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Abstract

The majority of patients with distal radius fracture (DRF) achieve a satisfactory outcome but up to one fifth have inferior subjective outcome including pain at rest. The underlying causes are multifactorial, including concomitant soft tissue injuries, malunion, development of post-traumatic osteoarthritis and comorbidity. Intraarticular injuries and ligament injuries are common in younger patients due to often high energy trauma, and outcome by speculation worse than in the elderly. The overall aim of this thesis was to follow the natural course of DRFs in younger patients to map potential, preferably preventable causes of unsatisfactory long term outcome. Paper I-III were long term follow-ups (13-15 years) of a prospective longitudinal study of associated ligament and cartilage injuries in DRFs. 51 patients with a dislocated distal radius fracture were included in an estimated pre-osteoporotic age (men<60, women> 50). In addition to conventional fracture treatment, all patients underwent diagnostic arthroscopy. Associated ligament and cartilage injuries were mapped but left untreated, with the aim to describe the natural course and final outcome. Paper IV was a prospective register study in which patients with an inferior subjective outcome at 1 year were summoned to a clinical follow up 6-13 years later with the aim to evaluate the fate at long term and potential causes of a persisting inferior outcome.

In paper I, only one of the 43/51 patients with TFCC (triangular fibrocartilage complex) injury had been operated for painful instability during the 13-15 year follow-up period. DRUJ (distal radioulnar joint) laxity due to TFCC tear had negative impact on the grip strength. No difference was found regarding subjective outcome, but a trend towards worse outcome was found in the complete peripheral type B TFCC injuries.

In paper II, the natural course of untreated scapholunate (SL) ligament injuries, grade I-III, was evaluated. None of the patients developed a static SL dissociation or a SL advanced collapse over time. No major difference was found in injured vs non-injured SL-ligaments in neither subjective, objective or radiographic outcome. However, no grade IV SL tear, with potentially worse prognosis, had been included in the original series.

In paper III, subchondral hematomas in unfractured radius joint surfaces (lunate and scaphoid fossae) were mapped at the original arthroscopy to evaluate whether these would lead to osteoarthritis with time. The presence of a subchondral haematoma did not cause osteoarthritis at long term and did not influence the clinical or radiological outcome.

In Paper IV, a younger cohort with inferior outcome at 1 year was selected from a large DRF register to evaluate long term outcome and the cause of persistent inferior outcome. In 932 consecutive younger patients with a DRF 2005-12, 612 returned a valid DASH. 54 patients had had a DASH > 35 at one year and were invited to a clinical FU 6-12 years after. 33 patients came and a high incidence of ulnar laxity was found, often accompanied by DRUJ osteoarthritis. Comorbidity was common, both chronic systemic disease but in particular musculoskeletal chronic conditions.

In conclusion, inferior subjective outcome at one year appears to be long-lasting in the majority of younger patients with DRF. Ulnar ligament injury appears to be a common cause, as well as chronic systemic and musculoskeletal disease.

Key words Distal radius fracture, long-term outcome, triangular fibrocartilage complex,scapholunate ligament injuries, bone bruise		
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LUND UNIVERSITY

To my family

"Effort only fully releases its reward after
a person refuses to quit"

Napoleon Hill

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   J Hand Surg Am. 2012 Aug;37(8):1555-60.

2. Arthroscopically diagnosed scapholunate ligament injuries associated with distal radial fractures: a 13- to 15-year follow up.
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3. No long-term risk of wrist osteoarthritis due to subchondral haematomas in distal radial fractures.
   Mrkonjic A, Geijer M, Lindau T, Tägil M.
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4. Ulnar- sided wrist pain and ligament injury in patients with persisting inferior subjective outcome after distal radius fracture. A long term register study.
   Mrkonjic A, Landgren M, Abramo A, Kopylov P, Teurneau V, Geijer M, Tägil M. *In manuscript*

Abbreviations

ADL	Activities of daily living
AO	Arbeitsgemeinschaft fur Osteosynthesfragen
CT	Computed tomography
DASH	Disability of the Arm, Shoulder and Hand, 30- item
DOB	Distal oblique band
DRF	Distal Radius Fracture
DRUJ	Distal radioulnar joint
ECU	Extensor carpi ulnaris
MRI	Magnetic Resonance Imaging
ORIF	Open Reduction and Internal Fixation
PQ	Pronator quadratus
ROM	Range of Motion
TFCC	Triangular FibroCartilage Complex
UCLC	Ulnocarpal ligament complex
VAS	Visual Analog Scale
QuickDASH	Quick Disabilities of the Arm, Shoulder and Hand, 11-item
SLiL	Scapholunate interosseous ligament
LTiL	Lunotriquetral interosseous ligament

Thesis at a glance

Paper I. *The natural course of TFCC tears associated with a distal radius fracture, a longitudinal outcome study*

Q: Is a traumatic TFCC injury associated with inferior long-term results after DRF?

Patients: In 1995-97, 51 consecutive patients (men<60, women<50 years) with a DRF were examined arthroscopically at the time of fracture. Forty-three patients had a complete or partial TFCC injury.

Methods: In 2010, 13-15 years after the injury, 38/51 patients were re-examined objectively, subjectively and radiographically.

Results: The 8 patients with a complete peripheral TFCC injury had median DASH 25, vs DASH 7 in the ones without or with partial tears. The difference was not significant.

Conclusion: We found no evidence that a TFCC injury associated with a DRF needs surgery at an early stage after trauma, but the number of patients was small.

Paper II. *Long-term follow up of scapholunate ligament injury associated with distal radius fracture*

Q: What are the long term consequences of an SL ligament injury (Geissler grade 1-3) associated with a DRF?

Patients: In the fifty-one consecutive patients with DRF above, 32/51 patients had an associated SL ligament tear.

Methods: Thirty-eight/51 patients in study 1 attended the clinical and radiographical examination focusing on SL-injuries.

Results: No differences were found in grip strength, DASH or VAS between patients with or without a partial grade 1-2 or complete grade 3 SL injury. None of the patients developed a static SL dissociation or SLAC wrist.

Conclusion: No long term consequences were found in grade 1-3 SL-injuries, but no patient had a grade 4 injury which has a potentially worse prognosis.

Paper III. *Subchondral hematoma due to wrist trauma and development of osteoarthritis over time*

Q: Does a subchondral hematoma in an unfractured compartment predict secondary osteoarthritis?

Patients: 41/51 patients in study 1 had at least one non-fractured radius compartment (scaphoid or lunate fossa). In 12 patients a subchondral hematoma was noted under the unfractured cartilage.

Methods: 28/37 surviving patients participated in the clinical and radiographical examination.

Results: No correlation was found between the presence of a subchondral hematoma at arthroscopy and the development of radiographic osteoarthritis at long term.

Conclusion: Patients with post-traumatic subchondral hematoma do not run a greater risk of secondary wrist osteoarthritis.

Paper IV. *Ulnar sided wrist pain in patients with persisting inferior subjective outcome after distal radius fracture. A long term register study.*

Q: Are ulnar-sided pain and DRUJ laxity as signs of ulnar ligament injuries common in a selection of younger patients with inferior outcome after DRF?

Patients: We used prospective data from the Lund Distal Radius Fracture Register between 2005-12 and selected 1) younger patient 18-55 years and 2) with a DASH score >35 at one year, indicating mid term inferior subjective outcome.

Methods: In 2018, 54 patients were alive and invited to an objective, subjective and radiological examination. 33 patients, 7 men and 26 women came to the follow-up.

Results: Only one patient returned to pre-fracture status (DASH 0-10). Ulnar laxity was common and found in one third of the patients, evenly distributed in the intermediate group (DASH 11-35) and the group still having severe residual problems (DASH >35). DRUJ OA was seen in 14/33 patients, accompanied by DRUJ laxity in 6/33.

Conclusion: In the group remaining at poor subjective outcome 6-13 years after a distal radius fracture, a high incidence of ulnar laxity was found, often with concomitant DRUJ osteoarthritis. Comorbidity was common, especially regarding musculoskeletal chronic conditions.

Background

Clinical background

The distal radius fracture is the most common fracture in the orthopedic emergency room. Although common in childhood, the majority occur in the adult population. Inadequately treated wrist fracture may lead to pain and impaired function, and cause large direct and indirect costs to the society. Known causes to inferior subjective and objective outcome are intracarpal and radioulnar ligament injuries, malunion or development of secondary osteoarthritis. Elderly, mainly women, with age-related osteoporosis may sustain a fracture by a simple fall, whereas the younger adults often sustain their fracture in more high energy trauma. In younger adults, associated injuries are assumed to be more common. Cartilage and subchondral bone injuries may in time lead to osteoarthritis, and ligament injuries to symptomatic instability[1]. As a consequence, different treatment algorithms are used for elderly and younger, with more active treatment in the latter[2].

Concomitant ligament injuries, associated with distal radius fractures are common and diagnosed in up to 89 % of the cases in arthroscopic studies[3-5]. The long-term consequences are largely unknown and the injuries may be overlooked as potential cause for residual pain and disability. But what ligament injuries do play a role for the outcome? Peripheral lesions of the triangular fibrocartilage complex (TFCC) Palmer type 1B are the most common overall[6-8], as well as type 1D injuries within the sigmoidal region[9, 10]. The patients with these injuries have, besides objective hyperlaxity, some but not all, also subjective symptomatic instability (pain and/or clicking) of the distal radio-ulnar joint (DRUJ). The frequency of secondary osteoarthritis in the DRUJ caused by a TFCC injury is unknown, and further whether the lesions are symptomatic at long term. The scapholunate interosseous ligament (SLiL) holds a similar key role for carpal stability. The SLiL is also commonly affected in wrist fractures[3] and also at risk being unnoticed by plain radiography initially after the trauma. Untreated, a progressive intercalated malalignment may develop with accompanying degenerative arthritis, known as scapholunate advanced collapse (SLAC). Primary osteoarthritis of the radiocarpal joint is unusual, but could develop secondarily due to ligamentary insufficiency, articular incongruence and/or traumatically induced cartilage lesions[11]. The influence of all these factors for an inferior long-term result is unknown and the subject of this thesis.

Introduction

History

In the primate and human evolution, the function of the hand and wrist changed with the transition to an upright posture and bipedal movement[12]. Bipedal walking and the development of the wrist joint with its unique distal radioulnar joint, evolved long before the human brain increased in volume or stone tools were developed. Evidence of bipedal walking has been found in Australopithecus fossils from 4.2-3.9 million years ago[13, 14], although Sahelanthropus may have walked on two legs as early as seven million years ago[15]. From being an entirely weight-bearing limb, the hand could now be used as a gripping tool, and by the ability to rotate the forearm in the distal radio-ulnar joint, the hand could be precisely positioned in space to use and manufacture tools. By raising up, not only flexion/extension became important for the wrist, but also sufficient stability of the former forefoot throughout the newly achieved mode of motion. A delicate ligamentous connection, the radioulnar and the ulnocarpal ligaments evolved, allowing for a stable moveable connection between the two forearm bones. But the new ligament construction was susceptible to injury.
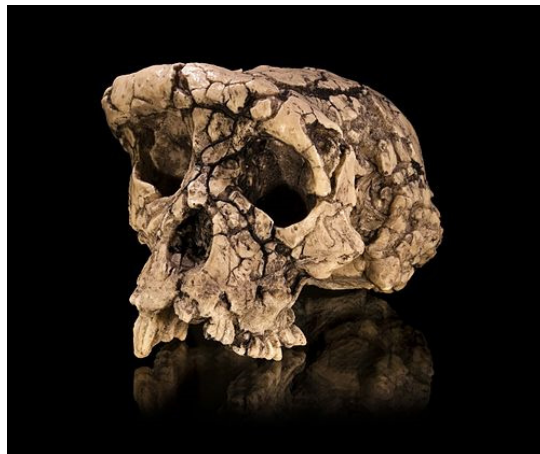
Figure 1:
Cast of a Sahelanthropus tchadensis skull named Toumai- hope of life; by Didier Descouens;
https://creativecommons.org/licenses/by-sa/4.0

When falling from the newly acquired upright bipedal position, a fracture of the wrist was probably common and also in these days associated with concomitant soft tissue injuries. The oldest known description of a distal radius fracture, however, took millions of years. It stems from ancient Greece, from Hippocrates, the father of western medicine, who wrongfully considered the wrist fracture as a dislocation. (*The genuine works of Hippocrates, 1849).* It was not until the eighteenth century the injury was finally described as a fracture by Petit (1705), and a few decades later by Pouteau (1783), based purely on clinical observations.

Abraham Colles was an anatomy professor in Dublin, Ireland and in his 1814 publication in The Edinburgh Medical Journal, Colles also questioned the previous theories of the wrist fracture being a dislocation. Colles, further pioneered pointing out an association between a distal radius fracture and DRUJ instability and noted that `*if the surgeon proceeds to investigate the nature of this injury, he will find that the end of the ulna admits of being readily moved backwards and forwards`*. The ballottement test was thereby described. Colles also proposed new ideas about fracture appearance, with suggestions of treatment and prediction of outcomes[16]. To his honor, a distal metaphyseal radius fracture with dorsal angulation and impaction has been named a Colles fracture, a term used globally today.
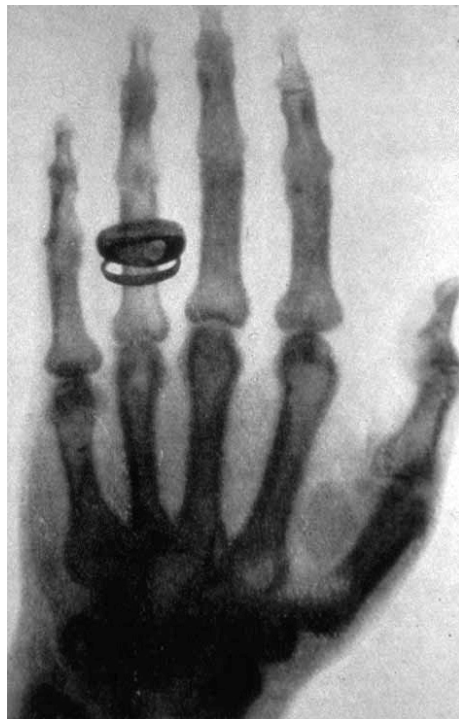
Figure 2:
One of the first x-ray images, taken by Wilhelm Röntgen

When the use of x-rays was introduced by Wilhelm Conrad Röntgen in 1896, a whole new era opened in fracture diagnostics. Only a few years later, in 1901, Röntgen was awarded the Nobel Prize. Still, soft tissue injuries were not possible to diagnose except at surgery or dissection. Scudder 1939[17] pioneered emphasizing not only the relationship between the radius and ulna in the DRUJ, but also the importance of TFCC, regarding treatment as well as prediction of the prognosis after a DRF. In the 1970s, wrist arthroscopy was introduced providing another new diagnostic tool of what was not visible with radiography, i.e. the soft tissue components of the wrist injury and the joint surfaces involved in a distal radius fracture. Whipple[18] described the safe entry-portals a few years later, and made the method safe. Arthroscopy gradually become the gold standard tool, both in ligament diagnostics and therapy. A decade later, in the 1980s, magnetic resonance investigation (MRI) established as a further method enabling diagnosis of hidden structures not visible by the scope, like bone marrow edemas or in particular ligament injuries, and still provides us with an excellent supplement to arthroscopy today.

Epidemiology

Distal radius fracture is one of the most common fractures and accounts for about a sixth of all fractures, at an incidence of 20 fractures /10000[19]. Within the last few decades, the overall incidence has been found to level out between 20-40 per 10000 person/year[20-22]. Distal radius fractures have a bimodal age distribution with the highest incidence in the growing individuals and in the elderly population[19]. The injury mechanism also differs between the age groups. In the elderly, lower energy trauma such as a fall from standing are most common. Fractures in the younger adult population are often caused by higher energy trauma e.g., sports injuries, fall from heights or vehicle accidents[23-26]. High-energy trauma, in combination with stronger bone, less likely to fracture, have been hypothesized to correlate with a higher incidence of associated injuries in the younger adult population[3].

Concomitant injuries are indeed common as presented in several studies[7, 9, 10]. Gologan et al[4] did a systematic preoperative survey and provided a prospective 1-year follow-up of 103 patients (104 dislocated distal radius fractures), in patients >18 years. Ninety-seven percent presented with concomitant intracarpal lesions, in particular intraarticular ligament injuries (74% TFCC, 34% radioulnar ligament-RUL lesion, 18% SL lesion). A preoperative examination using radiography, computer tomography (CT) and MRI was performed. ORIF was applied to all patients, but ligament injuries were left untreated. Clinical and radiographic outcome at one year were evaluated by the Castaign score[27] and showed 71% of the patients having excellent or good results (<6 points). In a cohort of young adults

consisting of men 20-60 years and women 20-50 years, 98% had ligament injuries[3]. In yet another arthroscopic study of thirty patients with an intraarticular distal radius fracture, TFCC injury was found in 77%, SLiL (scapholunate interosseous ligament) injury in 37% and LTiL (lunotriquetral interosseous ligament) injury in 7%. A cartilage injury, greater than three millimeters, was found in 33% of the cases [28].
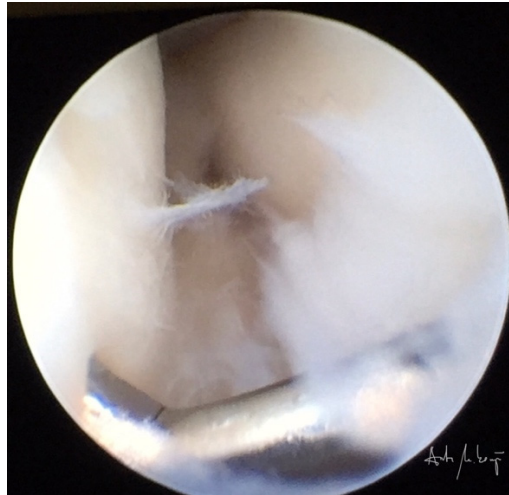
Figure 3:
Arthroscopic view of a complete scapholunate tear Geissler grade IV (Drive-Thru-Sign)

Various distal radius fracture classifications are available and the most commonly used is the AO classification dividing the fractures into three general groups, A, B, and C, which all in turn were divided into nine subgroups[29]. The extraarticular AO type A fracture is the most common among all age groups[20]. Group B and C are all intraarticular fractures and occur more often after high energy trauma. These are common in younger patients in pre-osteoporosis age[30]. Before the age of 50, the incidence between genders is relatively evenly distributed[31]. By increasing age, the incidence increases rapidly, especially among women, to reach a peak at 80 years and older[32, 33]. Interestingly, with an increasing incidence rate during almost half the twentieth century, the incidence has begun to decline after the turn of the century, as seen in several Scandinavian publications[20, 33-36]. However, other studies show an opposite trend[19, 22], as in a study based on a southern Swedish population analyzing 11.2 million patient years (Skåne Healthcare Register 1999-2010), with the total incidence rate increasing to 28 per 10000 person-years (31,233 fractures). Weather conditions and seasonal variations have also been shown to affect the incidence of upper extremity trauma[37-41].

Anatomy

The wrist truly represents one of the most ingenious articulations in the human body. The wrist combines the radiocarpal joint, with its many intracarpal articulations, with the forearm joints, the distal and proximal radio-ulnar joints (DRUJ and PRUJ), allowing for a complex movement pattern in all planes. The skeleton of the carpus is composed of eight carpal bones, each with a specialized form and function, working together with the ligaments and muscles to transfer load from the hand across the radiocarpal joint and the DRUJ to the radius and ulna.

The rows and columns

Shaped in a non-geometric mosaic and arch-like formation, the carpal bones build two parallel rows, the proximal and distal carpal row, which articulate to each other and to the forearm. The arrangement enables a further refinement and an intricate, multiplane mobility of the hand. Both rows contain four bones each, the proximal row consisting of the scaphoid, lunate, triquetrum, and pisiform, and the distal of the trapezium, trapezoid, capitate and hamate bones[42]. Unlike "the link mechanism" described above, another wrist mechanism theory is "the columnar theory", introduced in 1921 by Navarro and later modified by Taleisnik in the seventies[43]. The carpus was divided into three columns and the lunate together with the distal carpal row represents the central flexion-extension column, the scaphoid stands for the mobile lateral column, and the triquetrum for the rotatory medial column.

The radiocarpal and intracarpal ligaments

There are over thirty individual ligaments described around the wrist. The ligament support is strong within the distal carpal row and the metacarpus, allowing only for a limited motion between the bones. The proximal row is different and can be described as an intercalated segment. The stability is primarily maintained by the support of interosseous ligaments, self-balancing but susceptible to injury, through the articulations with the surrounding carpal bones. The arrangement and function of the ligaments are complex. The ligaments can be divided into intrinsic ligaments, which stabilize the 8 bones internally[44], and the extrinsic ligaments, which stabilize the joints from across the radiocarpal joint[43], thereby connecting the forearm bones to the carpus.

The extrinsic ligaments, can be divided further into the volar and dorsal ligaments. The dorsal radiotriquetral and the dorsal intercarpal ligaments, play an important role as secondary stabilizers of the scapholunate complex, in addition to scapho-lunate (SLiL) ligament as the primary stabilizer, during repetitive wrist motion[45,

46]. The volar extrinsic ligaments i.e., the radioscaphocapitate, the long radiolunate and the short radiolunate ligament, play a major role in stabilizing the wrist [42].

Intrinsic ligaments interlink all of the carpal bones to each other, except the lunate to the capitate. Two of the ligaments are considered to have key roles for the carpal stability in general, the scapholunate- and lunotriquetral interosseous ligaments. Both have a horseshoe-like shape (C-shape) and attach along the dorsal, proximal, and volar margins of the articulating surfaces. Both consist of a transverse ligament, a volar part, a dorsal part, and a proximal fibrocartilaginous membrane. The dorsal subregion of the SLiL is the thickest, strongest and crucial in distraction, torsion and translational forces. The volar part, although significantly thinner, has important contributions to the rotational stability of the SL joint. The membranous portion is considered to have no significant effect on stability[47]. Like the SLiL, the lunotriquetral (LTIL) interosseous ligament is also described as a 3-part structure, but in contrast to SLiL, the volar part of the ligament is considered the strongest part[48].

The radioulnar ligaments

The distal radioulnar joint (DRUJ) is the distal part of the assembled "forearm joint"[49] allowing rotation of the forearm and a positioning of the hand without interfering with the grasping function[50]. The shape of the ulnar head and the arc of the sigmoid notch are not matched. During an unloaded rotation, a simultaneous translation between the joint surfaces takes place allowing for low friction motion, which needs to be secured and stabilized during a loaded grip. This demanding function has been made possible in primates by ligaments, securing the position of the two joint surfaces during rotation. The ligaments can be divided into primary stabilizers, like the triangular fibrocartilage complex (TFCC) and the ulnocarpal ligament complex (UCLC), or secondary stabilizers like the extensor carpi ulnaris tendon and tendon sheath (ECU), the pronator quadratus (PQ) muscle. The interosseous membrane (IOM) with the reinforced distal oblique band (DOB)[31, 51, 52] , has been emphasized as an important stabilizer in the last decade.

The TFCC has been described as crucial for the stability of the DRUJ[53]. Structurally, several parts of the complex can be distinguished, which differ both morphologically and functionally. According to the original description, the TFCC consists of the triangular fibrocartilage (TFC), the ulnocarpal meniscus (meniscus homologue), the ulnar collateral ligament, the dorsal and volar radioulnar ligaments, and the sub-sheath of the extensor carpi ulnaris[53]. The central portion of TFC is a cartilaginous disc that acts as a shock absorber, responsible for load transmission between the carpus and forearm. Unlike the capsule-near portion, the inner part of the disc is avascular and incapable of spontaneous healing[54]. The radioulnar ligaments are peripheral to the disk and are divided into a distal superficial

component and a proximal deep part[55-57]. Both originate from the ulnar edge of the radius and attach to the base (deep part) and along the ulnar styloid process (the superficial component) and into the fovea where the area is well vascularized, hence the name *ligamentum subcruentum*[58]. From a functional point of view, the TFCC can be divided into three portions[59] with the distal component, functioning like a hammock and a suspension to the ulnar carpus; the proximal component with the fan-shaped triangular ligament; and the third component, the ulnar collateral ligament[59]. In analogy with this description of the TFCC, Atzei and Luchetti (2011)[60] have proposed a newer theory, coined as the "Iceberg Concept", because the deep portion is difficult to view in the standard set up during wrist arthroscopy. The distal component in their view, represents the superficial, "emerging tip of the iceberg" and the proximal part, the deeper as the "submerged part", which accounts for the greater and most important part for stability.

Figure 4:
Iceberg at the harbor entrance in Upernavik, Greenland, by Kim Hansen
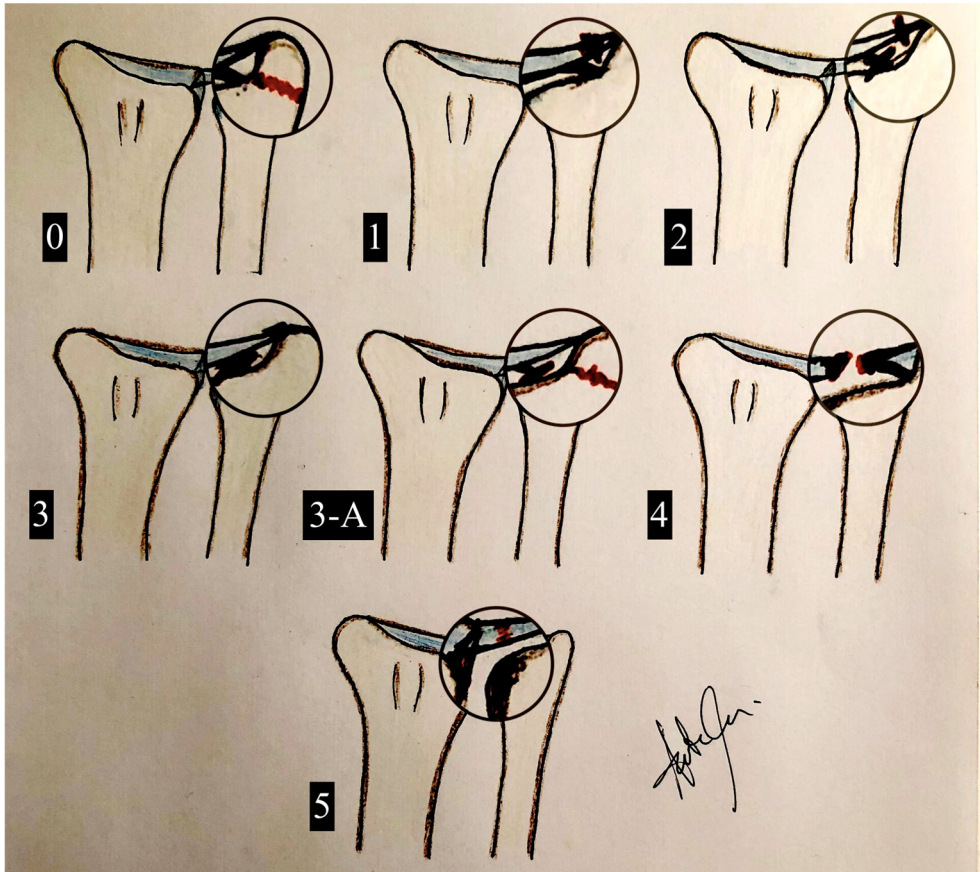
Figure 5:
Classification of TFCC tear according to Atzei and Luchetti (2011)

        0   Isolated styloid fracture without TFCC tear- stable

        1   Distal TFCC tear, tear of the distal layer- stable

        2   Complete TFCC, tear of the proximal & distal TFCC layer- with mild to severe laxity

        3   Proximal TFCC tear, tear of the proximal layer- with mild to severe laxity

        3-A   Fracture of the ulna styloid base with tear of the proximal TFCC – with mild to severe laxity

        4   Nonrepairable central TFCC tear- with mild to severe laxity

        5   DRUJ osteoarthritis following a TFCC tear- with laxity

Long term outcome of a DRF and the ligament injuries

Subjective outcome

In the short-term perspective the outcome of a distal radius fracture (DRF) is good. At 6 months, two thirds of the patients have no or minimal pain[61] and at 12 months, most patients are satisfied with the outcome[62]. In our local Lund Wrist Fracture Register, the median Disabilities of Arm, Shoulder and Hand (DASH) score in 3666 patients, 18 years and older, was 9 (IQR 2–25), one year after a distal radius fracture, regardless of being operated or not[62]. 52% had a DASH score indicating minor (0-10) and 31% moderate (11–35) residual symptoms. This may be considered as a good or even excellent result, but still 17% had a subjective outcome of DASH >35, indicating major disability including pain at rest.

