Disorders of the triangular fibrocartilage complex (TFCC) represent one of the most frequent causes of ulnar-sided pain and disability in the wrist. TFCC lesions are currently categorized according to the classification system proposed by Andrew K. Palmer1 in 1989, which considers two main classes: Class 1, Traumatic lesions and Class 2, Degenerative lesions. These classes are further divided into different types, depending on the location of the tear and the presence or absence of associated chondromalacic changes.

Class 1 traumatic lesions are organized according to the tear’s location. Type 1-B injuries consist of traumatic tears involving the ulnar periphery of the TFCC and may be associated with an ulnar styloid fracture. Histologic and functional anatomy show that the ulnar side of the TFCC is arranged in a complex tridimensional structure and consists of 3 components: the proximal triangular ligament, the distal hammock structure, and the ulnar collateral ligament (UCL).2 According to its structure and function, the UCL is assimilated to the distal hammock structure to make up the distal component of the TFCC (dc-TFCC), which supports and suspends the ulnar carpus.2 The proximal component of the TFCC (pc-TFCC) is represented by the proximal triangular ligament and consists of the strong ligamentous structure that stabilizes the distal radioulnar joint (DRUJ). It is also described as “ligamentum subcruentum,”3 and is made up of the DRUJ ligaments, palmar and dorsal, whose ulnar insertion is located in the fovea rather than in the ulnar styloid (Fig. 1).

The fovea ulnaris represents the “convergent point” of insertion for the pc-TFCC and for the fibers of the palmar unocarpal ligaments.4 Hence the foveal insertion of the TFCC plays a key role in the stability of both the DRUJ and the unocarpal joint.

Type 1-B TFCC tears may occur following a violent traction and twisting of the wrist or forearm or, more commonly, a fall on the outstretched hand, which may also cause a fracture of the distal radius. According to the magnitude and direction of the traumatic force acting on the ulnar wrist, the TFCC components may tear in a variable manner. When there is an isolated rupture of the dc-TFCC, DRUJ stability is preserved. However, when a Type 1-B TFCC tear involves disruption of the pc-TFCC the DRUJ becomes unstable, leading to ulnar-sided pain, reduced grip strength, decreased forearm rotation, and clinical signs of DRUJ instability. When overlooked, DRUJ instability may be a cause of an unsatisfactory result and require reoperation. Estrella and colleagues5 reviewed the clinical and functional outcomes of 35 patients treated by arthroscopic repair of TFCC tears and found that of the 26% of patients with an unsatisfactory result, 45% of these were related to persistent DRUJ instability.
Anderson and colleagues, comparing the clinical results of arthroscopic (36 patients) and open (39 patients) repair of traumatic TFCC tears, found a 26.6% rate of reoperation, without any statistically significant difference between the two groups. These investigators also found that 65% of the reoperations were required to address DRUJ instability, and related this finding to either failure to diagnose true DRUJ instability or an inadequate TFCC repair. Thus the controversy about the value of the arthroscopic repair method as compared with an open transosseous repair of peripheral tears is still unsolved, because it is currently assumed that only the latter method can restore the foveal insertion of the TFCC in the case of DRUJ instability.

IMPROVING UNDERSTANDING OF TFCC PERIPHERAL TEARS: THE ICEBERG CONCEPT

During the last two decades an increased knowledge of functional anatomy and pathophysiology of the TFCC, along with technical refinements in the arthroscopic and surgical repair of the TFCC, have contributed to a dramatic change of the surgeons’ perspective toward the TFCC. The earlier concept of the TFCC as the “hammock” structure of the ulnar carpus has been reconsidered and updated to the novel “iceberg” concept (see Fig. 1). In analogy with the iceberg, during arthroscopy of the radiocarpal joint (RCJ) the TFCC shows its “emerging” tip. The tip of the iceberg represents that part of the TFCC that functions as a shock absorber. It is of reduced size compared with the “submerged” part, which can be seen only through distal radioulnar (DRU) arthroscopy. The submerged TFCC represents the foveal insertions of the TFCC and functions as the stabilizer of the DRUJ and of the ulnar carpus. The larger size of the submerged portion of the iceberg corresponds to its greater functional importance.

