear of the deep fibers (left); anchor suture is put into the ulnar fovea (right); copyright Springer

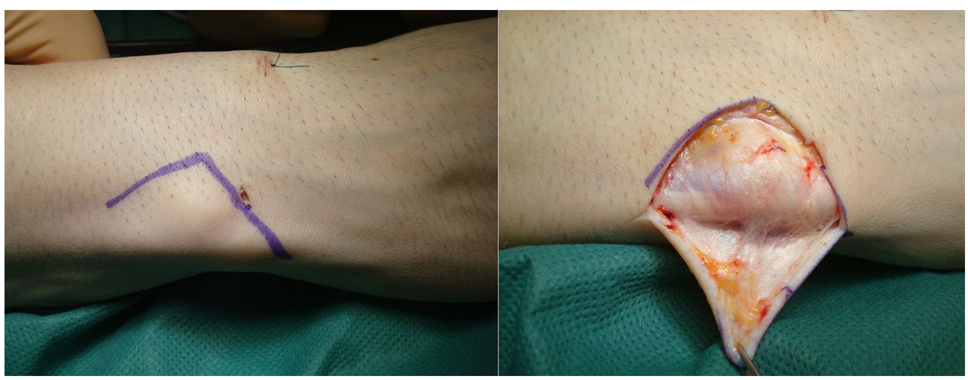


Fig. 13 Outlined skin incision for the Garcia–Elias approach (left); dissection to the extensor retinaculum (right) [51]; copyright Springer

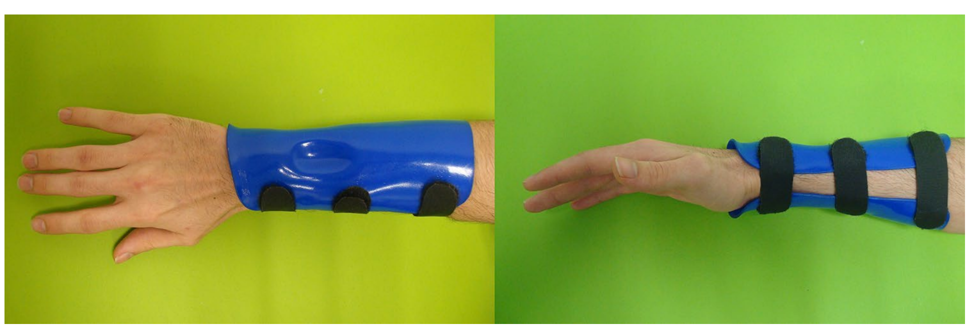


Fig. 14 Bowers splint to restrict forearm rotation; copyright Springer

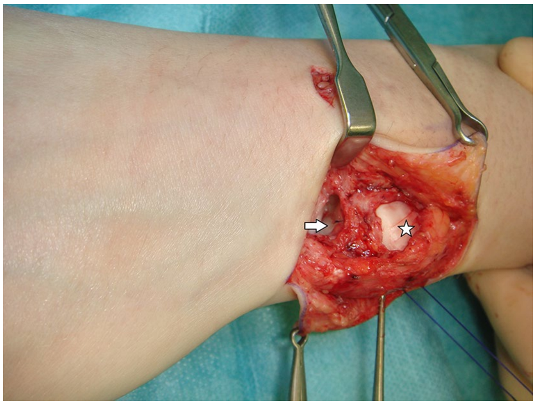


Fig. 15 Put transosseous mattress suture (→) to refixate the deep fibers; *ulna head; copyright Springer

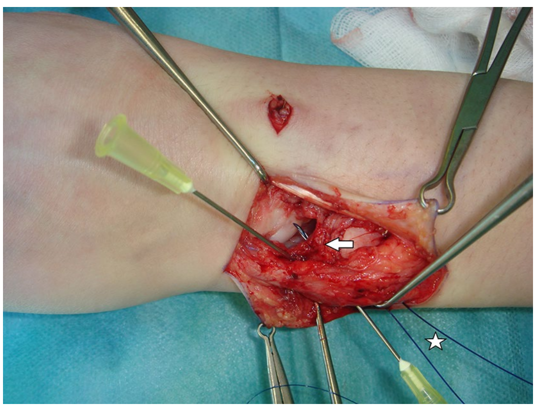


Fig. 16 Cannula with lasso loop perforates the ligament stump of the superficial fibers (→); second cannula identifies the ulnar styloid process; *engaged transosseous mattress suture for refixation of the deep fibers; copyright Springer

Immobilization is recommended for 4 weeks. Afterwards, a Bowers splint which restricts pronation and supination to 45° in each direction may be worn for further 4 weeks (Fig. 14) [52]. Activities without restrictions are encouraged after 3 months.