Studies beyond one year after a DRF are scarce. It appears that the majority of the subjective improvement takes place during the first year, even in patients followed for as long as 10-20 years [63]. Malunion was found to correlate with the one-year DASH score in 123 patients followed prospectively[64] but no improvement occurred between year one and two, neither in the malunion nor in the non-malunion group. Recently, the same authors published a long-term study using DASH both at inclusion and at follow up 12-14 years later. The patients with malunion still had 14 scale steps worse DASH than the patients without malunion[65].

TFCC

Besides malunion, soft tissue injuries are considered to influence the final result after a DRF, in particular the ulnar ligaments[66]. Also in this area long term studies are rare. The natural course of untreated TFCC injuries in DRFs was studied by Deniz et al[67] in 47 patients. The diagnosis was made by MRI at the time of fracture and 24 patients had a TFCC tear and 23 not. After 3-4 years, the subjective outcome using the Mayo Wrist Score was identical in the two groups and the authors concluded that no repair is necessary. Arthroscopy allows a more precise

diagnosis[68] and another prospective study also aimed at describing the natural course of untreated DRF associated TFCC injuries[3]. Fifty-one consecutive patients underwent a diagnostic arthroscopy at the time of fracture and 43/51 patients had a TFCC injury, which was left untreated. At one year 19 patients/43 with DRUJ laxity had worse outcome using the Gartland and Werley score[6]. The long term outcome of this study is presented in this thesis (study I). Swart and Tang[69] (2017) presented a 1 year outcome of 42 DRF patients who also were examined by arthroscopy at the time of fracture. In total 21 of the patients had TFCC injuries whereof 6 were complete peripheral tears. The injuries were left untreated. The authors concluded there were no differences between the patients with or without TFCC injury and confusingly the uninjured even had a better DASH! No results were presented separately for the complete tears and no further long term results have been presented. In repaired TFCC injuries in DRFs, the short to mid term results have been reported to be good. Eleven complete tears were found at arthroscopy out of 163 DRFs, and all were repaired and found to have a stable and pain-free DRUJ at follow-up six years later[70]. In another two-year follow up of similarly repaired TFCC injuries in DRFs, 13 patients had a good prono-supination and a mean DASH of 13 at two years[8]. Real long term studies are scarce but in a 20-year follow up study of treated TFCC- injuries, half were caused by a DRF[71] and a high rate of DRUJ osteoarthritis was found in these. Repeat surgery was common and the subjective outcome using the PRWE was intermediate, "acceptable but not impressive". The median PRWE score was 22, which is higher (worse) than in other studies using PRWE as outcome, in which the scores between 3 and 15 have been reported in a general DRF population[72, 73].

SL

The natural course of isolated, partial, and untreated SL tears, unrelated to a DRF, was described in 11 patients with an average follow-up of 7 years[74]. None developed a SLAC wrist or degenerative changes. The natural course of untreated SL tears occurring as part of a DRF is largely unknown. In one study, about one-quarter of patients with a static SL ligament injury developed SLAC wrists by radiography (3 of 13 cases in a series of 75 fractures) 3 years after a DRF[75]. Tang[76] identified 20 patients with DRF and static SL disruption (> 3 mm) with suboptimal wrist function after one year in a group of 474 patients with a DRF. In our series also, the clinical result after one year was inferior in the patients with a complete grade-3 SL tear, who had more severe pain[77].

Osteoarthritis

Intra-articular wrist fractures and fractures in the younger population are more often caused by high energy trauma. The joint surface is injured which can be seen by standard radiography as step-off and gaps. It is uncontroversial that these, in the longer term, may lead to development of post-traumatic osteoarthritis if not corrected and reduced [78, 79]. Cartilage damage, without a fracture, has been discussed first after the introduction of more sophisticated diagnostic tools like, wrist arthroscopy[3] and magnetic resonance imaging (MRI)[80]. Visually during arthroscopy, a subchondral hematoma can be regarded as a direct sign of an impaction trauma. A high signal on fluid-sensitive sequences on the MRI performed after trauma are regularly interpreted as signs of subchondral hematoma, edema and/or micro-fracture of the subchondral trabecular bone. To date, subchondral bone lesion have been have been studies mainly in knee injuries and are referred to as bone bruise, bone marrow edema or bone marrow lesions. They are identified as high-signal intensity on T2-weighted MRI images[81, 82]. In the short term, some studies have indicated that even apparently harmless subchondral changes may cause post-traumatic osteoarthritis[83, 84]. Long-term studies are lacking whether bone bruises progress into osteoarthritis and whether this in turn would affect the subjective and objective outcome.

Aims

The general aim of this thesis was to identify and evaluate associated injuries as risk factors for an unsatisfactory result at long term after a wrist fracture in a younger population. In the first three studies an unselected consecutive group was followed over a long period. Although the study originally was designed as prospective and longitudinal, the patients were not followed more than for the first year, and have since not been study objects of any kind until now. Therefore, the series can be described as a true study of the natural course of TFCC, SLiL and cartilage injuries, which was the original aim. After finishing the follow up, unique in many ways, we realized that the number of patients in a 51 patient series was small, and left conclusions at a risk of a type-II error, i.e. the risk of not showing a difference even if there were one. In the last study we therefore approached the same problem but from the opposite end. Instead of diagnosing the injury and follow the patients for 15 years, we extracted the very patients with the worst outcome from our prospective register. We evaluated objectively, subjectively and radiographically at long term if this group would have a high proportions of long term consequences of a TFCC (ulnar instability), SL (SLAC) and/or cartilage injury (osteoarthritis) in a similar young cohort.

Specific aims of the thesis

1. To evaluate whether an untreated traumatic triangular fibrocartilage complex (TFCC) injury affects long-term results after a distal radius fracture.

2. To investigate the natural course of untreated partial Geissler grade 1-3 scapholunate (SL) ligament tears associated with displaced distal radius fractures.

3. To determine if a subchondral hematoma in an unfractured compartment develops into secondary osteoarthritis.

4. To map potential causes of an unsatisfactory outcome after distal radius fracture at long term.

Methods

Patients

Paper I-III Prospective longitudinal study of ligament and cartilage injuries
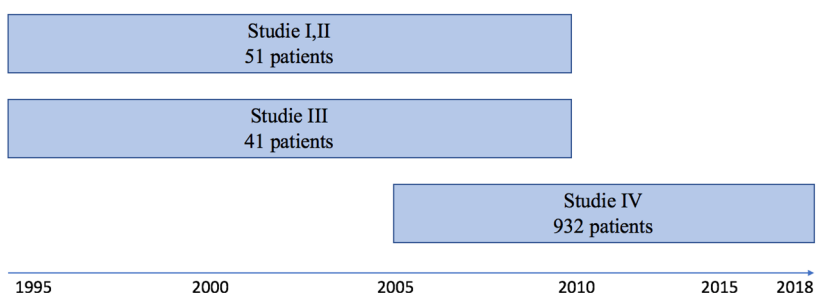
Figure 6:
Timeline of patients and study years, Paper I-IV

The first three papers are long term follow up of a series consisting of 51 consecutive patients with a dislocated distal radius fracture during a two-year period 1995-1997. The patients were treated both surgically and conservatively, but in addition to the conventional fracture treatment, all underwent a diagnostic arthroscopy within 15 days of injury [6]. All associated ligament and cartilage injuries were mapped but left untreated to be followed over longer term in order to describe the natural course and final outcome. At start, all the 24 men were younger than 60 (20 to 57) years and the 27 women younger than 50 (20 to 49) years, which at the time were considered as age-limits for osteoporosis, based on DEXA-studies. The fractures were considered displaced if the joint surface was tilted dorsally, more than 0 degree perpendicular to the axis of the radius. Exclusion criteria were any endocrinological disorder and/ or alcohol abuse. Twenty-one patients were treated with closed reduction and plaster, 11 with arthroscopy-assisted reduction and plaster, 5 with closed reduction and external fixation, 6 with arthroscopy-assisted reduction and external fixation, and 8 with open reduction and internal fixation. In 2010, forty-seven patients were alive and invited to a new clinical and radiological examination, which represents the basis of the first three papers in this thesis.
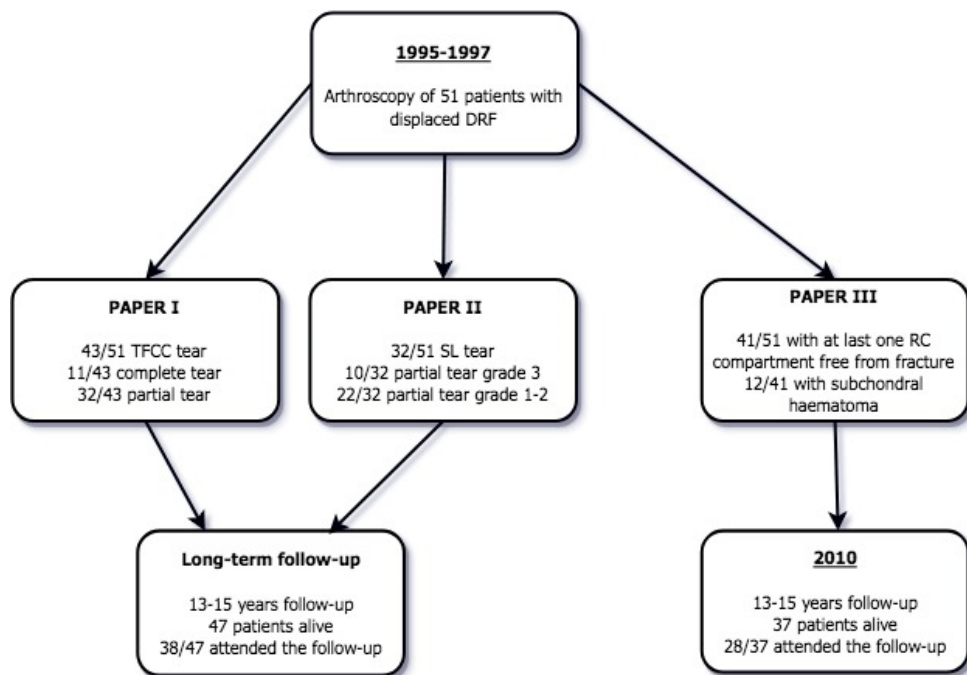
Figure 7:
Flowchart Paper I-III

Arthroscopic classifications at the time of fracture 1995-97 (original cohort)

TFCC

In the original series, 43/51 patients had a complete or partial tear of the TFCC, classified according to Palmer[53]. A bleeding point or a loss of the collagen continuity was interpreted as a partial tear, or both. A peripheral tear in the ligament was defined as complete if it caused a loss of tension in the TFCC during the hook and trampoline test at the initial arthroscopic assessment.

Figure 8:
Wrist arthroscopy by the author examining a suspected TFCC injury.
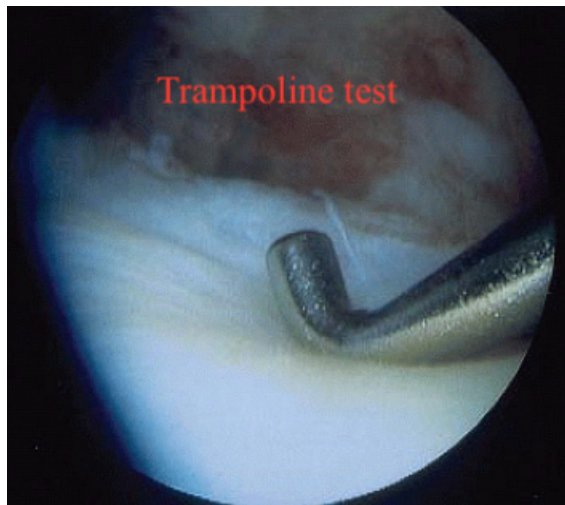
Figure 9:
Examination of the TFCC by "Trampoline test"

Table 1:
Palmer`s classification of acute traumatic TFCC injuries

Type	Description
1A	Central TFC perforation
1B	Peripheral ulnar side TFCC tear (ulna styloid fracture)
1C	Distal TFCC disruption (disruption from distal UC ligaments)
1D	Radial TFCC disruption (sigmoid notch fracture)

SL

The same patients as above were investigated. SL ligament injuries were classified using a modified Geissler score[85]. Partial SL lesions were defined as hematoma (grade 1) and/or a loss of the collagen continuity (grade 2), as tested with a probe. More extensive injuries (grade 3-4) were defined as having a step-off in the carpal alignment as seen from the midcarpal joint. Thirty-two of the original 51 patients had an SL ligament tear.
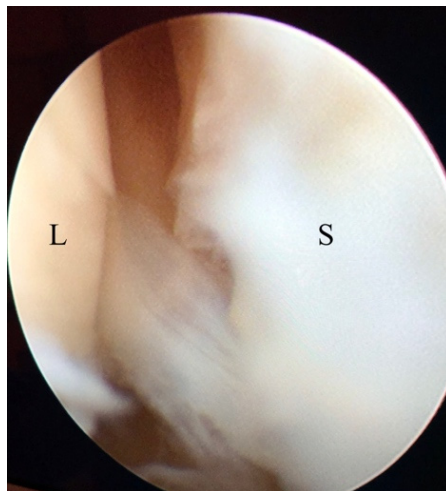
Figure 10:
SL complete tear, radiocarpal view

Table 2:
Geissler (1995) classification system for interosseous scapholunate and lunotriquetral ligament injuries and mobility of the joints, modified by Lindau (1997)

Grade	Radiocarpal arthroscopy Ligament appearance	Midcarpal arthroscopy	
		Diastasis (mm)	Step-off (mm)
1	Haematoma or distension	0	0
2	As above and/ or partial tear	0- 1	< 2
3	Partialt or total tear	1–2	< 2
4	Total tear	> 2	> 2

Cartilage injury

Forty-one of the above-mentioned 51 participants had at least one joint compartment, the scaphoid or lunate compartment, free from a fracture at the arthroscopy and were included in the sub-study. Twelve of the 41 patients had a hematoma in the non-fractured compartment.

Paper IV-prospective registry study

The fourth paper, was an analysis of data in younger adults, 18-55 years, from the Lund Distal Radius Fracture Register. The data was collected from an 8-year period between January 2005 and December 2012 and patients selected with an inferior outcome at one year, exceeding an arbitrarily defined DASH score cut-off level of 35. In 2018, 6-13 years after the fracture, 13 men and 41 women had yet a new DASH sent by mail and were invited to a new clinical and radiographical examination.

During the period between January 2003 and December 2012, in total 3666 patients in all ages >18 years were included in the Lund Distal Radius Fracture Register[62] and received a DASH questionnaire, a validated self-administered subjective outcome score[86], three and twelve months after the fracture. In the absence of response, a reminder was sent two weeks later. 2571/3666 (70%) returned the questionnaire at 12 months. One-year data revealed that 17% of the patients (445/3666) with a distal radius fracture still exceeded a DASH score of 35, indicating inferior subjective result[62]. In December 2014, 2-11 years after the fracture 346/2571 patients were still alive and received a new DASH questionnaire. 269 of the 346 (78%) patients returned the DASH questionnaire and about half of the patients had improved to a score below 35[87].

In the present study, we invited the patients from the 2014 follow up, with 1) a fracture between January 2005 and December 2012, 2) between 18 and 55 years at the time of fracture, and 3) with an inferior outcome score at one year. In total 932 patients 18 to 55 years had been included and 612/932 had returned a complete DASH at the twelve months follow up. 365/612 patients had a DASH score less than 10, which was considered a normal value, 179 patients had DASH ranging from 11-35, thus an intermediate outcome and 69 patients still had DASH value exceeding 35, indicating significant morbidity. In spring 2018, 54 patients, 41 women and 13 men, with a mean age of 47 years at fracture, had yet another new DASH sent by mail and were invited to the hospital for a full clinical and radiographical examination.
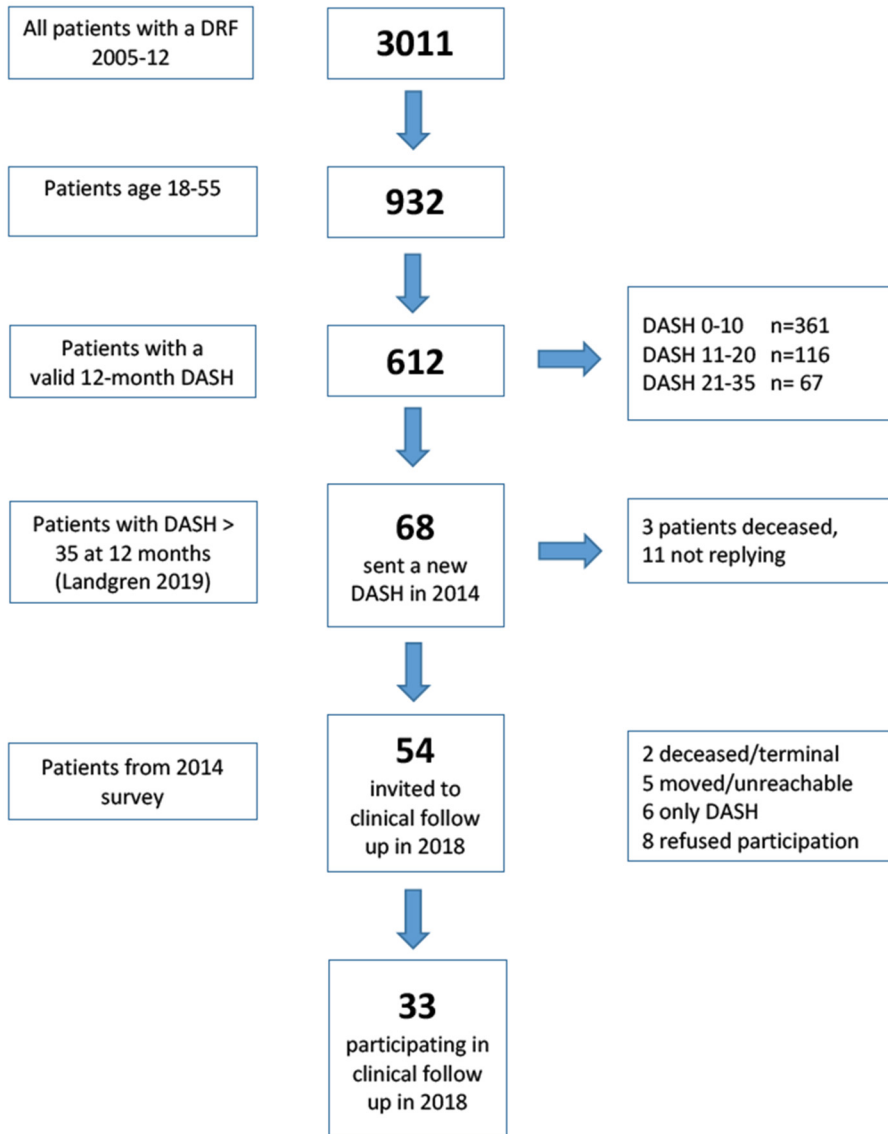
Figure 11:
Flowchart. Patients 18- 55 with an inferior subjective outcome DASH>35 between 2005-12 were selected from the Lund Distal Radius Fracture Register

Objective outcome

Clinical examination

One examiner (the author of this thesis), carried out the clinical examinations in all studies (I-IV) without knowing the initial arthroscopic findings or the results of the 1-year follow-up. Range of motion in radial/ ulnar deviation, flexion, and extension was assessed once using a goniometer. Grip strength was measured three times using a Jamar dynamometer (Preston, Bolingbrook, IL) and the mean value was used in the statistical analysis.
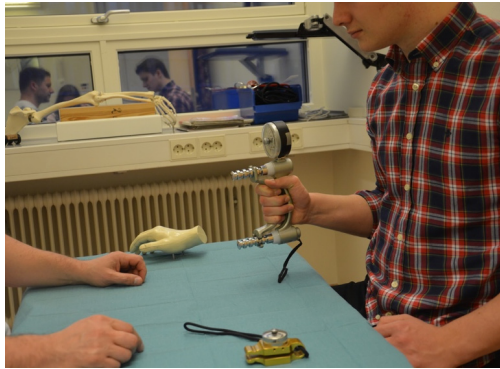
Figure 12:
Grip strength, measured with the Jamar dynamometer. The arm is held close to the body, the elbow in 90-degree flexion and forearm in neutral prono-supination.

DRUJ

DRUJ stability was carried out using the DRUJ stress test and compared with the one-year examination by the original examiner[6] in study I and II. Before the late follow-up, the examination technique was calibrated for consistency by the 2 examiners. The forearm was held in neutral rotation by the examiner, who stabilized the hand and the distal radius with a firm grip to make them one unit. The examiner then, using the other hand, forced the ulna as the second unit in dorsal/palmar direction relative to the stabilized unit of the hand and radius. The stability of the DRUJ was compared with that of the uninjured opposite side for reference, and objective laxity or triggered pain noted.

Figure 13:
Examination of DRUJ stability. The investigator forces the ulna manually in dorsal and palmar direction, with the radius held still.

SL

Scapholunate ligament stability was evaluated using the Watson scaphoid shift test[88]. Before the follow-up, the examination technique was calibrated for consistency by the 2 examiners. The patient`s forearm was held in light pronation, with flexed elbow, and the examiner pressed against the scaphoid tubercle with the thumb on the palmar side. The other fingers supported the back of the wrist at the distal part of the radius. With the examiner´s other hand, the wrist is passively moved from ulnar deviation and slight dorsal extension, towards radial deviation and slight palmar flexion. Meanwhile a constant pressure was given by the thumb on the scaphoid tubercle and the distal pole of the scaphoid tilts forward and thereby pushes against the examiner`s thumb causing stress on the joint. During the test both ligament laxity and pain were evaluated, and results were classified as positive or negative, compared with the other uninjured side. The test was interpreted as positive if the scaphoid appeared to be unstable with a tendency to sublux dorsally, in some cases with pain experienced at the dorsal side of the wrist

38

Figure 14:
The Watson scaphoid shift test was assessed, recording both ligament laxity and pain during the test.

Subjective outcome

Gartland and Werley

For evaluation of subjective (and objective) complaints, the Gartland and Werley score[89] (Appendix 1) was used in the original 1995-97 examination but complemented with the more modern Quick DASH[90] (Appendix 2), (Disabilities of the Arm, Shoulder and Hand, Beaton DE et al 2005) in paper I-III together with the visual analog scale (VAS). The Gartland and Werley score is based on a demerit point system and was modified by Sarmiento[91] with the addition of loss of pronation and grip strength. The score was originally designed to evaluate both subjective and functional outcome of wrist and hand function. This score is filled out by the examiner after the patient has been examined and is thus not self-administered. The outcome is classified as excellent, good or poor and was used both at the one-year follow-up[6] and in the late follow up for comparison.

DASH and QuickDASH

The DASH questionnaire was used in paper I-IV. It is a patient reported outcome measurement tool evaluating disability and symptoms of the upper extremity. DASH was initiated and developed by the American Academy of Orthopedic Surgeons and the Institute for Work and Health in Toronto, Canada [92] and validated in Swedish[86]. The original DASH questionnaire comprises a 30-item scale evaluating function, pain, and symptoms of the upper extremity the preceding week. For each item, 5 response options are available. A final score is calculated, ranging from 0 (no disability) to 100 (most severe disability). In 2005, a short version, the QuickDASH was developed with only 11 questions[90], translated to Swedish, validated, and correlated to the 30-item DASH[93]. At our center, the QuickDASH replaced the original DASH questionnaire from February 2008, and a strong correlation was found between the full 30 and the shorter 11 question versions ($r_s = 0.97$, $p < 0.001$; [2]).

Visual analogue scale- VAS

Using the VAS, the patients were asked to plot their subjective pain at 1) rest, 2) at activity, 3) describing a subjective overall function and 4) the cosmetic appearance. The scale was graded from 0 to 10 cm, with 0 representing best and 10 representing worst outcome.

Radiography

In paper I-III, posterior-anterior (PA) and lateral exposures were acquired, PA exposures with clenched fist, and PA exposures in radial and ulnar deviation with the wrist in slight extension. The SL angle and the SL distance were measured on PA radiographs in radial and ulnar deviation and in neutral position. In paper IV, the same exposures were used but without provocation. In paper I and III secondary osteoarthritis was assessed and graded according to Knirk and Jupiter[94] and in paper II according to Kellgren and Lawrence[95]. An experienced musculoskeletal radiologist examined the radiographs (M.G.), unaware of the initial arthroscopic findings.

Statistics

In the statistical analysis, variables were presented as mean (standard deviation) or median (range) due to distribution of data. The Student t test was used in quantitative continuous variables, such as grip strength, Mann-Whitney U test or Wilcoxon rank sum test for scale data (VAS, Gartland and Werley and DASH), and Fisher´s exact test for categorical data. In paper II, the patients were subdivided into two groups. Grade 3 and grade 4 SL tears were pooled into a "complete" tear group and grade 1 and grade 2 tears into a "partial" tear group for comparison. P-values less than 0.05 were considered statistically significant.

Results

Paper I

Forty-seven of the 51 originally treated patients were still alive and invited to the long-term follow-up. Four patients decided not to participate and 4 patients only returned the QuickDASH and VAS questionnaires. One patient was excluded from the follow up due to surgical TFCC reattachment one year after the original distal radius fracture. This was the only patient in the series operated due to subjective instability. In addition, at the time of the follow up, this patient was in a plaster due to a scaphoid fracture at the same side as the previous radius fracture and could not be examined clinically.

38 patients with a mean age of 57 years (range 38-73) had a full clinical and radiographical examination in 2010. 21 patients were considered stable at the DRUJ stress test and 17 were lax. Eleven of the 21 who were considered stable, had an excellent outcome using the Gartland and Werley score, compared to only 3/17 in the lax group. The median QuickDASH score for the lax group was 14 (range, 0-59), compared to 5 (range, 0-70) for those perceived to be stable (p =0.11). The mean grip strength was 83% (SD 15) of the contralateral side in the lax group compared to 103% (SD 33) in the group with a negative DRUJ stress test result (p = .03).

Table 3:
Subjective outcome related to the primary diagnosis

	Complete peripheral TFCC injury n=8	Partial peripheral, central or no TFCC injury n=30	p
DASH *median*	25 (0-59)	7 (0-70)	0.14
Gartland Werley	5 (0-15)	4 (0-13)	0.73
Grip strength	88% (13)	95% (31)	0.53

Table 4:
Subjective outcome related to DRUJ stability at 13-15 years

	Unstable DRUJ n=17	Stable DRUJ n=21	p
DASH *median*	14 (0-59)	5 (0-70)	0.11
Gartland Werley	5 (0-15)	1 (0-9)	0.07
Grip strength	83% (15)	103% (33)	0.03

Eight patients had developed a mild to medium grade OA in the DRUJ. 5/17 patients in the lax group and 3/21 in the group with a negative DRUJ stress test developed DRUJ OA (p =0.18).

