Distal Radioulnar Joint:
Arthroplasty and Strength assessments

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ABSTRACT

The growing interest in distal radioulnar (DRUJ) disorders underlines the need for further improved evaluations of treatment outcome. Load-bearing and optimising torque are important features of the DRUJ, but they are rarely measured when assessing DRUJ interventions. To make these measurements easily accessible in clinical situations, we developed two methods for quantifying lifting strength and forearm torque. In this thesis, we report the outcomes after surgery with two types of DRUJ implant arthroplasty and the result of our evaluation of the new strength measurement methods.

In Study I, we reviewed 21 patients treated with the Herbert ulnar head prosthesis and, in Study II, we included nine patients treated with the Scheker total DRUJ prosthesis after previously failed DRUJ surgery. For both types of arthroplasty, the patient-reported outcome was satisfactory, scores for pain were low and there were no signs of radiographic loosening. There was one re-operation (Herbert prosthesis), but no other major complications.

In Study III, we assessed the reliability and validity of our methods in quantifying lifting strength and forearm torque. Intraclass correlation coefficient calculations showed that the inter- and intrarater reliability was excellent and the new methods were also valid when the Baltimore Test Equipment was used as a reference.

In Study IV, we measured 499 healthy volunteers to obtain normal values for our new test methods. Normative data were defined and we were able to compute predictive equations based on gender, age and height.

In Study V, we evaluated the responsiveness and validity of the new strength measurement methods in 18 patients treated with DRUJ implant arthroplasty. We found that forearm torque was more sensitive to change than grip strength. Forearm torque also had a stronger correlation to the other outcome variables.

In conclusion, it was confirmed that the Herbert and Scheker implants are efficient and safe, in the mid-term perspective, in a selected group of patients. Our methods for measuring strength for lifting and forearm rotation were reliable and valid and normative values were defined. Forearm torque outperformed grip strength in the evaluation of DRUJ implant arthroplasty.

Keywords
Distal radioulnar joint arthroplasty, Forearm torque and lifting strength measurements, Normative data, Reliability, Validity, Responsiveness

SAMMANFATTNING PÅ SVENSKA

Utvärdering av resultatet efter behandling av olika sjukdomar och skador i den distala radioulnara leden har varit bristande och behöver förbättras. Distala radioulnara leden har en viktig funktion speciellt när underarmen belastas eller vrids med kraft. Dessa egenskaper mäts dock sällan varken före eller efter genomgången behandling. För att möjliggöra enkel och snabb klinisk mätning av dessa parametrar utvecklade vi två metoder med avsikt att kvantifiera lyftstyrka och underarmens vridmoment. I denna avhandling rapporterar vi resultaten efter protesersättning av den distala radioulnara leden med två olika ledimplantat och en validering av de nyutvecklade metoderna för att testa styrka, för vilka vi fastställt normalvärden utifrån en normalpopulation.

I studie I utvärderade vi 21 patienter som opererats med med ulnaprotes av typ Herbert. I studie II utvärderade vi nio patienter som opererats med distal radioulnar ledprotes av typ Scheker på grund av tidigare misslyckad kirurgisk behandling. Efter båda typerna av operation rapporterade patienterna låg smärtnivå och hög grad av nöjdhet. Vi fann inga tecken till proteslossning. En patient med Herbert protes fick reopereras i övrigt registrerades inga allvarliga komplikationer.

I studie III analyserade vi reliabilitet och validitet för våra nya metoder att mäta lyftstyrka och underarmens vridmoment. Beräkningar av Intra Class Correlation Coefficients visade att reliabiliteten för en och samma, samt mellan olika bedömare var utmärkt. De nya metoderna var också valida baserat på jämförelser med referensmetoden.

I studie IV mätte vi 499 friska försökspersoner för att fastställa normalvärden för våra nya testmetoder. Normaldata definierades och prediktiva ekvationer kunde konstrueras utifrån parametrarna kön, ålder och kroppslängd.

I studie V analyserade vi våra nya styrketestmetoders validitet samt hur väl de avspeglade en kliniskt relevant förändring efter genomgången behandling med DRU ledprotes. Arton patienter som behandlats med distal radioulnar ledprotes och mätts med våra nya mätmetoder, utvärderades. Vi fann att underarmens vridmoment hade en högre korrelation till förbättringsgraden efter operation baserat på patient rapporterade utfallsmått, jämfört med greppstyrka .

Sammanfattningsvis kunde vi konstatera att Herbert och Scheker proteserna fungerade väl och medförde låg komplikationsrisk för en utvald grupp av patienter i ett medellångt perspektiv. Våra metoder för att mäta lyftstyrka och underarmens vridmoment var reliabla, valida och normalvärden definierades. Underarmens vridmoment var en bättre parameter för att utvärdera distala radioulnara ledledproteser än greppstyrka.

LIST OF PAPERS

This thesis is based on the following studies, referred to in the text by their Roman numerals.

I Axelsson P, Sollerman C, Karrholm J.
Ulnar Head Replacement: 21 Cases; Mean Follow-Up, 7.5 Years.
J Hand Surg Am. 2015;40(9):1731-8.

II Axelsson P, Sollerman C.
Constrained implant arthroplasty as a secondary procedure at the distal radioulnar joint: early outcomes.
J Hand Surg Am. 2013;38(6):1111-8

III Axelsson P, Karrholm J.
New methods to assess forearm torque and lifting strength: reliability and validity.
(In press, J Hand Surg Am.)

IV Axelsson P, Fredrikson P, Nilsson A, Andersson JK, Karrholm J.
Forearm torque and lifting strength: normative data.
(In press, J Hand Surg, Am.)

V Axelsson P, Sollerman C, Karrholm J.
Validity and responsiveness of forearm strength measurements in the evaluation of distal radioulnar joint implant arthroplasty.
(In manuscript)

Additional relevant paper by the author not included in this thesis:

Andersson JK, Axelsson P, Stromberg J, Karlsson J, Friden J.
Patients with triangular fibrocartilage complex injuries and distal radioulnar joint instability have reduced rotational torque in the forearm.
J Hand Surg Eur Vol. 20116;41(7):732-8.

CONTENTS

ABBREVIATIONS

BTE	Baltimore Therapeutic Equipment
CR	Conventional radiographs
CT	Computed tomography
DRUJ	Distal radioulnar joint
ES	Effect size
IOM	Interosseous membrane
MRI	Magnetic resonance imaging
OA	Osteoarthritis
PRUJ	Proximal radioulnar joint
RA	Rheumatoid arthritis
RC	Radiocarpal joint
ROM	Range of motion
SRM	Standard response mean
TFCC	Triangular fibrocartilage complex
UC	Ulnocarpal

DEFINITIONS

Accuracy	The closeness of agreement between a test result and an accepted reference value or the true value
Bias	A systematic error or deviation from results. It can be corrected by calibration.
Bland-Altman plot	(difference plot) A method for analysing agreement between measurements. It identifies the mean difference (bias) between measurement methods, the fluctuation around the bias and outliers
Concurrent validity	A type of criterion validity that measures how well a (new) test/instrument correlates with a validated test measuring the same aspects, preferably to a "gold standard"
Construct validity	The extent to which a test or an instrument behaves as anticipated, measures what it is supposed to and whether it supports the underlying construct. It is established by examining associations with other variables that are expected to be related to it.
Content validity	The extent to which a test or an instrument covers all the essential areas or components of the concept for which the measurement is intended
Criterion validity	The extent to which a test is related to one outcome
DASH	Disability of the Arm, Shoulder and Hand. A regional outcome instrument that quantifies pain and disability in the upper extremities
Disability	Lack of ability to perform activities due to the impairment
ES	Effect size (mean change/standard deviation of the baseline value)
Force	An influence that causes an object to accelerate or deform. A force is a vector (has both magnitude and direction). Force is the amount of power a muscle or a group of muscles is able to generate. Unit: Newton (N)
Impairment	Abnormal function due to disease or injury
Inter-rater agreement	Variation between observers
Intraclass correlation	A statistical method that analyses the agreement of data structured as groups. The strength of correlations is computed as intraclass correlation coefficients, ICC.
Intra-rater agreement	Variations between observations for the same observer
Isometric (static) measurement	Recording of strength or force produced by muscle contractions without a change in their muscle lengths and thereby without motion
Load	The forces to which a given structure or object is subjected

MCID	Minimal clinically important difference. The minimal amount of change that is perceived as important or meaningful to the patient
Muscle power	The rate of doing work, the product of muscle force and contraction velocity. Work per time unit.
Muscle strength	The ability of a muscle to generate force. Strength = force output
Observer bias	(detection bias) arises when a researcher (usually unintentionally) influences the result.
Performance bias	Arises when a researcher/surgeon influences the care of the patient (usually unintentionally).
Precision	The closeness of agreement between repeated independent test results under unchanged conditions
PROM	Patient-Reported Outcome Measurement. An instrument used in a clinical trial or setting for the evaluation of outcome, where the responses are collected directly from the patient without interference from clinician, or others.
PRWE	Patient-Rated Wrist Evaluation. A wrist-specific outcome instrument that quantifies pain and disability
Reliability	The degree to which an assessment tool produces stable and consistent results
Repeatability	The variation in repeated measurements made on the same subjects under identical conditions. The variability can be ascribed to the measuring process.
Reproducibility	The variation in measurements made on the same subject under changing conditions, i.e. different raters or measurement methods
Responsiveness	The responsiveness of a scale or instrument is its ability to measure change in a clinical state.
Selection bias	Occurs when the subjects included in a study are not truly representative of the target population.
SRM	Standard response mean (mean change/standard deviation)
Torque (moment)	A force, or the measurement of a force, that produces or tends to produce rotation or torsion. Torque is a vector. SI unit: Newton-metre (Nm) Imperial unit: pounds-feet (lbs-ft). 1Nm = 0.74 lbs-ft
Validity	The extent to which an instrument measures what it is intended to measure and is free from bias
VAS	Visual Analogue Scale. An instrument to quantify the intensity or frequency of subjective characteristics believed to range across a continuum of values

"When you can measure what you are speaking about and express it in numbers, you know something about it"

– William Thomson, Lord Kelvin, Lecture on "electrical units of measurement" May 1883

01 INTRODUCTION

01

INTRODUCTION

1.1 Background

Since almost a century, the traditional treatment for a severely dysfunctional distal radioulnar joint (DRUJ) has been resection arthroplasty. A simple resection of the distal ulna was popularised by Darrach (1913) and this operation quickly became widespread and has withstood the test of time. The fusion of the DRUJ is not an option, as the complete loss of forearm rotation is severely disabling. Resection of the distal ulna often produces satisfactory results, especially in patients with low load-bearing requirements[1]. As a result, the "Darrach procedure" is still commonly performed in rheumatoid patients and sometimes in post-traumatic conditions. In patients with an active lifestyle, the risk of failure is higher and the disability may actually become worse, as the dynamic instability might lead to painful impingement of the distal forearm bones. This was noted at an early stage and several variations of resections with or without soft-tissue stabilisation or interposition were developed.

Examples of these procedures include the Watson procedure, the Bowers procedure and the Sauvé Kampandji procedure [2-4]. However, all types of distal ulnar resection suffer from the same problem, which is the lack of solid support for the loaded distal radius. The absence of an even joint surface also interferes with the smooth rotational movement of the radius. Furthermore, the ulnar head is needed to separate the radius from the ulna to create tension in the soft-tissue restraints needed for distal forearm stability [5, 6]. As the importance of the ulnar head was recognised, attempts with artificial replacements were initiated. The first commercially available implant was the Swanson silastic implant [7]. Initially, the results appeared promising, but it soon emerged that the failure rate was unacceptably high due to dislocations, implant breakage and synovitis. This implant was soon abandoned and replaced by metal-based implants. The first of these were the Herbert ulnar head prosthesis (Herbert UHP) and the Avanta U-head prosthesis [8, 9]. The early results with these implants were encouraging, in both the short- and mid-term perspective. Laboratory studies have supported this concept of a hemi-arthroplasty of the DRUJ joint [10, 11], but, in cases with gross instability or destruction of both joint surfaces in the DRUJ joint, the concept of hemi-arthroplasty is less successful. Another implant with properties of total joint arthroplasty is represented by the Scheker implant [12].

At our Department of Hand Surgery at Sahlgrenska University Hospital, we started using the Herbert UHP in 2000 and the Scheker total DRUJ prosthesis in 2006 for carefully selected patients. We assessed the clinical and radiographic results of the Herbert and Scheker implants and have presented them in two scientific reports [13, 14].

During these studies, we identified a need for more objective, accurate assessments of DRUJ function. Physical assessments of wrist or forearm disorders or their treatments are usually confined to measurements of range of motion (ROM) and grip strength. Load-bearing and optimising torque are important features of the DRUJ, but they are still rarely presented in scientific evaluations, probably because there is no agreement on how to quantify them objectively. Work simulators such as the Baltimore Therapeutic Equipment (BTE) and the Cybex are sometimes used for these strength measurements, but this equipment is expensive, stationary and occupies space. Some laboratories have used smaller, simpler devices to quantify forearm torque, but these instruments have been custom built and are not commercially available [15-17]. A simple, reliable method for measuring lifting strength and forearm rotational strength would improve the evaluation of different surgical methods related to the DRUJ. We therefore designed two new test procedures that would be quick and easy to use, for measurements of lifting strength and forearm rotational strength, in the clinical setting. The purpose of Studies III-V was to evaluate these test methods and define their normal values.

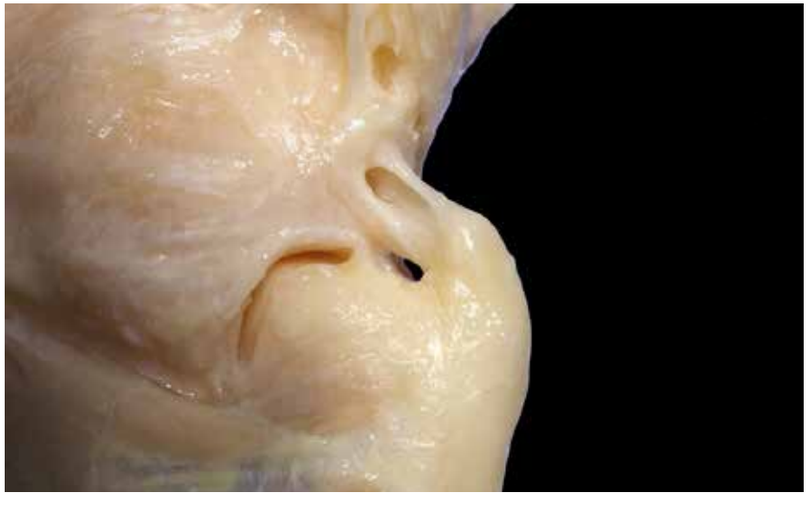


Figure 1. DRUJ, close up, specimen. Courtesy Dr. Makoto Tamai.

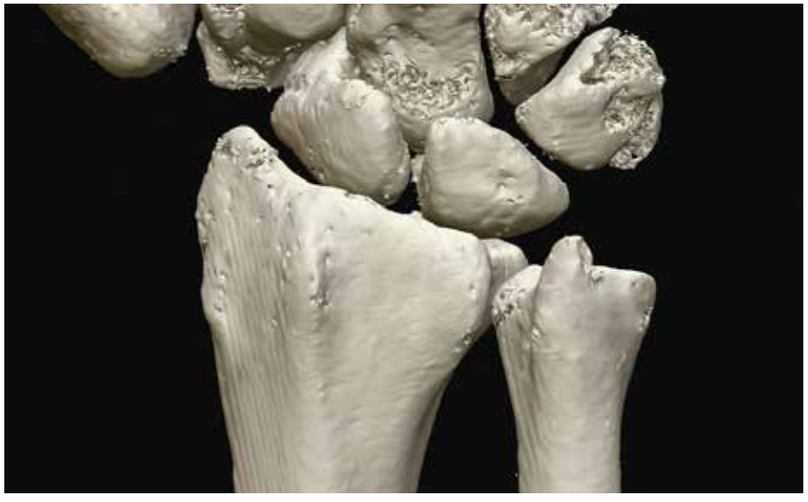


Figure 2. DRUJ, dorsal 3D view.

1.2 Anatomy

The two forearm bones, the radius and the ulna, are connected at two articulations, the distal radioulnar joint (DRUJ) and the proximal radioulnar joint (PRUJ). These joints permit the radius to rotate around the "fixed" ulna and can be regarded functionally as a single "forearm joint" [18]. The total arc of rotation is about 180 degrees and this is possible due to the bow of the radius *(Fig. 3)*.

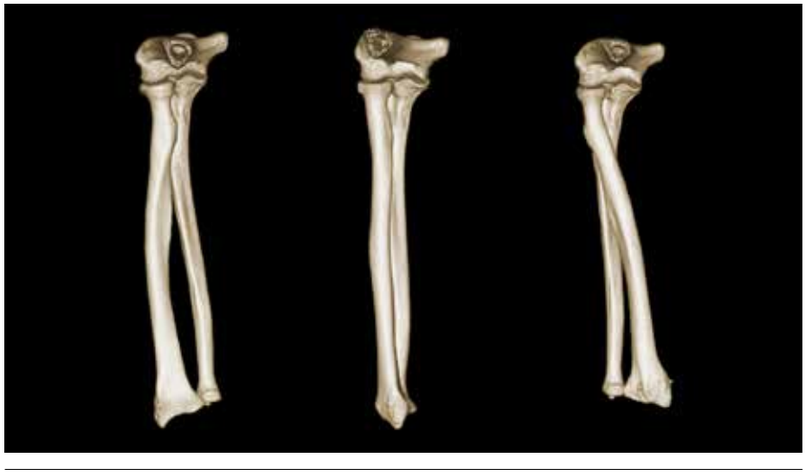


Figure 3. 3 D Views of forearm bones; neutral, supinated and pronated position.