Complete tears of the TFCC (Atzei 2)

Complete tears involve both the deep and superficial fibers of the distal radioulnar ligaments. These lesions should be refixated anatomically, especially for high demand patients such as athletes or adolescents [49, 53]. The conventional technique should be applied since this approach enables a precise distinction between the deep and superficial fibers [51, 53]. The deep fibers are to be attached according to the aforementioned section (Fig. 15). The superficial fibers are refixated at the base of the styloid process facilitating a third bone tunnel which is located distally to the first two parallel tunnels respectively (Fig. 16). The anatomic transosseous fixation of both fibers may restore a physiological situation [6, 10, 53, 54].

Contraindications are similar to the aforementioned technique regarding the refixation of the deep fibers.

Post-traumatic DRUJ instability with unrepairable TFCC

In case of an unrepairable TFCC the distinction between a dorsal uni-directional and a multi-directional instability is of uppermost importance. The capsule imbrication is a reliable procedure to treat dorsal uni-directional instabilities (Fig. 17) [55, 56]. This technique is easily performed and may be combined with further procedures.

It is crucial to elevate the forearm and to reduce the ulna before capsule imbrication is performed. The suturing is done in forearm supination. Contraindications are DRUJ osteoarthritis, and insufficient capsule tissue. Afterwards, a long arm cast is applied in 60° forearm supination for 4 weeks. Then a Bowers splint may be applied for further 4 weeks (Fig. 14).

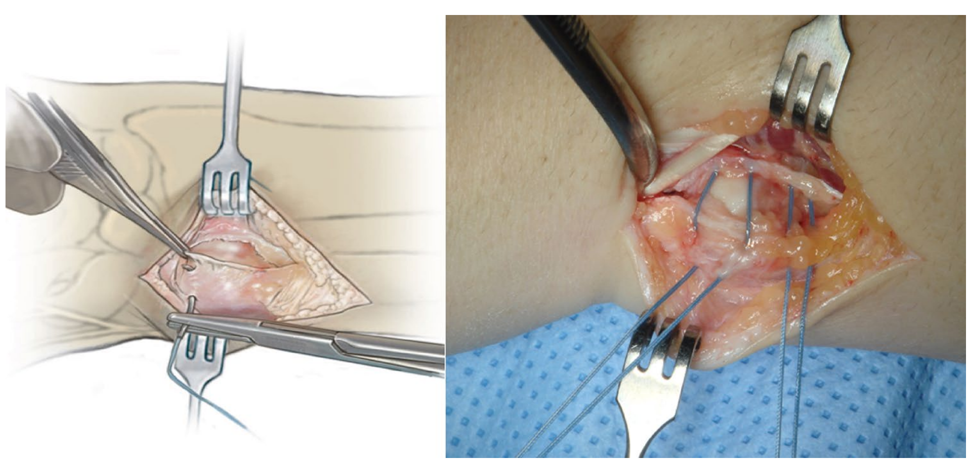


Fig. 17 Distal capsule suture for imbrication at the fifth extensor compartment (left); complete suture in situ (right); copyright Springer