Eight of the 11 patients with complete peripheral TFCC tear were re-examined after 13-15 years and 6/8 were considered lax at follow up. Of the 25 patients with initial partial TFCC tears, 15 patients remained stable over time. Subjectively, patients with a complete tear had a DASH score of 25 (0-59) compared to 7 (p=0.14) in the ones with a partial or without tear. In patients with a complete peripheral TFCC tear, the grip strength was 88% of the contralateral wrist compared to 95% (p =0.53) in patients without. We found no association between TFCC injury and OA, nor between residual laxity and OA. We found no association between ulnar styloid union/nonunion and clinical symptoms.

Table 5:
Literature review of outcomes of natural course of soft tissue injuries associated with distal radius fractures. * Same cohort of patients; SL- scapholunate; LT-lunotriquetral; TFCC-triangular fibrocartilage complex; DRUJ- distal radioulnar joint.

Study (year)	Lindau (2000) *	Forward (2007)	Mrkonjic (2012) *	Deniz (2014)	Finsen (2014)	Mrkonjic (2015) *	Swart and Tang (2017)
Subjects (n)	51	51	38 (51 in the original series)	47	12 index patients, 54 controls Extra-articular fractures with an increased SL gap (2.1-3.4 mm)	38	42
Follow-up (year)	1 year	1 year	13-15 years	2 years (36-48 months)	6.2 years	13-15 years	1 year
Mean age (range)	41 (20–57)	41	41 (20–60)	56 (24–87)	66 (55–85)	41 (20–60)	57 (20–85)
Soft tissue injury	43 TFCC tears; 32/51 Partial or no peripheral tears; 11/51 Complete peripheral tears	SL tears 44/55; Grade I-11; Grade II-23; Grade III-10	TFCC tears Partial tear (n-20); Complete tear (n-13); No tear 5; 17/38 had DRUJ laxity	TFCC tears; 24/47 MRI imaging	SL tears (an increased SL gap, radiologically assessed, mean 2.6 mm)	SL tears Complete Grade III 9/38 Partial or no tear 29/38	SL/TFCC tears Authors classification of SL tears: Grade I-11 pat, Grade II-7 pat; Grade III-1 pat 12/42 TFCC tears
Clinical outcome	10/11 With complete tear had DRUJ laxity vs 7/32 i the others	>Incidence of pain in pat with grade III	No difference except decreased grip strength in the lax group	No difference	No difference	No difference	No difference
Functional outcome	Patients with instability had worse Gartland and Werley score	No difference (Gartland and Werley score)	No difference (Q-DASH; Gartland and Werley)	No difference (Mayo wrist score)	No difference (Q-DASH, PRWE)	No difference (Q-DASH; Gartland and Werley)	No difference (DASH)
Radiological outcome	DRUJ laxity was not associated with x-ray findings	>Incidence of SL dissociation with grade III	No difference	No difference	No difference (X-ray)	No difference. None of patients had developed SLAC wrist	No difference

Paper II

Thirty-eight participants, same as above, came for the follow-up. None of these had had a complete grade 4 SL ligament tear at the initial arthroscopy. 9/38 patients had a grade 3, 17 had a partial tear (grades 1-2), and in remaining 12 patients the SL ligament was intact. At 13-15 years after trauma, none of the patients had been operated due to SL-related symptoms. SL tear grade 1-3 did not affect the range of motion in extension and flexion compared to the healthy side. The mean grip strength in patients with a grade 3 SL tear was 83% of the contralateral wrist, as compared with 92% (p =0.34, 95% confidence interval -7% to + 21%) in patients with partial or no tear. We found no significant difference in median DASH for patients with complete grade 3 injury compared to those who had partial grade 1-2 injury. Radiologically, no differences were found regarding SL angle or SL distance between patients with grade 3, compared to grade 1-2.

Table 6:
Radiographic findings after 13-15 years follow-up of arthroscopically diagnosed scapho-lunate (SL) ligament tears. NB – no grade 4 SL tears were found in the study cohort.

RC osteoarthritis (Kellgren/ Lawrence)	Complete SL tear (grade 3) n=9	Partial SL tear (grade 1 and 2) or no tear n=29
Grade 0	4	16
Grade 1	2	9
Grade 2	2	4
Grade 3	0	0
Grade 4	1∗	0

∗ Patient with bilateral arthritic changes, probably not related to trauma

Paper III

Twenty-eighth of the 41 patients with a subchondral bleeding at arthroscopy participated in the long-term follow-up. Eighteen were women, 10 were men and the dominant wrist was involved in 19/28 patients. More than half (17/28) of the fractures were intra-articular, and classified as 16 intra-articular type C, one type B, and 11 extraarticular type A according to the AO classification. High-energy trauma was the cause of injury in 23 of the 28 patients. The majority (22/28) of patients had reduced range of motion on the injured side, regardless of the type of cartilage injury. Secondary development of osteoarthritis was rare and not related to the presence of subchondral hematoma at arthroscopy.

Table 7:
Subjective and objective outcome at 13-15 years in patients with or without haematoma at arthroscopy.

	Patients with haematoma (n=8)	Patients without haematoma (n=20)	p
DASH: median (range)	16 (0-55)	14 (0-70)	.89
DASH: mean (SD)	20 (19)	20 (22)	
Gartland and Werley: median (range)	5 (0-7)	2 (0-9)	.66
VAS pain at rest: median (range)	1 (0-4)	1 (0-3)	.57
VAS pain at activity: medan (range)	1 (0-6)	1 (1-8)	.7
VAS subjective function: median (range)	2 (1-5)	2 (0-9)	.65
Extension fracture side: mean (SD)	67º (10)	68º (16)	.80
Flexion fracture side: mean (SD)	63º (8)	63º (16)	.97
Grip strength: mean (SD)	80% (32)	86% (25)	.61

Table 8:
The incidence of OA at 13-15 years after fracture, related to arthroscopically diagnosed subchondral hematomas and the presence of subchondral radiographic changes at the 1-year follow-up (Fisher`s exact test).

OA			
	Yes	No	p*
Hematoma			
Yes	2	6	.67
No	8	12	

Paper IV

54 patients, 13 men and 41 women, aged between 18-55 who responded to the 2014 late survey of the patients with an inferior subjective outcome at one year, were invited to participate in the present follow-up. Two deceased, 8 patients declined to participate, 3 had unknown address and could not be reached, 2 had moved far away and could not come and six patients only submitted the DASH via mail. The remaining 33 patients came and were re-examined, both clinically and radiologically in May 2018. Seven were men and 26 women, and the mean age was 47 years at fracture. 4 patients initially had had an unstable fracture and were operatively corrected at day 2-6. Two patients had their fractures primarily reduced but re-dislocated and were operated at day 11-15. Four patients had been operated using volar locking plates, one external fixators and one with combinations. 27 patients did not need surgery and completed plaster treatment. Until the current study, two patients had been reoperated with plate extraction, one had undergone a partial wrist arthrodesis (RL) and one a total wrist arthrodesis due to an SL-injury and DISI/SLAC. Two patients had been corrected with an ulna shortening

osteotomy due to malunion and radius shortening, and three with a radius-osteotomy due to multiplanar malunion. Three patients had been operated with a ulnar nerve or carpal tunnel release. Two patients were not working at present, 18 patients had non-manual work and 14 manual. Chronic systemic diseases were reported in 10/33 in particular chronic musculoskeletal conditions 12/33.

The patients had a high pain rating at rest (VAS 2.5 cm), especially at loading (VAS 4.5). Mobility was generally satisfactory, including rotation. The grip strength was good and 88% of the contralateral. 33% had DRU joint laxity, which in turn was often present with OA changes. SL instability with pathological Watson's test was found in only one patient with also radiological support in the form of an obvious midcarpal step off and SL dissociation.

Figure. 15
Patient with positive Watson´s test and radiological scapholunate step off.

The consequences of an undetected SL-injury were found in one patient rather quickly developing a static SL dissociation, DISI and SLAC wrist.

Figure 16:
Chronological x-ray follow-up of a patient in paper IV with initially seemingly harmless DRF and a concealed complete SL ligament injury grade IV

Discussion

The distal radius fracture- worse prognosis than previously expected?

In a previous report from the Lund Distal Radius Fracture Register, including all patients >18 years with an inferior subjective outcome at one year, the patients continued to have substantial problems in the following years. Only half the patients returned to an acceptable level of DASH <35 at the follow up 2-13 years later[87]. In study IV, selecting only the patients younger than 55 years in the register, the result was even worse. Only 1 of the 33 patients returned to a normal subjective outcome (DASH 0-10) and fourteen reached an acceptable level (DASH 11-35). Eighteen still were in the group with a DASH exceeding 35 indicating severe symptoms including pain at rest. Is this acceptable? What are the reasons and can they be prevented? The answer, as expected was not as clear as one would have hoped for, but is multifactorial. Many had comorbidities, especially from the locomotor apparatus, but after years of pain at rest from a distal radius fracture it is difficult to differentiate what is the primary cause and what are secondary consequences of year-long pain and suffering. Malunion was fairly common although mainly moderate, with some 15% already operated with an osteotomy. Osteoarthritis of the DRUJ was fairly common as was ulnar pain and instability with painful DRU laxity. By speculation even a moderate three-dimensional malunion may worsen the consequences of a concomitant TFCC injury, and as an isolated injury malunion or a TFCC injury alone maybe less important to inferior outcome. There is no single answer to what should be done to prevent that *one patient out of six end up with a painful wrist years after the fracture*.

The challenge- detection and early treatment of associated injuries

There are potential early interventions to consider. Definitely, the distal radius fracture needs more attention early on, to help the patient through the rehab time. Maybe we need better pain management, more careful rehab surveillance with a

more active attitude to diagnose and in particular prevent the complications to become manifest. A more individualized treatment may be necessary taking into account, not only the radiographic appearance of the fracture, but also the individual sustaining the fracture. Patients with previous musculoskeletal pain and a triggered hyperalgic nervous system may need much more attention to cope with the initial pain. We need better surveillance during early physiotherapy and a focus on patients who are incapable to endure the often painful anti-edema exercises. Maybe more fractures should be operated, but then every effort made to avoid all potential surgical complications. It has been anticipated that also soft tissue injuries play a role and the rate of symptomatic ulnar instability in paper IV implicate a more active early treatment. But, first studies are necessary as surgical treatment of TFCC injuries, although promising in the short term[96-101], was less successful evaluated at longer term[71].

In the present thesis all studies focused on younger patients, adults but still in a hypothetically less osteoporotic group. In the younger patient, the energy necessary to cause the fracture is higher than in the elderly osteoporosis patients. In non-osteoporotic adults, distal radius fractures are commonly intra-articular[30], and besides cartilage damage, ligament injuries are present to a large extent[3, 102-104]. The majority probably heal or at least leave no rest symptoms, but some, in particular TFCC injuries, remain symptomatic. How to sort out which need to be stabilized, remains a challenge. As a speculation, malunion and TFCC injury may be an ominous combination and a possible target for future research. One patient in the inferior outcome group had an SL injury primarily undetected, evolving into SLAC. We learned from paper II that Geissler 1-3 are harmless but this patient must have had a Geissler 4. Can these be extracted from the large volume of DRFs passing by in the clinics? Without arthroscopy probably not. Only an increased awareness of potential Geissler 4 injuries might make a change, detecting the injury during surgery or, in the conservatively treated, at least during the first year. Still long term results of treated SL injuries in DRFs are largely unknown. A Geissler 4 can be suspected in some high energy injuries, for example in a radial styloid fracture, in which SL ligament injuries are known to be associated with the DRF as a part of a greater arc perilunate dislocation, known as the Mayfield mechanism[105]. In these fractures, other injuries most certainly are present, including carpal fractures, associated scapho-lunate, luno-triquetral ligament injuries, and TFCC tears.

Figure 17:
SL dissociation indicative of greater arc injury, sometimes found in a" Chauffeurs" fracture.

A TFCC injury at the time of fracture may cause ulnar-sided wrist pain at long term?

Paper I was a prospective longitudinal outcome study of the natural course of TFCC tears associated with a distal radius fracture. It was primarily a radiographic and arthroscopic, descriptive study[3], with a follow-up at 1-year, evaluating the consequences of ulnar-sided injuries in distal radial fractures regarding objective laxity and symptoms[6]. The fractures were treated according to the guidelines at that time, conservatively or surgically, but any soft tissue injury was left to study the long-term consequences. Thirteen to 15 years after the initial injuries the follow up was undertaken and we found that only 1 patient had been operated on for painful DRUJ instability, secondary to a peripheral TFCC tear caused by the fracture. Osteoarthritis was not common and of minor grades. DRUJ laxity was more

common and of the 38 patients of the original 51 patients coming to the follow up, laxity of the DRUJ was found in 17. The only statistically significant measurable long-term difference was a decreased grip strength in the lax group but most other findings showed, at most, statistical trends indicating worse subjective outcome for patients with a complete peripheral TFCC injury and/or a positive DRUJ stress test after such a long time. We were unable to find that untreated DRUJ laxity isolated, led to secondary degenerative osteoarthritis, or at least less compared to a treated and stabilized series[71]. Secondary osteoarthritis is often found after both treated and untreated destabilizing injuries to the anterior cruciate ligament of the knee after similar time[106, 107]. Our early findings of DRUJ laxity during the first year after a distal radius fracture[1] have been reproduced recently with similar proportions of post-traumatic laxity (23/48)[108] . The authors in that study did not find any association between laxity of the DRUJ and subjective outcome.

The stress test for the DRUJ is used to assess hypermobility or laxity of the joint and should be separated from instability, which is a description of subjective symptoms, caused by laxity and experienced by the patient, such as pain, clicking or weakness. The distinction is well-known to the orthopedic community, where for instance clinical laxity is tested with the Lachman or anterior drawer test after an anterior cruciate ligament injury in knees, in contrast to subjective instability reflected by the patient's sense of give-way symptoms. The DRUJ stress test has been shown to be reproducible between individual investigators at the same time point with inter-observer kappa values ranging between 0.66 and 0.84[108, 109]. Our efforts to compare the present ulnar stress test results (A.M.) with the original ones (T.L.) in [3]) showed a high inter-rater agreement in patients with a complete peripheral tear (85%), but not in patients with partial/no tears (50%). A comparison between two time points, as widely separated as in our study, is probably impossible to do. Theoretically, a partial tear could heal and tighten with time, but it could also continue to deteriorate into a complete tear with a combination of stretching forces and degenerative changes in the radioulnar ligament. In contrast, a complete peripheral TFCC tear is not likely to heal, which could explain why the complete tears remained lax 13-15 years after the injury. Testing the inter- or intra-observer reliability between two investigational time points therefore appears less meaningful. In the present series, the clinical DRUJ stress test had a moderate sensitivity (0.56) but high specificity (0.96) for the arthroscopic diagnosis of a complete TFCC tear at the initial 1-year follow-up[6], compared to 0.75 and 0.63 respectively at the current follow-up. Time will tell whether we will have reliable methods to more objectively detect laxity such as measuring the radioulnar ratio using computed tomography or magnetic resonance imaging[110]. This method has been shown to be more sensitive for detecting laxity[109] but did not show any correlation to the DRUJ stress test after distal radial fractures[108].

To use the result of the initial arthroscopic findings or the DRUJ stress test at 1 year after a distal radial fracture to predict a symptomatic instability 15 years later, was found to be difficult. Only 1 patient was operated on due to painful instability, and the other patients with laxity may have adapted to their post-traumatic disability, still being lax but not with sufficient problems or symptoms to stand out in our present assessment. Using the Gartland and Werley score, the group of lax patients was found to have worse outcome in the 1-year follow-up, a finding which could not be repeated in the present long term study. The Gartland and Werley score is a hybrid outcome assessment with a mixture of subjective and objective data as well as a radiographic part, all summarized into one score. In the present study, we additionally used DASH, the standard subjective outcome instrument today, but were unable to show statistically significant differences regarding morphologic diagnosis, objective laxity, or subjective outcome, although trends were noted. Also, others, using the modern, examiner-independent, subjective DASH score, have not been able to show any association of laxity to worse outcome[108].

In the present series, we thus could not find sufficient evidence that a TFCC injury at the time of a distal radius fracture would influence the subjective outcome at long-term. There were, however, trends indicating that the group of patients with a partial or non-diagnosed TFCC tear was superior to the group with complete tears in the objective and subjective outcome. The absence of statistical significance might be due to a lack of statistical power to show such a difference. The number of patients was small, and there was a risk for a type 2 error and therefore the register study in paper IV was initiated. However, based on the findings of paper I, we concluded that we have no support for aggressive surgical management of TFCC tears, diagnosed in association with distal radius fractures, but larger and preferably randomized studies are needed.

Scapho-lunate tears are common but do not deteriorate into SLAC wrists

SL ligament tears have been the subject of several studies, mostly as an isolated injury, but in some studies also as a combination with other wrist injuries like DRFs. Often diagnostic or treatment options have been discussed rather than observing the natural course over time. In paper II, none of our 38 patients, regardless of the severity of the initially verified SL tear, developed a dorsal intercalated segment instability (DISI) deformity or the end stage SLAC during the long follow-up period. This may, in our view, be consistent with the absence of the more severe Geissler grade 4 SL tear, in which the secondary stabilizers may also be injured or attenuated. The absence of SLAC, 13-15 years after grade 1-3 SL tears seems

scientifically to be a true reflection of the long-term outcome. We do not know which traumatic tears have the capacity to heal. Even complete traumatic tears may heal, possibly when the extrinsic ligaments are intact, as grade 1–3 tears do, but without arthroscopy it is impossible to differ between grade 3 and 4. The issue is truly complex, knowing that SL ligament tears also can occur as part of a degenerative process without a recognized injury. The tears that are visible in standard radiographs in an acute DRF are often degenerative, sometimes found on the contralateral side, and repair should not be attempted.
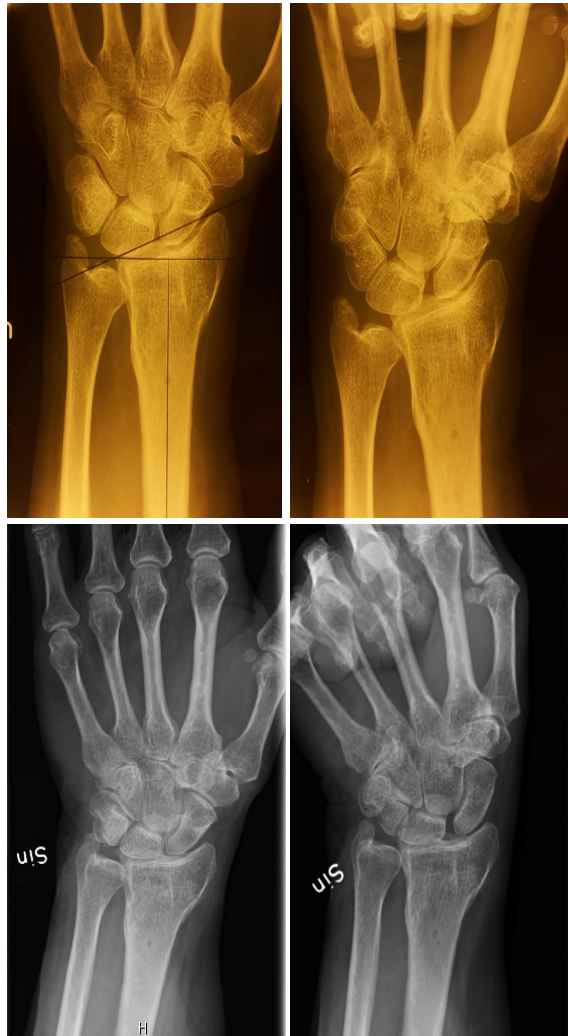
Figure 18:
Patient with SL grade 3 injury, no radiological progress over 10 years period (1997-2010)

In paper II, we defined subjective instability as a symptom that was only possible to surmise through the medical history, in contrast to objective hypermobility[108] found by the Watson test. Subjective instability, interpreted as a symptom, does not necessarily imply a dynamic or static radiographic dissociation. In an acute SL ligament tear as a part of a DRF, it is impossible to diagnose subjective instability. At the late follow-up, none of our patients complained of any clicking, and none of them had had any secondary stabilizing surgery performed during the follow-up period. However, even without subjective instability, it has been assumed that the risk of secondary arthritis may warrant surgery at the time of the injury[111]. In the current study, however, no advanced degenerative changes were found in patients with SL ligament tears up to and including grade 3. We found no evidence that untreated SL ligament tears, up to arthroscopic grade 3, associated with a distal radius fracture, negatively affected the subjective, objective, or radiological long-term outcome. Primary repair *per se* therefore seems unnecessary. We do not know the possible long-term outcome of grade-4 SL tears or traumatic static radiographic SL tears seen on trauma films, as these were not present in the cohort. We are therefore limited to suggest that the management of arthroscopically diagnosed grade 1–3 SL tears can be non-operatively.

No increased risk of radiocarpal osteoarthritis due to subchondral hematomas in the unfractured compartments

Histopathologically, a blunt joint injury may result in edema, hyperemia, bleeding and/or a micro-fracture of the subchondral trabecular bone[112]. In clinical practice, the diagnosis has to be made using some imaging technique and it is well known that radiography is unable to depict these early lesions. In wrist arthroscopy a direct, visual description of a subchondral haematoma can be done. Most studies of subchondral bone lesions, however, have been performed in knee injuries using MRI and the terms bone bruise, bone marrow oedema or bone marrow lesion are defined as an increased signal intensity on T2-weighted MRI images[81, 112]. It is currently under debate whether these bone marrow lesions play a role in the development of knee OA[82]. There are no long-term studies of bone bruises or bone marrow lesions after wrist trauma.

Figure 19:
Arthroscopic view from the 3-4 portal (between the third and fourth extensor compartment) showing a subchondral haematoma in the unfractured scaphoid compartment of the distal radius at the time of the fracture. The scaphoid is seen on top with the scaphoid facet of the distal radius below and the radio-carpal extrinsic ligaments behind.

In paper III, 12/41 patients in the original cohort had a subchondral haematoma in an unfractured compartment[3]. After one year, subchondral trabecular changes were noted in eight patients, whereof seven had had a subchondral hematoma within the same joint compartment at the original arthroscopy. Four of the eight patients had an incipient osteoarthritis (OA) grade 1[84]. In the present 13-15 years follow-up, the fear of a deterioration and development of a clinically manifest OA, as indicated in the one-year follow-up, could not be verified. Some of the patients with a subchondral hematoma, but not all, developed a mild joint space narrowing over the years, but approximately the same proportion of the patients without a subchondral hematoma did as well. Our interpretation is that this progression represents a more general degenerative process, rather than a direct consequence of the injury. Even in the compartments with an intraarticular fracture, OA seemed to be rare and limited. Furthermore, incipient grade 1 OA was found in less than a third of the fractured compartments (5/17). The patients with an arthroscopic hematoma developing a mild radiocarpal OA, seemed to do so early on and only one patient had deteriorated from no arthritis (grade 0) at one year to minimal OA (grade 1) at the late follow-up. The only patient in the whole cohort developing advanced arthritis was diagnosed with rheumatoid arthritis shortly after the fracture and the joint changes were bilateral and appeared to be independent of the distal radius fracture.

In knee injuries, the underlying mechanisms are well described with traction forces and bone contusions leading to a focal bone marrow lesion, with or without a subchondral fracture[113]. Even a minor trauma, maybe leading to a subchondral

fracture, has been proposed as the cause of spontaneous osteonecrosis of the knee (SPONK)[114, 115]. With the use of MRI, often a bone marrow lesion or even a subchondral osteonecrosis can be seen long before changes occur in plain radiographs[116, 117]. In major knee trauma, like in ACL injuries, almost all patients have bone marrow lesions in MRIs (98%), and 2/3 have a subchondral compression fracture[118-120]. Biopsies have shown necrotic cartilage cells and a decreased proteoglycan content but we do not know the effects of these biologic factors over time. In the majority, the bone marrow lesions disappear after 6-8 months but may persist longer[121]. However, 50% of the patients with an ACL-injury develop osteoarthritis after 10-15 years. In contrast to these knee injuries, we found no or only minor osteoarthritic changes as long as 13-15 years after a wrist injury, regardless whether the joint surface was fractured, had a bone bruise or was arthroscopically intact. We have no clear explanation to why a bone bruise in the wrist appears to be less progressive. The biomechanics differs and the radio-carpal joint is not weight-bearing as the knee joint. Further, the ACL-ligament injury per se with the subsequent instability and frequent give-away episodes, increases the risk of the degenerative progress, in addition to the primary direct/indirect cartilage injury and subchondral bone marrow lesion. In the wrist, an equivalent ligament injury may be the grade 4 scapholunate (SL)-tear which may lead to secondary arthritis. In the present series 9 patients had a grade 3 SL-tear and 2 of these a subchondral hematoma, but none developed OA.

Ulnar instability and comorbidity as causes for long term inferior subjective outcome after a distal radius fracture

The reason for long term inferior outcome after distal radius fracture (DRF) is truly multifactorial. Besides as previously described, ulnar sided wrist pain and DRUJ instability, SL-tears grade 4, DRUJ and radiocarpal OA, and malunion being important, other causes like socioeconomic factors, comorbidity and pain coping may be as well.

In the previous arthroscopic studies (study I-III), a substantial number of partial TFCC tears, LT-tears and SL-injuries were diagnosed but did not influence the long-term morbidity and subjective outcome. Also, in study IV, with the selected patients from the register, < 55 years and with a DASH> 35 at one year, LT and SL laxity were rare and without long term consequences, although one end-stage SLAC was found after an undetected Geissler grade 4 SL-injury. DRUJ instability, on the other hand, was common and present in 11/33 patients, as was DRUJ osteoartrhritis, although not exclusively in the lax patients. In study 1, 20% had a complete peripheral TFCC injury initially and 17/38 were lax in the DRUJ after 13-15 years.

Although major instability was found at examination, only one patient had been reconstructed during the 13 to 15-year period since the fracture. Also, in study IV, no TFCC reconstruction had been attempted in spite of one third being grossly unstable in the DRUJ.

The subjective outcome in this selected younger group was even worse than in the whole cohort of all ages, having a DASH score exceeding 35 at one year. A modest 24/137 returned to a pre-fracture status between DASH 0 and 10 in the following years [87] but in the selected younger group, the equivalent number was one/33 patients! We know that the younger DRF patients have more ligament injuries in general due to high energy trauma and, maybe as hypothesized in paper 1 but not statistically proven, these do play a role for the long term results. The two studies I and IV do differ in design. In paper I the cohort was unselected and followed for long time. The number of severe injuries in consequence was low. In paper IV the patients were selected and the number of patient with conditions that do matter over time was higher. For example, DRUJ OA was more common in the selected group in paper IV with 14 of the 33 patients having DRUJ OA, compared to 8/38 in paper I.

In other long term outcome studies after DRF, radiographic malunion has been the most important factor. Patients with malunion were found to have worse subjective outcome at one year[64] and continued to be worse for years to come, compared to patients without, or with a lower degree of malunion[65]. In the present study, malunion was present in about one third but the degree was rather moderate. Axial compression, which has been shown to correlate the best with the subjective outcome was not common.

The one patient who returned to pre-fracture status DASH 0-10 had no signs of DRUJ instability and was in general healthy at the final follow up. In the other two outcome groups (intermediate 11-35 and major disability >35), the incidences of ulnar ligament injuries, complications, reoperations and chronic systemic disease were similar and evenly distributed. The incidence of chronic musculoskeletal conditions however appeared to be higher in the group with major disability compared to the intermediate group. In a study following DRF patients for 10-20 years after the fracture, a result comparable to ours was found, with 85% remaining at an acceptable level or improving throughout the years [63]. In the small group that did not improve over the years, it was noted that these patients more often had other general health problem including high blood pressure, diabetes, depression, osteoarthritis, osteoporosis, or rheumatoid arthritis. The comorbidities were not unique, however, to the 'worsened' group. In our study we found systemic disease to be as common in the intermediate as in the major disability groups, and almost none returned to normal.