The hand is primarily attached to the radius and follows its motion. The axis of rotation passes roughly through the centre of the radial and ulnar head *(Fig. 4)* [19].

There is a "third connection" between the forearm bones, the interosseous membrane (IOM) *(Fig. 5)*. The IOM, the ligaments located at the radioulnar joints and the osseous anatomy act as an integrated osseoligamentous system in stabilising the forearm bones in relation to one another and distributing applied loads [20].

Figure 4. Forearm bones, axis of rotation.

Figure 5. The interosseous membrane ©.

There are anatomic variations of distal radioulnar joint, which need to be taken into consideration when dealing with injuries and treatment [21, 22] *(Fig. 6)*. The sigmoid notch is shallow and the difference in radius between the distal radial notch and the ulnar head makes the DRUJ incongruent [23]. About two thirds of the ulnar head are covered by hyaline cartilage.

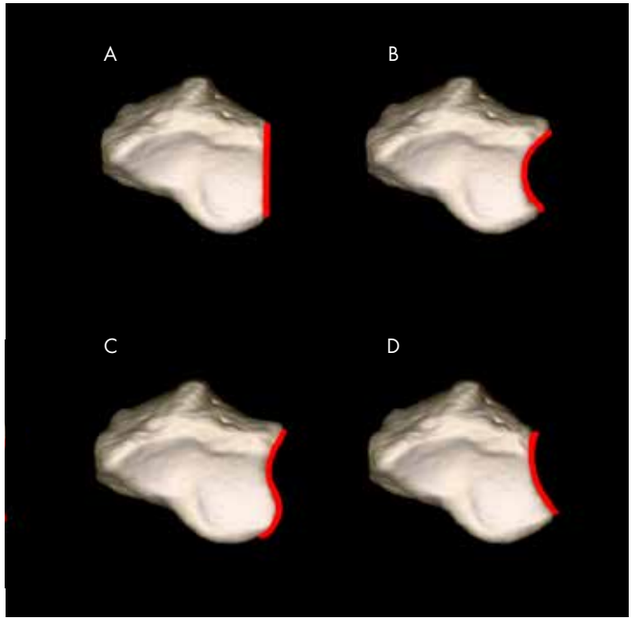


Figure 6. DRUJ Sagittal view, Notch types according to Tolat et al. J Hand surg Br 1996. A Flat face; B C-type; C S-type; D ski slope.

1.3 Biomechanics

1.3.1 Range of motion

Rotation of the forearm is an essential part of the ability to position the hand in space in order to grasp. In addition to the opposing thumb, forearm rotation has been of immense value through evolution.

1.3.2 Stability

Stability is a prerequisite when it comes to enabling load bearing and the transmission of force. The geometry of the DRUJ makes it inherently unstable, especially in the extremes of rotation where only about 10% of the joint surfaces are in contact [24]. *(Fig. 7)*. The soft-tissue restraints are therefore of paramount importance when it comes to providing stability. These stabilisers can be "passive" contributors, such as the TFCC and the IOM, or "active", such as the PQ and ECU [25].The primary constraining ligaments that ensure that the forearm bones remain together in loaded rotation conditions are the TFCC, IOM and the annular ligament. The ulnar head is kinetically important as the "fixed point" that acts as a fulcrum to permit load bearing [18]. It is also the anchor point for the

most important ligaments, like the TFCC and ulnocarpal ligaments, which keep the bones together. Furthermore, the ulnar head maintains the separation needed to tension the ligaments throughout full range of motion (ROM).

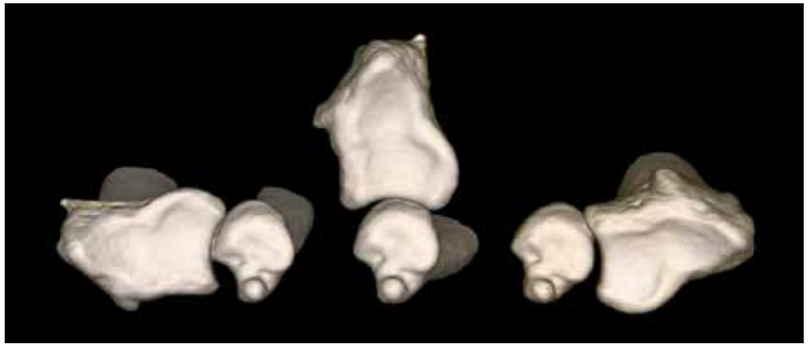


Figure 7. DRUJ Sagittal 3D view, contact area in supinated, neutral and pronated position ©.

1.3.3 Load

Apart from motion, it is also crucial that the forearm is able to manage loads and transfer forces. These forces can be a reaction to gravitation while lifting an object or can be created by muscles when twisting an item. Several types of force can act in the DRUJ when the forearm is loaded. Axial forces travel along the forearm from the carpus to the ulna via the TFCC [26]. Compressive forces are greatest in mid-rotation, while shearing forces affect the DRUJ in the palmar-dorsal direction and are greatest in full pronation or supination [27] *(Figure 8)*. Reaction forces are the sum of the forces from the load and counterforces from the muscles that act on the DRUJ. For example, when lifting an object with neutral rotation of the forearm, the gravity does not simply cause the radius to "fall" on the ulnar head. When M. brachialis lifts the ulna, the biceps brachii and the brachioradialis muscles act on the radius, thereby reducing compression forces in the DRUJ. The reaction forces are therefore a force balanced by different muscles and thereby usually far less than the loading forces. The fact that some patients with an unstable, damaged or missing DRUJ manage to "balance out" loads applied to the forearm and reduce the forces acting on the DRUJ by using a well-functioning neuromuscular system is probably the main reason why they experience far fewer symptoms than others [5]. Our knowledge of the forces acting in the DRUJ in vivo is limited, even if some cadaveric studies have been presented [24, 28, 29].

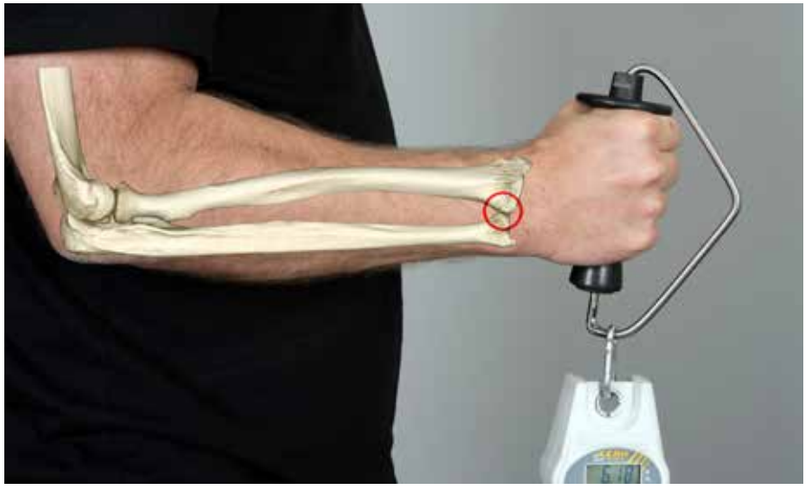


Figure 8. Location of compression forces during lifting ©.

1.3.4 Neuromuscular function

Several muscles contribute to DRUJ stability and also influence the loading of this joint by generating forces that result in forearm rotation. Muscles generally regarded as primary pronators are pronator quadratus and pronator teres. Additional contributors to pronation are brachioradialis, flexor carpi radialis and palmaris longus. The primary supinators are biceps brachii and the supinator with abductor pollicis longus acting as a secondary contributor[30].

It should be noted that biceps brachii only supinates when the elbow is flexed, that pronator teres is strongest with the elbow flexed and that the action of brachioradialis is the subject of debate in relation to forearm rotation. The primary elbow flexors are M. brachialis, biceps brachii and the brachioradialis. The pronators are mainly innervated by the median nerve and the supinators by the radial and musculocutaneous nerves.

1.4 Radiographic imaging *(Fig. 9)*

In the evaluation of DRUJ function, conventional radiography (CR) is one of the most important methods for assessing the anatomy and identifying pathological features of the joint *(Fig. 10)*.

The structure of the DRUJ and its effect on wrist function were described by Ekenstam and Hagert [23], who were pioneers in defining the normal architecture of the DRUJ. They highlighted the role of the ulnar head as the pivotal point of the wrist joint and analysed the consequences of the differences in radius between the ulnar head and the sigmoid notch. Sagerman and Tolat made important discoveries when they explored the geometry of the DRUJ and defined how joint

angles and different shapes of the sigmoid notch might influence the outcome of interventions[21, 22]. Scheker and Lees made a significant contribution to our knowledge of the mechanism for loading and the failure of ablative procedures at the DRUJ when they radiographically visualised "radioulnar impingement syndrome" [12] *(Fig. 11)*.

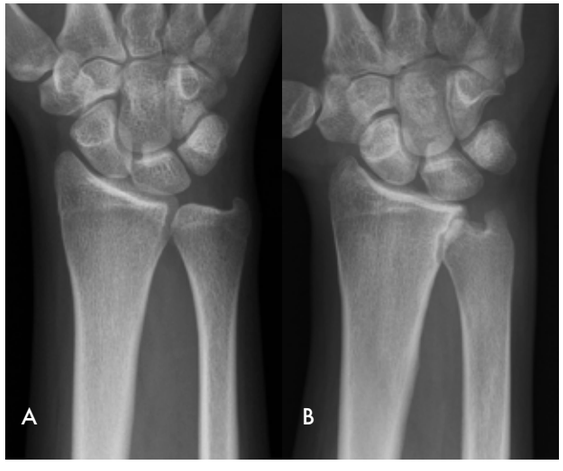


Figure 9. Wrist radiographs. A Normal DRUJ, B Osteoarthritic DRUJ.

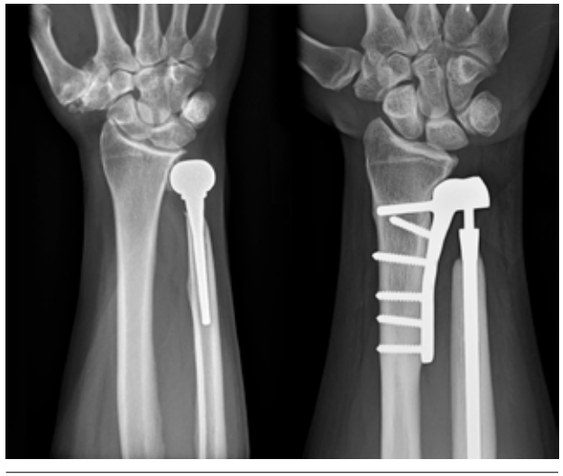


Figure 10. A Herbert UHP, B Scheker total DRUJ prosthesis ©.

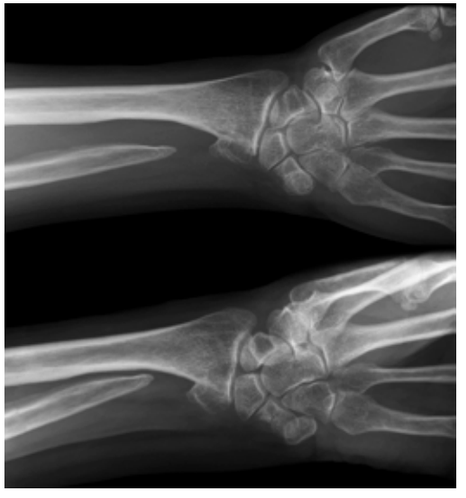


Figure 11. "Dynamic impingement" as demonstrated by Lees and Scheker. Unloaded condition and while lifting 1 kg.

Conventional radiography has proven to have high reliability and sensitivity regarding pathological changes in osteoarthritis and rheumatoid arthritis, where numerous studies of different scoring systems have been published [31-33].

Knowledge of the incidence of pathological findings and patterns of radiographic changes in the DRUJ in the general population is, however, limited. Some studies have found that the association between radiographic findings and clinical symptoms from wrist disorders is weak [31, 32, 34, 35]. The reliability and validity of CR in relation to DRUJ dysfunction appear not to have been analysed, apart from some studies of ulnar head abutment syndrome [36, 37]. Conventional radiography shows a weak association with impairment and symptoms of different types of DRUJ disorder and this is not completely unexpected, as soft-tissue problems and dynamic conditions are often the main cause. Kakar et al. performed a detailed analysis of the preoperative radiographic features of the DRUJ and changes after arthroplasty [38]. They claimed that radiography could be used to assess instability of the DRUJ. However, they were not able to correlate radiographic factors such as ulnar variance and implant dislocation to outcome measurements. Herzberg investigated radiographic changes at the distal ulna and the sigmoid notch after ulnar head arthroplasty and concluded that these changes were common but benign [39]. At present, there is no consensus on the radiographic changes that are important outcome predictors of implant survival after DRUJ arthroplasty. The development of these criteria is an important task, but it will require larger series of

patients with DRUJ implants.

Even if CR is sensitive in detecting structural changes in the DRUJ, it only produces a two-dimensional image and overlapping therefore makes the assessment of the concave sigmoid notch difficult. Computed tomography (CT) delineates the cross-sectional anatomy of the DRUJ and might therefore be a superior method for evaluating DRUJ function [40] *(Fig. 12)*.

However, in the case of CT, doubts have also been raised about the association between radiographic findings and clinical variables [41]. We believe that CT might be more helpful than CR in the evaluation of DRUJ function, both before and after arthroplasty, but we have not been able to use it systematically in our studies. Nor did we find any published data on its usefulness for any treatment of the DRUJ. Kakar et al. used CT for some of their patients and found a 50% failure rate for ulnar head implants in patients with a flat sigmoid notch according to Tolat classification [38].

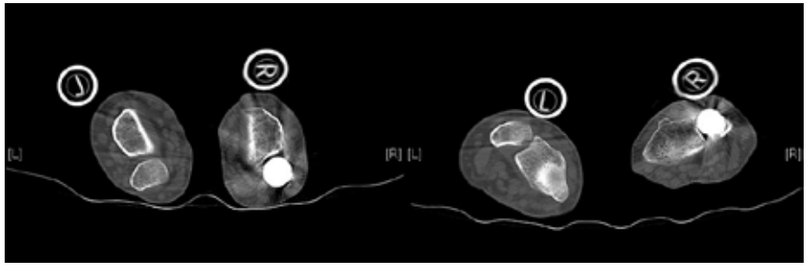


Figure 12. CT images showing position of Herbert prosthesis in neutral and pronated forearm rotation.

1.5 Clinical evaluation

1.5.1 Grip strength (Fig. 13)

Grip strength is probably the most frequent measurement used by hand surgeons and researchers as a determinant of specific and sometimes also general upper extremity function. Grip strength is a quick, easy quantitative test. It has shown high reliability in many studies, with test-retest coefficients above 0.90 [42-45]. Beaton et al. compared the Jamar and BTE instrument and found excellent ICCs, which was confirmed in our study [46]. There are many large studies that have investigated normative values for grip strength in different populations [47-51]. However, we are only aware of one study that has addressed the question of MCID for grip strength. In this study, Kim et al. found that a change of less than 6.5 kg, which was about 20% of the total strength, may not be relevant [52]. It has to be noted that their analysis was based on a traumatic

condition, distal radius fracture, where the majority of the patients were older women. Regarding the validity for different upper extremity conditions and responsiveness to change in relation to treatment, reports have been more infrequent and have had more varied results Karnezis found that grip strength was associated with changes in the PRWE after distal radius fracture [53]. Grip strength is often measured in studies of DRUJ treatment, despite the fact that very little is known about the extent to which grip strength mirrors DRUJ function.

Figure 13. Grip strength testing with the Jamar dynamometer ©.

1.5.2 Provocation tests (Fig. 14)

Provocation tests are essential in diagnosing dysfunction and for assessing interventions. There are several tests that assess wrist function and, even if they are empirically valuable, most have not been properly validated. Most tests primarily assess the presence or absence of instability and only a few of them relate to ulnar-sided wrist pathology [54]. We used the radioulnar ballottement test to assess instability for our DRUJ arthroplasty studies [55]. This test is sometimes also referred to as the DRU test, DRUJ stress test, radioulnar stress test or DRUJ laxity test. The radioulnar ballottement test is performed with the patient's elbow at 90 degrees of flexion and the forearm in a vertical position. The examiner grasps the distal ulna and radius firmly with each hand and then tries to force the ulna in a palmar-dorsal direction with respect to the radius. This manoeuvre is repeated with the forearm in full supination, pronation and in a neutral position. Testing in a neutral position is also performed with the wrist deviated radially, as suggested by Sanz and the Derby group. This pretensioning of the ulnocarpal ligaments facilitates their assessment.