This change of perspective went together with the growing need for a revised approach to the peripheral TFCC tear that can provide a more accurate definition of the spectrum of different tears, in order to provide reliable guidelines for surgical indications and allow an improved comparison of different surgical techniques.

According to the authors’ personal experience, this article presents an algorithm of the treatment of traumatic peripheral TFCC tear based on clinical, radiological, and arthroscopic findings.

CLINICAL ASSESSMENT

On a systematic examination of the painful wrist, the differential diagnosis and/or confirmation of the diagnosis of a peripheral TFCC tear is achieved by means of special provocative maneuvers and diagnostic tests. The most reliable clinical sign of a peripheral TFCC tear is the ulnar fovea sign, whereby the patient has point tenderness over the ulnar capsule just palmar to the extensor carpi ulnaris (ECU) tendon (Fig. 2). Pain is exacerbated by passive forearm rotation and may be associated with the presence of a “click” or “crepitus,” or an intra-articular grinding sensation. Resisted rotational movements are often weak and reproduce the patient’s complaints.

Fig. 1. Artist’s rendering of the ulnar portion of the TFCC. It is separated into the distal component (dc-TFCC) formed by the UCL and the distal hammock structure, and the proximal component (pc-TFCC), represented by the proximal triangular ligament, or ligamentum subcruentum, which originates from the ulnar fovea and the proximal styloid and stabilizes the DRUJ. The “iceberg” concept, with an immediate visual representation, summarizes TFCC functions, its importance, and difficulty of assessment from simple observation of the emerging part (as in radiocarpal arthroscopy).

Fig. 2. The fovea sign elicits pain in the dotted area between extensor carpi ulnaris (ECU) and flexor carpi ulnaris (FCU). It is positive for a peripheral TFCC laceration.
A simple and reliable test to assess DRUJ laxity is the ballottement test.\textsuperscript{13} This test consists of passive anteroposterior and posteroanterior translation of the ulna on the radius in neutral rotation, in full supination and pronation. Abnormal translation of the ulnar head suggests a complete TFCC disruption (Fig. 3). The test is repeated with the forearm in full supination and pronation, in an attempt to understand which limb of the DRUJ ligament is ruptured, either the dorsal or the palmar DRUJ, respectively. The authors recommend the evaluation of the resistance at the end point of the translation. This finding is of utmost importance because the amount of DRUJ laxity correlates with the clinical DRUJ instability. Although there may be increased laxity, the DRUJ that demonstrates a “firm” end point is unlikely to progress toward a clinically symptomatic instability. Conversely, the DRUJ showing an increased passive anteroposterior or posteroanterior laxity with a “soft” end point is prone to develop a clinical instability, that is, cause a patient’s complaint when left untreated.

Provided the forearm muscles are relaxed, provocative maneuvers for DRUJ instability may show greater laxity of the painful wrist as compared with the opposite side. Protective contraction of the muscular stabilizers, especially the ECU and the pronator quadratus of the DRUJ, may mislead the surgeon with false-negative findings. Because of this, it is recommended that the DRUJ stability should be retested when the patient is under regional anesthesia before the operation. In the acute setting, that is, when there is the suspicion of a TFCC tear associated with an intra-articular or extra-articular distal radius fracture, it is strongly recommended that the ballottement test be assessed intraoperatively after reduction and stable fixation of the fracture.

**IMAGING ASSESSMENT**

All patients presenting with acute or chronic wrist pain should have radiographs taken of the wrist. Usually these are of limited value for diagnosing isolated TFCC tears, but evidence of distal ulna displacement, the presence of DRUJ widening, or/and ulnar styloid fracture may give a hint of an associated DRUJ instability.