Conclusion

In the short perspective the overall outcome after a distal radius fracture (DRF) must be considered good with a return to a normal pre-fracture status in more than half the patients and with another third reaching an acceptable level[62]. *However, one-sixth of the patients in our large distal radius fracture register appear to have an outcome, far from expected, both in a patient/physician perspective as by other stakeholders in the healthcare* (SBU). Although being the most common fracture in medicine, with large costs both in direct[122, 123] and indirect[124] care, with one out of six patients ending up having pain at rest, as well as an impaired function in work and leisure, the fracture attains very little attention. Research is sparse. This may not be surprising if the general notion is that the patients will do well regardless of how they are treated. Maybe it is time for a change?

Strengths and weaknesses

Paper I-III

Long-term follow-up of a consecutively collected cohort of younger patients with meticulously mapped soft tissue injuries associated with a DRF are absent. Although the present study size is small, the three papers are unique. Leaving the injuries untreated to study the natural course was brave but not unfounded. We did not know, at the time, whether surgical repair would be better or even worse for the patients. We still do not know. Regarding SL-injuries grade 1-3 and the importance of subchondral hematomas, we might. These did not lead to even minor trends of influencing the long term outcome, and acute repair does not appear to be necessary. Somewhat disturbing, grade 4 injuries were absent in the SL-series and still may lead to inferior outcome as seen in one patient in study 4. Further, there was a trend of inferior DASH score in the small subset of patients with a complete peripheral TFCC-injury. The absolute difference in median DASH, 25 for the complete tears and 7 in the partial or no tears, would be considered clinically important if it were statistically significant, but it was not. The difference in grip strength, which can be seen as a compound and complex surrogate variable for subjective outcome including pain, would suggest such a conclusion, in particular given the high incidence of ulnar instability in paper IV. By speculation, the absence of statistical significance in the DASH analysis in paper I could be a type II error, in turn to be blamed on the study sample being too small, the number of patients showing up for the late follow up too few and the outcome instruments used to blunt. Thus, regarding SL-injuries Geissler 4 and complete peripheral TFCC injuries we still do not know whether we should treat or not.

Paper IV

Little is known about the subjective improvement over time in patients with a distal radius fracture, especially in patients with major disability after one year. This group of patients with poor outcome needs to be drawn into focus. Knowing the results of papers, I-III, with a too small study group to find differences in rare conditions like complete peripheral TFCC tears or Geissler 4 SL-tears, we decided to evaluate the

pattern of reasons to inferior outcome in a very selected group, where hopefully any condition leading to inferior outcome would be present. We chose a subset from our prospective outcome register.

To reach a sufficient numbers of patient replying to a questionnaire sent by post in some +400 patients yearly, long after treatment is completed, is a challenge. With a 65-70% follow up rate, the validity of the register is acceptable (Landgren 2017). Summoning the patients to come for a physical examination and a radiogram is even worse. Ideally, we would have liked to have a much better attendance but at each step, patients were lost. One must be aware that the patients in paper IV may not be representative to the whole cohort. But we tried our best. Still, the small cohort gives us a sense of what are the problems for this extremely selected group. It gives us a tool to decide what way to go, trying to select patients for intervention studies early on, long before the potentially harmful conditions become manifest.

Conclusions

1. Untreated traumatic triangular fibrocartilage complex (TFCC) injury appears to affect the long-term results after a dislocated distal radius fracture and are common in patients with inferior subjective outcome.

2. Untreated partial Geissler grade 1-3 scapholunate (SL) ligament tears associated with displaced distal radius fractures do not lead to inferior subjective outcome but grade 4 injuries may cause long term disability and may remain undetected primarily.

3. Subchondral hematomas in an unfractured compartment or even intraarticular fractures do not lead to symptomatic secondary osteoarthritis at long term. Radiocarpal osteoarthritis does not seem to be a major contributor to late inferior subjective outcome.

4. An inferior subjective outcome at one year remains over the years and almost none returned to normal pre-fracture status in a DRF cohort younger than 55 years at fracture.

5. Ulnar instability, DRUJ osteoarthritis and comorbidity, especially chronic musculoskeletal conditions, are common in younger patients with inferior subjective outcome at one year.

Future perspectives

Although the subjective long term outcome is good in the majority of patients, a subset of patients will continue to have substantial disability in years after the fracture. An improved care identifying potential complications early on, before complications become manifest should be aimed for. Today, the therapeutic focus is directed towards the radiographic appearance and whether surgery should be performed or not, whereas the interest in rehab resources and patient surveillance is sparse. A more individualized rehab may be successful, given the influence of comorbidity and in particular other chronic musculoskeletal conditions in this thesis. Patients are not all alike and the ones at risk may need more of the limited resources we have, and others less.

Ulnar ligament injuries do appear to play a role in the group with inferior outcome. Also here a more active surveillance may be important, to diagnose injuries early. Still, we do not know the long term outcome of surgical repair, and randomized studies are needed to compare. The incidence, however, is so low that the normally sized randomized study may be insufficient to show a clinically relevant difference. Better and sharper outcome instruments are needed as are larger study cohorts, preferably register based. Maybe pragmatic randomized studies using new techniques like mobile phones and apps for outcome research is a way to go. Further, machine learning and artificial intelligence may provide us with better tools to better predict which patients will achieve a good result and who will not. The computer will in the future be able to handle many more parameters compared to the treating physician using the present algorithm based treatment protocols. Finally, malunion which has been shown to influence the long term outcome in several studies should not be neglected, although not shown to have a large influence on long term outcome in our studies. By speculation, malunion, also minor, may be a worsening factor in patients with an ulnar ligament injury.

For the conservatively treated some improvement may be reached by improved manipulation and casting technique in the ER, but the challenge is probably rather to develop robust algorithms for selecting patients who benefit from surgery. In a professional setting the results of surgery with anatomical reduction are better, given the surgical complications are kept at a minimum. The race for better treatment is only to begin.

Summary

The outcome of the distal radius fracture is multifactorial. Malunion and joint incongruity are considered only parts of potential causes to residual disability. Fractures in younger pre-osteoporotic age often occur as a result of high energy trauma often with concomitant soft tissue lesions. These injuries are difficult to diagnose primarily using radiography, and arthroscopic techniques or MRI are necessary. Detected late, the rehabilitation process may have been delayed or even irreversible changes occurred. But do these injuries matter in the long run? Short term results of surgical procedures are published but the natural course of the often complex injuries is basically unknown. Further, we do not know how many of the patients with an inferior subjective outcome actually have residual symptoms of the associated injuries or if other problems dominate? Finding out was the goal of this thesis.

The first papers (**Paper I-III**) are prospective longitudinal studies with a 13-15 year follow-up of a distal radius fracture cohort. The fractures were treated according to the standard protocol at the time (1995-1997), with the addition of an arthroscopic examination, to aid in fracture management and to identify associated injuries. Our main focus was tears of the radio-ulnar (TFCC) and scapholunate ligaments (SL) as well as cartilage lesions. In the short-term, one-year follow-up, the ligament and cartilage injuries appeared to have worse scores, but in the current long term follow up, we did not find support for the initial fear of deterioration over time. In patients with peripheral TFCC injury, the only significant difference statistically at long-term was decreased grip strength in the lax group. Else, we found a trend that a complete peripheral TFCC tear may lead to worst subjective outcomes over a longer period of time.

We found no differences in the subjective, objective or radiographic outcome in patients with an SL injury grade III compared to grade I-II or without. None of the patients developed a static SL dissociation or a scapho-lunate advanced collapse wrist (SLAC). Subchondral hematoma in an unfractured compartment did not predict the development of post-traumatic radiocarpal osteoarthritis.

In **Paper IV** we used prospective registry data (the Lund Wrist Fracture Register) for a period between 2005- 2012 and selected a cohort of sixty-nine patients (18-55) with suboptimal subjective outcome based on a DASH score exceeding 35 at 12-month follow-up. Fifty-four were invited, and thirty-three participated in the present

survey. In 2018, 6-13 years after the fracture, the patients came for a clinical and radiographic follow-up. In addition to the objective and subjective evaluation, coexisting comorbidity was also recorded.

Painful ulnar laxity was found in 11/33 patients and laxity was often correlated to minor or moderate osteoarthritis of DRUJ. Moderate malunion was common. Chronic musculoskeletal disease was more common in patients with residual DASH> 35.

Sammanfattning på svenska

Handledsbrott (handledsfraktur) är en av de vanligaste orsaker till att man söker på en akutmottagning. Man räknar med att ca 20 000 patienter drabbas årligen i Sverige. Merparten av de drabbade är äldre och företrädesvis kvinnor. Med tilltagande ålder drabbas skelettet av urkalkning (osteoporos) och en försvagning, särskilt i handled, axel, rygg och höft. Handledsfrakturen tillhör de vanligaste benbrotten även hos yngre vuxna. Hos yngre är skelettet starkare vilket också innebär att det krävs mer energi för att ett benbrott ska uppstå. Vid behandling tar man hänsyn till patientens ålder, det allmänna hälsotillståndet och benbrottets utseende på röntgen. I normalfallet, hos ca 75% av patienterna, utgörs behandlingen av en tillrättaläggning av felställningen i frakturen och fixation av det uppnådda läget med gips i ca 4 veckor. Om ett acceptabelt läge inte går att uppnå genom manipulation eller om frakturen glider under de första 7–10 dagarna, utförs en operation där de frakturerade benbitarna fixeras med en metallplatta och skruvar. Utfallet av behandlingen är i stort bra och merparten av patienter med handledsbrott återfår sin normala funktion under det första året. Samtidigt har vi genom systematisk registrering av alla handledsfrakturer från 2002 och framåt funnit att ca 15% av de behandlade patienterna inte är återställda efter ett år.

Eftersom det krävs mer kraft att bryta sig i yngre ålder har man funnit att andra skador, såsom ledbands- eller broskskador är mer vanliga hos yngre i samband med handledsbrott. Med nyare metoder som titthålskirurgi (artroskopi) och magnetkameraundersökning (MR) kan man diagnosticera även dessa skador, kanske väl så viktiga för utfallet. Under senare tid har dessa utpekats som kanske en av de viktigaste orsakerna till kvarvarande smärta och obehag hos just yngre. Syftet med denna avhandling är att identifiera, kartlägga och utvärdera riskfaktorer som potentiellt kan leda till ett icke tillfredsställande resultat efter handledsbrott. Med den nyvunna kunskapen hoppas vi kunna förebygga ett dåligt slutresultat i fortsättningen genom förbättring av den primära diagnostiken, den kirurgiska och icke-kirurgiska behandlingen liksom den viktiga efterföljande rehabiliterings-kedjan.

Avhandlingen består av fyra delarbeten, tre kliniska och en registerstudie.

I de första tre studierna följer vi upp en yngre patientgrupp med handledsbrott 1995–97. I samband med handledsbrottet utfördes en titthålsoperation för att visuellt kartlägga associerade ledbands- och broskskador. Man fann ett mycket stort antal ledbands- och broskskador som då lämnades utan åtgärd med syftet att följa naturalförloppet. I denna avhandling undersöktes patienterna 13–15 år efter skada för att utvärdera utfallet och se vilka skador som hade betydelse på sikt.

I delarbete 1 undersökte vi om en skada på ledbanden som förbinder strålben och underarmsben påverkar utfallet av en handledsfraktur på sikt. Ledbandssystemet kallas TFCC, det triangulära fibro-cartilaginära komplexet, vilket sörjer för stabiliteten vid rotation av underarmen, en rörelse viktig för att kunna positionera handen i rummet. TFCC är gracil och skadas lätt, särskilt vid handledsbrott. Förekomsten av denna skada var hög i vår patientgrupp men under åren har bara en patient av de ursprungliga 51 patienterna blivit opererad med stabiliserande kirurgi. Vi fann att patienter med en komplett TFCC-skada hade en tydlig kvarstående instabilitet i den nedre underarmsleden (DRUJ) efter 13–15 år, men också en sämre greppstyrka och tendens till sämre utfall än de patienter som hade ingen eller ofullständig TFCC-skada. Vi kunde dock inte säkerställa skillnaden statistiskt och därmed inte övertygande visa att denna typ av skada inverkar på långtidsresultatet efter handledsbrott. Slutsatsen drogs med försiktighet eftersom patientgruppen, särskilt de med komplett skada var liten.

I delarbete II utvärderade vi skador på ledbandet som förbinder mån-och båtbenet. Detta kallas det scapholunära (SL) ledbandet och är precis som TFCC ett fascinerande och viktigt ledband för handlovens funktion. Vi befarade att skador på denna struktur kan leda till kollaps av handloven och utveckling av symptomatisk ledsvikt. Två tredjedelar av patienterna hade partiella skador av olika grad. Ingen av dessa försämrades över tid och vi fann inga skillnader mellan patienterna med eller utan skada. Den allra svåraste skadan, grad 4 i den amerikanske handkirurgen Geisslers klassificering, är ovanlig och saknades i serien. Denna skada tror vi fortfarande kan leda till kollaps och ledsvikt.

I delarbete III undersöktes patienter som vid ursprunglig titthålskirurgi hade broskskador i leden, synliga blödningar under broskytan. Det har diskuterats om denna typ av skada kan ge upphov till ledsvikt och vid tidigare ettårsuppföljning fann man en tendens till det. Nu 13–15 år senare fann vi att det inte var så. Inte ens frakturer som gick in i leden ledde till symptomatisk ledsvikt.

I det fjärde arbetet använde vi oss av det lokala handledsfrakturregister i Lund vi drivit sedan 2002 för att se hur det går för de15% av patienterna som har ett dåligt utfall efter ett år. Blir de bättre över tid? Vad är det för skador som gör att resultatet blir dåligt på sikt? Finns det andra faktorer än brosk- och ledbandsskador som är vanliga i detta urval? Vi valde ut yngre patienter i registret mellan 18–55 år, som

svarat på enkäten efter ett år, och som då hade ett dåligt utfall. En ny enkät skickades ut och patienterna bjöds in till undersökning och röntgen. 33 patienter kom och alla utom en hade fortfarande mer eller mindre subjektiva besvär. Endast en patient hade återfått full funktion. Vi fann en hög andel patienter med smärtsam instabilitet beroende på TFCC-skada. Vi fann en patient med en ledbandsskada mellan båt- och månben (SL) som gått till kollaps och ledsvikt med efterföljande steloperation av handleden. En annan hade också opererats med en steloperation mellan strålben och månben, på grund av att ledytan varit krossad och inte kunnat återställas. Fyra patienter hade opererats med osteotomi vilket innebär att den felställda läkta frakturen delats och korrigeras. Slutligen fann vi att ett stort antal patienter hade andra sjukdomar, dels generella såsom hjärt-, lung- och njur-sjukdomar men framför allt andra kroniska tillstånd i rörelseapparaten.

Sammanfattningsvis fann vi att prognosen för yngre patienter med kvarstående besvär ett år efter skadan är dålig och att de fortsätter att ha besvär under lång tid. Orsakerna är skiftande, men ledbandsskador och andra sjukdomar framförallt i rörelseapparaten var vanligast. Vi kunde utesluta att mer begränsade, partiella skador i TFCC eller SL-ligamenten har betydelse på sikt men totala TFCC och Geissler grad 4 kan inverka på sikt. Kanske kan vi förbättra behandlingen av dessa, men nya studier är viktiga för att se om eventuell behandling ändrar prognosen på sikt. Våra nuvarande vetenskapliga metoder är otillräckliga i de ovanliga skademönster vi undersökt och nya innovativa vetenskapliga metoder är nödvändiga.

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References

1. Lindau T, Hagberg L, Adlercreutz C, Jonsson K, Aspenberg P. Distal radioulnar instability is an independent worsening factor in distal radial fractures. Clin Orthop Relat Res. 2000:229-35. Epub 2000/07/25.

2. Abramo A, Kopylov P, Tagil M. Evaluation of a treatment protocol in distal radius fractures: a prospective study in 581 patients using DASH as outcome. Acta Orthop. 2008;79:376-85. Epub 2008/07/16.

3. Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg Br. 1997;22:638-43.

4. Gologan R, Ginter VM, Haeffner A, Obertacke U, Schreiner U. 1-Year outcome of concomitant intracarpal lesions in patients with dislocated distal radial fractures: a systematic assessment of 78 distal radial fractures. Arch Orthop Trauma Surg. 2016;136:425-32. Epub 2015/12/02.

5. Fischer M, Denzler C, Sennwald G. [Carpal ligament lesions associated with fresh distal radius fractures: arthroscopic study of 54 cases]. Swiss Surg. 1996;2:269-72; discussion 72-3. Epub 1996/01/01.

6. Lindau T, Adlercreutz C, Aspenberg P. Peripheral tears of the triangular fibrocartilage complex cause distal radioulnar joint instability after distal radial fractures. J Hand Surg Am. 2000;25:464-8. Epub 2000/05/16.

7. Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am. 1996;78:357-65. Epub 1996/03/01.

8. Ruch DS, Yang CC, Smith BP. Results of acute arthroscopically repaired triangular fibrocartilage complex injuries associated with intra-articular distal radius fractures. Arthroscopy. 2003;19:511-6. Epub 2003/05/02.

9. Richards RS, Bennett JD, Roth JH, Milne K, Jr. Arthroscopic diagnosis of intra-articular soft tissue injuries associated with distal radial fractures. J Hand Surg Am. 1997;22:772-6. Epub 1997/10/23 22:19.

10. Mehta JA, Bain GI, Heptinstall RJ. Anatomical reduction of intra-articular fractures of the distal radius. An arthroscopically-assisted approach. J Bone Joint Surg Br. 2000;82:79-86. Epub 2000/03/04.

11. Lameijer CM, Ten Duis HJ, Dusseldorp IV, Dijkstra PU, van der Sluis CK. Prevalence of posttraumatic arthritis and the association with outcome measures following distal radius fractures in non-osteoporotic patients: a systematic review. Arch Orthop Trauma Surg. 2017;137:1499-513. Epub 2017/08/05.

12. Diaz-Garcia RJ, Chung KC. The evolution of distal radius fracture management: a historical treatise. Hand Clin. 2012;28:105-11. Epub 2012/05/05.

13. Lovejoy CO. Evolution of human walking. Sci Am. 1988;259:118-25. Epub 1988/11/01.

14. Latimer B, Lovejoy CO. The calcaneus of Australopithecus afarensis and its implications for the evolution of bipedality. Am J Phys Anthropol. 1989;78:369-86. Epub 1989/03/01.

15. Staff. " What Does It Mean To Be Human?- Walking Upright". Smithsonian Institution.; August 14, 2016.

16. Colles A. On the Fracture of the Carpal Extremity of the Radius. Edinb Med Surg J. 1814;10:182-6. Epub 1814/04/01.

17. CL S. Treatment of Fractures.: Philadelphia: WB Saunders; 1939. p. 716-48.

18. Whipple TL, Marotta JJ, Powell JH, 3rd. Techniques of wrist arthroscopy. Arthroscopy. 1986;2:244-52.

19. Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review. Injury. 2006;37:691-7. Epub 2006/07/04.

20. Brogren E, Petranek M, Atroshi I. Incidence and characteristics of distal radius fractures in a southern Swedish region. BMC Musculoskelet Disord. 2007;8:48. Epub 2007/06/02.

21. Bentohami A, Bosma J, Akkersdijk GJ, van Dijkman B, Goslings JC, Schep NW. Incidence and characteristics of distal radial fractures in an urban population in The Netherlands. Eur J Trauma Emerg Surg. 2014;40:357-61. Epub 2014/06/01.

22. Jerrhag D, Englund M, Karlsson MK, Rosengren BE. Epidemiology and time trends of distal forearm fractures in adults - a study of 11.2 million person-years in Sweden. BMC Musculoskelet Disord. 2017;18:240. Epub 2017/06/04.

23. Khosla S, Melton LJ, 3rd, Dekutoski MB, Achenbach SJ, Oberg AL, Riggs BL. Incidence of childhood distal forearm fractures over 30 years: a population-based study. JAMA. 2003;290:1479-85. Epub 2003/09/18.

24. Ryan LM, Teach SJ, Searcy K, Singer SA, Wood R, Wright JL, et al. Epidemiology of pediatric forearm fractures in Washington, DC. J Trauma. 2010;69:S200-5. Epub 2010/10/22.

25. Wood AM, Robertson GA, Rennie L, Caesar BC, Court-Brown CM. The epidemiology of sports-related fractures in adolescents. Injury. 2010;41:834-8. Epub 2010/06/16.

26. Ferree S, van der Vliet QMJ, Nawijn F, Bhashyam AR, Houwert RM, Leenen LPH, et al. Epidemiology of distal radius fractures in polytrauma patients and the influence of high traumatic energy transfer. Injury. 2018;49:630-5. Epub 2018/02/13.

27. Castaing J. [Recent Fractures of the Lower Extremity of the Radius in Adults]. Rev Chir Orthop Reparatrice Appar Mot. 1964;50:581-696. Epub 1964/09/01.

28. Araf M, Mattar Junior R. Arthroscopic study of injuries in articular fractures of distal radius extremity. Acta Ortop Bras. 2014;22:144-50. Epub 2014/07/26.

29. Müller ME KP, Nazarian S, Schatzker J. The comprehensive classification of fractures of long bones. Springer Science & Business Media; 1990.

30. Lindau TR, Aspenberg P, Arner M, Redlundh-Johnell I, Hagberg L. Fractures of the distal forearm in young adults. An epidemiologic description of 341 patients. Acta Orthop Scand. 1999;70:124-8. Epub 1999/06/15.

31. Hove LM LT, Hølmer P. Distal radius fractures: current concepts: Springer; 2014.

32. Flinkkila T, Sirnio K, Hippi M, Hartonen S, Ruuhela R, Ohtonen P, et al. Epidemiology and seasonal variation of distal radius fractures in Oulu, Finland. Osteoporos Int. 2011;22:2307-12. Epub 2010/10/26.

33. Solvang HW, Nordheggen RA, Clementsen S, Hammer OL, Randsborg PH. Epidemiology of distal radius fracture in Akershus, Norway, in 2010-2011. J Orthop Surg Res. 2018;13:199. Epub 2018/08/15.

34. Sigurdardottir K, Halldorsson S, Robertsson J. Epidemiology and treatment of distal radius fractures in Reykjavik, Iceland, in 2004. Comparison with an Icelandic study from 1985. Acta Orthop. 2011;82:494-8. Epub 2011/09/03.

35. Wilcke MK, Hammarberg H, Adolphson PY. Epidemiology and changed surgical treatment methods for fractures of the distal radius: a registry analysis of 42,583 patients in Stockholm County, Sweden, 2004-2010. Acta Orthop. 2013;84:292-6. Epub 2013/04/19.

36. Lofthus CM, Frihagen F, Meyer HE, Nordsletten L, Melhuus K, Falch JA. Epidemiology of distal forearm fractures in Oslo, Norway. Osteoporos Int. 2008;19:781-6. Epub 2007/11/07.

37. Thompson PW, Taylor J, Dawson A. The annual incidence and seasonal variation of fractures of the distal radius in men and women over 25 years in Dorset, UK. Injury. 2004;35:462-6. Epub 2004/04/15.

38. Stirling ERB, Johnson NA, Dias JJ. Epidemiology of distal radius fractures in a geographically defined adult population. J Hand Surg Eur Vol. 2018;43:974-82. Epub 2018/07/19.

39. Wilson JM, Staley CA, Boden AL, Boissonneault AR, Schwartz AM, Schenker ML. The Effect of Season and Weather on Orthopaedic Trauma: Consult Volume Is Significantly Correlated with Daily Weather. Adv Orthop. 2018;2018:6057357. Epub 2018/09/25.

40. Warrender WJ, Henstenburg J, Maltenfort M, Lutsky K, Beredjiklian PK. Seasonal Variation in the Prevalence of Common Orthopaedic Upper Extremity Conditions. J Wrist Surg. 2018;7:232-6. Epub 2018/06/21.

41. Jo YH, Lee BG, Kim HS, Kim JH, Lee CH, Kim SJ, et al. Incidence and Seasonal Variation of Distal Radius Fractures in Korea: a Population-based Study. J Korean Med Sci. 2018;33:e48. Epub 2018/01/24.

42. Kawamura K, Chung KC. Management of wrist injuries. Plast Reconstr Surg. 2007;120:73e-89e. Epub 2007/09/28.

43. Taleisnik J. The ligaments of the wrist. J Hand Surg Am. 1976;1:110-8. Epub 1976/09/01.

44. Berger RA. The ligaments of the wrist. A current overview of anatomy with considerations of their potential functions. Hand Clin. 1997;13:63-82. Epub 1997/02/01.

45. Mitsuyasu H, Patterson RM, Shah MA, Buford WL, Iwamoto Y, Viegas SF. The role of the dorsal intercarpal ligament in dynamic and static scapholunate instability. J Hand Surg Am. 2004;29:279-88. Epub 2004/03/27.

46. Short WH, Werner FW, Green JK, Sutton LG, Brutus JP. Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate: part III. J Hand Surg Am. 2007;32:297-309. Epub 2007/03/06.

47. Kitay A, Wolfe SW. Scapholunate instability: current concepts in diagnosis and management. J Hand Surg Am. 2012;37:2175-96. Epub 2012/10/02.

48. Kijima Y, Viegas SF. Wrist anatomy and biomechanics. J Hand Surg Am. 2009;34:1555-63. Epub 2009/10/06.

49. Hagert CG. The distal radioulnar joint in relation to the whole forearm. Clin Orthop Relat Res. 1992:56-64. Epub 1992/02/01.

50. Haugstvedt JR, Langer MF, Berger RA. Distal radioulnar joint: functional anatomy, including pathomechanics. J Hand Surg Eur Vol. 2017;42:338-45. Epub 2017/04/13.

51. Moritomo H. The distal oblique bundle of the distal interosseous membrane of the forearm. J Wrist Surg. 2013;2:93-4. Epub 2014/01/18.

52. Trehan SK, Orbay JL, Wolfe SW. Coronal shift of distal radius fractures: influence of the distal interosseous membrane on distal radioulnar joint instability. J Hand Surg Am. 2015;40:159-62. Epub 2014/10/06.

53. Palmer AK, Werner FW. The triangular fibrocartilage complex of the wrist--anatomy and function. J Hand Surg Am. 1981;6:153-62. Epub 1981/03/01.

54. Bednar MS, Arnoczky SP, Weiland AJ. The microvasculature of the triangular fibrocartilage complex: its clinical significance. J Hand Surg Am. 1991;16:1101-5. Epub 1991/11/01.

55. Berger RA, Landsmeer JM. The palmar radiocarpal ligaments: a study of adult and fetal human wrist joints. J Hand Surg Am. 1990;15:847-54. Epub 1990/11/01.

56. Haugstvedt JR, Berger RA, Nakamura T, Neale P, Berglund L, An KN. Relative contributions of the ulnar attachments of the triangular fibrocartilage complex to the dynamic stability of the distal radioulnar joint. J Hand Surg Am. 2006;31:445-51. Epub 2006/03/07.

57. Kleinman WB. Stability of the distal radioulna joint: biomechanics, pathophysiology, physical diagnosis, and restoration of function what we have learned in 25 years. J Hand Surg Am. 2007;32:1086-106. Epub 2007/09/11.

58. Kauer JM. The articular disc of the hand. Acta Anat (Basel). 1975;93:590-605. Epub 1975/01/01.

59. Nakamura T, Yabe Y, Horiuchi Y. Functional anatomy of the triangular fibrocartilage complex. J Hand Surg Br. 1996;21:581-6. Epub 1996/10/01.

60. Atzei A, Luchetti R. Foveal TFCC tear classification and treatment. Hand Clin. 2011;27:263-72. Epub 2011/08/30.

61. MacDermid JC, Roth JH, Richards RS. Pain and disability reported in the year following a distal radius fracture: a cohort study. BMC Musculoskelet Disord. 2003;4:24. Epub 2003/11/01.

62. Landgren M, Abramo A, Geijer M, Kopylov P, Tagil M. Similar 1-year subjective outcome after a distal radius fracture during the 10-year-period 2003-2012. Acta Orthop. 2017;88:451-6. Epub 2017/03/16.