The findings are compared with the contralateral side and excessive displacement, pain or apprehension is suggestive of ligament injury. The ballottement test has shown fair to moderate correlations with instability and pathology assessed by CT and arthroscopy [41, 54, 56]. Lindau et al. found that the ballottement test had good inter-rater agreement and correlated with unfavourable outcome after distal radius fracture but not radiographic findings [57]. Scheer and Adolfsson, who also analysed the results after distal radius fractures, did not find that the test correlated to outcome measured by the DASH [58]. Scheer and Adolfsson underlined the fact that hypermobility is not "necessarily correlated to symptoms".

Figure 14. DRUJ ballottement test ©.

1.6 New methods developed to measure strength

1.6.1 New method - lifting strength (Fig. 15)

Gripping and lifting are two of the main functions of the upper limbs. Gripping strength has been extensively investigated and is commonly used in clinical evaluations, often as a measurement of general upper extremity function, but lifting strength is rarely assessed.

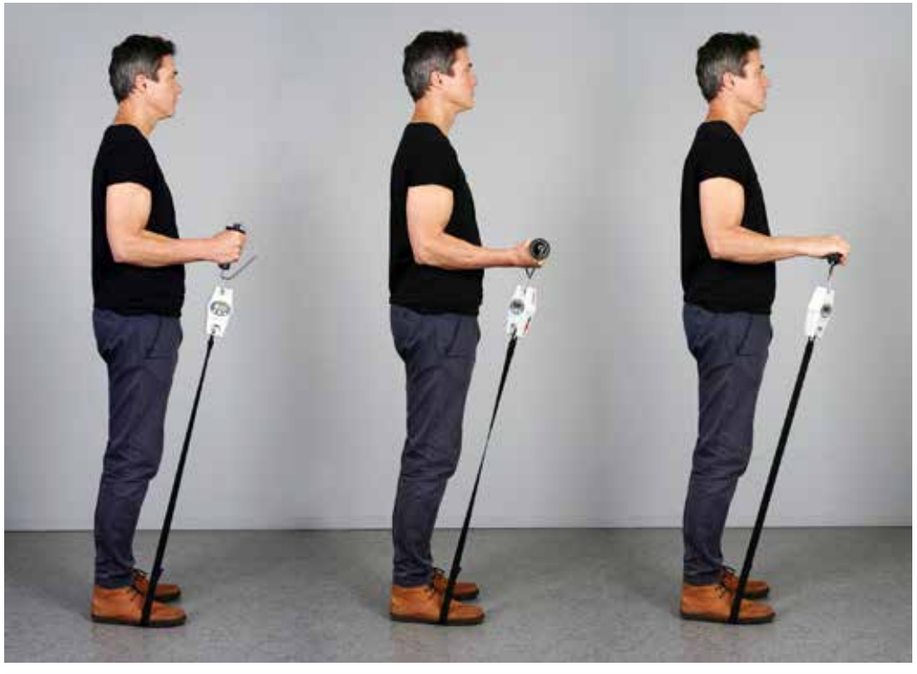


Figure 15. Lifting strength measurement using Kern dynamometer. Neutral, supinated and pronated position ©.

Loads that pass through the DRUJ from the hand and further proximally have been studied during certain activities, but knowledge in this field is limited [24, 28, 59]. To improve diagnostics, the preoperative evaluation and follow-up of the treatment of DRUJ disorders, I initiated a project to develop objective testing procedures for lifting capacity and forearm rotation *(Fig. 16)*.

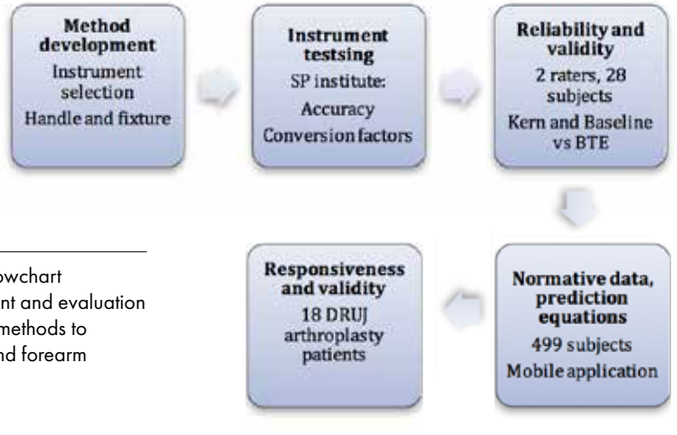


Figure 16. Schematic flowchart illustrating the development and evaluation of the Kern and baseline methods to measure lifting strength and forearm torque.

The first experiments on loading the forearm were performed in 2005. The primary method meant that the patients lifted weights of increasing amounts from a table to test lifting capacity *(Fig. 17)*.

This method was abandoned at an early stage, as it did not appear accurate enough for research purposes. Instead, a different concept using a hanging scale type of dynamometer was developed. In 2006, I started using the Daiwa Mission scale hanging dynamometer for assessments of lifting strength *(Fig. 18)*. I evaluated a series of nine Scheker arthroplasties (Study II) pre and postoperatively, with this device, but the data could not be published because the method had not been validated.

Figure 17. Scheker arthroplasty patient during lifting strength test in 2006. With permission from the patient.

Figure 18. Lifting strength measurement using Daiwa Mission dynamometer.

In 2012, I decided to abandon the Mission scale for several reasons. Strength could only be measured in neutral forearm rotation and there were ceiling effects and uncertainty about its accuracy and quality. At this time, I had found the Kern hanging scale dynamometer (KHCB 50kg/20g, Kern & sohn GmbH, Balingen, Germany) that was used for industrial purposes *(Fig. 19)*. A new and specific handle was constructed to allow easy changes between testing in the neutral, supinated and pronated position *(Fig. 20) (Appendix 1)*.

The Kern dynamometer was evaluated by the SP Technical Research Institute of Sweden and the maximum error during stepwise calibration up to 500 N (maximum range of the instrument) was found to be 1% *(Appendix 2)*. A standardised testing procedure that included examination in the standing position, straight wrist position, 90 degrees of elbow flexion and fully adducted upper arm was formulated. A handle is attached to the top of the Kern dynamometer

Figure 19. The Kern dynamometer.

Figure 20. Custom-made handle used with the kern dynamometer.

with an inflexible strap at the bottom, which is fixed to the floor by the subject's foot. Before use, the strap is pretensioned with the upper limb in the desired position. This creates a rigid unit with the Kern dynamometer in between and peak strength can be quantified.

A first study was initiated to assess the reliability and validity of our instrument (Study III). Intraclass correlation coefficients for two raters on repeated test occasions and based on studies of 28 subjects showed that our methods were reliable and valid when compared with a BTE work simulator that was used as a standard reference. In a subsequent study, we defined normal values for a Swedish population of 499 healthy subjects (Study IV). We were able to create prediction equations based on gender, age and height. In a third study of our methods (study V), we compared the sensitivity to change and correlation to other outcome variables, when used to evaluate DRUJ implant arthroplasty. Lifting strength was significantly correlated to improvements in the PRWE and pain during activity. Torque strength had still stronger correlations, whereas grip strength did not correlate to any of the outcome measurements or strength tests. Responsiveness to the grip and lifting strength tests was similar.

1.6.2 New method – forearm torque (Fig. 21)

The ability to rotate the forearm with various forces is an essential upper limb function. Congruent and stable distal and proximal radioulnar joints, normally aligned forearm bones and intact neuromuscular function are important factors for optimal forearm rotational strength. Measuring torque could therefore be an indirect way of assessing the functions of joints, muscles and nerves involved in forearm rotation. Reduced torque strength can also reflect the presence of pain during this action.

The importance of torque strength as a measurement of DRUJ function was recognised at an early stage and several researchers developed instruments to measure this parameter [15-17]. As these instruments were custom made and not available for purchase, I started experimenting with commercially available torque screwdrivers that could capture peak values. Experiments with Tohnichi screwdrivers (Tohnichi, MFG co 2-chome ota–ku, Tokyo, Japan) started in 2008 *(Fig. 22)*.

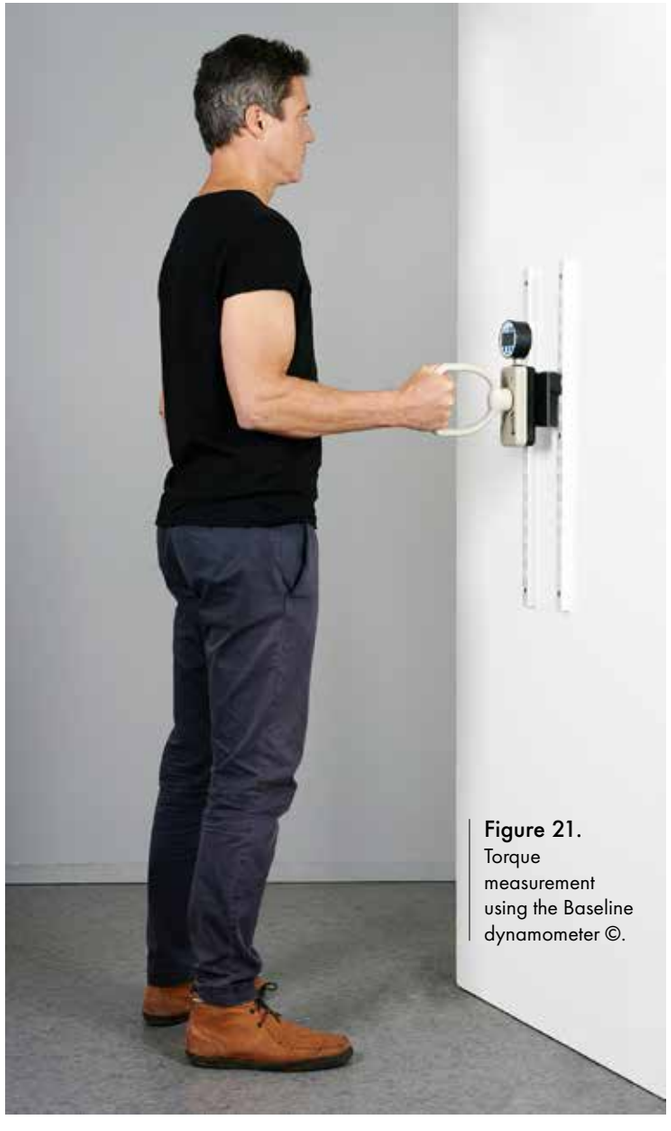


Figure 21. Torque measurement using the Baseline dynamometer ©.

Figure 22. Torque measurement using the Tohnishi screwdriver.

After some time, I realised that the ulnar deviation as a result of gripping a screwdriver might influence recordings and an extension that permitted forearm rotation with a straight wrist was therefore added to the screwdriver *(Fig. 23)*.

Figure 23. Tohnishi torque screwdriver with custom-made handle.

As there was uncertainty about the reproducibility of this testing technique related to the choice of appropriate screwdriver, this concept was abandoned when the Baseline wrist dynamometer caught my attention. The Baseline dynamometer was combined with a shovel handle in order to execute tests with a neutral wrist. To have immediate access to the Baseline dynamometer in order to make rapid measurements, an attachment plate was made for wall placement *(Fig. 24) (Appendix 3)*.

Figure 24. Attachment plate used with the Baseline dynamometer.

With this fixture, we were able to mount the Baseline on rails in order to adjust it according to the subject's height *(Fig. 25)*. In this way, the Baseline could also be placed out of the way for ordinary examination procedures. A bar has since been added to the attachment plate for table mounting if necessary *(Fig. 26)*. The attachment plate is easy to manufacture and blueprints can be found in the appendix. Our first clinical measurement with the Baseline method was made in April 2010.

One major issue with the Baseline dynamometer is that the readout is in kgs or lbs, which are not units of torque. I was not able to obtain a clear solution to this problem from the manufacturer. To be able to translate the Baseline kgs to Nm, I asked the SP Technical Institute of Sweden to test a new dynamometer. A stepwise calibration revealed a constant relationship of 0.053 ± 0.005 Nm/kg in the clockwise direction and 0.055 ± 0.004 Nm/kg in the counter-clockwise direction *(Appendix 4)*. With these conversion factors, we were able to compare our recordings with previous reports. With the aim of validating our Baseline test method for torque, we performed repeated measurements for direct comparisons of the same individuals with both the Baseline dynamometer and a BTE work simulator. The BTE was chosen as a reference as it was available at our department and is an established device for measuring different types of strength performance.

The new torque measurement method was found to be valid and previous tests showed excellent intra- and inter-rater reliability. We have therefore initiated assessments of different types of forearm disorder using this technique. Our preliminary evaluation of suspected TFCC injuries showed that confirmed injuries had about 30% lower forearm torque [60]. A recent review of a series of DRUJ implant arthroplasties demonstrates that forearm torque is more responsive and has a stronger correlation to other outcome parameters than grip strength.

We have obtained normative data for our method of testing torque. Comparisons with other studies have been challenging due to the diversity of techniques for measuring torque, differences in study populations and units used in reports.

Figure 25. Baseline dynamometer with shovel handle, wall-mounted on rails.

Figure 26. Table mounted Baseline dynamometer.

1.7 Patient-reported outcome measurements

Previous evaluations of injuries, diseases and treatments of the upper extremities have focused primarily on physical examinations as judged by the examiner, measurements of grip strength and assessments of radiographs. Loss of function and impairment are frequently recorded, although disability is more important to the patient. This can only be reported by the patient and should be the most important parameter to estimate the success of interventions. Patient-reported outcome measurements (PROMs) have recently been more frequently incorporated into the evaluations of treatments and the need for extended incorporation has recently been emphasised [61, 62].

A PROM is a questionnaire used in a clinical trial or setting to evaluate disability, where the responses are collected directly from the patient without interference from clinicians, or others. This reduces observer bias. Another advantage is that PROMs enable comparisons between different upper extremity conditions and interventions. One weakness is that comorbidities may influence the scores, especially region-specific PROMs, such as the disability of the arm, shoulder and hand (DASH). In relation to wrist disorders, the DASH and the patient-rated wrist evaluation (PRWE) instruments appear most frequently in the literature [63].

The DASH is a regional outcome questionnaire that measures pain and disability in the upper extremities. It was first formulated in 1996 by Hudak and exists in many validated translations [64]. In our studies, we have used the Swedish version, which was validated by Atroshi et al. [65] *(Appendix 5)*. The DASH contains 30 items that measure functional status, symptoms and quality of life. The

questions relate to both upper extremities as a single functional unit. A score from 1-100 is calculated, where 0 represents zero disability and 100 the severest form of disability. The normal value for a DASH score in a non-clinical population has been reported to be between 10-13 [66, 67]. De Smet reported that a group of patients with "chronic wrist disorders" had a mean DASH score of 24. A patient group with ulnar impaction syndrome had a mean score of 42 [68].

The reliability, repeatability, internal consistency and validity of the DASH instrument have been extensively investigated and deemed acceptable for several upper extremity pathologies [44, 65, 69]. Some studies of wrist conditions have reported that the DASH has acceptable responsiveness, even if it is not as good as disease-specific outcome tools [44, 70]. Gupta et al. found that the DASH was highly correlated to the PRWE ($r = 0.79$ and 0.9), but the association with pain was somewhat lower ($r = 0.67$) [71]. De Smet studied the outcome of 205 wrist operations and found that the DASH had a significant correlation to grip strength ($r = 0.47$) but a weak correlation to ROM ($r = 0.24$) [72]. Jester et al. made similar observations [67]. In a systematic review, Scoeneveld found low correlations between the DASH and impairment scores, whereas the responsiveness and correlation to joint-specific questionnaires were good [73]. The minimal clinical important difference (MCID) has been estimated to 10 points. [74]. One weakness of the DASH is that patients rate their ability to complete specific tasks, regardless of which hand they use for this purpose. As disease or injury in the dominant limb is expected to give a higher disability, it is likely that this will influence the scores and responsiveness of interventions. According to Kachooei et al. there is a small yet significant difference in the DASH score for one and the same condition, depending on whether or not the dominant side is involved [75].

The PRWE was described by MacDermid et al. in 1996 [76]. It was originally developed to measure pain and disability after wrist trauma. It contains 15 items that rate wrist-related pain and disability equally in functional activities. The questions only relate to the injured wrist. A score from 1 to 100 is calculated and the scores rise with increasing disability. The reliability of the PRWE has been investigated in several studies. MacDermid et al. and Schmitt et al. found excellent test-retest reliability with ICCs of > 0.9 [77, 78]. In a review article, Metha et al. were able to confirm that, in all the examined studies, the ICCs exceeded 0.75 and, in several of them, 0.9 [79]. The validity of the PRWE has most frequently been above 0.7 across studies [79]. Gupta found a strong correlation between the PRWE and the DASH for patients treated for distal radius fractures. The authors suggested that only the PRWE should be used, as the DASH is more sensitive to concomitant upper limb problems [71]. Boeckstyns compared the PRWE and quick DASH when used to evaluate wrist arthroplasties and found a strong correlation [80]. Three studies have reported

that the MCID for the PRWE is between 11.5 and 24 for distal radius fractures and groups with a variety of upper extremity conditions [74, 78, 81]. Kim and Park (2013) evaluated patients with ulnar impaction syndrome and determined that the MCID was 17. In a review by Metha et al. of the use of the PRWE for wrist and hand conditions, moderate to low correlations were found with radiological assessment, ROM and grip strength [79]. The responsiveness of the PRWE, reported as effect size, was high (above 0.8) in studies of distal radius fractures and also in studies of a variety of hand and wrist conditions. MacDermid found that the PRWE was more responsive to change after distal radius fracture than the DASH [82]. Changulani was able to confirm this observation in a study of wrist disorders, but, as expected, the DASH was found to be more sensitive when evaluating disorders involving multiple joints [83]. Omokawa showed that the PRWE was highly responsive and better than the DASH in detecting clinical changes after treatment for ulnar abutment syndrome [84]. They also found a significant correlation between improvement in the PRWE and satisfaction. Furthermore, they reported that improvement in the PRWE was significantly correlated to improvement in pronation-supination after treatment, whereas almost no correlation was found with grip strength or flexion-extension of the wrist [84].