The presence of an ulnar styloid fracture is no longer considered an absolute indicator of DRUJ instability, but only as a risk factor,\textsuperscript{14–16} regardless of the fragment size and displacement. The supposition by Hauck\textsuperscript{17} that DRUJ is unstable when the styloid is fractured at the base, and the opposite when the fracture is at the tip, has not been confirmed in several arthroscopic studies,\textsuperscript{14,18–20} which did not find any predictable correlation between an ulnar styloid fractures and a TFCC tear. Although the ulnar styloid fracture is related to the pattern and magnitude of the injury sustained, it also depends on the bone quality and the relative strength of the ligaments. Thus an ulnar styloid fracture is more common in cases of osteoporotic bone, which may explain the scarcity of isolated ligamentous injury in the elderly as compared with young active patients, in whom DRUJ instability often results from a midsubstance tear of the TFCC.\textsuperscript{21}

When the TFCC tear is associated with a distal radius fracture, it should be evaluated and eventually repaired at the time of fracture fixation, after the fracture realignment. Likewise, when a TFCC tear is associated with a malunited extra-articular fracture of the radius and/or ulna, it is advisable to reduce any angulation, shortening, and/or translation of the malunited fragment with a corrective osteotomy before any TFCC repair or reconstruction.
The Galeazzi fracture-subluxation is a particular condition that is frequently associated with a TFCC tear. When the fracture is located within 7.5 cm of the distal epiphysis of the radius, DRUJ instability is a common finding even after proper fracture reduction, and may require a TFCC reattachment to the ulna, although forearm immobilization in full supination for 8 weeks may also suffice.

Yet another controversial issue concerns the usefulness of magnetic resonance imaging (MRI) in the diagnosis of a peripheral TFCC tear. Whereas an MRI arthrogram may be both sensitive and specific in diagnosing a tear, it has not shown similar accuracy in assessing the tear size and location, and eventually the quality of the tear’s edges and its healing potential. Studies comparing specificity and sensitivity of arthrography, MRI, and arthroscopy confirm arthroscopic visualization of a TFCC tear to be the gold standard for definitive diagnosis. However, MRI may be useful to exclude associated pathologies of the ulnar compartment.

**ARTHROSCOPIC ASSESSMENT**

Accurate classification of the different conditions affecting the TFCC requires evaluation of both the distal and proximal component of the TFCC, which should be done by radiocarpal and DRU arthroscopy, respectively.

Radiocarpal arthroscopy permits one to evaluate the dc-TFCC. With the scope in the standard 3–4 portal, the tear is visualized in the dorsoulnar corner of the TFCC and probed through the 6-R portal. As a rule TFCC tension is assessed by the trampoline test,8 which evaluates the TFCC resilience (“trampoline effect”) by applying a compressive load across it with the probe. The test is positive when the TFCC is soft and compliant, usually due to a tear at its periphery (Fig. 4).

To achieve a specific assessment of the foveal insertion of the proximal component of the TFCC, the hook test has been recently proposed.10,26,27 The hook test consists of applying traction to the ulnar-most border of the TFCC with the probe inserted through the 4–5 or 6-R portal, and is considered positive when the TFCC can be displaced toward the center of the radiocarpal joint (Fig. 5). DRU arthroscopy is the only method to directly visualize any ligamentous tear of the pc-TFCC or avulsion from the fovea. As the DRUJ is a very narrow and tight joint, occasionally DRU arthroscopy is difficult to perform in the healthy joint, when the pc-TFCC is still intact. However, when the pc-TFCC is torn, the articular disk is loose and more space is available for DRUJ exploration. An 18-gauge hypodermic needle may be placed percutaneously through the dorsal DRUJ portals to localize the joint. A more accurate assessment can be made by probing the pc-TFCC through the direct foveal (DF) portal, located 1 cm proximal to the 6-U portal (Fig. 6). The DF portal is less technically demanding than establishing a volar portal,28 but its use is limited to the introduction of working instruments in the area of the ulnar styloid and fovea.