63. Lalone E, MacDermid J, Grewal R, King G. Patient Reported Pain and Disability Following a Distal Radius Fracture: A Prospective Study. Open Orthop J. 2017;11:589-99. Epub 2017/10/06.

64. Brogren E, Hofer M, Petranek M, Wagner P, Dahlin LB, Atroshi I. Relationship between distal radius fracture malunion and arm-related disability: a prospective population-based cohort study with 1-year follow-up. BMC Musculoskelet Disord. 2011;12:9. Epub 2011/01/15.

65. Ali M, Brogren E, Wagner P, Atroshi I. Association Between Distal Radial Fracture Malunion and Patient-Reported Activity Limitations: A Long-Term Follow-up. J Bone Joint Surg Am. 2018;100:633-9. Epub 2018/04/18.

66. Geissler WB, Fernandez DL, Lamey DM. Distal radioulnar joint injuries associated with fractures of the distal radius. Clin Orthop Relat Res. 1996:135-46. Epub 1996/06/01.

67. Deniz G, Kose O, Yanik S, Colakoglu T, Tugay A. Effect of untreated triangular fibrocartilage complex (TFCC) tears on the clinical outcome of conservatively treated distal radius fractures. Eur J Orthop Surg Traumatol. 2014;24:1155-9. Epub 2013/12/10.

68. Thomsen NOB, Besjakov J, Bjorkman A. Accuracy of Pre- and Postcontrast, 3 T Indirect MR Arthrography Compared with Wrist Arthroscopy in the Diagnosis of Wrist Ligament Injuries. J Wrist Surg. 2018;7:382-8. Epub 2018/10/24.

69. Swart E, Tang P. The Effect of Ligament Injuries on Outcomes of Operatively Treated Distal Radius Fractures. Am J Orthop (Belle Mead NJ). 2017;46:E41-E6. Epub 2017/02/25.

70. Fujitani R, Omokawa S, Akahane M, Iida A, Ono H, Tanaka Y. Predictors of distal radioulnar joint instability in distal radius fractures. J Hand Surg Am. 2011;36:1919-25. Epub 2011/11/01.

71. Moloney M, Farnebo S, Adolfsson L. 20-Year outcome of TFCC repairs. J Plast Surg Hand Surg. 2018;52:193-7. Epub 2017/12/21.

72. Grewal R, MacDermid JC, Pope J, Chesworth BM. Baseline predictors of pain and disability one year following extra-articular distal radius fractures. Hand (N Y). 2007;2:104-11. Epub 2008/09/10.

73. MacFarlane RJ, Miller D, Wilson L, Meyer C, Kerin C, Ford DJ, et al. Functional Outcome and Complications at 2.5 Years Following Volar Locking Plate Fixation of Distal Radius Fractures. J Hand Microsurg. 2015;7:18-24. Epub 2015/06/17.

74. O'Meeghan CJ, Stuart W, Mamo V, Stanley JK, Trail IA. The natural history of an untreated isolated scapholunate interosseus ligament injury. J Hand Surg Br. 2003;28:307-10. Epub 2003/07/10.

75. Pilny J, Kubes J, Hoza P, Mechl M, Visna P. [Scapholunate instability of the wrist following distal radius fracture]. Acta Chir Orthop Traumatol Cech. 2007;74:55-8. Epub 2007/03/03.

76. Tang JB, Shi D, Gu YQ, Zhang QG. Can cast immobilization successfully treat scapholunate dissociation associated with distal radius fractures? J Hand Surg Am. 1996;21:583-90. Epub 1996/07/01.

77. Forward DP, Lindau TR, Melsom DS. Intercarpal ligament injuries associated with fractures of the distal part of the radius. J Bone Joint Surg Am. 2007;89:2334-40. Epub 2007/11/03.

78. Strange-Vognsen HH. Intraarticular fractures of the distal end of the radius in young adults. A 16 (2-26) year follow-up of 42 patients. Acta Orthop Scand. 1991;62:527-30.

79. Kopylov P, Johnell O, Redlund-Johnell I, Bengner U. Fractures of the distal end of the radius in young adults: a 30-year follow-up. J Hand Surg Br. 1993;18:45-9.

80. Tamburrini O, Bianchi D, Capparelli G, Barresi D, Arcuri PP, Barbalace G, et al. ["Occult" posttraumatic lesions of the knee: can magnetic resonance substitute for diagnostic arthroscopy?]. Radiol Med. 1997;94:433-9.

81. Wilson AJ, Murphy WA, Hardy DC, Totty WG. Transient osteoporosis: transient bone marrow edema? Radiology. 1988;167:757-60. Epub 1988/06/01.

82. Mink JH, Deutsch AL. Occult cartilage and bone injuries of the knee: detection, classification, and assessment with MR imaging. Radiology. 1989;170:823-9.

83. Burr DB, Radin EL. Microfractures and microcracks in subchondral bone: are they relevant to osteoarthrosis? Rheum Dis Clin North Am. 2003;29:675-85.

84. Lindau T, Adlercreutz C, Aspenberg P. Cartilage injuries in distal radial fractures. Acta Orthop Scand. 2003;74:327-31. Epub 2003/08/06.

85. Geissler WB. Arthroscopically assisted reduction of intra-articular fractures of the distal radius. Hand Clin. 1995;11:19-29. Epub 1995/02/01.

86. Atroshi I, Gummesson C, Andersson B, Dahlgren E, Johansson A. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: reliability and validity of the Swedish version evaluated in 176 patients. Acta Orthop Scand. 2000;71:613-8. Epub 2001/01/06.

87. Landgren M, Teurneau V, Abramo A, Geijer M, Tagil M. Intermediate-Term Outcome After Distal Radius Fracture in Patients With Poor Outcome at 1 Year: A Register Study With a 2- to 12-Year Follow-Up. J Hand Surg Am. 2019;44:39-45. Epub 2018/12/07.

88. Watson HK, Ashmead Dt, Makhlouf MV. Examination of the scaphoid. J Hand Surg Am. 1988;13:657-60. Epub 1988/09/01.

89. Gartland JJ, Jr., Werley CW. Evaluation of healed Colles' fractures. J Bone Joint Surg Am. 1951;33-A:895-907. Epub 1951/10/01.

90. Beaton DE, Wright JG, Katz JN, Upper Extremity Collaborative G. Development of the QuickDASH: comparison of three item-reduction approaches. J Bone Joint Surg Am. 2005;87:1038-46. Epub 2005/05/04.

91. Sarmiento A, Pratt GW, Berry NC, Sinclair WF. Colles' fractures. Functional bracing in supination. J Bone Joint Surg Am. 1975;57:311-7. Epub 1975/04/01.

92. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The

Upper Extremity Collaborative Group (UECG). Am J Ind Med. 1996;29:602-8. Epub 1996/06/01.

93. Gummesson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (QuickDASH): validity and reliability based on responses within the full-length DASH. BMC Musculoskelet Disord. 2006;7:44.

94. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am. 1986;68:647-59.

95. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16:494-502. Epub 1957/12/01.

96. Anderson ML, Larson AN, Moran SL, Cooney WP, Amrami KK, Berger RA. Clinical comparison of arthroscopic versus open repair of triangular fibrocartilage complex tears. J Hand Surg Am. 2008;33:675-82. Epub 2008/07/02.

97. Iwasaki N, Nishida K, Motomiya M, Funakoshi T, Minami A. Arthroscopic-assisted repair of avulsed triangular fibrocartilage complex to the fovea of the ulnar head: a 2- to 4-year follow-up study. Arthroscopy. 2011;27:1371-8. Epub 2011/08/27.

98. Kim B, Yoon HK, Nho JH, Park KH, Park SY, Yoon JH, et al. Arthroscopically assisted reconstruction of triangular fibrocartilage complex foveal avulsion in the ulnar variance-positive patient. Arthroscopy. 2013;29:1762-8. Epub 2013/11/12.

99. Shinohara T, Tatebe M, Okui N, Yamamoto M, Kurimoto S, Hirata H. Arthroscopically assisted repair of triangular fibrocartilage complex foveal tears. J Hand Surg Am. 2013;38:271-7. Epub 2013/01/29.

100. Luchetti R, Atzei A, Cozzolino R, Fairplay T, Badur N. Comparison between open and arthroscopic-assisted foveal triangular fibrocartilage complex repair for post-traumatic distal radio-ulnar joint instability. J Hand Surg Eur Vol. 2014;39:845-55. Epub 2013/08/22.

101. Atzei A, Luchetti R, Braidotti F. Arthroscopic foveal repair of the triangular fibrocartilage complex. J Wrist Surg. 2015;4:22-30. Epub 2015/02/25.

102. Khanchandani P, Badia A. Functional outcome of arthroscopic assisted fixation of distal radius fractures. Indian J Orthop. 2013;47:288-94. Epub 2013/06/27.

103. Kordasiewicz B, Podgorski A, Klich M, Michalik D, Chaberek S, Pomianowski S. Arthroscopic assessment of intraarticular distal radius fractures--results of minimally invasive fixation. Ortop Traumatol Rehabil. 2011;13:369-86. Epub 2011/08/23.

104. Kasapinova K, Kamiloski V. Influence of associated lesions of the intrinsic ligaments on distal radius fractures outcome. Arch Orthop Trauma Surg. 2015;135:831-8. Epub 2015/03/26.

105. Mayfield JK, Johnson RP, Kilcoyne RK. Carpal dislocations: pathomechanics and progressive perilunar instability. J Hand Surg Am. 1980;5:226-41. Epub 1980/05/01.

106. Tsoukas D, Fotopoulos V, Basdekis G, Makridis KG. No difference in osteoarthritis after surgical and non-surgical treatment of ACL-injured knees after 10 years. Knee Surg Sports Traumatol Arthrosc. 2016;24:2953-9. Epub 2015/04/10.

107. Racine J, Aaron RK. Post-traumatic osteoarthritis after ACL injury. R I Med J (2013). 2014;97:25-8. Epub 2014/11/05.

108. Scheer JH, Adolfsson LE. Radioulnar laxity and clinical outcome do not correlate after a distal radius fracture. J Hand Surg Eur Vol. 2011;36:503-8. Epub 2011/04/07.

109. Kim JP, Park MJ. Assessment of distal radioulnar joint instability after distal radius fracture: comparison of computed tomography and clinical examination results. J Hand Surg Am. 2008;33:1486-92. Epub 2008/11/06.

110. Scheer JH, Hammerby S, Adolfsson LE. Radioulnar ratio in detection of distal radioulnar joint instability associated with acute distal radius fractures. J Hand Surg Eur Vol. 2010;35:730-4. Epub 2010/07/14.

111. Abe Y, Katsube K, Tsue K, Doi K, Hattori Y. Arthoscopic diagnosis of partial scapholunate ligament tears as a cause of radial sided wrist pain in patients with inconclusive x-ray and MRI findings. J Hand Surg Br. 2006;31:419-25. Epub 2006/05/24.

112. Newberg AH, Wetzner SM. Bone bruises: their patterns and significance. Semin Ultrasound CT MR. 1994;15:396-409.

113. Conaghan PG, Felson D, Gold G, Lohmander S, Totterman S, Altman R. MRI and non-cartilaginous structures in knee osteoarthritis. Osteoarthritis Cartilage. 2006;14 Suppl A:A87-94. Epub 2006/05/23.

114. Yamamoto T, Bullough PG. Spontaneous osteonecrosis of the knee: the result of subchondral insufficiency fracture. J Bone Joint Surg Am. 2000;82:858-66.

115. Akamatsu Y, Mitsugi N, Hayashi T, Kobayashi H, Saito T. Low bone mineral density is associated with the onset of spontaneous osteonecrosis of the knee. Acta Orthop. 2012;83:249-55. Epub 2012/04/28.

116. Bjorkengren AG, AlRowaih A, Lindstrand A, Wingstrand H, Thorngren KG, Pettersson H. Spontaneous osteonecrosis of the knee: value of MR imaging in determining prognosis. AJR Am J Roentgenol. 1990;154:331-6. Epub 1990/02/01.

117. Yates PJ, Calder JD, Stranks GJ, Conn KS, Peppercorn D, Thomas NP. Early MRI diagnosis and non-surgical management of spontaneous osteonecrosis of the knee. Knee. 2007;14:112-6. Epub 2006/12/13.

118. Sanders TG, Medynski MA, Feller JF, Lawhorn KW. Bone contusion patterns of the knee at MR imaging: footprint of the mechanism of injury. Radiographics. 2000;20 Spec No:S135-51.

119. Vellet AD, Marks PH, Fowler PJ, Munro TG. Occult posttraumatic osteochondral lesions of the knee: prevalence, classification, and short-term sequelae evaluated with MR imaging. Radiology. 1991;178:271-6. Epub 1991/01/01.

120. Yoon KH, Yoo JH, Kim KI. Bone contusion and associated meniscal and medial collateral ligament injury in patients with anterior cruciate ligament rupture. J Bone Joint Surg Am. 2011;93:1510-8. Epub 2011/12/29.

121. Costa-Paz M, Muscolo DL, Ayerza M, Makino A, Aponte-Tinao L. Magnetic resonance imaging follow-up study of bone bruises associated with anterior cruciate ligament ruptures. Arthroscopy. 2001;17:445-9. Epub 2001/05/19.

122. SBU. Behandling av armfraktur hos äldre. En systematisk översikt och utvärdering av medicinska, hälsoekonomiska, sociala och etiska aspekter. 2017;SBU-rapport nr 262. ISBN 978-91-88437-04-4.

123. Pang EQ, Truntzer J, Baker L, Harris AHS, Gardner MJ, Kamal RN. Cost minimization analysis of the treatment of distal radial fractures in the elderly. Bone Joint J. 2018;100-B:205-11. Epub 2018/02/14.

124. MORSE rapportserie; Riktlinjer för sjukskrivning vid sjukdomar i rörelseorganen- ett kunskapsunderlag. 2009;2009:1 ; ISBN 978-91-976020-3-7.

Appendix I

Demerit point system of Gartland and Werley with Sarmiento et al. modification

Result	Points
Residual deformity	
Prominent ulnar styloid	1
Residual dorsal tilt	2
Radial deviation of hand	2-3
Point range	0-3
Subjective evaluation	
Excellent-no pain, disability or limitation of motion	0
Good- occasional pain, slight limitation of motion, no disability	2
Fair- occasional pain, some limitation of motion, feeling of weakness in wrist, no particular disability if careful, activities slightly restricted	4
Poor- pain, limitation of motion, disability, activities more or less markedly restricted	6
Point range	0-6
Objective evaluation*	
Loss of dorsiflexion	5
Loss of ulnar deviation	3
Loss of supination	2
Loss of palmar flexion	1
Loss of radial deviation	1
Loss of circumduction	1
Loss of pronation	2
Pain in distal radioulnar joint	1
Grip strength-60% or less of opposite side (Using dynamometer)	1
Point range	0-5
Complications	
Arthritic change	
Minimum	1
Minimum with pain	3
Moderate	2
Moderate with pain	4
Severe	3
Severe with pain	5
Nerve complications (Median)	1-3
Poor finger functions due to cast	1-2
Point range	0-5
End result point ranges	
Excellent	0-2
Good	3-8
Fair	9-20
Poor	21 and above

*The objective evaluation is based on the following ranges of motion as being the minimum for normal function: dorsiflexion 45°; palmar flexion 30°; radial deviation 15°; ulnar deviation 15°; pronation 50°; supination 50°

Appendix II

<div align="center">Hälsoenkät (arm/axel/hand)</div>

Denna enkät berör Dina symtom och Din förmåga att utföra vissa aktiviteter.

Svara på **varje fråga**, baserat på hur Du har mått **den senaste veckan**, genom att kryssa för ett svarsalternativ för varje fråga.

Om det är någon aktivitet Du inte har utfört den senaste veckan får Du kryssa för det svar som Du bedömer **stämmer bäst** om Du hade utfört aktiviteten.

Det har ingen betydelse vilken arm eller hand Du använder för att utföra aktiviteten. Svara baserat på Din förmåga oavsett hur Du utför uppgiften.

	Ingen svårighet	Viss svårighet	Måttlig svårighet	Stor svårighet	Omöjligt att göra
1. Öppna en ny burk eller hårt sittande lock	☐	☐	☐	☐	☐
2. Utföra tunga hushållssysslor (t ex tvätta golv, putsa fönster, hänga tvätt)	☐	☐	☐	☐	☐
3. Bära matkassar eller portfölj	☐	☐	☐	☐	☐
4. Tvätta Din rygg	☐	☐	☐	☐	☐
5. Använda en kniv för att skära upp maten	☐	☐	☐	☐	☐
6. Fritidsaktiviteter som tar upp viss kraft eller stöt genom arm, axel eller hand (t ex spela golf, använda hammare, spela tennis, skytte, bowling)	☐	☐	☐	☐	☐

7. Under **den senaste veckan**, i vilken utsträckning har Dina arm-, axel- eller handproblem stört Ditt vanliga umgänge med anhöriga, vänner, grannar eller andra?

☐ Inte alls ☐ Lite ☐ Måttligt ☐ Mycket ☐ Väldigt mycket

8. Under **den senaste veckan**, i vilken utsträckning har Dina arm-, axel- eller handproblem stört Ditt vanliga arbete eller andra dagliga aktiviteter?

☐ Inte alls ☐ Lite ☐ Måttligt ☐ Mycket ☐ Väldigt mycket

Ange svårighetsgraden på Dina symtom **den senaste veckan**:

	Ingen	Lätt	Måttlig	Svår	Mycket svår
9. Värk/smärta i arm, axel eller hand	☐	☐	☐	☐	☐
10. Stickningar (sockerdrickskänsla) i arm, axel eller hand	☐	☐	☐	☐	☐

11. Har Du haft svårt att sova, under **den senaste veckan**, på grund av värk/smärta i arm, axel eller hand?

☐ Inte alls ☐ Viss svårighet ☐ Måttlig svårighet ☐ Stor svårighet ☐ Mycket stor svårighet

<div align="right">*Quick*DASH Gummesson/Atroshi 2006</div>

Appendix III

Charlson Comorbidity Index*

Score	Condition
1	Myocardial infarction (history, not ECG changes only)
	Congestive heart failure
	Peripheral vascular disease (includes aortic aneurysm >6 cm)
	Cerebrovascular disease: CVI with mild or no residua or TIA
	Dementia
	Chronic pulmonary disease
	Connective tissue disease
	Peptic ulcer disease
	Mild liver disease (without portal hypertension, includes chronic hepatitis)
	Diabetes without end-organ damage (excludes diet-controlled alone)
2	Hemiplegia
	Moderate or severe renal disease
	Diabetes with end-organ damage (retinopathy, neuropathy, nephropathy, or brittle diabetes)
	Tumor without metastases (exclude if >5 years from diagnosis)
	Leukemia (acute or chronic)
	Lymphoma
3	Moderate or severe liver disease
6	Metastatic solid tumor
	AIDS (not just HIV-positive)

Abbreviations: AIDS= acquired immunodeficiency syndrome; CVI= cerebrovascular insult; ECG= electrocardiogram; HIV= human immunodeficiency virus; TIA= transient ischemic attack
*For each decade >40 years of age, a score of 1 is added to the above score

Paper I

The Natural Course of Traumatic Triangular Fibrocartilage Complex Tears in Distal Radial Fractures: A 13–15 Year Follow-up of Arthroscopically Diagnosed but Untreated Injuries

Ante Mrkonjic, MD, Mats Geijer, MD, PhD, Tommy Lindau, MD, PhD, Magnus Tägil, MD, PhD

Purpose To evaluate the long-term results of a prospective, longitudinal case series of untreated, traumatic triangular fibrocartilage complex (TFCC) tears found in displaced distal radial fractures.

Methods Between 1995 and 1997, 51 patients (24 men, 27 women; age, 20–57 y) with a displaced distal radius fracture had wrist arthroscopy to identify associated injuries. Forty-three patients had complete or partial tears of the TFCC, which were not treated. All patients were contacted in 2010, 13–15 years after the injury. One patient had had a TFCC reattachment due to painful distal radioulnar joint instability and was excluded. Thirty-eight patients returned for a radiographic and clinical follow-up that recorded strength, distal radioulnar joint laxity, range of motion, pain scale score, and subjective and objective outcome scores.

Results After 13–15 years, 17/38 patients were lax in the distal radioulnar joint. The mean grip strength was worse in the patients with a lax distal radioulnar joint (83%, SD 15 of the contralateral side vs 103%, SD 33). The median Gartland and Werley score was 5 (good; range, 0–15) in the lax group compared to 1 (excellent; range, 0–9) in the non-lax group, and the median Disabilities of the Arm, Shoulder, and Hand scores were 14 (range, 0–59) and 5 (range, 0–70) respectively.

Conclusions In this 13–15 year, prospective, longitudinal outcome study of the natural course of TFCC tears associated with distal radius fracture, only 1 patient had been operated on for painful instability since the injury. The subjective and objective results did not provide evidence that a TFCC injury would influence the long-term outcome. However, trends were found and, by speculation, the low number of patients in the series and the risk for a type II error could be the cause of absent statistical significance. Larger, preferably prospective, randomized studies are needed to find out whether a more aggressive treatment is beneficial. *(J Hand Surg 2012;37A:1555–1560. Copyright © 2012 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Diagnostic I.

Key words Distal radial fractures, long-term outcome, triangular fibrocartilage complex tears.

T HE MOST COMMON cause of prolonged pain and disability after distal radial fractures is ulnar-sided wrist pain.[1] Previously, the main explanation has been an ulnocarpal abutment, caused by the relative shortening of the fractured and later malunited radius. This leads to ulnar-sided pain due to the relative length discrepancy to the ulna. Over the last decades, it has become apparent that associated soft tissue injuries might be responsible for some of these ulnar-sided symptoms.[2,3] Apart from radiographically visible ulnar styloid avulsion fractures, injuries of the triangular fibrocartilage complex (TFCC) have been detected in up to 80% of patients with displaced distal radial fractures in arthroscopic studies.[4,5] In some of these patients, the peripheral TFCC tears caused clinical symptomatic instability of the distal radioulnar joint (DRUJ). There has been no clear relationship between an ulnar styloid fracture or a peripheral TFCC tear and resultant objective hyperlaxity and subjective symptomatic instability. It therefore remains unclear when TFCC injuries should be repaired or styloid fractures reattached.

In a prospective arthroscopic study in 51 young adults with distal radial fractures between 1995 and 1997, the morphologic presence of a TFCC tear at the time of the fracture was correlated to the presence of objectively recorded laxity (ulnar stress test) and the presence of subjective instability (Gartland Werley, Table 1) 1 year after the fracture/injury.[4] Seventy-eight percent of the patients (40 of 51) had complete or partial TFCC injury. The distal radius fracture was treated according to the standard treatment at that time, but the TFCC injury was left untreated to study the long-term, natural course of these previously unknown, associated injuries. One year after the arthroscopically diagnosed but untreated TFCC tears, complete peripheral TFCC tears were found to cause objective DRUJ laxity, which in turn was found to worsen the subjective outcome after the fracture, independent of other parameters.[3] In the present study, we report the prospective, longitudinal, long-term outcome of the patients in those 2 studies to determine whether there are findings that might influence future treatment or study protocols.

MATERIALS AND METHODS

Patients

Between 1995 and 1997, 51 patients (24 men and 27 women; age, 20–49 y; mean age, 41 y) had wrist arthroscopy by one of the authors (T.L.) within a week after a displaced distal radial fracture. The fractures were treated according to the standard protocol at the time, with the addition of arthroscopy to aid in fracture management and to identify associated injuries. Twenty-

TABLE 1. Gartland and Werley Score Related to DRUJ Laxity at 13–15 Years				
Gartland and Werley Score	Excellent	Good	Fair	Poor	Total
Normal ulnar stress test	11	8	2	0	21
Lax DRUJ	3	11	3	0	17
Total	14	19	5	0	38

one patients were treated with closed reduction and plaster, 11 with arthroscopy-assisted reduction and plaster, 5 with closed reduction and external fixation, 6 with arthroscopy-assisted reduction and external fixation, and 8 with open reduction and internal fixation.

In the original series, 43/51 patients had a complete or partial tear of the TFCC, all of which were left untreated. All 51 patients were located in 2010, 13–15 years after the injury, and 47 still-living patients were invited for clinical and radiographic follow-up. The study was approved by the local research ethics committee.

Objective outcome

The TFCC tears were classified at the initial arthroscopic examination according to Palmer.[6] A bleeding point or a loss of the collagen continuity was interpreted as a partial tear, or both. A peripheral tear in the ligament was defined as complete if it caused a loss of tension in the TFCC during the hook and trampoline test at the initial arthroscopic assessment.

Both at the 1-year follow-up[3] and at the present follow-up, the patients were evaluated regarding DRUJ stability, with both a physical examination and an interview. Stability test was carried out using the DRUJ stress test[3] (by T.L.) at the 1-year follow-up and (by A.M.) at the 13–15 year follow-up. Before the second follow-up, the examination technique was checked for consistency by the 2 examiners. The forearm was held in neutral rotation by the examiner, who stabilized the hand and the distal radius with a firm grip to make them one unit. The examiner then, using the other hand, forced the ulna as the second unit in dorsal/palmar direction relative to the stabilized unit of the hand and radius. The stability of the DRUJ was compared with that of the uninjured, opposite side for reference. It was recorded whether the DRUJ was deemed lax and whether the test caused pain. At the initial study, the stability test was done without any knowledge about the previous arthroscopic findings. The present late follow-up was also blinded; that is, neither the result of the

initial arthroscopic findings nor the stability test at 1 year were known. Grip strength was measured with a Jamar dynamometer (Preston, Bolingbrook, IL).

Subjective outcome

In the initial study, the Gartland and Werley[7,8] demerit point system was used to evaluate the subjective/functional outcome. For comparison, we used the same score again in the present follow-up study. The examiner completed the score after the patient was examined, and the outcome was classified as excellent, good, fair, or poor (Table 1). In the present follow-up study, the subjective outcome was also evaluated using the Quick Disabilities of the Arm, Shoulder, and Hand (Quick-DASH) questionnaire,[9] The validated Swedish version of the questionnaire was used.[10] Further, at the present follow-up, the patient's subjective experience of pain at rest, pain with activity, overall function, and appearance were recorded on a visual analog scale.

Radiography

Radiography was done, obtaining posteroanterior and lateral projections of the wrist.[11] Radiographic osteoarthritis (OA) was assessed and graded according to Knirk and Jupiter[12] in grades 0–3.

Statistics

The Student's t- test was used for continuous variables, such as grip strength, and the Mann-Whitney test, Wilcoxon rank sum, and Fisher exact tests were used for scale data (visual analog scale, Gartland and Werley, and QuickDASH scores).

RESULTS

In the present follow-up study, 38 of the 51 originally treated patients (75%) participated in both the clinical examination and radiographic investigation. Four patients had died, 4 patients could not participate, 4 patients only returned the QuickDASH and VAS questionnaires, and 1 patient was excluded because she had had a TFCC reattachment 1 year after the original distal radius fracture. Twenty-three of the 38 patients were women, and the mean age was 57 years (range, 38–73 y).

Initial arthroscopic TFCC tear related to outcome after 13–15 years

Eight of the 38 patients had had a complete peripheral tear at the initial presentation, 25 had had a partial peripheral or central tear, and 5 had had no TFCC tear at all (Table 2).

Complete peripheral tears. In the original group of 51 patients, 11 patients were diagnosed with an arthroscopi-

TABLE 2. Patients Participating in the 13–15 Year Follow-up, Subdivided into the Different Types of TFCC Tear at the Initial Arthroscopy

Type of Tear	Partial Tear	Complete Tear	Total
Central perforation	2	5	7
Peripheral tear			
Ulnar avulsion	4	3*	7
Distal avulsion	2	0*	2
Radial avulsion	6	3*	9
Combined tears	6	2*	8
Total	20	13	33†

*Peripheral tears that were found to correlate to laxity and an inferior outcome at the 1-year follow-up.
†Five of 38 patients had no TFCC tear.