Based on this review of the literature, it appears that the PRWE is a more suitable instrument to study disorders of the DRUJ when compared with the DASH. In our studies, we have used the Swedish version of the PRWE, which was validated by Wilcke et al. [85] *(Appendix 6)*.

1.8 DRUJ implant arthroplasty

Distal radioulnar prostheses can be classified as constrained (total DRUJ implant) or non-constrained (partial or complete ulnar head implants). In this thesis, we report our experiences from two prosthetic designs, each representing one of these two concepts.

1.8.1 The Herbert ulnar head prosthesis (UHP) (Fig. 27)

The Herbert UHP (Martin Medizin Technik, Tuttlingen, Germany) is a modular total head endoprosthesis with a ceramic head. The head is available in three different sizes, which fit any of the nine sizes of titanium-coated stems (three different thicknesses and three different neck lengths) that are press-fitted into the ulnar medullar cavity. The implant was designed by Dr. Timothy Herbert and the first patients were treated in 1995. The surgical technique and rehabilitation protocol have been described in detail by Van Schoonhoven et al. and Herbert and Schoonhoven [8, 86].

All ulnar head implants are non-constrained implants, as they are not attached to the radius. The ceramic head of the Herbert UHP prevents soft-tissue

attachment, whereby stability is completely dependent on a sufficiently tight capsuloretinacular flap. The position and shape of the contact area on the ulnar side of the radius are also of importance. The main concern with these implants is therefore their ability to achieve stable articulation between the radius and ulna, especially as the soft-tissue conditions can only be confirmed intraoperatively in the majority of cases. Other fears with ulnar head implants have been the risk of erosion of the prosthetic head into the ulnar facet of the radius and bone resorption beneath the collar of the implant. Mid-term reports have, however, found that these changes are self-limiting. It has been suggested that these phenomena are adaptive changes representing tolerable bone remodelling and stress shielding respectively [38, 39, 87].

Figure 27. Herbert ulnar head prosthesis ©.

1.8.2 The Scheker total joint prosthesis (Fig. 28)

The Scheker DRUJ prosthesis, also referred to as the Aptis implant, is a modular total DRUJ prosthesis. The implant was developed and designed by Dr. Luis Scheker. The ulnar component consists of a long titanium plasma-sprayed stem that is press-fitted into the ulnar medullar cavity. The distal end of the stem is a highly polished peg that fits inside an ultrahigh molecular weight polyethylene ball. The radial component is made of a cobalt chromium alloy and is fixed by a peg and screws to the ulnar side of the distal radius. The distal end of the radial plate consists of a hemi-socket. A cover with a corresponding hemi-socket is fitted intraoperatively to secure the polyethylene ball inside the radial component. Because the peg on the ulnar stem is locked inside the central tunnel of the ball, which is locked by the cover of the radial component, stable linkage is created between the distal radius and ulna. This constrained construction prevents the separation of the distal radius and ulna. It allows full rotation, axial translation and physiological angulation in the distal radioulnar articulation but prevents the normal palmar-dorsal sliding of the distal radius in relation to the ulna. The distal radius and ulna are permanently and in all forearm positions firmly connected to one another, but, due to the multi-dimensional motions that are actually allowed, this prosthesis has been described as "semi-constrained". There is, however, no consensus on or clear definition of what this term actually means. Until some agreement is reached on this matter, we discourage the use of the term "semi-constrained" to avoid further confusion.

The Scheker prosthesis has several unique features. It replaces the whole DRUJ, namely the distal ulna, the sigmoid notch of the radius and the TFCC, with secondary soft-tissue stabilisers. The long ulnar stem makes it useful, even when a large portion of the ulna is missing. The radial component makes the surgeon largely independent of any structural damage in the sigmoid notch area. The constrained construction is perhaps the most useful feature, as it makes the arthroplasty completely independent of the soft-tissue conditions. This is beneficial, as the DRUJ is susceptible to instability and the use of alternative solid implants prevents the re-attachment of the ligaments. The immediate stability of the implant allows soft-tissue resection and early mobilisation, which is another advantage, not least in cases where stiffness is an issue. The disadvantages are that this prosthesis cannot be combined with total wrist arthroplasty and that the long stem may interfere with any deformity of the ulna. The complexity of the modular design and the constrained construction have also raised concerns, as similar concepts have shown high failure rates when used in other joints [88, 89]. Cautiousness is advised, but, so far, and in the mid-term perspective, the failure rate does not appear to differ from that of other DRUJ implants [90, 91].

The surgical technique and rehabilitation protocol have previously been described in detail by Dr. Scheker and by us [12, 13].

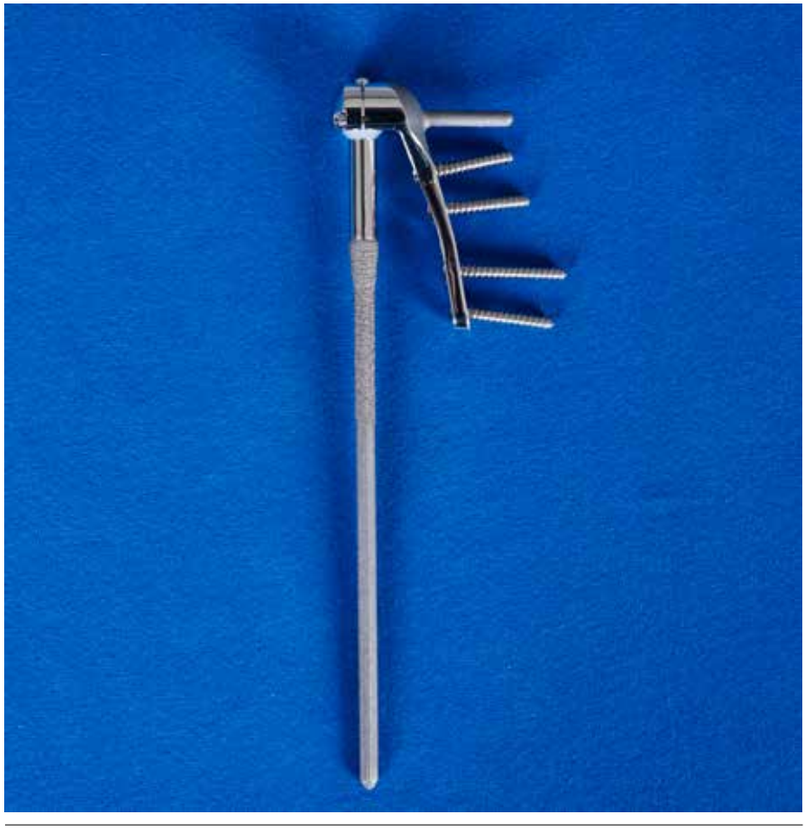


Figure 28. Scheker distal radioulnar joint prosthesis ©.

02

AIMS

The overall aims in this thesis are to evaluate the outcome of two DRUJ implants and to investigate the potential for improving assessments of DRUJ function.

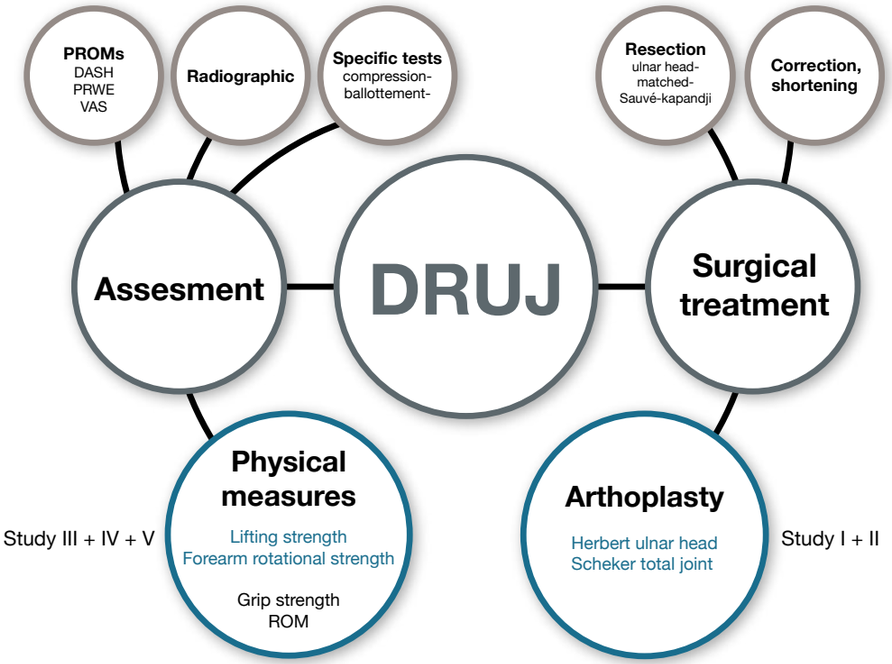


Figure 29. A. Schematic illustration of the different parts in the thesis.

02 AIMS

The specific aims were to study:

– The clinical and radiological outcomes for Herbert Ulnar Head Prosthesis arthroplasty in the mid-term perspective (Study I).

– The clinical and radiological outcomes for the Scheker total joint prosthesis when used for previously failed surgeries at the distal radioulnar joint (Study II).

– The reliability and validity of new methods for measuring lifting and forearm rotational strength and the influence of body position (standing or sitting) on the recorded values. Validity tests were performed using the Baltimore Test Equipment as a reference (Study III).

– Normal values for lifting strength and forearm torque in a Swedish population using the new method for measuring strength and comparing these data with values for grip strength in the same population (Study IV).

– The responsiveness of grip, lifting and forearm rotational strength and the presence of any correlation to patient-reported outcome measurements used in the evaluation of distal radioulnar joint implant arthroplasty (Study V).

03

METHODS

3.1 Study I

Implant: The Herbert Ulnar Head Prosthesis (UHP) (Martin Medizin Technik, Tuttlingen, Germany) is a modular total head endoprosthesis with a ceramic head. The implant replaces the distal ulna *(Fig. 30)*.

Patients: A consecutive series of 21 patients treated with the Herbert UHP with at least two years' follow-up was available. Twenty patients (11 men and 9 women) with 21 arthroplasties could be included. One patient died before the scheduled follow-up. The mean age at surgery was 55 years (range 31-74) and the mean follow-up was 7.5 years (range 2.0 – 12.5). The indications for arthroplasty were painful instability after previous resection arthroplasty (n=10) and pain due to osteoarthritis (n=9) or rheumatoid arthritis (n=3). The arthroplasty was the first wrist surgery in five cases. Seventeen patients had previously undergone a total of 34 surgical procedures on the wrist (mean 2, range 1-5).

Figure 30. Herbert ulnar head prosthesis implanted in bone model ©.

Radiographic evaluation: The bone resorption index and the sigmoid notch erosion index were calculated as proposed by Herzberg (39). Radiographic instability was evaluated as proposed by Kakar et al. for a similar implant (38). The position of the head of the implant in relation to the joint surface line of the radius, the condition of the sigmoid notch and signs of instability or loosening were evaluated subjectively (Fig. 31 A and B).

Clinical evaluation: At the latest follow-up, patients underwent a physical examination including recordings of ROM, grip strength, ballottement and compression tests and the subjective results were evaluated using the DASH, PRWE and VAS for pain and satisfaction. From charts, we were only able to obtain reliable preoperative values for ROM.

Statistical analysis: A paired t-test was used when ROM and grip strength were compared with the contralateral wrist. Any change in ROM was to be analysed using Wilcoxon's signed-rank test. For group comparisons, the Mann-Whitney U test was used.

Figure 31A. Radiographic analysis, measurements, anterio-posterior view.

Figure 31B. Radiographic analysis, measurements lateral view.

3.2 Study II

Implant: The Scheker Prosthesis (Aptis, Louisville, KY, USA) is a modular, constrained, total DRUJ implant. The implant replaces the distal ulna, the sigmoid notch and the DRUJ soft-tissue restraints *(Fig. 32)*.

Figure 32. Scheker distal radioulnar joint prosthesis implanted in bone model ©.

Patients: Nine consecutive patients (6 woman and 3 men) treated with the Scheker prosthesis after previously failed DRUJ surgeries were studied. Their median age was 44 (range 33-71) and the mean follow-up period was 3.7 years (range 2-5). The rationale for using the Scheker implant was post-traumatic DRUJ synostosis in one patient. The other eight patients had pain and gross instability, in addition to DRUJ destruction. The total number of previously failed surgeries at the DRUJ was 32 (median 2, mean 3.6, range 1-7).

Radiographic and clinical assessment: Pre- and postoperative radiographs were subjectively reviewed. Pre- and postoperative recordings of ROM, grip strength, the DASH and the VAS for pain and satisfaction were analysed.

Statistical analysis: Wilcoxon's signed-rank test was used for pre- and postoperative outcome comparisons, a paired t-test was used for side comparisons and the Mann-Whitney U test was used for group analysis.

3.3 Study III

Methods: We designed two test procedures in order easily to measure isometric peak strength for lifting and forearm rotation in a clinical setting *(Fig. 15, Fig. 21)*. We used a Kern hanging scale dynamometer (KHCB 50kg/20g, Kern & sohn GmbH, Balingen, Germany) to quantify lifting strength. The method for recording forearm torque included a Baseline digital wrist dynamometer (Fabrication enterprises, White Plains, NY, USA) equipped with a shovel handle. To compare measurements of lifting strength and forearm torque, we used a work simulator, Baltimore Therapeutic Equipment (Baltimore, Maryland, USA) (BTE), as a reference *(Fig. 33)*.

Participants and data sampling

Twenty-eight healthy volunteers (19 women and 9 men) were recruited to the study. Two raters measured each subject on three occasions with the different strength tests for grip, lifting and forearm rotation. One rater repeated the strength tests on three occasions with the BTE to analyse validity. Grip strength and forearm torque were also measured in a seated position to evaluate any possible influence of body position *(Fig 34)*.

Statistical analysis: Calculations of intraclass correlation coefficients (ICC) were used to assess inter- and intra-rater reliability. ICCs were used to assess agreement and Bland Altman plots were used for assessments of differences between the new test methods and the BTE tests and for comparisons between tests in a standing or seated position.

Figure 33. Torque strength measurement using the Baltimore therapeutic equipment.

Figure 34. Torque strength measurement, seated position.

3.4 Study IV

Participants: 499 healthy volunteers (262 males and 237 females), aged 15-85 (mean 44) years, were included. The subjects were enrolled at shopping centres, hospital entrances and a primary care centre based on willingness to participate. All the participants were examined with our new methods to measure lifting strength and forearm torque. Grip strength was also recorded. Each test was performed once on both sides. All the patients provided information about age, gender, hand dominance, height, weight and whether their jobs were associated with high or low manual strain.

Statistical analysis: Spearman's correlations were used to analyse associations between variables. Several multivariate regression models were constructed to compute prediction equations.

3.5 Study V

Patients: Eighteen patients (9 women and 9 men) who were treated with DRUJ implant arthroplasty, 12 Herbert UHP and 6 Scheker prostheses, were reviewed. Their average age was 56 years (range 24-72). Eleven patients had previous surgery performed at the DRUJ. They were examined for grip, lifting and forearm rotational strength. Subjective evaluations were made using the VAS for pain and satisfaction, the DASH and the PRWE. All the patients were examined preoperatively and after one year. The only inclusion criterion was the presence of a complete dataset on both occasions.

Statistical analysis: Wilcoxon's signed-rank test was used to compare pre- and one-year follow-up values. We analysed responsiveness as the standard response mean (SRM) and effect size (ES). Spearman's rank correlations were calculated to evaluate any relationship between pre- and postoperative change in the selected outcome variables.

04 RESULTS

04

RESULTS

4.1 Study I

The data for grip strength and PROMs are shown in *Table 1*. Grip strength was significantly higher for patients who had the procedure performed due to a post-traumatic condition (P= .02), but preoperative baseline values were not available. We did not find any significant differences between patients who underwent surgery owing to painful instability or arthritis. There was a trend towards less residual pain and better functional scores if no wrist surgery had been performed previously, but neither of these differences was statistically significant. Wrist range of motion was not affected by the arthroplasty except for supination, which improved significantly from 55° to 70°.

Table 1. Grip strength and patient-rated outcome at the latest follow-up visit.