The probe is inserted into the joint close to the fovea to lift the articular disk and palpate the foveal insertion of the pc-TFCC. In the authors’ early experience with this test, DRU arthroscopy was used routinely to inspect the proximal TFCC, and showed a high correlation between the positive hook test and a disruption of TFCC foveal insertion. In the authors’ practice a positive hook test is a consistent indicator of a TFCC foveal avulsion, and confirmatory DRU arthroscopy is no longer considered necessary. However, DRU arthroscopy is still advisable to detect any posttraumatic chondromalacia or even cartilage loss of the distal ulna or sigmoid notch that may be the cause of a poor outcome after TFCC foveal repair.10

Radiocarpal and DRU arthroscopy provide a combination of findings that should be considered when deciding on the appropriate treatment for a TFCC tear. These findings are summarized by the following classes.
Lacerated Components of the Triangular Fibrocartilage Complex

Establishing the extent of TFCC peripheral tear is of outmost importance, because each component, namely dc-TFCC and pc-TFCC, may be involved either separately or in association. Therefore 3 different types of lesion are possible:

1. Distal tear (isolated tear of the distal component of the TFCC). When only the dc-TFCC is lacerated, the trampoline test is positive for loss of TFCC resilience, but the hook test is negative. The Integrity of pc-TFCC insertion onto the ulna may be confirmed by DRU arthroscopy.

2. Complete tear (tear of both distal and proximal component of the TFCC). A Complete peripheral TFCC tear involves both components of the TFCC. A tear of the dc-TFCC is visible during radiocarpal arthroscopy, and pc-TFCC avulsion may be demonstrated by DRU arthroscopy. Both trampoline and hook tests are positive.

3. Proximal tear (isolated tear of the proximal component of the TFCC). Standard radiocarpal arthroscopy fails to show any abnormalities of the TFCC’s peripheral contour and capsular reflection. However, both trampoline and hook tests are positive. The tear involves a laceration of only the pc-TFCC or avulsion from the fovea ulnaris. It can be confirmed by DRU arthroscopy (Fig. 7).

Understanding which TFCC component is lacerated leads to an appropriate treatment modality. In

Fig. 5. The hook test. The probe is inserted through the 6-R portal into the prestyloid recess in an attempt to pull the TFCC in multiple directions. The TFCC can be displaced toward the center of the radiocarpal joint only when the proximal component of the TFCC is torn or avulsed from the fovea. In this case the test is considered positive.

Fig. 6. The direct foveal (DF) portal is located about 1 cm proximal to the 6-U portal and allows exposure of the basi-styloid and foveal area. It can also be prepared as a mini open approach through an oblique skin incision between the ECU and FCU tendons, protection of the dorsal branch of the ulnar nerve, and splitting of the extensor retinaculum.

Fig. 7. In Class 2 and 3 TFCC peripheral tears, the hook test is positive and DRU arthroscopy confirms the laceration of the proximal TFCC close to its foveal insertions.
the case of a proximal or complete tear, TFCC reinsertion onto the fovea ulnaris is recommended. However, in cases of a distal tear, arthroscopic suturing of the TFCC to the dorsal ulnocarpal joint capsule and the ECU tendon subsheath is appropriate.

Reparability of the Triangular Fibrocartilage Complex Tear

When there is a small TFCC tear, as well as in the case of an avulsion type of rupture, the tear’s edges can be reapproximated or reduced easily and the TFCC repair can be performed with success. By contrast, in the presence of a massive rupture of the TFCC and/or retraction of the ligamentous remnants (Fig. 8), proper tear closure or reapproximation of the avulsed ligament to its anatomic position is not feasible. Furthermore, chronic mid-substance ligamentous tears may show degenerated or necrotic edges that are difficult to debride with the shaver to a well-vascularized area. A repair is unlikely to provide adequate healing. The same applies for the elongated and frayed ligament following a failed suture: direct repair is unlikely to be successful, and TFCC reconstruction with a tendon graft is recommended (Fig. 9). In the authors’ experience, a pc-TFCC tear has a good healing potential for up to 3 months after injury (acute tears), whereas tears treated from 3 to 6 months after injury (subacute tears) have unpredictable characteristics, and more chronic tears usually have a poor healing potential. Moreover, ligamentous disorders (eg, chondrocalcinosis) or congenital dysmorphisms of the styloid and foveal area of the ulna (eg, styloid hypoplasia, flattened ulnar head) represent further conditions that are associated with a poor healing potential after repair (Fig. 10).