TABLE 3. Laxity of the DRUJ at the 1-Year and 13–15 Year Follow-ups Related to the Initial Arthroscopic TFCC Diagnosis

Type of TFCC Tear	Lax at 1 Year	Stable at 1 Year	Lax at 13–15 Years	Stable at 13–15 Years
Complete peripheral	7/8	1/8*	6/8	2/8*
Partial peripheral or central	7/25	18/25	10/25	15/25
No tear	2/5	3/5	1/5	4/5

*One patient with a complete tear was evaluated as stable at both the 1-year and the 13–15 year follow-up. One patient with a complete tear was considered lax at 1 year but stable at the late follow-up.

cally complete peripheral TFCC tear, of which 8 patients were assessed at the present follow-up (Tables 3, 4). Of these 8 patients with initial complete peripheral TFCC tears, the median QuickDASH score after 13–15 years was 25 compared to a score of 7 in the patients with no, central, or partial peripheral TFCC injury (P = .14). The grip strength was 88% of the contralateral in patients with a complete peripheral TFCC tear compared to 95% (P = .53) in patients without (Table 4).

Partial tears. In the 9 patients with a partial peripheral tear and laxity after 1 year, 2 were found to be stable in the present study (Table 3).

Subjective and objective outcome related to clinical laxity at 13–15 years

Seventeen of the 38 patients had positive results of a DRUJ stress test (lax group). Using the Gartland and Werley outcome score, 11/21 had an excellent outcome

TABLE 4. Subjective and Objective Outcome at 13–15 Years Related to Initial Arthroscopic TFCC Diagnosis

	Complete Peripheral Tear (N = 8)	Partial Peripheral Or Central Tear (N = 30)	P Value
DASH			
Median (range)	25 (0–59)	7 (0–70)	.14
Mean (SD)	26 (23)	14 (18)	.12
Gartland and Werley	5 (0–15)	4 (0–13)	.73
VAS at rest	0 (0–4)	1 (0–5)	.63
VAS at activity	3 (0–6)	1 (0–8)	.46
Grip strength*	88% (13)	95% (31)	.53

*Grip strength as percentage of the contralateral.

TABLE 6. Subjective and Objective Outcome at 13–15 Years Related to the Radiographic Outcome of the Ulnar Styloid Fracture at 13–15 Years After Injury

	Ulnar Styloid Nonunion (N = 15)	Absence of Styloid Fracture Plus Union of Styloid Fracture (N = 23)	P Value
DASH			
Median (range)	25 (0–70)	5 (0–55)	.15
Mean (SD)	24 (23)	12 (15)	.06
Gartland and Werley	5 (0–15)	3 (0–10)	.24
VAS at rest	2 (0–8)	1 (0–4)	.11
VAS at activity	2 (0–8)	1 (0–5)	.21
Grip strength	87% (15)	99% (34)	.22

TABLE 5. Subjective and Objective Outcome at 13–15 Years Related to the Assessment of Stability in the DRUJ at 13–15 Years After Injury

	Lax DRUJ at 13–15 Years (Positive Ulnar Stress Test; N = 21)	Stable DRUJ at 13–15 Years (Negative Ulnar Stress Test; N = 17)	P Value
DASH			
Median (range)	14 (0–59)	5 (0–70)	.11
Mean (SD)	21 (20)	14 (18)	.24
Gartland and Werley	5 (0–15)	1 (0–9)	.07
VAS at rest	1 (0–4)	1 (0–5)	.89
VAS at activity	1 (1–6)	3 (0–8)	.04
Grip strength	83% (15)	103% (33)	.03

in the group with a normal ulnar stress test, compared to 3/17 in the lax group (Table 1). When using the modern, pure subjective and patient-administered *Quick*-DASH score, the median *Quick*DASH score for the lax group was 14 (range, 0–59), compared to 5 (range, 0–70) for those with a negative DRUJ stress test (P = .11; Table 5). The mean grip strength was 83% (SD 15) of the contralateral side in the lax group compared to 103% (SD 33) in the group with a negative DRUJ stress test result (P = .03). Of the 21 patients being lax at the 1-year follow-up, 8 were lax at the present follow-up. Of the 9 patients with initial partial TFCC injury found to be lax at the 1-year follow-up, 4 remained lax, and 5 had a negative DRUJ stress test at the late follow-up.

Radiographic assessment

Eight patients had developed a mild to medium grade OA in the DRUJ. We found no association between late laxity and OA, and 5/19 patients in the lax group and 3/21 in the group with a negative DRUJ stress test developed DRUJ OA (P = .18). There was no association between arthroscopic TFCC injury and OA.

Further, there was no association between ulnar styloid union/nonunion and clinical symptoms, although similar trends were found as in the arthroscopically diagnosed TFCC injuries and regarding the laxity found by the ulnar stress test (Table 6). In total, 16 patients had an ulnar styloid nonunion; 12 of these were distal to the base. Eleven of 21 patients in the group with a negative DRUJ stress test result had an ulnar styloid nonunion compared to 5 of 17 patients in the lax group at the latest follow-up.

DISCUSSION

Distal radius fractures in adults without osteoporosis are commonly intra-articular[13] and often associated with ligament injuries.[4] In some high-energy injuries—for example, in a radial styloid fracture–ligament injuries are known to be associated with the fracture as part of a greater arc perilunate dislocation, known as the *Mayfield mechanism*.[14] In these fractures, other injuries can be present, including carpal fractures, associated scapholunate or lunotriquetral ligament injuries, and TFCC tears. In younger patients without osteoporosis

and with distal radius fractures, the energy necessary to cause the fracture is higher than in patients with osteoporosis.

This 13–15 year, prospective, longitudinal outcome study of the natural course of TFCC tears associated with a distal radius fracture is based primarily on a radiographic and arthroscopic descriptive study,[4] which was followed by a follow-up at 1 year evaluating the consequences of ulnar-sided injuries in distal radial fractures regarding objective laxity and symptoms.[3] Thirteen to 15 years after the initial injuries, only 1 patient had been operated on for painful instability of the DRUJ secondary to a peripheral TFCC tear sustained at the time of the fracture. Of the remaining 38 of the original 51 patients, laxity of the DRUJ was found in 17. The only statistically significant, measurable, long-term difference was decreased grip strength in the lax group. Most other findings showed only trends indicating worse subjective outcome for patients with a complete peripheral TFCC injury, a positive DRUJ stress test, an ulnar styloid nonunion, or a combination of these after 13–15 years. We were unable to find that DRUJ laxity led to degenerative secondary osteoarthritis, which often is found a similar time after destabilizing injuries to the anterior cruciate ligament of the knee. Our early findings of DRUJ laxity during the first year after a distal radius fracture[3] have been reproduced recently[15] with similar proportions of posttraumatic laxity (23/48) and with the laxity not being related to ulnar styloid fracture/nonunion. The authors in that study did not find any association between laxity of the DRUJ and subjective outcome.

The stress test for the DRUJ is used to assess hypermobility or laxity of the joint and should be separated from instability, which is a description of subjective symptoms experienced by the patient, such as pain or weakness. This is well known to the orthopedic community where, for instance, clinical laxity is tested with the Lachman or anterior drawer test after an anterior cruciate ligament injury in knees, in contrast to the patient's sense of give-way symptoms reflecting the subjective instability. The DRUJ stress test has been shown to be reproducible between individual investigators at the same time point with inter-observer kappa values[15,16] ranging between 0.66 and 0.84. Our efforts of comparing the present ulnar stress test results (by A.M.) with the original ones[4] (by T.L.) showed a high inter-rater agreement in patients with a complete peripheral tear (7 of 8; 85%) but not in patients with partial/no tears (15 of 30; 50%). A comparison between 2 time points as widely separated as in our study is probably impossible to do. Theoretically, a partial tear could heal and tighten with time, but it could, alternatively, continue to deteriorate into a complete tear with a combination of stretching forces and degenerative changes in the radioulnar ligament. Conversely, a complete peripheral TFCC tear is not likely to heal, which could explain why the complete tears remained lax 13–15 years after the injury. Testing the inter-observer or intra-observer reliability between 2 investigational time points, therefore, appears less meaningful. In the present series, the clinical DRUJ stress test had a moderate sensitivity (0.56) but high specificity (0.96) for the arthroscopic diagnosis of a complete TFCC tear at the initial 1-year follow-up[3] compared to 0.75 and 0.63, respectively, at the current follow-up. Time will tell whether we will have reliable methods to more objectively detect laxity, such as measuring the radioulnar ratio using computed tomography or magnetic resonance imaging. This method has been shown to be more sensitive for detecting laxity,[16] but it did not show any correlation to the DRUJ stress test after distal radial fractures.[15]

To use the result of the initial arthroscopic findings or the DRUJ stress test 1 year after a distal radial fracture to predict a symptomatic instability 15 years later was found to be difficult. Only 1 patient was operated on due to painful instability, and the other patients with laxity might have adapted to their posttraumatic disability, still being lax but not with sufficient problems or symptoms to stand out in our present assessment. Using the Gartland and Werley score, the group of lax patients was found to have worse outcome in the 1-year follow-up, a finding that could not be shown in the present study. The Gartland and Werley score is a hybrid outcome assessment with a mixture of subjective and objective data as well as a radiographic part, all summarized into one score. In the present study, we also used the *Quick*DASH, the standard subjective outcome instrument today, but we were unable to show statistically significant differences regarding morphologic diagnosis, objective laxity, or subjective outcome, although trends were noted. Also others, using the modern, examiner-independent, subjective *Quick*DASH score, have not been able to show any association of laxity to worse outcome.[15]

In the present series, we could not find sufficient evidence that a TFCC injury at the time of a distal radius fracture would influence the subjective outcome long term. There were, however, trends indicating that the group of patients with a partial or nondiagnosed TFCC tear was superior to the group with complete tears in the objective and subjective outcomes. The absence of statistical significance might be due to a lack

of statistical power to show such a difference. The number of patients was small, and there was a risk for a type 2 error. However, based on the present findings, we find no support for aggressive surgical management when TFCC tears are diagnosed in association with distal radius fractures, but larger and preferably randomized studies are needed.

REFERENCES

1. Brogren E, Hofer M, Petranek M, Wagner P, Dahlin LB, Atroshi I. Relationship between distal radius fracture malunion and arm-related disability: a prospective population-based cohort study with 1-year follow-up. BMC Musculoskelet Disord 2011;13:9.
2. Lindau T, Adlercreutz C, Aspenberg P. Peripheral tears of the triangular fibrocartilage complex cause distal radioulnar joint instability after distal radial fractures. J Hand Surg 2000;25A:464–468.
3. Lindau T, Hagberg L, Adlercreutz C, Jonsson K, Aspenberg P. Distal radioulnar instability is an independent worsening factor in distal radial fractures. Clin Orthop Relat Res 2000;376:229–235.
4. Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg 1997;22B:638–643.
5. Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg 1996;78A:357–365.
6. Palmer AK, Werner FW. The triangular fibrocartilage complex of the wrist—anatomy and function. J Hand Surg 1981;6:153–162.
7. Gartland JJ Jr, Werley CW. Evaluation of healed Colles' fractures. J Bone Joint Surg 1951;33A:895–907.
8. Sarmiento A, Pratt GW, Berry NC, Sinclair WF. Colles' fractures. Functional bracing in supination. J Bone Joint Surg 1975;57A:311–317.
9. Beaton DE, Wright JG, Katz JN; Upper Extremity Collaborative Group. Development of the QuickDASH: comparison of three item-reduction approaches. J Bone Joint Surg 2005;87A:1038–1046.
10. Gummesson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (QuickDASH): validity and reliability based on responses within the full-length DASH. BMC Musculoskelet Disord 2006;18;:44.
11. Dobbins JT III, Godfrey DJ. Digital x-ray tomosynthesis: current state of the art and clinical potential. Phys Med Biol 2003;7:R65–106. Review.
12. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg 1986;68A:647–659.
13. Lindau TR, Aspenberg P, Arner M, Redlundh-Johnell I, Hagberg L. Fractures of the distal forearm in young adults. An epidemiologic description of 341 patients. Acta Orthop Scand 1999;70:124–128.
14. Mayfield JK. Mechanism of carpal injuries. Clin Orthop Relat Res 1980;149:45–54.
15. Scheer JH, Adolfsson LE. Radioulnar laxity and clinical outcome do not correlate after a distal radius fracture. J Hand Surg 2011;36E:503–508. Epub 2011 Apr 5.
16. Kim JP, Park MJ. Assessment of distal radioulnar joint instability after distal radius fracture: comparison of computed tomography and clinical examination results. J Hand Surg 2008;33A:1486–1492.

Paper II

Arthroscopically Diagnosed Scapholunate Ligament Injuries Associated With Distal Radial Fractures: A 13- to 15-Year Follow-Up

Ante Mrkonjic, MD, Tommy Lindau, MD, PhD, Mats Geijer, MD, PhD, Magnus Tägil, MD, PhD

Purpose To evaluate the natural history of untreated complete or partial scapholunate (SL) ligament tears associated with displaced distal radius fractures.

Methods Between 1995 and 1997, 51 consecutive patients aged < 60 years with displaced distal radius fractures were examined arthroscopically to assess for concomitant soft tissue injuries. Thirty-two of 51 patients had an SL ligament tear, 10 had a complete tear (Lindau grade 3), and 22 had a partial tear (Lindau grades 1 and 2). Thirty-two patients had AO type-C fractures, 3 had type-B fractures, and 16 had type-A fractures. In 2010, 47 of the 51 patients were still alive, and they were invited for an interview, clinical examination, and radiography.

Results Thirty-eight of the 51 original patients participated in the long-term follow-up. Mean grip strength was 83% relative to the contralateral hand in patients with a complete tear, as compared with 92% in patients with partial or no SL tears (nonsignificant). Median Disabilities of the Arm, Shoulder, and Hand questionnaire score was 2 (range, 0–55) for complete SL tears, compared with 9 (range, 0–70) for the others (nonsignificant). No differences were found regarding visual analog scale pain or wrist motion/forearm rotation. None of the patients developed a static SL dissociation or a SL advanced collapse wrist.

Conclusions No major differences were found in the subjective, objective, or radiographic outcome after a complete (grade 3) or partial (grade 1 or 2) SL untreated tear associated with displaced distal radius fracture. It should be noted that none of the patients had a grade 4 SL tear, which may have a different outcome. *(J Hand Surg Am. 2015;40(6):1077−1082. Copyright © 2015 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Prognostic II.

Key words Osteoarthritis, radius fracture, scapholunate ligament.

L IGAMENT INJURIES ARE COMMON in distal radius fractures (DRFs).[1] Apart from triangular fibrocartilage complex injuries, scapholunate (SL) ligament injuries are the most common.[2] The SL ligament

is an essential structure of the intercalated wrist segments,[3−5] and tears may lead to a change in the carpal kinematics and secondary degenerative changes.[6−9] There is no consensus regarding whether or not these injuries should be treated surgically at the time of fracture.[10]

A DRF with an SL ligament injury indicates a high-energy injury.[11,12] According to Mayfield,[13] an isolated SL ligament injury can be classified as a stage of progressive perilunar instability. By analogy, in some DRFs, the energy that strikes the wrist at impact and causes the fracture may also involve the soft tissues.

We report a prospective long-term follow-up of patients who sustained DRFs in the period 1995−1997, and who, apart from fracture treatment, also had

diagnostic arthroscopy.[14] SL tears were found in 32 of the 51 patients, 10 of whom had complete tears. The ligament injuries were not treated. The purpose of our study was to determine the long-term results and to define the natural course of untreated SL tears after a DRF.

MATERIALS AND METHODS

Patients

Fifty-one consecutive patients with DRFs treated at Lund University Hospital were included in the study. The exclusion criteria were the presence of any endocrinological disorder and/or alcohol abuse. To minimize the influence of osteoporosis, younger patients were selected. The women were 20–50 years old, and the men were 20–60 years old. Median age was 41 years (range, 20–57 y).

Thirty-five of the 51 patients had an intra-articular fracture (Table 1). All the patients were treated according to the standard fracture treatment protocol at that time. Twenty-one patients had closed reduction and plaster immobilization, 17 patients had arthroscopy-assisted reduction (6 of whom were supplemented with external fixation), 5 had external fixation, and 8 had open reduction and internal fixation. The operative procedures were performed within 15 days of injury (median, 3 d; range, 1–15 d) and were supplemented with a diagnostic wrist arthroscopy by one of the authors (T.L.) during the same procedure. Any associated ligament and cartilage injuries were recorded. The arthroscopic SL ligament tears were classified using a modified Geissler score.[2] SL ligament tears were classified as partial if there was a hematoma (grade 1) and/or a loss of the collagen continuity (grade 2), as tested with a probe. More complete tears (grades 3–4) were characterized by a larger step-off in carpal alignment as seen from the midcarpal joint. The study was approved by the local ethics committee of Lund University.

Objective outcome at one year

At a median time of 1 year after the fracture (range, 11–27 mo), radiographic and clinical follow-up was performed and published.[14] At 1 year, 3 patients had an increased SL distance (> 2 mm) in the plain radiographs, defined as static dissociation. Seven others had increased distance on stress radiographs only, but none had developed a scapholunate advanced collapse (SLAC) at one year.

Objective outcome at a minimum of 13 years

In 2010, at least 13 years (range, 13–15 y) after the trauma, all 51 patients were traced, and the 47 patients who were still alive were invited for interview and clinical and radiologic examinations. One examiner (A.M.) carried out the clinical examinations without knowing the initial arthroscopic findings or the results of the 1-year follow-up. Range of motion in radial and ulnar deviation, flexion, and extension was assessed once using a goniometer. The Watson scaphoid shift test[15] was done, assessing both ligament laxity and pain during the test, and results were classified as positive or negative. The test result was defined as being positive if there was a click on radial deviation of the wrist, associated with pain, compared with the healthy side. No criterion was used for generalized ligamentous laxity. Grip strength was measured 3 times using a Jamar dynamometer (Preston, Bolingbrook, IL), and the mean value was used in the statistical analysis.

Subjective outcome

The Gartland and Werley demerit point system[16] was originally designed to evaluate both subjective and functional outcome of wrist and hand function, and it was used both at the 1-year follow-up and the most recent follow-up for comparison. At the most recent follow-up, the Quick-Disabilities of the Arm, Shoulder, and Hand (DASH) questionnaire[17] was also used. A validated Swedish version of the questionnaire

was used.[18] In addition, in the present follow-up the patients were asked to plot their subjective pain at rest and with activity and general subjective function and appearance using a visual analog scale (VAS) from 0 to 10, with 0 representing *no pain* and 10 representing *severe pain*.

Radiography

A series of radiographs were taken, similar to those at the one-year follow-up, comprising a posterioanterior (PA), lateral, PA with a clenched fist, and PA exposures in radial and ulnar deviation with the wrist in slight extension. The radiographs were analyzed and compared with those on the uninjured contralateral side by an experienced musculoskeletal radiologist (M.G.). Both the SL angle and the SL distance were measured on PA radiographs in radial and ulnar deviation and in neutral position. Secondary degenerative changes were scored according to Kellgren and Lawrence.[19]

Statistical analysis

In the statistical analysis, the patients were divided into 2 groups. Grade 3 and grade 4 SL tears were pooled into a "complete" tear group and grade 1 and grade 2 tears were pooled into a "partial" tear group for comparison (Tables 2−4). The Student *t* test was used for quantitative continuous variables such as grip strength, and the Mann-Whitney U test, Wilcoxon rank sum test, and the Fisher exact test were used for scale data (VAS, Gartland and Werley score, and DASH score). All *P* values less than .05 were considered statistically significant.

RESULTS

Thirty-eight of the 47 patients who were still alive participated in the clinical and radiographic examinations. Of the patients not participating, 4 patients decided not to participate for personal reasons. Four patients responded to the questionnaires only, and 1 patient, although participating, was excluded because of ongoing treatment of an ipsilateral scaphoid fracture. Five of the patients not participating in the follow-up were men with a mean age of 51 years. Three of them had no SL tear at all, and 2 had partial grade 2 tears. Four of the nonparticipating patients were women with a mean age of 54 years. None of these women had an SL ligament injury.

Nine of the 38 patients who attended the long-term follow-up had a grade 3 SL ligament tear at the initial arthroscopy, none had a grade 4 tear, 17 had a partial tear (grades 1−2), and the remaining 12 patients had no SL ligament tear. Twenty-three of the 38 patients had

TABLE 2. The Objective Outcome at 13−15 Years (N = 38) Related to the Initial Arthroscopic SL Diagnosis

	Complete SL Tear (Grade 3) N = 9	Partial SL Tear (Grade 1 and 2) or No Tear N = 29	P
ROM (extension) Mean (SD)	66° (11°)	70° (14°)	.33
ROM (flexion) Mean (SD)	63° (18°)	64° (11°)	1
SL angle Mean (SD)	52° (7°)	50° (9°)	.89
SL gap, mm Clenched fist Mean (SD)	1.6 (1)	1.5 (1)	.97
Grip strength* Mean (SD)	83% (5)	92% (14)	.34

No grade 4 SL tears were found in the study cohort.
ROM, range of motion.
*As percentage of the contralateral wrist.

TABLE 3. Subjective Outcome at 13−15 Years Follow-Up in 38 Patients Related to the Initial Arthroscopic SL Diagnosis

	Complete SL Tear (Grade 3) N = 9	Partial SL Tear (Grade 1 and 2) or No Tear N = 29	P
DASH Median (range) Mean (SD)	2 (0−55) 20 (24)	9 (0−70) 16 (18)	.68 .60
Gartland and Werley Median (range)	3 (0−15)	4 (0−13)	.86
VAS pain at rest Median (range)	1 (0−3)	1 (0−5)	.63
VAS pain at activity Median (range)	3 (1−5)	1 (0−7)	.29
VAS subjective function Median (range)	1 (0−9)	2 (0−7)	.54
VAS cosmesis Median (range)	1 (0−9)	1 (0−7)	.37

No grade 4 SL tears were found in the study cohort.

injured their dominant side. At the time of the latest follow-up, none of the patients had been operated on because of SL instability or other SL-related problems.

At the most recent clinical examination, range of motion in extension and flexion in the patients with neither a complete nor a partial SL tear was not reduced

TABLE 4. Radiographic Findings After 13–15 Years Follow-Up of Arthroscopically Diagnosed SL Ligament Tears

Radiocarpal Osteoarthritis (Kellgren/ Lawrence)	Complete SL Tear (Grade 3) N = 9	Partial SL Tear (Grade 1 and 2) or No Tear N = 29
Grade 0	4	16
Grade 1	2	9
Grade 2	2	4
Grade 3	0	0
Grade 4	1*	0

No grade 4 SL tears were found in the study cohort.
*Patient with bilateral arthritic changes.

TABLE 5. Relationship Between Range of Motion in the Injured Wrist Compared With the Uninjured Wrist, in the Patients With a Grade 3 SL Ligament Tear

	Complete SL Tear (Grade 3) Injured Hand N = 9	Complete SL Tear (Grade 3) Uninjured Hand N = 9	P
Flexion Mean (SD)	63° (18°)	75° (12°)	.1
Extension Mean (SD)	66° (11°)	70° (10°)	.5

No grade 4 SL tears were found in the study cohort.

on the injured side compared with the contralateral wrist (Table 5). Increased SL mobility, as indicated by a positive Watson test result, was found in 5 of 38 patients. Two of these patients had been considered unstable at the 1-year follow-up. Five other patients had pain at the stress test without any concomitant clinical hypermobility.

The mean grip strength in patients with a grade 3 SL tear was 83% of the contralateral wrist, as compared with 92% (P = .33, 95% confidence interval = −7% to +21%) in patients with partial or no tear (Table 2). No significant difference in grip strength at the last follow-up compared to the 1-year follow-up was found in the patients with a grade 3 tear (100%, P = .69). The median DASH score for patients with a grade 3 SL ligament tear did not differ to a statistically significant degree from the patients with partial SL tears (Table 3). No correlation was found between the degree of SL tear and VAS scores for pain at rest or with activity (Table 3).

Radiographic assessment

No significant differences were found in SL angle or in SL distance between the group with grades 1–2 SL injury, the group with grade 3 SL injury, and the group with no SL injury (Table 2). In the 3 patients who had an increased SL distance on plain radiographs after 1 year, 1 patient had advanced bilateral rheumatoid arthritic changes at the last follow-up. The other 2 had a similar radiographic SL distance (2.0 mm and 3.2 mm, respectively) to that on the contralateral, unfractured side; these were considered to be congenital and of nontraumatic origin. None of these 3 patients with increased SL distance at 1 year or the 7 with increased SL distance only on stress radiographs at 1 year had developed SLAC wrist at the most recent follow-up (Table 4).

DISCUSSION

Scapholunate ligament tears have been the subject of numerous studies, mostly as an isolated injury but also in combination with other wrist injuries. The natural course of isolated, partial, and untreated SL tears, unrelated to a DRF, has been described in 11 patients with an average follow-up of 7 years,[20] and none of these patients developed a SLAC wrist or degenerative changes. The natural course of untreated SL tears occurring as part of a DRF is largely unknown. In accordance with one previous study,[21] none of our patients developed a SLAC wrist or any noteworthy degenerative changes. In another study, about one-quarter of patients with a static SL ligament injury developed SLAC wrists by radiography (3 of 13 cases in a series of 75 fractures) 3 years after a DRF.[22] Tang[21] identified 20 patients with static SL disruption (> 3 mm) with suboptimal wrist function after 1 year in a group of 474 patients with a DRF. In our series as well, the clinical result after 1 year was inferior in the patients with a complete grade 3 SL tear, who had more severe pain.[14] This trend was not seen in the present long-term study, nor was a radiographic progression of the SL widening apparent. None of our 38 patients, regardless of the severity of the initially verified SL tear, developed a dorsal intercalated segment instability deformity during the long follow-up period. In our view, this finding may be consistent with the absence of more severe (grade 4) SL tears, in which the secondary stabilizers may also be injured or attenuated. In our series, one patient had severe wrist arthritis at follow-up, but this patient also had arthritis in the contralateral, nonfractured wrist.

The absence of SLAC 13–15 years after grade 1–3 SL tears seems scientifically to be a true reflection of

the long-term outcome. The findings, however, may be explained by the fact that a slightly increased proportion (15 of 26) of the injuries in our study group occurred in less-loaded nondominant wrists. Further research elaborating the amount of load in dominant and nondominant hands and the consequences of primary and secondary osteoarthritis may be warranted on this important issue.

Scapholunate ligament tears can occur as part of a degenerative process without a recognized injury. We do not know which traumatic tears have the capacity to heal. Even complete traumatic tears may heal, possibly when the extrinsic ligaments are intact, as do grade 1–3 tears.

In the present study, we defined subjective instability as a symptom that was only possible to surmise through the medical history, in contrast to objective hypermobility[23] found by performing the Watson test. Subjective instability, interpreted as a symptom, does not necessarily imply a dynamic or static radiographic dissociation. In an acute SL ligament tear that is part of a DRF, it is impossible to diagnose subjective instability. At the late follow-up, none of our patients complained of any clicking, and none of them had had any secondary stabilizing surgery done during the follow-up period. Nevertheless, even without subjective instability, it is assumed that the risk of secondary arthritis may warrant surgery at the time of the injury.[24] In the current study, however, no advanced degenerative changes were found in patients with SL ligament tears up to and including grade 3.

The current study had several limitations. First, the number of patients was small, which risks a type II error, and a 75% follow-up (38 of the 47 patients still alive) risks a selection bias. Second, using different radiologists in the studies may have influenced the interpretation of the radiographs. Unfortunately, the original radiographs were to a large extent missing at the latest follow-up. Third, clinical examinations performed 13–15 years apart, by 2 different clinicians, using a semi-subjective evaluation method such as the Watson test, could be difficult to interpret. At 1 year, only 2 of the 10 patients with grade 3 SL tears had objective increased mobility according to the Watson test results, 1 with static dissociation and 1 with dynamic dissociation radiographically. Thirteen years later, the first patient had developed an arthritic appearance bilaterally, and the second had normal radiographic appearance because the contralateral side had a similar SL joint width.