	Mean	CI*	Range
Grip strength, A° kg	25	20-30	10-48
Grip strength, NA# kg	31	21-38	8-74
DASH score	27	20-35	5-50
PRWE score	31	20-41	0-90
VAS pain activity	2.9	1.6-4.1	0-8.7
VAS pain rest	1.7	0.6-2.8	0-7.0
VAS satisfaction	8.9	8.2-9.6	4.3-10

CI*, 95% confidence interval of mean; A°, Arthroplasty side; NA#, Nonartroplasty side.

Five arthroplasties were found to be partially or completely unstable for the ballottement test, but this could not be correlated to any clinical outcome or radiographic features. One patient underwent a re-operation with a capsuloplasty nine months after the arthroplasty because of a recurrence of painful instability. Full stability was not achieved, but the pain resolved. No other major complications were registered, but five patients recorded VAS pain above 5 during activity and one patient was dissatisfied and regretted having undergone the arthroplasty. The radiographic evaluation revealed bone resorption beneath the collar of all implants, but this was self-limiting and none of the implants showed any signs of loosening. Several implants had signs of sigmoid notch attrition, but only in one asymptomatic patient did this progress to a deep major erosion into the distal radius *(Fig. 35)*. Fifteen implants were judged to be radiographically unstable according to the criteria formulated by Kakar, but this could not be correlated to clinical outcome. None of the implants was loose.

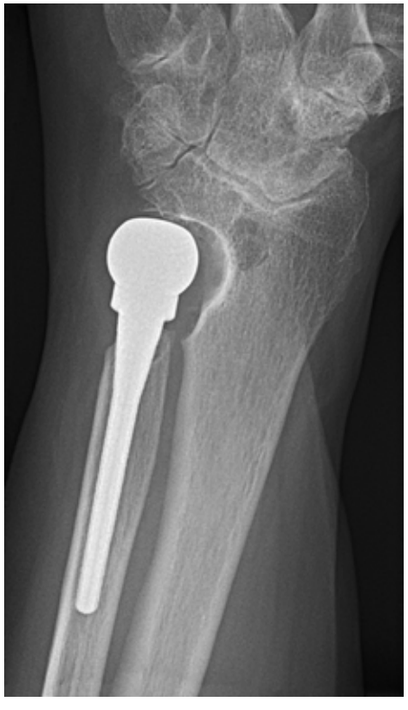


Figure 35. Herbert prosthesis with radial erosion 12 years after insertion.

4.2 Study II

Figure 36 shows differences between the preoperative and postoperative values after 1 year for pain, DASH and grip strength. There was a statistically significant improvement in median scores for DASH from 43 preoperatively to 26 at the last follow-up. The median VAS scores for pain also improved significantly from 6 to 0.3. Grip strength improved from medium values of 17 kg to 21kg, but this was not statistically significant, *Table 2*. Range of motion was unchanged. We encountered no major complications, but two patients had persistent high levels of pain. Radiographic evaluations showed bone resorption at the distal ulna for most patients and at the tip of a screw in one patient, but we found no evidence of implant loosening.

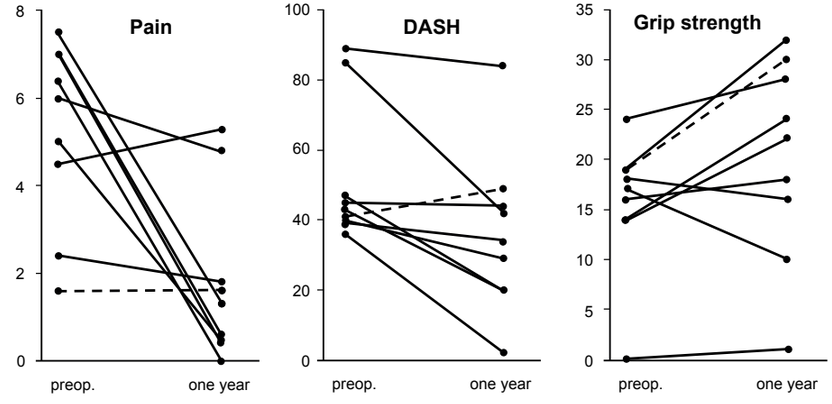


Figure 36. Change between preoperative and 1-year follow-up values . A Pain (cm), B DASH (score) C grip strength (kg).

Table 2. Clinical measurements before arthroplasty and at the latest follow-up.

Patient	Grip strength (kg)	VAS pain	DASH
1	19/24 (30)	7.0/0.3	43/ 8
2	14/18 (20)	6.4/0.0	36/ 7
3	14/21 (29)	7.5/0.3	85/28
4	17/32 (62)	2.4/0.4	45/37
5	24/54 (74)	1.7/0.8	42/25
6	18/10 (26)	4.5/0.3	39/48
7	0/ 0 (4)	6.0/5.2	89/92
8	19/30 (50)	5.0/0.0	40/26
9	16/16 (22)	7.0/0.1	47/16
Median	17/21 (29)	6.0/0.3	43/26
P value	0.09	0.01	0.03

The grip strength values that are shown are preoperative values, the latest follow-up values and, within parentheses, the non-treated side values. Pain level on a 10 cm VAS, disabilities of the arm, shoulder and hand scores; the values that are shown are preoperative and the latest follow-up values.

4.3 Study III

Intra- and interrater ICCs were > 0.8 for all strength test methods. Comparisons between recordings with the new test methods and the BTE revealed ICCs above 0.8, except for pronation torque. ICC values for test-retest in either the standing or sitting position were similar. Intra-class correlation coefficients are listed in *Table 3*. The agreement between torque measurements made with the baseline and BTE methods showed a mean difference of .3 Nm for supination and .8 Nm

for pronation. However, in some individuals, the difference between the methods reached values slightly above 2 Nm. The mean difference between measuring forearm torque sitting or standing was < 0.2 Nm and only one individual was outside 2 SD. When the Kern and BTE methods were compared, the mean differences varied from 2.8 N to 4.5 N, with a maximum individual difference of about 20 N.

Table 3. Class correlation coefficients for intra- and interrater reliability and between testing methods and between body positions when tested.

	Rater 1# Baseline or Kern	Rater 2Ɣ Baseline or Kern	Rater 1 BTEΦ	Rater 1 vs 2*	Baseline or Kern vs BTE@	Sitting vs standingΔ
Torque supination	0.96	0.95	0.94	0.94	0.88	0.95
Torque pronation	0.92	0.91	0.91	0.88	0.74	0.89
Lifting neutral	0.95	0.96	0.96	0.96	0.92	
Lifting supinated	0.91	0.95	0.91	0.94	0.95	
Lifting pronated	0.84	0.94	0.92	0.92	0.91	

Rater 1#, Intrarater reliability Baseline and Kern tests; Rater 2Ɣintrarater reliability Baseline and Kern tests; Rater 1ΦInterrater reliability BTE tests; Rater 1 vs 2* Interrater reliability Baseline and Kern tests; Baseline or Kern tests vs BTE@, Validity (Interdevice reliability) Baseline or Kern tests versus BTE tests; Sitting vs standingΔ, Interposition reliability.

4.4 Study IV

Men had about 70% higher forearm torque and lifting strength compared with females, *Table 4*. Male subjects aged 26-35 years and female subjects aged 36-45 obtained the highest strength values. At higher ages, there was a gradual decline, *(Fig. 37)*.

Separate comparisons of the dominant versus the non-dominant side revealed that the side claimed by the subject as the dominant one was not the strongest in a predictable manner. In patients with a dominant right side, 61-78% had higher or equal strength on this side in the different tests that were performed. In patients with a dominant left side, the corresponding proportions varied between 41% and 65%.

There was no significant correlation between hand dominance and the strength measurements (p> .19). Evaluations of the dominant and non-dominant side also showed small differences. Nineteen % of the 499 subjects graded their work duties as "manually strenuous". This variable showed a significant but weak (r = .12 - .16) correlation to the strength measurements. There was a high correlation between grip strength and forearm torque and lifting strength. Gender, body height, body weight and age showed a significant correlation to the strength measurements. In a multiple regression model, gender and age (entered as linear and squared) were able to explain 51-63% of the total variances in forearm torque strength and 30-36% in lifting strength.

Figure 37. Mean supination torque with 95% confidence intervals for males and females stratified by age groups. A right side, B left side.

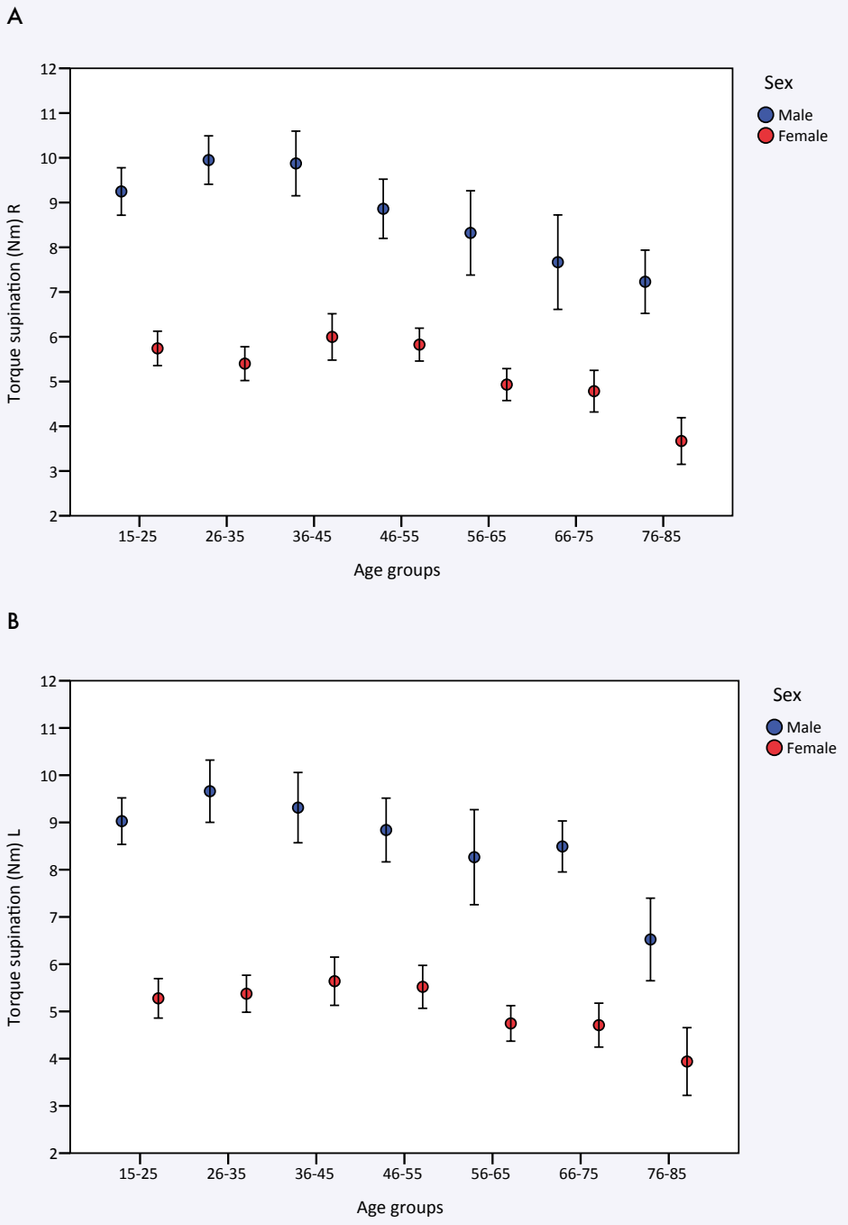


Table 4. Mean values, standard deviation, related to type of test, side and gender. Ratios between males and females.

	Grip Right (kg)	Grip Left (kg)	Torque S† Right (Nm)	Torque S† Left (Nm)	Torque P‡ Right (Nm)	Torque P‡ Left (Nm)
Male	53 ± 11	51 ± 11	9.1 ± 2.3	8.9 ± 2.3	7.9 ± 2.2	7.6 ± 2.2
Female	34 ± 8	31 ± 7	5.4 ± 1.3	5.2 ± 1.4	4.5±1.2	4.3 ± 1.2
Ratio	1.56	1.64	1.68	1.71	1.76	1.77

	Lift N* Right (N)	Lift N* Left (N)	Lift S† Right (N)	Lift S† Left (N)	Lift P‡ Right (N)	Lift P‡ Left (N)
Male	238 ± 89	229 ± 87	239 ± 89	230 ± 87	157 ± 62	153 ± 57
Female	142 ± 57	136 ± 57	137 ± 58	132 ± 55	96 ± 41	94 ± 40
Ratio	1.68	1.68	1.81	1.74	1.64	1.63

*Neutral position †Supination position or direction ‡Pronation position or direction.

4.5 Study V

Patient-reported outcome measurements and forearm torque values were significantly improved by arthroplasty, *Table 5*. Changes in forearm torque had a moderate to strong correlation to changes in PRWE, VAS for satisfaction and VAS for pain during activity (r = -0.55-0.70), while grip strength was not significantly correlated to changes in any outcome measurement *(Fig. 38)*. Changes in PRWE proved to have a significant and moderate to strong correlation to changes in all measurements of strength, except for grip strength. The change in DASH did not correlate significantly to any of the changes in the strength measurements.

PRWE and VAS for pain during activity were most sensitive to change, but DASH and VAS for pain at rest also showed a large effect and significant change. Forearm torque was more sensitive to change (SRM 0.70-0.95, ES 0.75-0.78) after DRUJ arthroplasty than grip strength (SRM 0.39, ES 0.49).

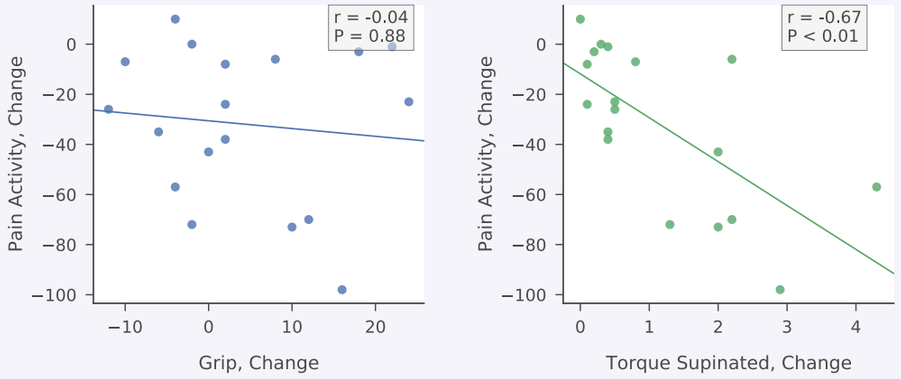
Table 5. Test differences and responsiveness.

	SRM*	ES^	Preop (SD)#	One-year (SD)#	Difference (SD)¤	p-value**
VAS satisfaction	n.a.	n.a.	n.a.	72 (30)	n.a.	n.a.
VAS pain rest	-0.75	-1.02	49 (24.5)	24 (24.6)	-25 (33.4)	0.01
VAS pain activity	-1.02	-1.60	71 (19.9)	39 (32.3)	-32 (31.2)	< 0.01
PRWE score	-1.01	-1.48	65 (17)	40 (24)	-25 (25)	< 0.01
DASH score	-0.86	-0.94	52 (18.4)	36 (23)	-17 (20)	< 0.01
GRIP (kg)	0.39	0.49	21.0 (8.6)	25.2 (13.2)	4.2 (10.7)	0.21
LIFT neutral (kg)	0.35	0.40	8.1 (4.7)	10.0 (5.4)	1.8 (5.3)	0.18
LIFT sup. (kg)	0.32	0.33	7.6 (4.5)	9.0 (5.4)	1.5 (4.7)	0.27
LIFT pron. (kg)	0.41	0.54	5.9 (2.5)	7.2 (3.5)	1.3 (3.2)	0.11
TORQUE sup. (Nm)	0.95	0.78	3.4 (1.5)	4.6 (1.8)	1.1 (1.2)	< 0.01
TORQUE pron. (Nm)	0.70	0.75	2.8 (1.2)	3.7 (1.8)	0.9 (1.3)	0.03

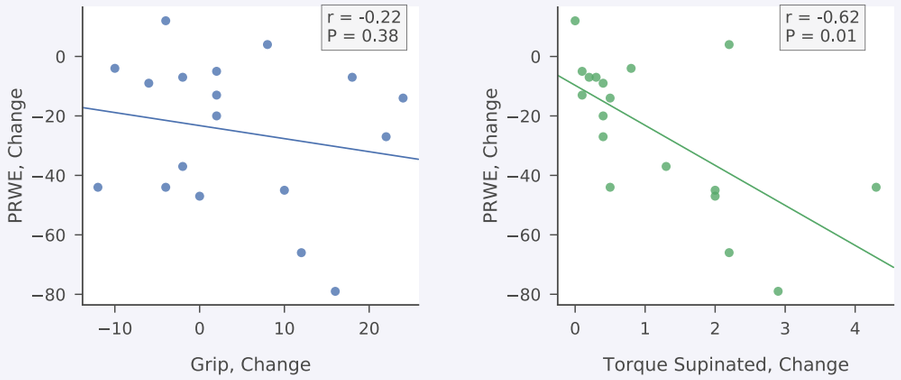
* Mean standard response ^Effect size #Mean value (standard deviation, SD)
¤ Mean difference (standard deviation, SD) **Wilcoxon's signed-rank test
n.a. = not applicable

Figure 38. Comparison of correlations for change in grip and forearm torque to change in A pain, B PRWE.