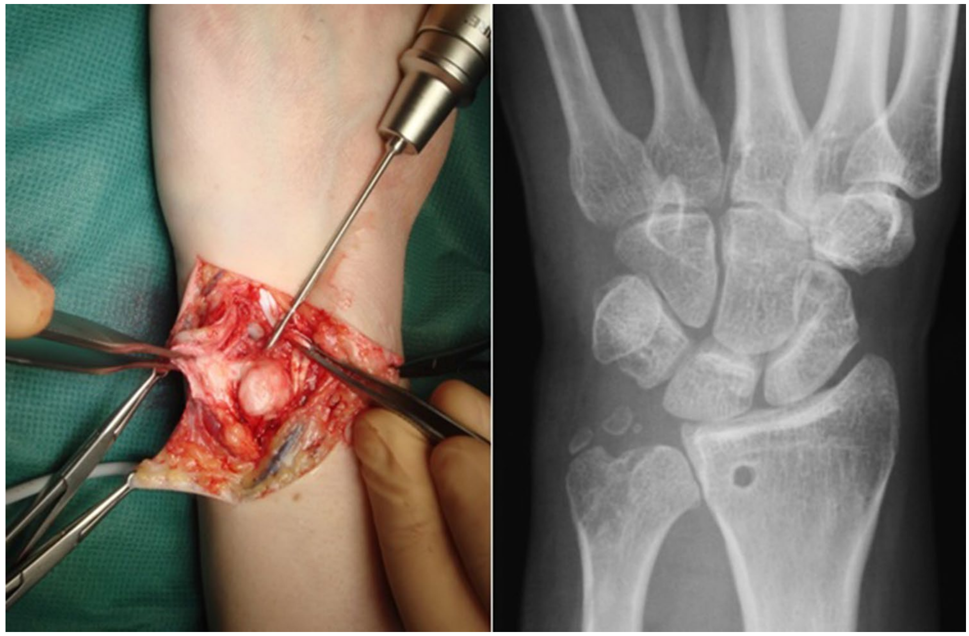


Fig. 18 Drilling of the ulnar bone tunnel at the ulnar fovea (left); bone tunnels at the distal radius and ulna head for the Adams' procedure (right); copyright Springer

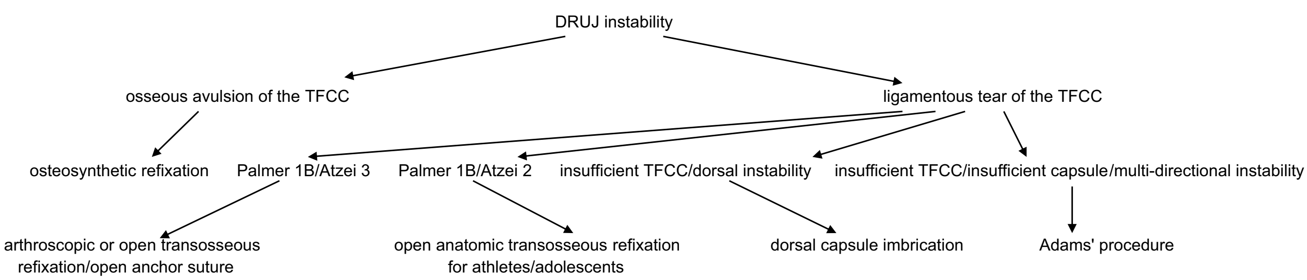


Fig. 19 Current treatment concept for DRUJ instability

In case of a multi-directional instability with unrepairable TFCC the radioulnar ligaments ought to be reconstructed. The Adams' procedure has proved its reliability [57]. Adams facilitates the palmaris longus tendon and put this tendon through a dorsal-palmar bone tunnel at the distal ulnar corner of the radius. Then the tendon is transfered and anchored within a second bone tunnel through the ulnar fovea (Fig. 18). An interference screw secures the tendon within the tunnel at the distal ulna in neutral forearm rotation. Contraindications are the same as mentioned above. Immobilization is recommended for 6 weeks in a long arm cast in neutral forearm rotation. Afterwards a Bowers splint is applied for further 4 weeks. Strenuous exercises are allowed after 6 months.

In case of a partially shrunken TFC which cannot be reattached at the ulnar fovea, Nakamura uses half of the extensor carpi ulnaris tendon which remains attached distally and fixes the tendon at the remains of TFC [58].

Current treatment concept for DRUJ instability (Fig. 19).

Conclusion

A systematic examination is crucial to diagnose and treat DRUJ instability correctly. The precise analysis of instability is the cornerstone of an adequate therapeutic strategy. Anatomic reconstruction of the TFCC is to be preferred whenever possible. Osseous avulsions with concomitant instability require osteosynthetic refixations. Ulnar-sided ligamentous TFCC tears (Palmer 1b/Atzei 3) may be treated either by transosseous mattress suture or anchor suture respectively. Ulnar-sided ligamentous TFCC tears (Palmer 1b/Atzei 2) may be treated by anatomic transosseous refixation of both superficial and deep fibers for high demand patients such as athletes or adolescents. Otherwise refixation of the deep fibers may suffice. Unrepairable, multi-directional instabilities (Atzei 4) may be reconstructed applying the Adams' procedure.

Distal radius fractures do not alter this treatment algorithm.

Up to now neither arthroscopic refixations nor open procedures have been proven to be superior regarding functional outcome [59–61].

Compliance with ethical standards

Conflict of interest The authors declare that there is no conflict of interest regarding the review article.

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