We found no evidence that untreated SL ligament tears, up to arthroscopic grade 3, associated with a distal radius fracture negatively affected the subjective, objective, or radiological long-term outcome. Primary repair *per se* therefore seems unnecessary, but larger randomized studies are needed. We do not know the possible long-term outcome of grade 4 SL tears or traumatic static radiographic SL tears seen on trauma films, as these were not present in the cohort. We are therefore limited to suggesting that the management of arthroscopically diagnosed grade 1–3 SL tears can be nonsurgical.

ACKNOWLEDGMENT

REFERENCES

1. Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. *J Bone Joint Surg Am*. 1996;78(3): 357–365.
2. Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. *J Hand Surg Br*. 1997;22(5):638–643.
3. Stanley JK, Trail IA. Carpal instability. *J Bone Joint Surg Br*. 1994;76(5):691–700.
4. Linscheid RL, Dobyns JH, Beabout JW, Bryan RS. Traumatic instability of the wrist: diagnosis, classification, and pathomechanics. *J Bone Joint Surg Am*. 2002;84(1):142.
5. Carlsen BT, Shin AY. Wrist instability. *Scand J Surg*. 2008;97(4): 324–332.
6. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. *J Hand Surg Am*. 1984;9(3): 358–365.
7. Watson HK, Ryu J. Evolution of arthritis of the wrist. *Clin Orthop Relat Res*. 1986;202:57–67.
8. Hergenröeder PT, Penix AR. Bilateral scapholunate dissociation with degenerative arthritis. *J Hand Surg Am*. 1981;6(6):620–622.
9. Sebald JR, Dobyns JH, Linscheid RL. The natural history of collapse deformities of the wrist. *Clin Orthop Relat Res*. 1974;104:140–148.
10. Chennagiri RJ, Lindau TR. Assessment of scapholunate instability and review of evidence for management in the absence of arthritis. *J Hand Surg Eur*. 2013;38(7):727–738.
11. Mudgal C, Hastings H. Scapho-lunate diastasis in fractures of the distal radius. Pathomechanics and treatment options. *J Hand Surg Br*. 1993;18(6):725–729.
12. Garcia-Elias M, Geissler WB. Carpal instability. In: Green DP, ed. *Green's Operative Hand Surgery*. 5th ed. Philadelphia, PA: Churchill Livingstone; 2005:535–604.
13. Mayfield JK, Johnson RP, Kilcoyne RK. Carpal dislocations: pathomechanics and progressive perilunar instability. *J Hand Surg Am*. 1980;5(3):226–241.
14. Lindau T, Adlercreutz C, Aspenberg P. Peripheral tears of the triangular fibrocartilage complex cause distal radioulnar joint instability after distal radial fractures. *J Hand Surg Am*. 2000;25(3):464–468.
15. Watson HK, Ashmead D 4th, Makhlouf MV. Examination of the scaphoid. *J Hand Surg Am*. 1988;13(5):657–660.
16. Gartland JJ Jr, Werley CW. Evaluation of healed Colles' fractures. *J Bone Joint Surg Am*. 1951;33(4):895–907.

17. Beaton DE, Wright JG, Katz JN, Upper Extremity Collaborative Group. Development of the QuickDASH: comparison of three item-reduction approaches. *J Bone Joint Surg Am.* 2005;87(5): 1038−1046.

18. Gummesson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (QuickDASH): validity and reliability based on responses within the full-length DASH. *BMC Musculoskelet Disord.* 2006;18(7):44.

19. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. *Ann Rheum Dis.* 1957;16(4):494−502.

20. O'Meeghan CJ, Stuart W, Mamo V, Stanley JK, Trail IA. The natural history of an untreated isolated scapholunate interosseus ligament injury. *J Hand Surg Br.* 2003;28(4):307−310.

21. Tang JB, Shi D, Gu YQ, Zhang QG. Can cast immobilization suc-cessfully treat scapholunate dissociation associated with distal radius fractures? *J Hand Surg Am.* 1996;21(4):583−590.

22. Pilný J, Kubes J, Hoza P, Mechl M, Visna P. Scapholunate instability of the wrist following distal radius fracture. *Acta Chir Orthop Traumatol Cech.* 2007;74(1):55−58.

23. Scheer JH, Adolfsson LE. Radioulnar laxity and clinical outcome do not correlate after a distal radius fracture. *J Hand Surg Eur.* 2011;36(6):503−508.

24. Abe Y, Katsube K, Tsue K, Doi K, Hattori Y. Arthroscopic diagnosis of partial scapholunate ligament tears as a cause of radial sided wrist pain in patients with inconclusive X-ray and MRI findings. *J Hand Surg Br.* 2006;31(4):419−425.

Paper III

ORIGINAL ARTICLE

No long-term risk of wrist osteoarthritis due to subchondral haematomas in distal radial fractures

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ABSTRACT

Objective: The objective of this study of distal radius fractures was to determine if a subchondral haematoma in an unfractured compartment predicts secondary osteoarthritis.

Methods: In 1995–1997, 41 patients, 22 women, a median age of 41 years (20–57 years) with a displaced distal radius fracture underwent diagnostic wrist arthroscopy in addition to the fracture treatment. In 12 patients (7/12 women), subchondral haematomas were identified in a joint compartment not involved in the fracture.

Results: At 13–15 years, 37 patients were still alive. Twenty-eight patients attended the follow-up and 8/28 had had a subchondral haematoma within an uninjured compartment at the time of arthroscopy. The range of motion at 13–15 years was impaired in the injured wrist, but unrelated to the presence of a subchondral haematoma. The mean grip strength in patients with subchondral haematoma was 80% of the contralateral, compared to 78% in patients without. No correlation was found between the presence of a subchondral haematoma at arthroscopy and the development of radiographic osteoarthritis in the long term.

Conclusion: The presence of a subchondral hematoma in an uninjured compartment at the time of fracture did not alter the long-term clinical or radiographic outcome after a distal radius fracture.

Introduction

In high-energy wrist trauma with intra-articular fractures and articular step-off and gaps, obvious cartilage injuries can be surmised from radiography. The injury may in the long term lead to secondary arthritis if not corrected and reduced [1,2]. When no radiographically manifest intra-articular fracture is present, more sophisticated methods must be used to diagnose cartilage injuries, such as arthroscopy [3] or magnetic resonance imaging (MRI) [4]. With arthroscopy, a subchondral haematoma can be regarded as a direct sign of an impaction trauma and an indirect sign of cartilage injure (Figure 1). With MRI, a high signal on fluid-sensitive sequences may be associated with subchondral haemorrhage and, in some cases, fracture. In the short term, some studies indicate that even apparently harmless subchondral changes may cause post-traumatic osteoarthritis (OA) [5,6], but long-term studies are lacking on whether an injury showing a bone bruise progresses into OA and, if so, this affects the subjective and objective outcome [7].

Between 1995 and 1997, 41 patients were treated for a displaced distal radius fracture and underwent a diagnostic arthroscopy in addition to the standard fracture treatment, at the time of the primary treatment [3]. A standardized protocol was used to map (1) soft tissue ligament lesions, and (2) subchondral haematomas in an unfractured scaphoid or lunate compartment of the radius. In the 1-year follow-up, there was a correlation between the presence of a haematoma in an unfractured compartment and an increased subchondral density on radiography. This was interpreted as early signs of OA [6] and the aim of the present follow-up was to describe the natural course in these patients and determine if a post-traumatic haematoma would progress into OA at long term.

Material and methods

The original cohort

During 1995–1997, 41 patients with a displaced distal radius fracture were included in the study [3]. The median age was 41 years (20–57) and 19 patients were men and 22 women. In addition to the standard fracture treatment, all patients during this period (men 20–60 years, women 20–50 years), were examined by arthroscopy to map ligamentous and cartilage injuries within 15 days by one surgeon (T.L.). Both the radiocarpal as well as the midcarpal joint were assessed systematically according to a standardized protocol [8]. The radial part of the radiocarpal joint, with the articulation between the scaphoid and the radius, was defined as the scaphoid compartment, and the ulnar part with the articulation between the lunate and the radius as the lunate compartment. In all patients, at least one of the two radiocarpal compartments was not involved radiographically in the fracture. Subchondral changes were mapped arthroscopically, and were defined as a local haemorrhage under an intact cartilage surface (Figure 1). Haematomas were recorded as either being present or not and without measurment of size. At arthroscopy, 12/41 patients had a haematoma in the non-fractured compartment.
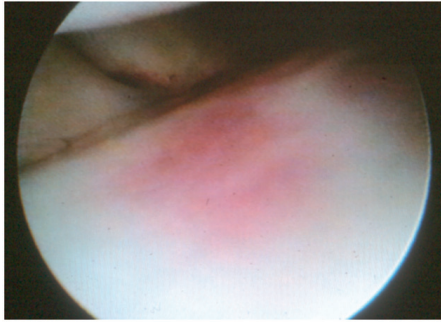
Figure 1. Arthroscopic view from the 3–4 portal (between the third and fourth extensor compartment) showing a subchondral haematoma in the unfractured scaphoid compartment of the distal radius at the time of the fracture. The scaphoid is seen on top with the scaphoid facet of the distal radius below and the radio-carpal extrinsic ligaments behind.

Follow-up at 13–15 years after the injury

The clinical and radiographic results at 1-year have been reported [6] as well as long term results regarding triangular fibrocartilage complex (TFCC) [9] and scapholunate ligament (SL)-injuries [10]. At 13–15 years after the fracture, all 41 patients were traced. Thirty-seven patients were still alive and were invited for an interview, clinical examination and radiographic assessment. Three patients did not reply to mail/phone calls or lived too far away to come, and five patients declined participation. One patient came for radiographic examination but was excluded from the clinical examination due to ongoing plaster treatment of a scaphoid fracture in the ipsilateral wrist. One examiner, unaware of the previous arthroscopic findings performed the clinical evaluation (A.M.). Range of motion (ROM) was measured with a goniometer. Grip strength was measured using a Jamar® dynamometer (Preston, Bolingbrook, IL) and the mean value of three repeated measurements was used for statistical analysis. Gartland and Werley score [11] was used for evaluation of the subjective and functional outcome. This demerit point system includes both subjective symptoms as well as the functional outcome, with higher scores related to poorer wrist function. In addition, a validated Swedish version of the Quick-DASH questionnaire [12] was used at the 13–15 years follow-up. The Quick-DASH questionnaire consists of 11 questions evaluating physical activity, severity of symptoms, and the effect of the injury on social activities. The DASH score ranges from 0 to 100 and a higher score suggests a more severe disability. A visual analogue scale (VAS) was used for self-assessment of pain at rest, pain at activity, subjective function and cosmesis.

Radiography of both wrists included a posterior–anterior (PA) and a lateral exposure, a PA exposure with clenched fist, and PA exposures in radial and ulnar deviation with the wrist in slight extension. A senior radiologist examined the radiographs (M.G.), unaware of the initial arthroscopic findings. Radiographic OA was assessed and graded according to Knirk and Jupiter [13] (grade 0–3; 0 = none; 1 = slight joint-space narrowing; 2 = marked joint-space narrowing; 3 = bone on bone).

Statistics

Student's t-test was used for quantitative continuous variables such as grip strength and ROM, and the Mann–Whitney U-test for

Table 1. Subjective and objective outcome at 13–15 years in patients with or without haematoma at arthroscopy.

	Patients with haematoma (n = 8)	Patients without haematoma (n = 20)	p
DASH: median (range)	16 (0–55)	14 (0–70)	.89
DASH: mean (SD)	20 (19)	20 (22)	
Gartland and Werley: median (range)	5 (0-7)	2 (0–9)	.66
VAS pain at rest: median (range)	1 (0–4)	1 (0–3)	.57
VAS pain at activity: median (range)	1 (0–6)	1 (1–8)	.7
VAS subjective function: median (range)	2 (1–5)	2 (0–9)	.65
Extension fracture side: mean (SD)	67° (10)	68° (16)	.80
Flexion fracture side: mean (SD)	63° (8)	63° (16)	.97
Grip strength: mean (SD)	80% (32)	86% (25)	.61

SD: standard deviation.

Table 2. The incidence of OA at 13–15 years after fracture, related to arthroscopically diagnosed subchondral haematomas and the presence of subchondral radiographic changes at the 1-year follow-up (Fisher's exact test).

	OA		
	Yes	No	p[a]
Hematoma			
Yes	2	6	.67
No	8	12	

[a]Fisher's exact test.

scale data (VAS, Gartland and Werley, and DASH scores). Fisher's exact test was used for qualitative comparisons. p values <0.05 were considered statistically significant.

Results

Twenty-eight of the original 41 patients were able to attend both the clinical and radiological examinations at the 13–15 years follow-up. Eighteen were women and 10 men, and the dominant wrist was involved in 19/28 patients. More than half (17/28) of the fractures were intra-articular, according to the AO classification (16 intra-articular type C, one partly articular type B, and 11 extra-articular type A). Twenty-three patients were exposed to high-energy trauma, i.e. more than a fall in the same level.

Eight of the 12 patients with a subchondral haematoma at the initial arthroscopic examination participated in the follow-up and the presence of a haematoma did not impact the range of motion. Twenty-two/twenty-eight patients had reduced range of motion in the injured side compared to the contralateral, regardless of the type of cartilage injury. No differences were found between the groups regarding subjective parameters such as DASH, Gartland and Werley score, or VAS (Table 1). The mean grip strength in patient with subchondral haematoma at arthroscopy was 80% of the contralateral wrist compared to 86% of the patients without (p = .61; Table 1).

Radiographic assessment

Two of the eight patients with subchondral haematoma at the initial arthroscopy had grade 1 mild changes in the non-fractured compartment. In comparison, eigth/twenty without subchondral haematoma also had grade 1 mild changes in the non-fractured compartment (Table 2), whereas 12 of these 20 patients remained radiographically intact. One patient with type A fracture and without haematoma developed a severe grade 3 joint destruction between the 1 year and the 13–15 years follow-up and was diagnosed with rheumatoid arthritis. In the 16 compartments with an intra-articular fracture, five developed a mild grade 1 OA and 11 patients did not.

Discussion

In the original cohort, 12/41 patients had a subchondral haematoma in an unfractured compartment [3]. After 1 year, subchondral trabecular changes were noted in eight patients, whereof seven had had a subchondral haematoma within the same joint compartment at the original arthroscopy. Four of the eight patients were graded as having an incipient OA grade 1 [6]. The fear for a deterioration and the development of a clinically manifest OA, as indicated in the 1-year follow-up, could, however, not be verified in the present 13–15 years follow-up. Only two (2/8) of the patients with a subchondral haematoma developed a mild joint-space narrowing over the years, and it could be noted that approximately the same proportion of the patients without a subchondral haematoma did as well. Our interpretation is that this progression represents a more general degenerative process than a consequence of the injury. Even in the compartments with an intra-articular fracture, OA seemed to be rare and limited, with an incipient, grade 1, OA found in less than a third of the fractured compartments (5/17). The patients with an arthroscopic haematoma developing mild OA seemed to do so early on and only one patient had deteriorated from no arthritis (grade 0) at 1 year to minimal OA (grade 1) at the late follow-up. The only patient in the whole cohort developing advanced arthritis was diagnosed with rheumatoid arthritis shortly after the fracture. The joint changes were bilateral and appeared to be independent of the distal radius fracture.

Histopathologically, a blunt joint injury may result in oedema, hyperaemia, bleeding and/or a micro-fracture of the subchondral trabecular bone [14]. In clinical practice, the diagnosis has to be made using some imaging technique and it is well-known that radiography is unable to depict these lesions. In wrist arthroscopy, a direct visual description of a subchondral haematoma can be made (Figure 1). Most studies of subchondral bone lesions, however, have been performed in knee injuries using MRI. The terms bone bruise, bone marrow oedema or bone marrow lesion are defined as an increased signal intensity on T2-weighted MRI images [15,16]. It is currently under debate whether these bone marrow lesions play a role in the development of knee OA [17]. Fifty percent of the patients with an anterior cruciate ligament (ACL)-injury do develop OA after 10–15 years.

There are no long-term studies of bone bruises or bone marrow lesions after wrist trauma, but in contrast to knee injuries, we found no or only minor osteoarthritic changes 13–15 years after a wrist injury, regardless whether the joint surface was fractured, had a bone bruise or was arthroscopically intact. We have no clear explanation to why a subchondral haematoma, likely to be strongly correlated with, in the wrist appears to be less progressive than a bone bruise in a knee, but the biomechanics differ. The radio-carpal joint is not weight-bearing as the knee joint which may play a role in the development of knee OA.

There are limitations to the study, in particular the small number of patients, and the risk of a type II error should be taken into account. We did not use MRI at the time of the fracture and can therefore not correlate our arthroscopic findings with MRI. We also chose not to use MRI at the follow-up since minor changes not detectable in standard radiograms hardly will play a role after 13–15 years. The strength of the study, on the other hand, is the long-term follow-up at 13–15 years after the initial injury.

In conclusion, subchondral haematomas diagnosed with arthroscopy in an unfractured compartment in a distal radius fracture do not develop into secondary OA in the wrist.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

[1] Strange-Vognsen HH. Intraarticular fractures of the distal end of the radius in young adults: a 16 (2–26) year follow-up of 42 patients. Acta Orthop Scand. 1991;62:527–530.

[2] Kopylov P, Johnell O, Redlund-Johnell I, et al. Fractures of the distal end of the radius in young adults: a 30-year follow-up. J Hand Surg Br. 1993;18:45–49.

[3] Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg Br. 1997;22:638–643.

[4] Tamburrini O, Bianchi D, Capparelli G, et al. "Occult" posttraumatic lesions of the knee: can magnetic resonance substitute for diagnostic arthroscopy? Radiol Med. 1997;94:433–439.

[5] Burr DB, Radin EL. Microfractures and microcracks in subchondral bone: are they relevant to osteoarthrosis? Rheum Dis Clin North Am. 2003;29:675–685.

[6] Lindau T, Adlercreutz C, Aspenberg P. Cartilage injuries in distal radial fractures. Acta Orthop Scand. 2003;74:327–331.

[7] Gelber AC, Hochberg MC, Mead LA, et al. Joint injury in young adults and risk for subsequent knee and hip osteoarthritis. Ann Intern Med. 2000;133:321–328.

[8] Whipple TL, Marotta JJ, Powell JH III. Techniques of wrist arthroscopy. Arthroscopy. 1986;2:244–252.

[9] Mrkonjic A, Geijer M, Lindau T, et al. The natural course of traumatic triangular fibrocartilage complex tears in distal radial fractures: a 13–15 year follow-up of arthroscopically diagnosed but untreated injuries. J Hand Surg Am. 2012;37:1555–1560.

[10] Mrkonjic A, Lindau T, Geijer M, et al. Arthroscopically diagnosed scapholunate ligament injuries associated with distal radial fractures: a 13- to 15-year follow-up. J Hand Surg Am. 2015;40:1077–1082.

[11] Gartland JJ Jr, Werley CW. Evaluation of healed Colles' fractures. J Bone Joint Surg Am. 1951;33:895–907.

[12] Gummesson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (QuickDASH): validity and reliability based on responses within the full-length DASH. BMC Musculoskelet Disord. 2006;7:44.

[13] Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am. 1986;68:647–659.

[14] Newberg AH, Wetzner SM. Bone bruises: their patterns and significance. Semin Ultrasound CT MR. 1994;15:396–409.

[15] Wilson AJ, Murphy WA, Hardy DC, et al. Transient osteoporosis: transient bone marrow edema? Radiology. 1988;167:757–760.

[16] Mink JH, Deutsch AL. Occult cartilage and bone injuries of the knee: detection, classification, and assessment with MR imaging. Radiology. 1989;170:823–829.

[17] Conaghan PG, Felson D, Gold G, et al. MRI and non-cartilaginous structures in knee osteoarthritis. Osteoarthritis Cartilage. 2006;14(Suppl. A):A87–A94.

Paper IV

Ulnar-sided wrist pain and ligament injury in patients with persisting inferior subjective outcome after distal radius fracture. A long-term register study

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Abstract

Introduction; The outcome of a distal radius fracture is good in most patients, but about 15% have a major disability including pain at rest one year after the fracture. The reason is multifactorial. A younger cohort with inferior mid-term subjective outcome was selected from a prospective register, with the specific aim to evaluate the influence of ulnar ligament injuries for long term disability.

Methods; Prospective register data from an 8-year period was used, and patients 18-55 years with a DASH score exceeding 35 at 12 months were identified. In 2018, 6-13 years after the fracture, the patients were invited for a clinical and radiographic follow-up. Coexisting comorbidity was recorded as well as range of motion, grip strength, ligament laxity, patient-reported outcome (Disabilities of Arm, Shoulder, and Hand, DASH) and pain (VAS).

Results; 33 patients, 7 men and 26 women, mean age 47 years at fracture, completed a full clinical and radiographic examination. Six patients had been operated primarily and 11 secondarily. Only one patient had returned to pre-fracture status with a DASH between 0-10. Ulnar laxity was common and found in 11/33 patients, 5 in the intermediate (DASH 11-35, n=14) and 6 in the poor (DASH >35, n=18) outcome group. Ulnar laxity accompanied by a DRUJ osteoarthritis was found in 6/33 patients and malunion in 10/33. Fifteen patients had coexisting comorbidity and 13 chronic musculoskeletal conditions.

Conclusion; In the group remaining at poor subjective outcome 6-13 years after a distal radius fracture, a high incidence of ulnar laxity was found, often with concomitant DRUJ osteoarthritis. Comorbidity was common, especially regarding musculoskeletal chronic conditions.

Word count 250

Introduction

In the short-term perspective, the outcome of a distal radius fracture (DRF) is good. At 6 months, two-thirds of the patients have no or minimal pain[1] and at 12 months most patients are satisfied with the outcome[2]. In our local Lund Wrist Fracture Register, the median Disabilities of Arm, Shoulder, and Hand (DASH) score in 3666 patients, 18 years and older, was 9 (IQR 2–25), one year after a distal radius fracture, regardless of being operated or not[2]. Fifty-two percent had a DASH score indicating minor (0-10) and 31% moderate (11–35) residual symptoms. This may be considered as a good or even excellent result, but nevertheless, 17% had a subjective outcome of DASH >35, indicating major disability, including pain at rest.

Studies measuring subjective outcome beyond one year after a DRF are scarce. It appears that the majority of the subjective improvement takes place during the first year, even in patients followed for as long as 10-20 years[3]. Although 85% reported good and lasting subjective outcome (PRWE) after one year, 15% had persistent inferior subjective outcome. The inferior outcome could not be predicted from demographics or fracture characteristics but all patients in the inferior outcome group had coexisting comorbidity. In another study in 123 patients, malunion was found to correlate with the one-year DASH score [4] and no improvement occurred between year one and two. Recently, the same authors published a long-term study using DASH both at inclusion and at follow-up 12-14 years later. The patients with malunion still at this time had 14 scale steps worse DASH than the patients without malunion[5].

Besides malunion, soft tissue injuries, and in particular injuries to the ulnar ligaments are considered to influence the final result after a DRF [6]. Also in this area, long term studies are rare. The natural course of untreated TFCC injuries in DRFs was described in a study of 47 patients using MRI at the time of fracture. Twenty-four patients had a TFCC tear and 23 had not. After 3-4 years, the subjective outcome using the Mayo Wrist Score was identical in the two groups and the authors concluded that immediate repair is not necessary[7]. Arthroscopy allows for a more precise diagnosis[8], and was used as diagnostic tool in another prospective study, also with the aim to describe the natural course of untreated TFCC injuries in DRFs. Fifty-one consecutive younger patients underwent a diagnostic arthroscopy at the time of fracture[9]. Forty-three had a TFCC injury. Eleven/43 were complete, peripheral TFCC tears and all injuries were left untreated. In 2010, 13-15 years later, the patients were invited for a clinical and radiographic examination and 38 patients completed a full clinical and radiologic examination [10]. The subjective outcome score using DASH was 25 in the patients with complete peripheral tears, compared to 7 in the others. Clinically, this difference would be highly significant but

statistically it was not. We speculated that the lack of statistical significance could be due to a type II error and a too small sample size. We hypothesized that ulnar instability, if clinically important, would be common in a selection of patients with inferior subjective outcome at long term. The aim of the present study was therefore to map the incidence of ulnar instability, as well as other potential causes for long term disability, in patients with inferior subjective outcome at mid term. Patients 18-55 years with DASH exceeding 35 at one year, were extracted from the Lund Wrist Fracture Register and evaluated objectively, subjectively and radiographically 6-13 years after fracture.

Methods

The Lund distal radius fracture register

At our hospital, approximately 450 adult patients, 18 years or older, are treated for a DRF each year. Since March 2001, the patients are prospectively and consecutively registered, and a subjective outcome questionnaire (DASH) is sent to the patients after 3 and 12 months[11]. Three weeks later a reminder is sent out to the non-responders. To improve the response rate, the original 30-item DASH questionnaire was replaced in 2008 with the shorter 11-item QuickDASH questionnaire and a strong correlation was found between the two (r = 0.97; p < 0.001)[11]. In the registry, a total of 3666 patients with a distal radius fracture were included between 2003 and 2012. Of these, 2571 patients (70%) returned the questionnaire at 12 months. The one-year subjective outcome for the whole cohort was described in relation to age, sex, surgical/ non-surgical treatment, type of surgery and complication rate[2].

Long-term outcome studies

In 2014, 2-11 years after the fracture, a new DASH questionnaire was sent by mail to 346/2571 patients with a DASH score exceeding 35, arbitrarily set as a cut-off indicating major disability. 269 of the 346 (78%) patients returned the DASH questionnaire and about half the patients had improved to a score below 35, whereas half of the patients remained at a high level, independent of the time elapsed from the fracture[12].

Present clinical follow-up

In the present study, we focused on younger patients with suboptimal outcome. We selected patients from the register, 1) included between January 2005 and December 2012, 2) 18 to 55 years at the time of fracture and 3) with a DASH score exceeding 35 (Flowchart in Fig 1). In total, 932 younger patients had been included in the register, and 612/932 had returned a complete DASH at the one-year follow-up. 171 patients had a DASH score of 0, and 194 patients between 1-10, previously defined as a good outcome with full or almost full recovery[2]. 112 patients had a DASH between 11 and 20, and 67 patients a score between 21 and 35, previously defined as an intermediary subjective outcome. 68 patients had a DASH at one year exceeding 35. Fourteen patients were deceased, not possible to locate or had refused to participate in the 2014 survey and were excluded. The remaining 54 patients, 13 men and 41 women with a mean age of 45 years at fracture, had yet a new DASH sent by mail and were invited to the hospital in May 2018 for a full clinical and radiographical examination to evaluate factors potentially causing inferior outcome.

Subjective outcome

The DASH questionnaire was developed by the American Academy of Orthopedic Surgeons and the Institute for Work and Health[13] and has been validated in Swedish[14]. The DASH evaluates function, pain, and symptoms of the upper extremity during the preceding week and ranges from 0 (no disability) to 100 (most severe disability). In 2006, a short version, the QuickDASH, was developed[15] and validated in Swedish[16].

Objective outcome

Range of motion was assessed bilaterally, including radial and ulnar deviation, flexion, and extension. Grip strength was measured using a Jamar dynamometer (Preston, Bolingbrook, IL, USA). The patients were evaluated regarding DRUJ stability, with both a physical examination and an interview. A stability test was carried out using the DRUJ stress test[9]. The forearm was held in neutral rotation by the examiner, who stabilized the hand and the distal radius with a firm grip to make them one unit. The examiner, using the other hand, forced the ulna as the second unit in the dorsal/palmar direction, relative to the stabilized unit of the hand and radius. The stability of the DRUJ was compared with the uninjured, opposite side for reference. It was recorded whether the DRUJ was deemed lax, and whether the test caused pain or not. The scapholunate joint was examined by the Watson scaphoid shift test[17] and assessed both regarding ligament laxity and pain during the test. The test was defined as positive if there was a click at radial deviation of

the wrist associated with pain, compared to the healthy side. The lunotriquetral joint was examined using the LT shear test and the LT ballottement test[18].