A



B



05 LIMITATIONS

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LIMITATIONS

5.1 Studies I and II

The mixture and limited number of patients in both studies are major problems that not only make general conclusions uncertain but also prevent differentiated analysis. These limitations are universal problems applicable to most published DRUJ arthroplasty studies and will be difficult to overcome even in the future, as a limited number of patients are in line for this type of procedure. Although both studies were retrospective, Study II was conducted prospectively and preoperative data were available for comparisons of all variables. In Study I, however, there were only reliable preoperative recordings of ROM. It is therefore difficult to ascertain how the Herbert arthroplasty made a difference. This is a shortcoming that also prevents valid comparisons of subgroups. Study II is a single-surgeon study, which means that there is a substantial risk of performance bias. There are many questions about the way radiographs and other outcome measurements are related to disorders and treatment of the DRUJ. These problems initiated the development of the new strength test methods that were evaluated in the subsequent studies in this thesis. There are no defined standards for evaluating DRUJ arthroplasties. We have used the most common measurements, which makes it possible to some extent to contrast our results with others. In both Study I and Study II, it was noted that several patients had severe pathologies in adjacent joints or suffered from other wrist conditions. Although symptoms and impairment from these conditions are not related to the DRUJ, they may significantly influence outcome measurements. This was confirmed for some patients who were subsequently treated with wrist fusions or wrist arthroplasty, for example.

5.2 Studies III-V

The participants in Study IV were volunteers, which might have caused selection bias. It is probable that subjects who felt confident about their physical performance were more inclined to participate than those who were afraid of performing poorly. As a result, our normative data might show somewhat higher strength values than those found in the general population. This type of selection bias is very difficult, if not impossible, to avoid in a study based on voluntary participation.

Our strength tests are performed by gripping a handle. This means that both physiological and pathological conditions in the hand and wrist will influence results. To overcome this problem, forces have to be directly transfered from the forearm to the testing device. The construction of suitable equipment for a test of this kind would be challenging and its use would probably be both impractical and difficult to replicate in the clinical situation. Testing via the hand also better reflects normal upper extremity function. In reality, lifting or forceful rotation of the arm are rarely performed with an unloaded hand.

We found that the all measurements in the pronated position or directions had somewhat lower reliability and validity. Regarding torque measurements in the direction of pronation, we noted that many subjects tended to let their arm leave their body during maximum effort. This may have influenced the results. We have now modified the method by getting the subjects to squeeze an object between their arm and body to make it easier to detect whether the arm leaves the body and the object drops to the floor.

In the strength testing studies, we did not standardise the verbal instructions that were given. Nor did we specify how to encourage the subjects to make a maximum effort. These potential weaknesses might have increased the variation in the results.

The subjects in Study IV were asked which hand they considered to be dominant. This question might have been perceived differently by different subjects. It might have been more relevant to specify the question as, for example, "with which hand do you write" or "with which hand would you catch a ball". Hand dominance is not, however, an absolute perception, but it is probably best regarded as a continuum between individuals that are completely right handed and completely left handed, with a number of subjects somewhere in between. It is also known that there are different aspects of handedness. People may prefer to use one hand for fine precision tasks like writing and the other hand for power gripping or heavy lifting. It is known that left-handed individuals have different strength characteristics compared with right-handed ones, but the number of left-handed individuals in our study was too small to enable a valid analysis.

It could be argued that we did not clearly specify the question about type of work. This question is, however, complicated, as changes of job are common, work duties may include strenuous tasks to a varying degree and the perception of a heavy physical work load is highly subjective. It has also been reported that free time activity is more strongly associated with strength performances, a question we did not pose.

The main concern with Study V is the small sample size. A larger number of patients would be desirable, but our aim was not to evaluate the effectiveness of the arthroplasty but the responsiveness to change in the outcome variables. We therefore believe that our findings can form the basis of valid assumptions.

06 DISCUSSION

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DISCUSSION

6.1 Introduction

Pain and instability are the main indications for DRUJ salvage procedures. When surgical treatment is considered, more or less advanced destruction of the joint surfaces, chronic instability or both these conditions are present. Fusion of the DRUJ is hardly ever an option, because the loss of forearm rotation causes severe disability. For this reason, some kind of resection used to be the only option, regardless of indication. However, the ulnar head is not redundant and cannot be removed without serious consequences.

Removal of the ulnar head was described by Darrach [92], although it was previously mentioned in the literature by Moore in 1880 and Lauenstein in 1887. This procedure produces satisfactory results for some patients, but the risk of failure was recognised at an early stage. A variety of resections were developed to avoid complications such as instability and impingement. However, none of these or added soft-tissue procedures are totally able to overcome the observed problems, as these operations fail to provide the firm support and the offset needed for stable, smooth rotational motion of the wrist during loaded conditions.

In clinical practice, only a limited group of patients will benefit from a resection arthroplasty. At present, we are, however not able to distinguish these patients from those who need a replacement. Patients with low loading requirements, such as elderly rheumatoid patients, often experience good results and a low risk of failure after resection, whereas young manual workers are known to run a high risk of ending up in an even worse situation than before surgery. The outcome is more difficult to predict for the majority of patients who fall in between these categories. New, more expensive techniques for replacement might carry other risks and have to be balanced against simple, established resection methods. Some questions will need to be answered before we are able to make reliable choices between procedures. In relation to implant arthroplasty, the most imperative questions are safety, efficacy and indications for the different generic implant types available.

The first implant to be used to overcome complications following ulnar head resections was a silicone cap designed by Watson (1973). Although the early results were encouraging, it was soon abandoned due to high rates of

failure from dislocation, breakage and synovitis. More durable, metal-based ulnar head implants were introduced in the mid 1990s. The Herbert ulnar head prosthesis (Herbert UHP) and the Avanta U-Head prosthesis had this design and demonstrated good results with low complication rates in the first studies [8, 9]. A different concept for a total DRUJ prosthesis was developed by Dr. Luis Scheker, who also reported initial favourable results [12]. Although several promising reports followed, few included established outcome instruments such as the DASH, PRWE or VAS. Only some studies included data collected pre- and postoperatively from clinical visits, and most reports originated from the units involved in the development of the implants [38, 93-99]. Due to these and other limitations, we decided to review our experience of the Herbert and Scheker implants, which were first used at our department in 2000 and 2006 respectively.

6.2 Study I Herbert UHP arthroplasty

6.2.1 Safety

We observed a comparatively low complication rate with this prosthesis. Only one patient experienced recurrent pain after the arthroplasty, which was found to be unstable. Capsuloplasty was performed and the pain resolved, even though the DRUJ did not become clinically stable. A further four patients showed instability at examination, but we were unable to correlate this to inferior outcome. Clinical instability has been the main concern in relation to ulnar head implants. Herbert and van Schoonhoven stated that the procedure might be contraindicated in patients with severe ligamentous laxity [86]. This can be difficult to determine preoperatively on clinical examination. Instability due to arthritis or previous ablative surgery could be corrected when the implant head is in position and separates the distal ulna from the radius in the appropriate manner. On the other hand, even a small amount of instability might sometimes be difficult to correct during surgery. In such cases, the recommendation is that this type of prosthesis should not be used [9, 100]. The alternative, resection arthroplasty, might be a poorer solution, however. If complete stability is not achieved after surgery and prolonged immobilisation, the risk of continuous symptoms is higher, but the result might still be acceptable and many patients with laxity have only minor or no symptoms at all. In a systematic review, Calcagni and Giesen found that radiographic instability appeared to be the main problem with ulnar head implants, but fewer revisions than anticipated were needed [91]. According to this report, "only half the radiologically unstable replacements required any further surgery".

Even if there are no standards for radiographically evaluating DRUJ instability, instruments of this kind have been described [38]. We used the criteria proposed by Kakar, despite the fact that this method not has been validated.

We found that 15 of the 21 implants were radiologically unstable, but this could not be correlated statistically with any particular outcome.

Failures such as instability or persistent pain have also been associated with malalignment of the distal radius. This condition has been described as a relative contraindication for distal ulnar replacement and should always be corrected before or in combination with arthroplasty [87, 100]. The influence of distal radius malalignment could, however, be questioned, as we observed several patients with a good outcome, despite remaining malalignment. Although interesting, this observation cannot constitute the grounds for any conclusions and we still think that distal radial malalignment should be addressed before or during these procedures.

Several authors have reported radiolucency at the distal ulna beneath the collar of the implant. There have also been concerns about the possibility that the implant head will erode into the sigmoid notch. We were able to confirm both these phenomena, but, as observed by others [38, 39, 87], both processes were self-limiting, even if pronounced in one of the cases *(Fig. 35)*. This rheumatoid patient already had a radiolucent cyst beneath the radioulnar facet before the operation. The prosthesis eroded deeply into the distal radius and the process appears to be self-limiting without causing any symptoms. In the majority of cases, the early radiographic changes that are observed can probably be regarded as an adaptation to the implant, with remodelling of the sigmoid fossa and stress shielding of the distal ulna.

Aseptic loosening is another risk with implant arthroplasties. Our radiographic evaluation did not reveal any signs of loosening. Nor did Calcagni and Giesen or Moulton and Giddins find that this was a major problem [90, 91]. The number of revisions due to loosening cannot be determined with certainty from published reports, as some of the larger series present mixed cases without defining which implant has failed. However, fewer than 10 revisions due to the loosening of Herbert UHP arthroplasties have been documented in the literature [90, 91]. Infection in connection with DRUJ arthroplasties appears to be a minor problem. Only two revisions due to this reason have been reported, corresponding to 0.5% of all Herbert UHP operations documented in the literature. Other complications have occasionally resulted in surgical treatment. Examples of these complications are tendonitis, tendon ruptures, carpal tunnel syndrome and stiffness. Several revisions have been performed due to recalcitrant pain without any obvious reason being found. Moulton and Giddins reported an overall survival rate exceeding 90% at four years for 327 ulnar head implants [90]. Sabo et al. analysed a series of 79 ulnar head arthroplasties and found a five- and 15-year survival rate of 90% [101]. Schoonhoven reported on 23 patients of whom sixteen were evaluated at two and 11 years after surgery [100]. There were no signs of deteriorating results between these two occasions.

Even if the reports published so far include comparatively few patients, it appears that failures are comparatively few and occur at an early stage.

6.2.2 *Efficacy*

The average score for satisfaction in our cohort was 8.9 of 10. This is the same score as Schoonhoven et al. reported in their long-term follow-up [100]. Other authors also report high satisfaction rates for ulnar head implant arthroplasties [93, 102].

We found VAS scores of pain at rest of 1.7 and activity of 2.9. Even though the pain scores are low, five patients in our series scored > 5. Nonetheless, these patients were content with the procedure and scored 8.3 on average for satisfaction, because they felt greatly improved in relation to their preoperative pain situations. One of our patients who reported moderate pain regretted having the operation. Even though reports including patient-rated outcome are few in number, our findings agree well with existing publications of the clinical results after ulnar head implants [38, 93, 100, 103]. While the results regarding pain are impressive, there are reports of a number of implants that have been removed due to unexplained pain [39, 93]. The results for the DASH and PRWE in our series were 27 and 31 respectively. Only a few studies have used the DASH to evaluate the Herbert implant. Sauerbier found a DASH score of 33, but this was for a mixed group in which most of the patients had received ulnar head implants with a similar design. Sabo reported that the average final PRWE was 52 also in a mixed group where many implants were not defined. We found an improvement from 55 to 70 degrees for supination. This was the only statistically significant change in ROM. Most papers have not shown a significant improvement in ROM for pronation-supination or wrist flexion-extension, which is not unexpected, as the majority of the patients did not have any stiffness before the arthroplasty. The mean grip strength at our final follow-up was 25 kg, which was 83% of the strength in the contralateral hand. Schoonhoven and Willis reported that grip strength was significantly increased and with the same final levels as those found by us. Some other authors reported significant improvements in grip strength [97, 99, 104], while other authors did not and some even observed a reduction in grip strength after the operation [38, 97, 105]. These conflicting reports may question the relevance of grip strength as an outcome variable for DRUJ arthroplasty.

To summarise, the information available in terms of indications, contraindications and prerequisites for successful or unsuccessful treatment with DRUJ prosthesis is divergent. The main problem is probably that well-performed clinical studies of homogeneous patient groups of sufficient size are lacking. Those presented do not or very seldom include pre-, postoperative and a systematic evaluations with validated instruments.

6.3 Study II Scheker total DRUJ arthroplasty

6.3.1 *Safety*

We did not encounter any major complications in our published series of nine patients. In a recent review of our cohort of Scheker arthroplasties (unpublished) that has now grown to 22 patients with a minimum follow-up of one year, we have observed several complications. They include two periprosthetic fractures occurring at the index operation or as a result of a fall five weeks after the operation *(Fig. 39)*.

One patient suffered a late rupture of the extensor tendons to the small finger. Tendon transfer was performed, but, after this surgery, the patient developed a deep infection and the implant finally had to be removed. In a further patient undergoing surgery because of a previously failed total DRUJ implant (U-Head with stability component), the Scheker prosthesis was removed due to a suspicion of osteolysis due to infection. This implant was loose, but no infection could be verified. In one patient, we successfully changed a stem to a larger size with a good result. Bellevue et al recently published a review were they report a complication rate of 29% [106]. They describe similar kinds of complications as we experienced in our late case series. These included 4 periprostetic fractures, 3 infections, 2 aseptic loosening's and 2 implant component failures.

In our published report on the outcome of Scheker arthroplasty, we reported on a slowly progressive osteolysis around a screw tip in one patient. As this continued and we were unable to exclude a low-grade infection, an exploration was finally performed seven years after the index operation *(Fig. 40)*.

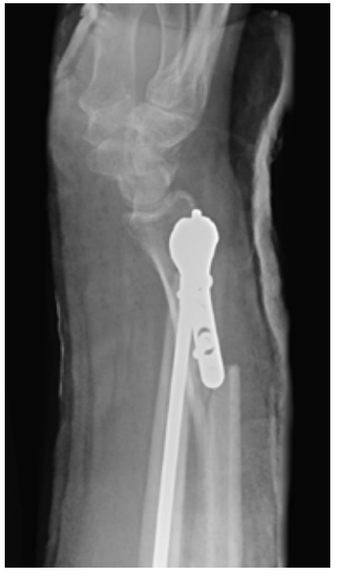

Figure 39. Scheker prosthesis with periprosthetic fracture.

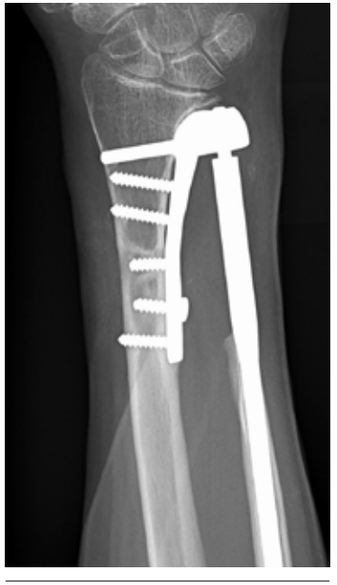

Figure 40. Osteolysis due to synovitis caused by protruding screw, 6 Year Follow-up.

Severe myotendinitis was found in the immediate area of the screw tip, but we found no proof of infection. We cut the screw tip and debrided the area. Follow-up radiographs have not shown any signs of remaining infection and radiographs indicate healing. Another patient is scheduled for the levelling of a protruding screw tip in an area of radially localised pain. In all, we have so far recorded nine more or less severe complications in this cohort of 22 Scheker prostheses. The complications that have been observed appeared at an early stage, all within 18 months. In the previously presented group of patients, now followed for seven to 10 years, there are no new complications and still no sign of loosening, despite this being a constrained implant.

It therefore appears that in-vivo loads are lower than expected or that the long ulnar stem and the radial screw fixation are able to withstand forces transferred during daily activity.

In a recent systematic review of some 300 Scheker implants, the overall complication rate was 28% [90]. The majority of them could probably be regarded as minor (i.e. ECU tendonitis, radial neuropathy or tendonitis due to the excessive length of the radial screws, heterotopic bone formation and soft-tissue infection). Calcagni and Giesen found that 21% of the Scheker arthroplasty patients required secondary surgery, but mostly for minor complications, as, in 98% of the followed cases, implants were not removed or exchanged at five years [91]. This number did, however, only include revisions associated with radiographic loosening or failure of the implant itself.

Moulton reported 15 cases in which the implants had been revised or removed [90]. Five of the implants were revised for loosening, five were not accounted for and the others had been revised or removed due to infection or trauma resulting in the fracture of the implant.

6.3.2 Efficacy

Calcagni and Giesen found that 98% of the patients were satisfied after surgery involving the Scheker arthroplasty [91]. This could be confirmed in a review by Moulton and Giddins, who found that all authors reported a good outcome and patient satisfaction [90]. In this context, it has to be noted that there is a risk of bias, as five of 13 included studies originated from the unit of the inventor, who had operated on more than two-thirds of all the documented cases. However, we have also found impressive patient satisfaction levels, albeit somewhat lower. In a recent evaluation of our consecutive series of 22 Scheker arthroplasties with a mean follow-up of 5.2 years (minimum one year), we found a mean satisfaction value of 8.5 (median 9.6, unpublished data).