When direct repair is likely to fail because of the aforementioned conditions, reconstruction with a tendon graft should be taken into consideration.

Cartilage Status of the Distal Radioulnar Joint

Well-preserved cartilage is the prerequisite of utmost importance when planning any repair or reconstruction for a TFCC disruption. Following high-energy trauma, a cartilage defect over the ulnar head or sigmoid notch may have been produced at the time of injury. Alternatively, degenerative chondromalacia may be the consequence of the altered joint kinematics, resulting in chronic DRUJ instability. When DRU arthroscopy shows a chondral defect in the DRUJ, salvage arthroplasty techniques are recommended as an alternative.

A COMPREHENSIVE CLASSIFICATION OF TFCC PERIPHERAL TEARS

Based on clinical, radiographic, and arthroscopic findings, 6 classes (Classes 0 to 5) are defined in a comprehensive classification that considers the different types of peripheral TFCC lesions and the ulnar styloid. Each class is provided with guidelines for specific treatment modalities: suture repair, foveal refixation, reconstruction with tendon graft, or salvage procedures (arthroplasty or joint replacement) (Fig. 11).
Clinical assessment by the ballottement test permits evaluation of DRUJ instability as: Negative (Stable DRUJ); Hyperlax joint/Slight instability (increased translation with hard end point); Mild to Severe instability (increased translation with soft end point).

Plain radiographs of the wrist are taken to confirm correct alignment of the distal radius and ulna and to reveal any fracture of the ulnar styloid. Two conditions are defined: when the styloid is intact or shows a fracture at the tip and when the styloid fracture is close to its base (basilar fracture).

Radiocarpal arthroscopy is used to reveal a laceration of the TFCC along its peripheral margin and to evaluate the tear’s size and the quality of TFCC remnants to determine the feasibility of repair. The arthroscopic hook test is used to assess proper tautness of the proximal insertion of the TFCC. When the TFCC is taut (negative hook test) the proximal foveal insertion of the TFCC is preserved. However, the presence of a loose TFCC (positive hook test) is suggestive of a disruption of the TFCC foveal insertion, due to either ligamentous tearing or avulsion with a basilar fracture of the ulnar styloid. DRU arthroscopy allows for an evaluation of the DRUJ cartilage to assess any cartilage defect that contraindicates repair or reconstruction.

AN ALGORITHM OF TREATMENT

The most common clinical conditions involving traumatic TFCC peripheral tear are summarized according to the aforementioned classes with the intention of providing a foundation for the therapeutic algorithm.

**Class 0: Isolated Styloid Fracture Without TFCC Tear**

An ulnar styloid fracture is present as an isolated finding. This condition is frequently associated with a distal radius fracture, especially in the elderly. Arthroscopy, which may be performed for the assisted reduction of the radius fracture, shows a normal TFCC appearance. The DRUJ is clinically stable. Acute cases require wrist splinting for pain relief for about 3 weeks. When there is an associated distal radius fracture, the patients are treated according to the rehabilitation protocol for a distal radius fracture. Patients may seldom develop chronic pain due to a persistent ulnar styloid nonunion or ulnar styloid impaction syndrome, and require fragment removal.