Comorbidity

The electronic medical records were scrutinized and chronic medical conditions at the time of the final follow-up were noted and classified according to the Charlson Comorbidity Index (CCI)[19]. Charlson, originally used to predict the one-year mortality is also used to quantitate comorbidity. Age was not included in the calculation and the patients were divided into three groups: mild, with CCI 1–2; moderate, with CCI 3–4; and severe, with CCI ≥5. Musculoskeletal chronic conditions, as well as diseases not included in the Charlson index, were recorded separately.

Radiography

Radiographs were taken in posterior-anterior (PA) and lateral projections. Radial shortening was measured as ulnar variance from the distal radial surface to the distal ulnar surface, according to the method of perpendiculars on PA radiographs of the wrist obtained in the neutral position[20]. The radial inclination angle was measured on the PA radiographs. Dorsal angulation was measured on the lateral projection and expressed as the angle of the joint surface relative to the radial axis[20]. Posttraumatic osteoarthritis (OA) was classified according to Kellgren and Lawrence[21] (grade 0-4; with 0 defined as no OA, to the highest as severe OA). One radiologist (MG) performed all radiographic measurements, blinded to the functional outcome but not to the method of treatment.

Statistics

Demographic data are described using frequency and percentage. Continuous variables with normal distribution are presented using mean and standard deviation (SD). Since DASH data are skewed and ordinal, non-parametric tests are used and median and interquartile range (IQR) to describe the central tendency and variation. Categorical data were analyzed using the Fischer exact test. A two-sided p-value < 0.05 was considered statistically significant.

Ethics

The study was approved by the Ethics Committee at the Lund University (2009-318) with an extension for the long-term follow up (2018-102).

Results

Fifty-four patients were invited, 1 patient had died, 1 was terminally ill, 8 declined to participate, 3 were not possible to contact, and 2 had moved. 6 patients only submitted the DASH via mail. In May 2018, the remaining 33 patients came for a full clinical and radiographic examination, 7 were men and 26 women and the mean age at fracture was 47 years (Table 1).

The men were younger (41) at fracture than the women (49). Four patients had primarily unstable fractures and were operated on day 2 to 6. Two patients had been possible to manipulate into an acceptable position but the fractures redisplaced and were operated at day 11 and 15. Four patients had been operated using volar locking plates (VLP), one with external fixators and one with a combination. Twenty-seven patients had been treated conservatively. One plate had been removed before the late follow-up, two patients had an ulna osteotomy, three a radius osteotomy, one a partial wrist fusion (radio-lunate), one a total wrist fusion, and three a neurolysis. At the present follow-up, 2 patients were not working, 18 patients had non-manual and 13 manual work. Chronic systemic disease was common (10/33) as were chronic musculoskeletal conditions (12/33). 6 patients had a Charlson score 1-2, one patient 3-4 and three patients > 5.

In general, the patients, had a high pain rating at rest (VAS 2,5 cm) and in particular when asked for pain at load (VAS 4,5, Table 2). The range of motion in the radiocarpal joint was 92% of the flexion/extension of the contralateral side. 18/33 had full pro-supination and only three patients had supination of 60 degrees or less. The grip and pinch strength were 88 and 95% strength, respectively, of the contralateral side. Painful ulnar laxity was found in 11/33 patients with positive ulnar translation test i.e. objectively verified laxity and pain during the examination (Table 2 and 3). Three patients had a positive fovea sign test without laxity. Laxity was accompanied by minor or moderate osteoarthritis of the DRUJ in six patients. DRUJ OA was seen in 14/33 patients, the majority (10/14) grade 1 and 4 patients grade 2. LT shear and ballottement tests were positive in one patient but no radiographic VISI was seen on the radiographs. Watson´s test for SL injury was positive in one patient, who radiographically had a midcarpal step off but no increased SL distance. One patient had had a traumatic SL injury at the time of the DRF. No gap was visible initially but was after one year (Fig 2) and the patient was operated with a four-corner fusion and later total wrist fusion.

Moderate malunion was fairly common. Only two patients had an axial compression exceeding 3 mm. In the lateral view, 17 patients had a neutral or volarly tilted final position (volar 0-17 degrees). Eight patients had a dorsal compression between 0-10 degrees and 8 between 10-20 degrees. In total 10/33 patients met the malunion criterion of >10 degrees dorsal, >3 mm compression, and <15 degrees radial inclination.

The patients were divided into the three subgroups based on the subjective outcome; group 1) DASH 0-10, group 2) 11-35 and group 3) DASH >35. Only one patient returned to DASH 0-10 from > 35 at one year. This patient had no systemic/musculoskeletal disease, no ligament instability and a DASH of 0. One patient with DASH 0 at the 2014 follow-up had increased to 52 due to elbow conditions unrelated to the wrist. Else, the change between DASH 2014 and 2018 was minor. The rate of ulnar ligament injury or OA of the DRUJ was similar in the intermediate outcome group with final DASH between 11-35, and the group with major disability and DASH >35. Chronic musculoskeletal disease was more common in the major disability group with 10/18 vs 2/14 (p=0.03) whereas chronic systemic disease was similar: 5/18 vs 5/14.

Discussion

The reason for long-term inferior outcome after distal radius fracture (DRF) is multifactorial. Besides ulnar-sided wrist pain and DRUJ instability, other causes like fracture type or anatomic position at healing, as well as socioeconomic factors, comorbidity and pain coping have been discussed. We found DRUJ instability to be rather common in the group with persisting inferior subjective outcome and DRUJ instability by itself has been identified as a a prognostic factor for inferior outcome after a DRF[22, 23]. Patients with or without a positive DRUJ stress test after a DRF were compared at 6 months[24] and only minor difference was found in the DASH score, only to disappear during the following 6 months. Repair studies report good results at short term[25], but long term follow ups are rare. In a 15-25-year follow up of delayed TFCC repair sutures, the cause was a previous DRF in about half the patients. The subjective outcome was acceptable with two-thirds reporting a good outcome using the PRWE, but repeat surgery was common. Osteoarthritis of the DRUJ was found in almost 50%, more commonly in TFCC tears caused by a DRF. Prospective series comparing repair vs no repair would be most welcome, but are missing[26], and we need randomized studies with long term outcome to tell if surgery make a difference in the younger population.

Ligament injuries are hypothesized to be more common in younger patients, due to higher energy involved in the trauma. Ipsilateral concomitant wrist ligament injuries were found to be very common in a younger cohort (women < 50, men <60) investigated by arthroscopy at the time of fracture[27]. A substantial number of *partial* TFCC tears, LT tears and SLiL injuries were diagnosed but did not appear to influence the long-term morbidity and subjective outcome[10, 28]. In analogy, LT and SL laxity were rare also in the present study apparently without long-term consequences. Only one patient had sequels of an obvious traumatic SL injury, unnoticed at the time of the fracture (Fig 2) but clearly visible in the radiographs one year later. On the other hand, DRUJ instability was common and present in 11/33 patients. In the present series, no TFCC reconstruction has been attempted, in spite of one third being grossly unstable in the DRUJ. In the Lindau study, 20% had a complete peripheral TFCC injury and a worse outcome one year after the fracture, using the Gartland and Werley score[9]. Although major instability was found at the examination, only one patient in that series had been reconstructed during the 13-15-year follow-up.

Only one of the 33 patients at one year had returned to what we have previously defined as the pre-fracture status, at a DASH score between 0-10. This implies an even worse prognosis for this younger patient cohort compared to the total cohort. In the unselected total 3666 patients DRF register cohort study, more than 50% of the patients had a DASH score between 0-10 at one year. Even in the study of register patients with inferior subjective outcome at one year, but of all ages, 25% returned to the interval between DASH 0-10 in the following years[12]. Maybe the younger DRF patients in the present study are different and have more ligament injuries, due to higher trauma energy, and maybe these do play a role for the long-term results, as suggested but not verified in the Lindau arthroscopy study[9]. Further, in the present study, ligament laxity and DRUJ OA coincided, with 6 of the 33 patients having both, a finding that was not noted in the long-term arthroscopy study, in which OA was rare[10]?

In other long-term outcome studies after DRF, radiographic malunion has been noted as the most important prognostic factor of inferior subjective outcome. Patients with malunion were found to have a worse subjective outcome at one year[29] and continued to be worse for the years to come, compared to patients without, or with a lower degree of malunion[5]. In the present study, malunion was present in about one third but the degree was moderate. Axial compression, which has been shown to correlate the best with the subjective outcome was not common.

The only patient who returned to pre-fracture status DASH 0-10 had no signs of DRUJ instability and was in good health at the final follow up. In the other two outcome groups (intermediate DASH 11-35 and major disability DASH >35), the incidences of ulnar ligament injuries, complications, reoperations, and chronic
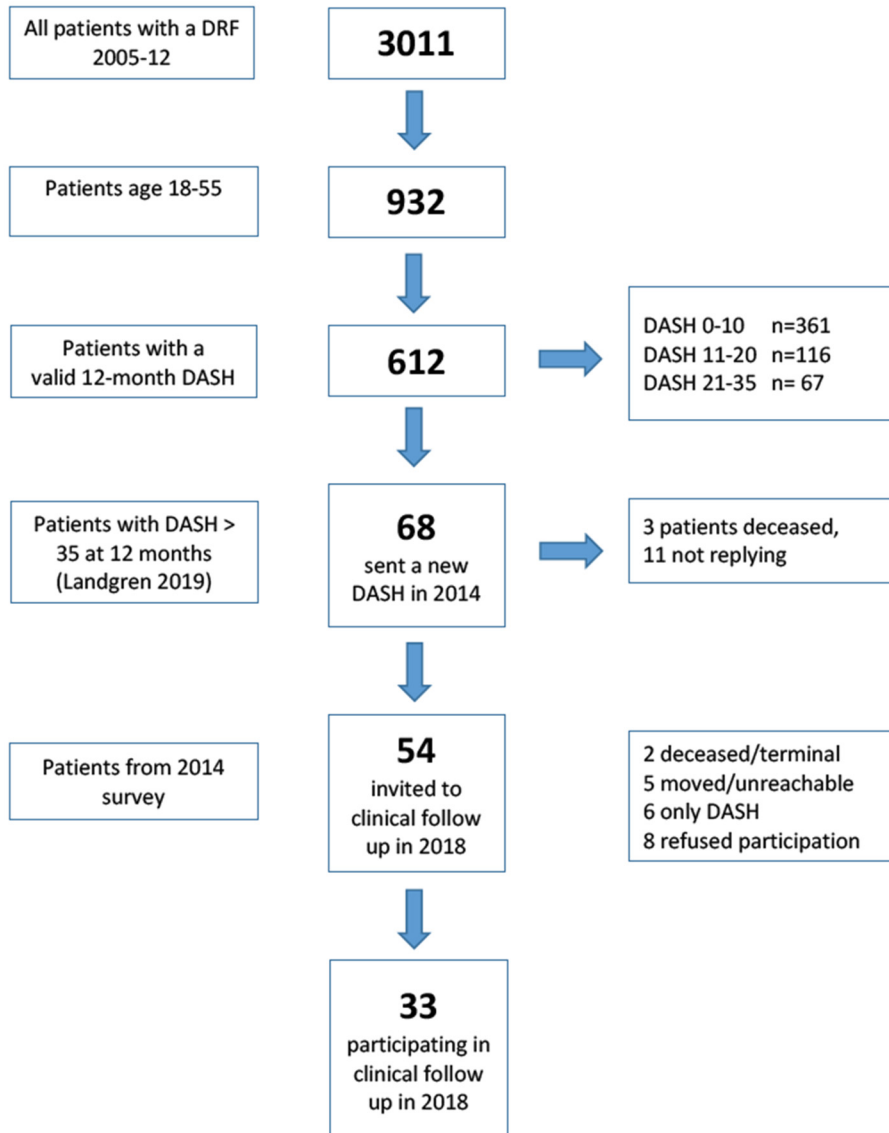
systemic disease were similar and evenly distributed. The incidence of chronic musculoskeletal conditions, however, appeared to be higher in the group with remaining major disability compared to the intermediate group. In 8 patients who had an almost undisplaced fracture, i.e. fractures with a radiographically favourable prognosis, comorbidities with general health issues were noted in 7 patients. In these, no fracture-related secondary surgeries were performed, no DRUJ laxity was found, except in one patient, and no osteoarthritis developed. Will it be possible to improve outcome in these patients? Also in other studies, comorbidities have been found to influence the long-term outcome. In a study following DRF patients for 10-20 years after the fracture, 85% remained at an acceptable level or improved throughout the years[3]. In the small group that did not, it was noted that all these patients had other general health problem including high blood pressure, diabetes, depression, OA, osteoporosis, or rheumatoid arthritis. The comorbidities were not unique to the 'worsened' group. In our study we found systemic disease to be as common in the intermediate as in the major disability groups.

There are limitations to this study. First, the final sample size is small, even if it is based on a register containing several thousand patients. The patients were, however, somewhat reluctant to attend. Many have other health issues, as shown, and may not have the inclination or energy to come. Some have substantial problems but rightfully doubt that healthcare will be able to solve their problems, if not successful before. Others may even have returned to a level of acceptable symptoms and simply want to continue life as it is.

It must, however, be considered rather challenging that once an inferior outcome is reached at one year, only a limited fraction of the younger adults will regain full and pain-free function. In the present study, less than half of the patients improved to below the cut-off at DASH 35, and still had substantial subjective problems, years after the fracture. What can then be made to improve the results at one year in terms of treatment and diagnosis? Do we have to accept that musculoskeletal comorbidity predisposes to an inferior outcome or is it a combination of fragile patients with comorbidities having fewer capabilities to deal with the increased pain and stress due to the fracture? Is it coping strategies we should support? Preferably, attempts to diagnose and treat should be made early, before the complications become manifest.

Original 3666 DRF patient cohort 2003-12
(Landgren 2017)

All patients with a DRF 2005-12	**3011**

Patients age 18-55	**932**

Patients with a valid 12-month DASH	**612**	DASH 0-10 n=361 DASH 11-20 n=116 DASH 21-35 n= 67

Patients with DASH > 35 at 12 months (Landgren 2019)	**68** sent a new DASH in 2014	3 patients deceased, 11 not replying

Patients from 2014 survey	**54** invited to clinical follow up in 2018	2 deceased/terminal 5 moved/unreachable 6 only DASH 8 refused participation

33 participating in clinical follow up in 2018

Figure 1

Flowchart. Patients 18- 55 with an inferior subjective outcome DASH>35 between 2005-12 were selected from the Lund Distal Radius Fracture Register.

11
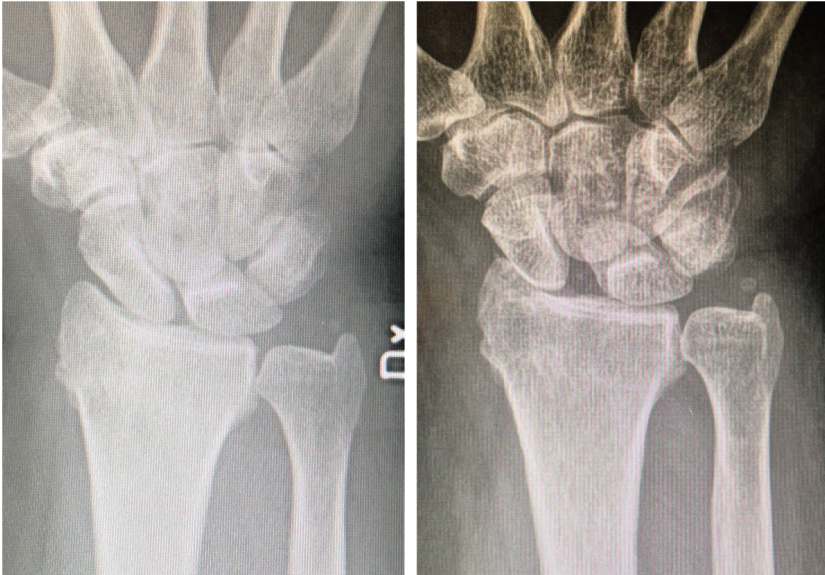
Figure 2:
Radiogram of a patient in the series with a traumatic SL-injury, not suspected at the time of fracture but seen in the radiogram after one year. The patient had since been operated with a four-corner fusion and finally a total wrist arthrodesis.

Table 1:
Demographic characters

Age (years)
    Men
    Women
	*41 (18-55)
	*49 (18-55)

Sex	
M	n=7
F	n=26
AO	
A	18
B	0
C	14
Radius+ulna metaphysis	1
Treatment	
Conservative	27
Surgery	6
Primary surgery early/late	
day 0-7	4
day 8-15	2
Primary surgery type	
VLP	4
Ex Fix	1
Combo	1
Secondary surgery	
Plate extraction	2
Ulna osteotomy	2
Radius osteotomy	3
Wrist fusion (1 RL, 1 total)	2
Neurolysis	3
Employment	
Not working	2
Manual labour	13
Non-manual labour	18

*The values are given as the mean and range.

Table 2:
Demographics at time of fracture, subjective outcome at one year and the final outcome at 6-13 year follow-up. Data not given for normal values or lack of findings.

		Demographics					Subjective			Objective				Comorbidity			Radiography				
	Age	Sex	AO	†Prim	*Sec surg	DASH 1 y	DASH 2018	VAS rest	VAS load	Sup	Pro	TFCC lax	SL Watson	^Co-morb	Musc skel	Charl son	Axial mm	Dorsal deg°	Mal union	OA RC	OA DRUJ
1	31	F	C	R+P		45	0	0	0							0		>10°			
2	48	M	A	R+P		50	11	0	3					HT		0		0-10			1
3	18	M	C	R+P	RO	47	14	1	4			pos				0		0-10			1
4	49	F	C	P		43	14	3	0	70		pos	pos			0					2
5	53	F	A	none		66	14	0	0					HB		2					
6	54	M	A	R+P	RO	39	14	0	0	70		pos				1		>10	yes		
7	48	F	A	ORIF		45	18	4	4					GI		0				1	
8	30	M	C	ORIF	PE	45	20	2	8							0		0-10			1
9	53	F	C	R+P	UO	38	20	2	3	60				tum		6				2	2
10	54	F	A	R+P	CTS	50	25	0	3					tum		2		>10	yes	1	
11	55	F	C	ORIF		36	25	1	1						yes	0				1	
12	40	F	A	R+P		41	27	0	8	80		pos				0		>10	yes		1
13	55	F	A	R+P		64	30	5	4					EP		1			yes		
14	55	F	C	ORIF		59	32	0				pos			yes	0					1
15	55	F	C	P		57	34	1	3	65	70	pos		DM	yes	2	4		yes		2
16	49	F	C	R+P		45	36	4	6	75		pos		GI		1		>10	yes		
17	48	F	A	P		43	39	0	3						yes	0					
18	51	F	A	R+P		61	39	1	4			pos			yes	0					
19	52	F	A	R+P		73	39	2	5						yes	0		0-10			
20	46	M	C	R+P	RL	64	43	8	9	10	70					0		0-10		4	1
21	35	F	C	R+P	RO	37	45	2	5	70	65			GU	yes	0					1
22	46	F	RU	P	UO	57	45	0	8					vasc		0	4	0-10	yes	1	
23	51	F	A	P		43	45	2	8		70			DM+	yes	5					
24	39	F	A	P		59	52	1	3	50				DM+	yes	3					
25	40	F	A	R+P	CTS	48	52	5	7		70				yes	0					
26	53	F	A	P		70	52	3	6	70	60	pos				0		>10	yes		1
27	53	F	C	CREF		36	52	2	8						yes	0		>10	yes		
28	53	M	C	R+P		64	52	2	5	30					yes	0		0-10		1	1
29	51	F	A	P	UNN	59	57	1	1					psy		0		0-10			
30	52	F	C	R+P		50	61	7	9	60		pos				0		>10	yes		
31	44	F	A	P	deQ	56	70	1	7					HB		5					1
32	41	M	A	ORIF	PE	57	73	5	5							0					2
33	47	F	A	P	TWA	63	66	8	9	70		pos		neph	yes	4					

†Primary treatment
R= reduction, P=plaster, ORIF= open reduction internal fixation. CREF= closed reduction external fixation

*Secondary surgery
RO= radial osteotomi, UO = ulna osteotomi, PE = plate extraction, CTS = carpal tunnel release, RL = radiolunate fusion, TWA=total wrist fusion, UNN= ulnar neurolysis, 4-CF= 4-corner fusion, deQ = de Quervain

^ Comorbidity
HT = Hypertonia, EP =epilepsy, GU genitourinary disease, CV= cardiovascular, HB = hepatobiliary, GI= gastrointestinal, Psy= psychiatric disorders, Tum= tumor.

Table 3 :
Objective and subjective results

TFCC		
	Translational test	10
	Fovea sign	7
	Combined	4
	Either or	13
SL		
	Pain	4
	Watson	1
LT		
	LT shear	2
	LT ballotment	1
ROM		
	Flexion-Extension*	92%
	Supination-Pronation*	93 %
Strength		
	Grip strength*	88%
	Pinch strength*	95%
Subjective outcome		
	DASH	37 (0-73)
	VAS pain at rest	2.1 (SD 2.1)
	VAS pain at activity	4.5 (SD 2.9)
	VAS subjective function	3.8 (SD 2.7)
	VAS cosmesis	2.5 (SD 3.0)

*% of uninjured side

References

1. MacDermid JC, Roth JH, Richards RS. Pain and disability reported in the year following a distal radius fracture: a cohort study. BMC Musculoskelet Disord. 2003;4:24. Epub 2003/11/01.

2. Landgren M, Abramo A, Geijer M, Kopylov P, Tagil M. Similar 1-year subjective outcome after a distal radius fracture during the 10-year-period 2003-2012. Acta Orthop. 2017;88:451-6. Epub 2017/03/16.

3. Lalone E, MacDermid J, Grewal R, King G. Patient Reported Pain and Disability Following a Distal Radius Fracture: A Prospective Study. Open Orthop J. 2017;11:589-99. Epub 2017/10/06.

4. Brogren E, Petranek M, Atroshi I. Cast-treated distal radius fractures: a prospective cohort study of radiological outcomes and their association with impaired calcaneal bone mineral density. Arch Orthop Trauma Surg. 2015;135:927-33. Epub 2015/05/04.

5. Ali M, Brogren E, Wagner P, Atroshi I. Association Between Distal Radial Fracture Malunion and Patient-Reported Activity Limitations: A Long-Term Follow-up. J Bone Joint Surg Am. 2018;100:633-9. Epub 2018/04/18.

6. Geissler WB, Freeland AE, Savoie FH, McIntyre LW, Whipple TL. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am. 1996;78:357-65. Epub 1996/03/01.

7. Deniz G, Kose O, Yanik S, Colakoglu T, Tugay A. Effect of untreated triangular fibrocartilage complex (TFCC) tears on the clinical outcome of conservatively treated distal radius fractures. Eur J Orthop Surg Traumatol. 2014;24:1155-9. Epub 2013/12/10.

8. Thomsen NOB, Besjakov J, Bjorkman A. Accuracy of Pre- and Postcontrast, 3 T Indirect MR Arthrography Compared with Wrist Arthroscopy in the Diagnosis of Wrist Ligament Injuries. J Wrist Surg. 2018;7:382-8. Epub 2018/10/24.

9. Lindau T, Adlercreutz C, Aspenberg P. Peripheral tears of the triangular fibrocartilage complex cause distal radioulnar joint instability after distal radial fractures. J Hand Surg Am. 2000;25:464-8. Epub 2000/05/16.

10. Mrkonjic A, Geijer M, Lindau T, Tagil M. The natural course of traumatic triangular fibrocartilage complex tears in distal radial fractures: a 13-15 year follow-up of arthroscopically diagnosed but untreated injuries. J Hand Surg Am. 2012;37:1555-60.

11. Abramo A, Kopylov P, Tagil M. Evaluation of a treatment protocol in distal radius fractures: a prospective study in 581 patients using DASH as outcome. Acta Orthop. 2008;79:376-85. Epub 2008/07/16.

12. Landgren M, Teurneau V, Abramo A, Geijer M, Tagil M. Intermediate-Term Outcome After Distal Radius Fracture in Patients With Poor Outcome at 1 Year: A Register Study With a 2- to 12-Year Follow-Up. J Hand Surg Am. 2019;44:39-45. Epub 2018/12/07.

13. Hudak PL, Amadio PC, Bombardier C. Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med. 1996;29:602-8. Epub 1996/06/01.

14. Atroshi I, Gummesson C, Andersson B, Dahlgren E, Johansson A. The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: reliability and validity of the Swedish version evaluated in 176 patients. Acta Orthop Scand. 2000;71:613-8. Epub 2001/01/06.

15. Beaton DE, Wright JG, Katz JN, Upper Extremity Collaborative G. Development of the QuickDASH: comparison of three item-reduction approaches. J Bone Joint Surg Am. 2005;87:1038-46. Epub 2005/05/04.

16. Gummesson C, Ward MM, Atroshi I. The shortened disabilities of the arm, shoulder and hand questionnaire (QuickDASH): validity and reliability based on responses within the full-length DASH. BMC Musculoskelet Disord. 2006;7:44.

17. Watson HK, Ashmead Dt, Makhlouf MV. Examination of the scaphoid. J Hand Surg Am. 1988;13:657-60. Epub 1988/09/01.

18. Lindau T, Hagberg L, Adlercreutz C, Jonsson K, Aspenberg P. Distal radioulnar instability is an independent worsening factor in distal radial fractures. Clin Orthop Relat Res. 2000:229-35. Epub 2000/07/25.

19. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis. 1987;40:373-83. Epub 1987/01/01.

20. Mann FA, Wilson AJ, Gilula LA. Radiographic evaluation of the wrist: what does the hand surgeon want to know? Radiology. 1992;184:15-24. Epub 1992/07/01.

21. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis. 1957;16:494-502. Epub 1957/12/01.

22. Geissler WB, Fernandez DL, Lamey DM. Distal radioulnar joint injuries associated with fractures of the distal radius. Clin Orthop Relat Res. 1996:135-46. Epub 1996/06/01.

23. Cheng HS, Hung LK, Ho PC, Wong J. An analysis of causes and treatment outcome of chronic wrist pain after distal radial fractures. Hand Surg. 2008;13:1-10. Epub 2008/08/20.

24. Scheer JH, Adolfsson LE. Radioulnar laxity and clinical outcome do not correlate after a distal radius fracture. J Hand Surg Eur Vol. 2011;36:503-8. Epub 2011/04/07.

25. Gong HS, Cho HE, Kim J, Kim MB, Lee YH, Baek GH. Surgical treatment of acute distal radioulnar joint instability associated with distal radius fractures. J Hand Surg Eur Vol. 2015;40:783-9. Epub 2015/06/04.

26. Andersson JK RB, Karlsson J. Level of evidence in wrist ligament repair and reconstruction research: a systematic review. J Exp Orthop. 2018;Jun 7;5 (1): 15.

27. Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg Br. 1997;22:638-43.

28. Mrkonjic A, Lindau T, Geijer M, Tagil M. Arthroscopically diagnosed scapholunate ligament injuries associated with distal radial fractures: a 13- to 15-year follow-up. J Hand Surg Am. 2015;40:1077-82.

29. Brogren E, Hofer M, Petranek M, Wagner P, Dahlin LB, Atroshi I. Relationship between distal radius fracture malunion and arm-related disability: a prospective population-based cohort study with 1-year follow-up. BMC Musculoskelet Disord. 2011;12:9. Epub 2011/01/15.