In our published report, the final median VAS score for pain was 0.3 (mean 0.9). Others have also found very low values for residual pain. The reported mean values have been between 1 and 3. Studies that included a preoperative evaluation

of pain have all reported a significant improvement after the operation and this also applies to our study [38, 98, 99]. We found that final grip strength for the treated wrist was 81% of that on the non-surgical side. The improvement from the preoperative value of 17 kg to 21 kg was not statistically significant. Other studies have found that grip strength was between 47% [75] and 90% [97] of the strength of the contralateral hand and only one study found a significant change [99]. Several studies report a significant improvement in DASH and PRWE scores and final DASH scores close to our 26 [38, 98, 99]. Neither our study nor others have found significant changes in ROM. The final values are often near normal. As the majority of these patients did not have any limited ROM preoperatively, no further improvement is expected. It could instead be anticipated that ROM will decrease after surgery, especially as it is a constrained implant. The inherent stability of the prosthesis does, however, also permit early rehabilitation and the revision of soft tissues with a potential influence on range of motion. These features of the Scheker prosthesis may have an opposite effect and contribute to improved mobility.

6.3.3 DRUJ arthroplasty: patient and implant selection

There are no reports of direct comparisons between different types of DRUJ implant. Some larger series include mixed implants [101, 107], but the different implants that were studied were not compared. As there are often a wide variety of indications and rarely sub-group analyses, valid assumptions regarding the influence of patient selection cannot be performed. The influence of preoperative diagnosis and demographics has therefore rarely been analysed, perhaps because too few cases have been included. Some studies do, however, report that there is a trend towards better results for primary arthroplasties [93, 100, 101, 103]. Comparisons are also difficult, as there is great disparity in the reporting of results and the limited use of established outcome measurements. Most studies are small case series, which would jeopardize any generalisability.

For a patient with a stable DRUJ and only minor joint damage, it is rational to choose an ulnar head implant. A patient with an initial trauma and multiple previous surgeries who presents with gross instability in combination with joint damage would require a Scheker implant. The choice is also easy if there is a short ulna due to previous resections, a tumour or a failed implant or if a total wrist arthroplasty is already in place. However, the majority of patients fall between these extremes and, in those cases, the current evidence does not provide support for the use of a specific implant.

The overall results for DRUJ implants are good. In particular, the Scheker implant is a powerful tool, as it replaces not only the joint but also the ligaments.

It appears that the Herbert and Scheker implants carry about the same risks, but we do not have any long-term follow-up. It appears reasonable to use the less invasive, less expensive procedure as the primary choice for the majority

of patients. This could mean that the Herbert UHP would be the first option if there are no specific instability problems such as a suspicion of severely deficient ligaments, a short ulna stump and so forth. Saving the Scheker implant as a last resort might be a good choice. It is possible to salvage a distal ulnar implant with a Scheker implant but not the other way around. In the event of failure and permanent implant removal, the patient will be left in a situation similar to that after a Darrach procedure.

6.4 Study III reliability and Validity

With a few exceptions, only ROM and grip strength have been used as objective physical measurements in scientific evaluations of DRUJ interventions. Grip strength has been accepted as a good estimate of DRUJ function, and for upper extremity function in general, even though this has not been validated. Forearm torque and loading of the forearm have attracted surprisingly little attention, even though they are important features of the DRUJ.

At an early stage, several researchers showed an interest in measurements of forceful forearm rotation. Instruments to measure torque were developed and evaluated, but they were never used by any other research groups or for clinical evaluations of DRUJ treatment [15-17, 108]. More advanced instruments, work simulators such as BTE, Biodex, and Cybex have been available but not commonly used, probably because they are stationary, space consuming and expensive. For the past decade, a smaller device that quantifies torque, the Baseline wrist dynamometer, has been available for purchase, but it has only occasionally been used for clinical evaluation [109, 110].

Lifting capacity has attracted some interest in recent years. At present, there are three studies from the Scheker group, which report assessments of the inventors' implant [95, 98, 99], and Reissner et al. , who assessed the same implant [104]. This method, which consists of lifting weights with increasing heaviness from a table, has, however, not been validated. The same situation applies to the "pronosupinator", a device invented by Garcia-Elias to assess dynamic load-bearing capacity during forearm rotation [111]. This method has been used to evaluate a partial ulnar head implant [112].

We believe that assessments of strength for lifting and forearm rotation could be used to improve evaluations of DRUJ and upper limb function. We therefore developed two methods to quantify lifting ability and forearm rotational strength. The primary aims were to enable quick and easy use in a clinical setting, while maintaining high reproducibility and validity of the measurements. Two commercially available dynamometers were used for the measurement methods. The Kern hanging scale, to quantify lifting strength, and the Baseline wrist dynamometer, to quantify forearm torque.

Both methods were evaluated in a test-retest experiment and reliability was

analysed by intraclass correlation coefficients (ICCs). We found that the ICCs for both forearm torque and lifting strength in all positions were excellent. This is also what Wong and Moskowitz found when they investigated the reliability of a Baseline dynamometer [113]. The BTE work simulator has been shown to be valid for many strength tests and is sometimes used in research. We therefore chose it as a reference standard. Our inter- and intrarater comparisons using the BTE produced excellent ICCs, thereby confirming that our test methods are consistent and react in a similar way. It does not, however, provide information about whether the test methods are interchangeable. Bland-Altman plots were therefore performed and the mean difference between torque measurements performed with the Baseline and BTE devices was less than 0.8 Nm with almost all subjects within the 95% difference of agreement and a maximum individual difference of 2.7N. For the comparisons of lifting ability, the mean difference between measurements was 2.8-4.5 N and the maximum individual difference was 32N. We believe the differences are acceptable, but with a reservation for the fact that there are no established clinical recommendations for acceptable levels of agreement. Nor is any information available about Minimum Clinically Important Differences for lifting strength or forearm torque. Until these matters have been further explored, we recommend that, if patients are to be re-tested, this should be done using the same technique and protocol.

For all tests, the uncertainty of measurements was higher in the pronated position or pronated direction. It could be that most subjects felt that this direction was more strenuous than the corresponding tests in supination, but the true reason for this discrepancy remains uncertain.

Most investigators have used the sitting position during tests of forearm torque [15-17, 109, 113, 114]. We felt it was more practical to make recordings in the standing position, as we could have the Baseline dynamometer permanently mounted on a wall where it was easy to access but still out of the way. As we were measuring lifting strength in the standing position, it was also easier to combine the methods. To investigate whether body position influenced forearm torque measurements, we tested the same subjects in both positions. We found that intra- and interreliability, as well as reliability, between positions were similar, with ICCs above 0.8. Bland-Altman plots showed a mean difference of 0.1 Nm and most individuals were well between the 95% limits of agreement, except for one individual with a difference of 1.2 Nm. There are few reports of comparisons between strength measurements performed sitting and standing, but Liao et al. found that grip strength measurements were similar, regardless of body position [115]. Our comparisons for grip strength measurements in sitting and standing positions (unpublished data) revealed that ICCs between positions was 0.95, with a mean difference of 0.2 kg. We conclude that a measurement of upper limb strength is influenced either not at all or only to a very limited extent by patient positioning while sitting or standing.

6.5 Study IV Normative values

Mean forearm torque and lifting strength were about 60% higher for males, but the individual variations were large. Lifting and forearm rotation strength peak in young adulthood and gradually decline with age, which has been documented by others as regards grip strength [49-51]. There was a trend suggesting that female strength peaks at a higher age than that of males. According to our knowledge, this type of gender-related difference has not previously been described for these types of testing situation. Our observation must, however, be regarded as preliminary and needs confirmation in future studies.

The strength testing showed that the average strength was higher for the right-hand side for all tests, but the difference between right and left was small. As previously noted, this difference was still smaller for left-handed individuals. However, the side claimed by the subject to be the dominant side was not the strongest in a predictable way. The subjects with a dominant right-hand side displayed higher or equal strength in 61-78% for the different tests. These proportions were even smaller for the left-handed subjects. We decided to exclude hand dominance from our prediction equations, as the side-related difference was small, the number of left-handed subjects was low and, finally, it emerged that hand dominance did not affect our prediction models.

Rey et al. and Wong and Moskowitz used a Baseline dynamometer to determine forearm torque, but they did not report their results in SI units [113, 114]. We interpreted their results with the aid of our previously acquired conversion variables. Their peak values showed large variability compared with ours. Several explanations are possible, such as a difference in study population, body position, elbow angle and the fact that Wong and Moskowitz used a door-knob instead of a shovel handle [113]. A number of possible confounders, such as variations in study populations, testing procedures and the reporting of results, make comparisons of absolute values difficult.

Comparisons of normative values for lifting strength are even more challenging, due to differences in techniques, ways of reporting values and variations in the number and types of subject studied. The method that the Scheker group uses, lifting different weights, has some similarities to ours, but they have not reported normal values. Moreover, the "pronosupinator" method quantifies loading via the hand and an elbow flexion of 90 degrees, but there are several differences. Peak values are, for example, recorded when the patient feels discomfort during dynamic testing, while we record the isometric peak strength. Some other investigations define elbow flexion strength or elbow flexion torque and several investigators place the resisting force over the distal forearm, which means that the method is not truly comparable to ours.

We believe 499 subjects is a sufficient number to define normal values for our strength testing methods and we present these values in tables based on

gender and age. From regression models, we were also able to compute prediction equations based on gender, age and height. We have developed a mobile application, "GTB forearm tests", to facilitate estimations of normal values. This app can be downloaded free of charge from App store *(Fig. 41)*.

Figure 41. Mobile Application "GTB Forearm tests" ©.

6.6 Study V Responsiveness and validity

We decided to assess the sensitivity of our test methods to changes in DRUJ function and to compare their performance, as outcome measurements, with traditional methods used for DRUJ interventions. A series of patients that were treated with DRUJ implants and were pre- and postoperatively assessed for lifting strength and forearm torque, in addition to ROM, grip strength, DASH, PRWE and VAS for pain and satisfaction, were reviewed.

All the PROMs, but only forearm torque of the physical variables, showed a statistically significant improvement. We are not able to exclude the possibility that there might also have been a real change in grip and lifting strength,

since the post-hoc analysis showed that the study was underpowered for these parameters. The numbers of patients were only sufficient for pain experienced during activity. Although we were not interested in the absolute values of outcome variables, the size of the change matters when responsiveness is analysed. However, the group of patients is the same for all variables, which makes it possible to analyse the different characteristics of the outcome variables.

The pain scores were most sensitive to change. The response levels for torque were not as high but almost as high as for the DASH and PRWE, whereas the responsiveness for both grip and lifting strength was low. Another interesting finding was that forearm torque showed a significant correlation to outcome measurements such as the PRWE, pain during activity and satisfaction but not to the DASH. The strongest correlation was to the PRWE and pain during activity. When patient-reported outcomes were assessed, it emerged that the PRWE had significant correlations to all other PROMs and to all strength tests except grip. The strength of correlation was highest for satisfaction and pain. The DASH only had a significant correlation to the PRWE.

There is conflicting evidence regarding the correlation between grip strength and other outcome measurements. Some have found strong associations with the PROMS for certain wrist conditions [53, 72] and some have not [73]. Our finding that the responsiveness for grip strength was low and correlations to other measurements were non-significant could be a reason why we have found only one investigator, apart from those from units involved in the development of studied implants [97, 99, 100], that has reported a significant increase in grip strength after DRUJ arthroplasty [104].

In a recent review of 34 Herbert arthroplasties performed at our unit (unpublished data), we found that there was a large difference in achieved grip strength between patients that had surgery due to osteoarthritis compared with rheumatoid arthritis. However, this correlation did not hold when preoperative strength was subtracted. This illustrates the problem associated with a lack of appropriate preoperative recordings and this is why we are unable to draw definite conclusions about grip strength in our published report on Herbert arthroplasty. Our finding was that grip strength was significantly higher in the group that had an initial trauma, but we were unable to make comparisons with preoperative values.

Taken as a whole, our findings suggest that forearm torque is the most relevant physical measurement to use after DRUJ arthroplasty and perhaps to evaluate DRUJ function.

If we were to use only three outcome variables after DRUJ arthroplasty, the PRWE, VAS for pain experienced during activity and forearm torque testing appear to be the most reasonable choices.

07 CONCLUSIONS

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CONCLUSIONS

From a mid-term perspective, for a selected group of patients, both the Herbert ulnar head prosthesis and the Scheker total joint prosthesis:

- were able effectively to reduce pain
- produced a high satisfaction rate
- demonstrated an acceptable complication rate
- showed no signs of loosening after an average follow-up of 7.5 and 3.7 years

Our new methods for measuring strength for lifting and forearm rotation:

- had excellent intra- and interrater reliability
- had high validity with reference to the BTE work simulator
- produced normal values that could be predicted based on age, gender and height
- were more responsive to change after DRUJ arthroplasty than grip strength
- were significantly correlated to established outcome measurements of DRUJ arthroplasty

Clinical relevance

The Herbert ulnar head prosthesis and the Scheker total joint prosthesis produced sufficiently good clinical results to justify continued use, preferably in well-designed clinical studies.

The strength tests for lifting and forearm rotation have the potential to:

- improve the diagnostic accuracy of DRUJ disorders
- allow more accurate comparisons between interventions
- reduce the number of patients needed to make valid assumptions about treatments

08 FUTURE PERSPECTIVES

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FUTURE PERSPECTIVES

In general

Today, DRUJ implant arthroplasty is an established treatment option with the potential to become the future standard of care for severely destroyed damaged joints. The safety and efficacy of these procedures require further confirmation in studies of more homogeneous, sufficiently large patient groups with long-term follow-ups. There are, however, many reasons why this goal is difficult to achieve.

Knowledge in this field could be increased in several ways to facilitate the choice between surgical interventions. One option is to increase the number of evaluated patients, which will be difficult, as DRUJ implant arthroplasty will probably never be a common procedure. Multicentre register studies could be an alternative, but this, as well as randomised and comparative studies, will be difficult to accomplish in the near future. Another option is to increase the knowledge acquired from each patient. I believe this is the way to proceed, because, at present, the best way, using both approaches, does not appear to be feasible.

The best and easiest way to improve the quality of outcome evaluations is to make prospective assessments. Conducting a true prospective study might be time consuming, but preoperative data can be recorded with little effort at a low cost. This is of paramount importance, as subsequent evaluations can be made at any time but are of little value without baseline data for comparison. With regard to the status of DRUJ prosthetic surgery today, I think that documentation of preoperative data should be compulsory before anyone is allowed to perform such an implant arthroplasty. If possible, the preoperative assessment should be performed by an independent rater according to a standardised protocol. Our current DRUJ arthroplasty protocol *(Appendix 8)* should be further evaluated and, if necessary, modified.

Specific tasks

It would be interesting to validate our methods for measuring lifting strength and forearm rotational strength for a number of different upper extremity disorders and treatments, such as TFCC injuries, elbow and forearm fractures and injuries to the spinal cord, plexus brachialis or peripheral nerves.

As all our pronation tests turned out to be somewhat less accurate than the supination tests, we propose a refinement of our method for measuring pronation torque by getting the test subject to squeeze a suitable object between his/her upper arm and body. In this way, it will be easy to see whether the arm leaves the body when the object is dropped.

We have recently initiated a process for developing a patient-reported outcome questionnaire designed specifically for assessing the DRUJ. This will subsequently be validated against the PRWE instrument. There is also an immediate need to improve the quality of radiographic assessments. We conducted a preliminary investigation, where three raters independently evaluated pre- and postoperative radiographs for 21 Herbert arthroplasties and found that the intrarater correlation was very weak (unpublished data). It is possible that a larger number of implants for evaluation might have been needed to define radiographic signs of clinical relevance or that CT will be the required modality for DRUJ assessment.

Defining MCID for different outcome measurements in relation to DRUJ disorders would be of great value in order correctly to estimate the power of predictive studies. This would also aid in the creation of the most useful combination of patient-reported outcome and physical variables for evaluations. Agreement on the outcome parameters that should be used would greatly increase the potential for comparing implants and defining patient preconditions of importance. From our studies, we found that the most relevant parameters were pain experienced during activity, PRWE and forearm torque. These observations should also be validated for the treatment of other conditions of the DRUJ joint.