**Class 1: Distal Peripheral TFCC Tear**

A peripheral tear of the TFCC involves an isolated laceration of the distal component, which may be associated with an ulnar styloid fracture. The DRUJ may be slightly lax, but the ballottement test demonstrates a hard end point. Radiocarpal arthroscopy shows a distal peripheral tear, and the hook test is negative for a proximal TFCC disruption. DRUJ cartilage is unaffected. Healing of a small tear usually requires at least 4 weeks of wrist immobilization, followed by 2 weeks in which splinting is weaned. A larger tear requires
Fig. 11. Comprehensive classification of TFCC peripheral tears and associated ulnar styloid fracture. The classification system considers clinical, radiographic and arthroscopic findings. Clinical assessment of DRUJ instability is performed by the ballottement test. Radiographic findings are divided into two basic conditions according to the evidence of an intact ulnar styloid/tip fracture, or a basilar fracture of the ulnar styloid. Arthroscopy evaluates the TFCC by radiocarpal inspection and the hook test. DRUJ arthroscopy evaluates the cartilage of the sigmoid notch and ulnar head. Treatment is suggested according to the different Classes. See text.
arthroscopic suture to the ulnar wrist capsule or ECU tendon sheath.\textsuperscript{10,38–40}

**Class 2: Complete Peripheral TFCC Tear**

A peripheral tear of the TFCC involves a laceration of both the distal and proximal component. The ballottement test demonstrates DRUJ laxity with a soft end point. Radiocarpal arthroscopy shows the distal peripheral tear, and the hook test is positive for a proximal TFCC disruption. The DRUJ cartilage is unaffected. The ulnar styloid may be intact, or fractured at the tip or mid-portion. Often the large ulnar styloid fragment may retain only a few ligamentous fibers. This particular condition is called a “floating styloid.” In Class 2 lesions, the TFCC should be repaired to the fovea.\textsuperscript{3,30} However, the floating styloid (the large styloid fragment with few ligamentous attachments) may require excision.

**Class 3: Proximal Peripheral TFCC Tear**

A Peripheral tear of the TFCC involves isolated laceration of a proximal component. The ballottement test demonstrates DRUJ laxity with a soft end point. The diagnosis of a Class 3 TFCC peripheral tear is often challenging because radiocarpal arthroscopy shows a normal, uninterrupted TFCC. However, the hook test is positive, suggesting a proximal TFCC disruption. DRU arthroscopy may be performed to confirm a foveal avulsion of the TFCC and the good quality of the cartilage. The ulnar styloid may be intact, or fractured at various levels. When the ulnar styloid is intact, when the fractured styloid is too small for internal fixation, or there is poor bone quality, TFCC foveal reattachment is recommended by transosseous sutures or a suture anchor.\textsuperscript{3,7,9,26} The smaller or comminuted ulnar styloid is left in situ and rarely removed, though it may develop the radiographic appearance of a nonunion. When DRUJ instability is restored, the unrepaired or repaired ulnar styloid is seldom the cause of pain and it can be removed if it becomes symptomatic. However, a basilar fracture of the ulnar styloid that may occur following an avulsion injury from the proximal insertion of the TFCC can maintain its ligamentous attachments (Class 3-A). The persistence of a firm connection to the TFCC differentiates it from the floating styloid (Class 2) and provides the rationale for fixation with a small cannulated screw, K-wires, and/or tension band.

**Class 4: Nonrepairable Peripheral TFCC Tear**

A TFCC tear can be irreparable due to a sizable defect (Class 4-A) or poor healing potential (Class 4-B). The DRUJ is unstable. During radiocarpal arthroscopy, the TFCC may show a significant defect (Class 4-A), which may be due primarily to an extensive laceration following a high-energy injury or may result from the debridement that is required to refresh the degenerated or retracted TFCC tear’s edges. Likewise, the TFCC tear may demonstrate frayed edges or elongated ligamentous remnants with reduced healing capacity (Class 4-B), due to ligamentous pathology or osseous dysmorphism or to the failure of a previous repair. Because cartilage erosion is likely to occur in long-standing conditions such as this, an accurate assessment of the quality of the DRUJ cartilage is mandatory. A nonrepairable TFCC tear requires reconstruction with a tendon graft, regardless of the presence of any ulnar styloid fracture.\textsuperscript{10,29}

**Class 5: DRUJ Arthritis Following Peripheral TFCC Tear**

When DRU arthroscopy shows a significant degenerative or traumatic cartilage defect, the TFCC tear should not be repaired regardless of the variable clinical and arthroscopic findings. However, a resection arthroplasty or prosthetic replacement is recommended.\textsuperscript{31–36}

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