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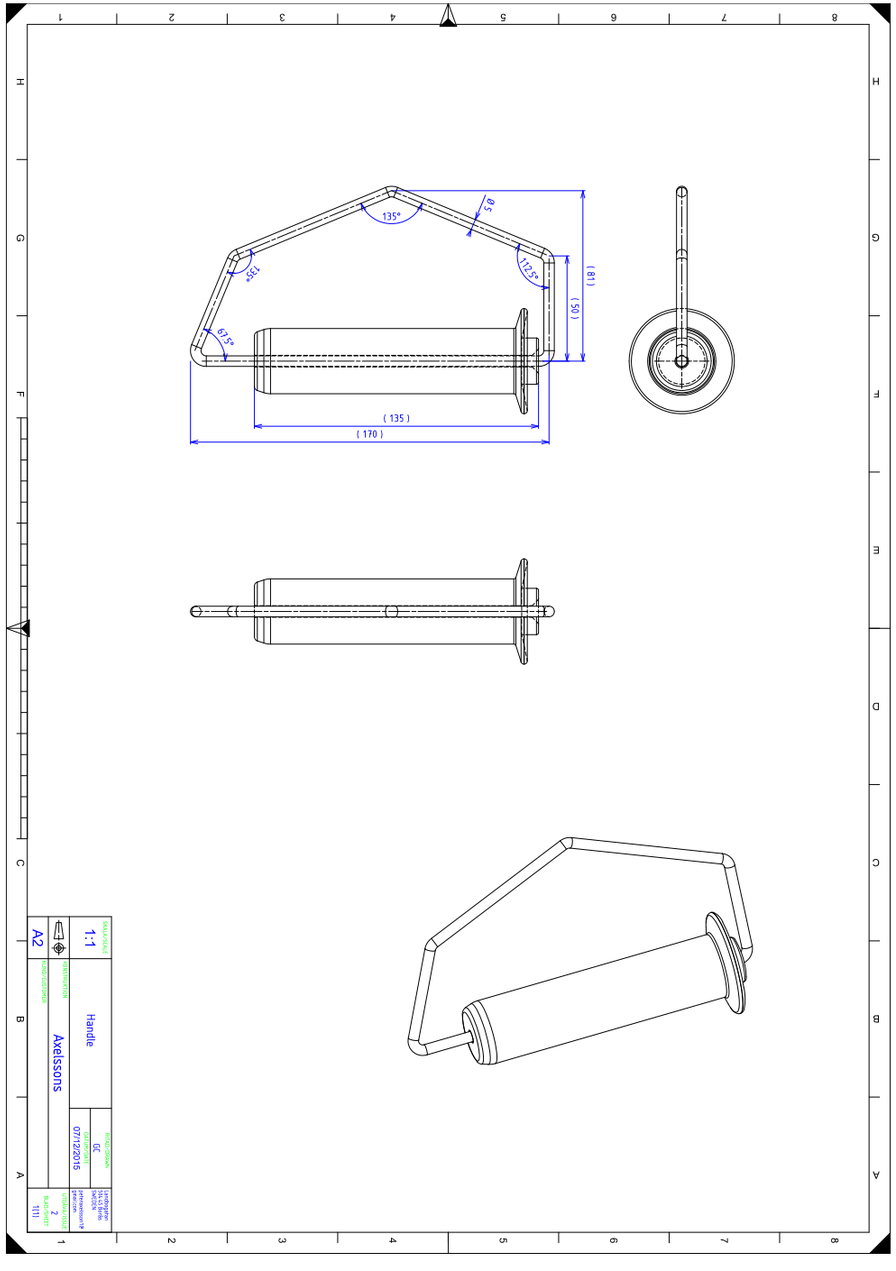
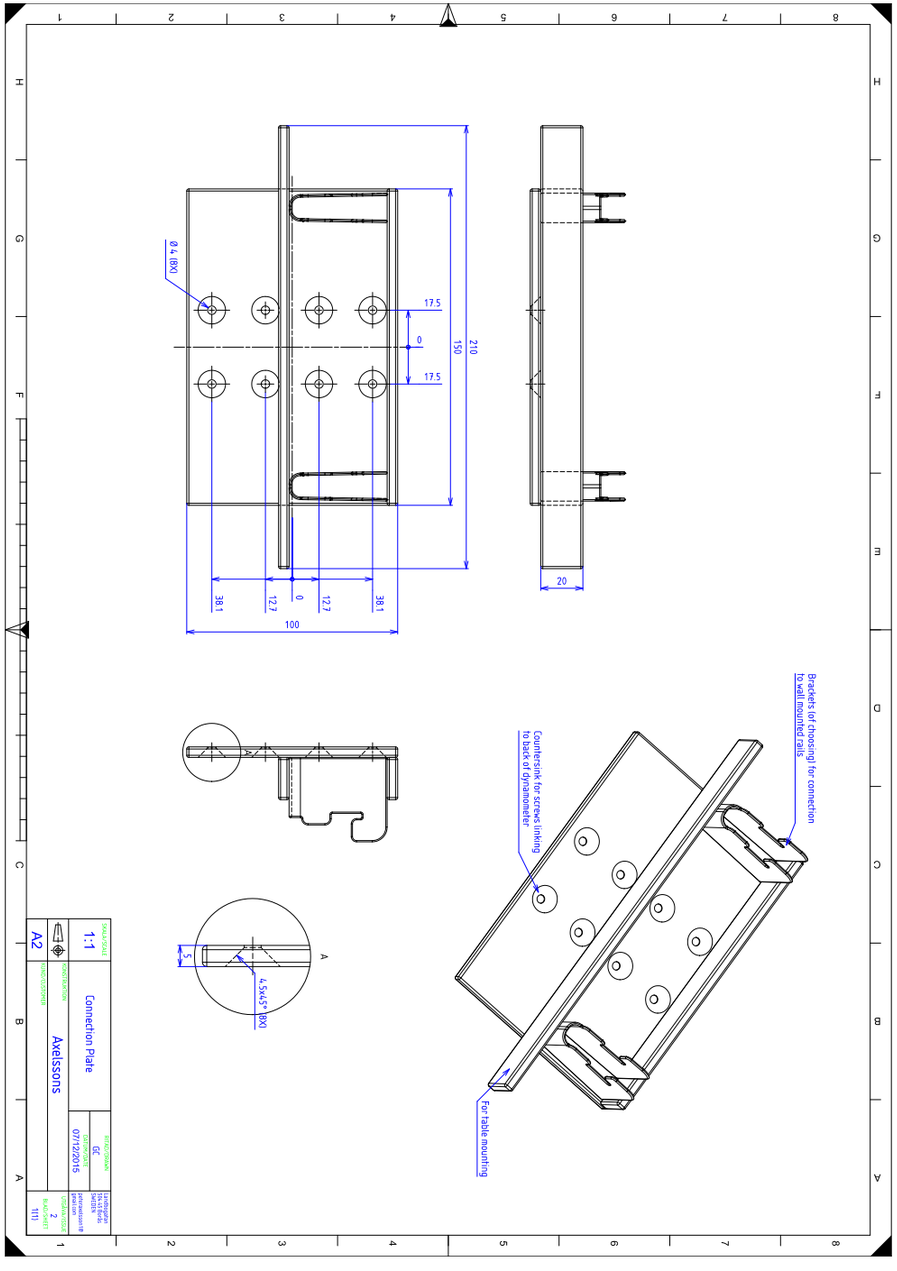
APPENDIX

1. BLUEPRINT OF THE KERN HANDLE



3. BLUEPRINT OF THE BASELINE FIXTURE



KALIBRERINGSBEVIS

utfärdat av ackrediterat kalibreringslaboratorium
CALIBRATION CERTIFICATE issued by an Accredited Calibration Laboratory

Contact person
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Date
2015-05-12

Reference
MTm5F010117-K01

1002
ISO/IEC 17025

Sahlgrenska University Hospital
Department of Hand Surgery
405 83 Gothenburg

Calibration of dynamometer

Identification

Object	KERN HCB 50K20, no. WD140104061.
Object state	The object had no visual damages.
Calibration location	Borås
Calibration date	2015-05-12

Measurement methods and procedures

Calibration up to 500 N, according to SP-method M1301. The object was loaded stepwise up to maximum calibration force three times before start of calibration.

Measurement conditions

Ambient temperature	21 °C
Mechanical coupling	SP's tension rods

Results

The results refer only to the object specified in this document.

Table 1. Tension results, based on three measurement series.

True force F [kg]	True force F [N]	Mean of displayed values F_m [kg]	Deviation F_m-F [kg]	Measurement uncertainty ±U [kg]
0	0	0		
1,01866	10	1,01	-0,01	0,02
5,0933	50	5,08	-0,01	0,02
10,1866	100	10,16	-0,03	0,02
20,3732	200	20,35	-0,03	0,02
30,560	300	30,49	-0,07	0,02
40,746	400	40,65	-0,09	0,02
50,933	500	50,83	-0,11	0,02
0	0	0,01 [1)]		

1) Zero error relative to maximum value, f_0 = 0,01%

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In the conversion of true force from unit N to unit kg, the measured value of the local gravitational acceleration g = (9,81680 ± 0,00002) m/s^2, was used.

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty has been determined in accordance with EA Publication EA-4/02. The long term stability of the calibrated object is not included in the reported expanded uncertainty of measurement.

Traceability

The measurement results are by regular calibrations of the laboratory's standards traceable to the Swedish National Laboratory for mass at SP in Borås. The value of the local gravity is traceable to Lantmäteriet in Gävle.

Equipment

Loading weights, inv. no. 401489

SP Technical Research Institute of Sweden
Measurement Technology - Mass, Force and Pressure

Performed by

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Calibration of torque measuring device

Identification

Object	Wrist dynamometer Baseline with digital pressure gauge BL-2000
Object state	The object had no visual damages.
Calibration location	Borås
Calibration date	2015-05-12

Measurement methods and procedures

Calibration clockwise and counter-clockwise up to 16 Nm, according to SP-method M1302.
The object was exposed to maximum calibration torque three times before the calibration.

Measurement conditions

Room temperature 21 ±1 ºC

Results

The results refer only to the objects specified in this document.

Table 1. Results Clockwise torque, based on three measurement series.

True torque M [Nm]	Mean of displayed values X_m [kg]	a Nm/kg	Measurement uncertainty ±U [kg]
0	0		
0,5	10	0,0484	1
1	21	0,0484	1
2	42	0,0476	2
4	82	0,0488	2
8	162	0,0493	1
12	227	0,0529	1
16	289	0,0553	1
0	0 [1)]		

1) Zero error, f_0 = 0,3 kg

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Reference
MTm5F010117-K02

Table 2. Results Counter-clockwise torque, based on three measurement series.

True torque M [Nm]	Mean of displayed values X_m [kg]	a Nm/kg	Measurement uncertainty ±U [kg]
0	0		
0,5	10	0,0500	1
1	20	0,0500	1
2	42	0,0480	1
4	82	0,0490	1
8	154	0,0521	1
12	217	0,0552	2
16	282	0,0567	2
0	0 [1)]		

1) Zero error, f_0 = 0 kg

The relation between displayed value, X_i, and applied torque, M, can be described with a calibration polynomial $M = a \cdot X_i$. The sensitivity factor, a, is determined using the method of least squares.

For Clockwise torque, the sensitivity factor, a_c, is:

a_c = (0,053 ± 0,005) Nm/kg

For Counter-clockwise torque, the sensitivity factor, a_{cc}, is:

a_{cc} = (0,055 ± 0,004) Nm/kg

The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty has been determined in accordance with EA Publication EA-4/02. The long term stability of the calibrated object is not included in the reported expanded uncertainty of measurement.

Traceability

The measurement results are by regular calibrations of the laboratory's standards traceable to the Swedish National Laboratories for length and mass at SP in Borås. The value of the local gravity is traceable to Lantmäteriet in Gävle.

Equipment

SP torque rig inv. no. 602476, with loading weights inv. no. 401489

SP Technical Research Institute of Sweden
Measurement Technology - Mass, Force, Pressure and Length

Performed by

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5. SWEDISH VERSION OF THE DASH QUESTIONNAIRE (1/2)

Gradera din förmåga att utföra följande aktiviteter under den senaste veckan genom att kryssa för ett svarsalternativ för varje fråga.

	Ingen svårighet	Viss svårighet	Måttlig svårighet	Stor svårighet	Omöjligt att utföra
1. Öppna en burk, eller hårt sittande lock	☐	☐	☐	☐	☐
2. Skriva	☐	☐	☐	☐	☐
3. Vrida om en nyckel	☐	☐	☐	☐	☐
4. Förbereda en måltid	☐	☐	☐	☐	☐
5. Öppna en tung dörr	☐	☐	☐	☐	☐
6. Lägga upp något på en hylla över Ditt huvud	☐	☐	☐	☐	☐
7. Utföra tunga hushållssysslor (t ex tvätta golv och väggar, putsa fönster, hänga tvätt)	☐	☐	☐	☐	☐
8. Trädgårdsarbete	☐	☐	☐	☐	☐
9. Bädda sängen	☐	☐	☐	☐	☐
10. Bära matkassar eller väska	☐	☐	☐	☐	☐
11. Bära tunga saker (över fem kilo)	☐	☐	☐	☐	☐
12. Byta en glödlampa ovanför Ditt huvud	☐	☐	☐	☐	☐
13. Tvätta eller föna håret	☐	☐	☐	☐	☐
14. Tvätta din rygg	☐	☐	☐	☐	☐
15. Ta på en tröja	☐	☐	☐	☐	☐
16. Använda en kniv för att skära upp maten	☐	☐	☐	☐	☐
17. Fritidsaktiviteter som kräver lite ansträngning (t ex spela kort, sticka, boule)	☐	☐	☐	☐	☐
18. Fritidsaktiviteter som tar upp viss kraft eller stöt genom arm, axel eller hand (t ex spela golf, använda hammare, spela tennis, skytte, bowling)	☐	☐	☐	☐	☐
19. Fritidsaktiviteter där Du rör på armen fritt (t ex spela badminton, simma, gympa)	☐	☐	☐	☐	☐
20. Färdas från en plats till en annan	☐	☐	☐	☐	☐
21. Sexuella aktiviteter	☐	☐	☐	☐	☐

5. SWEDISH VERSION OF THE DASH QUESTIONNAIRE (2/2)

22. Under *de senaste sju dagarna* 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

23. Under *de senaste sju dagarna*, i vilket 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 *de senaste sju dagarna.*

	Ingen	Lätt	Måttlig	Svår	Mycket Svår
24. Värk/smärta i arm, axel eller hand	☐	☐	☐	☐	☐
25. Värk/smärta i arm, axel eller hand i samband med aktivitet	☐	☐	☐	☐	☐
26. Stickningar (sockerdrickskänsla) i arm, axel eller hand	☐	☐	☐	☐	☐
27. Svaghet i arm, axel eller hand	☐	☐	☐	☐	☐
28. Stelhet i arm, axel eller hand	☐	☐	☐	☐	☐

29. Har Du haft svårt att sova, *under de senaste sju dagarna*, på grund av värk/smärta i arm, axel eller hand?

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

30. Jag känner mig mindre kapabel, har sämre självförtroende eller känner mig mindre behövd på grund av mina arm-, axel- eller armproblem.

☐ Instämmer absolut inte ☐ Instämmer inte ☐ Vet inte ☐ Instämmer ☐ Instämmer absolut

6. SWEDISH VERSION OF THE PRWE QUESTIONNAIRE (1/2)

Namn/Nr_____Datum_____

PATIENTUPPLEVD HANDLEDSFUNKTION

Nedanstående frågor ska hjälpa oss att förstå hur mycket besvär du har haft från din handled densenaste veckan. Du skall ange dina genomsnittliga handledsbesvär den senaste veckan på en skala från 0 till 10. Var vänlig och besvara ALLA frågor. Om du utförde en viss aktivitet, vänligen UPPSKATTA den grad av smärta eller svårighet som du tror hade uppstått. Om du ALDRIG har utfört en viss aktivitet kan du lämna raden obesvarad.

1. SMÄRTA

Ange Din genomsnittliga handledssmärta den gångna veckan och ringa in siffran som bäst motsvarar smärtan på en skala från 0 till 10. Noll (0) betyder ingen smärta och (10) betyder att Du har haft den värsta tänkbara smärtan eller att du inte kunde utföra aktiviteten på grund av smärta.

	Ingen smärta										Värsta tänkbara smärta
1.1 I vila	0	1	2	3	4	5	6	7	8	9	10
1.2 När du uppför en uppgift med upprepade handledsrörelser, t ex skruva	0	1	2	3	4	5	6	7	8	9	10
1.3 När du lyfter ett tungt föremål	0	1	2	3	4	5	6	7	8	9	10
1.4 När smärtan är som värst	0	1	2	3	4	5	6	7	8	9	10
1.5 Hur ofta har du haft ont i handleden den senaste veckan	0 Aldrig	1	2	3	4	5	6	7	8	9 Alltid	10

6. SWEDISH VERSION OF THE PRWE QUESTIONNAIRE (2/2)

2. FUNKTION

SPECIELLA AKTIVITETER

Ange graden av svårighet som du haft den senaste veckan att utföra nedanstående aktiviteter genom att ringa in siffran som beskriver svårigheten på en skala från 0 till 10. En nolla (0) betyder att Du inte haft någon svårighet och tio (10) betyder att Du haft så stor svårighet att Du inte kunde utföra aktiviteten alls.

	Ingen smärta										Värsta tänkbara smärta
2.1 Vrida ett dörrhantag med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
2.2 Använda kniv för att skära mat med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
2.3 Knäppa skjortknappar med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
2.4 Använda den påverkade handen för att skjuta ifrån och resa mig upp från en stol	0	1	2	3	4	5	6	7	8	9	10
2.5 Bära ett 5 kilos föremål med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10
2.6 Använda toalettpapper med den påverkade handen	0	1	2	3	4	5	6	7	8	9	10

VARDAGLIGA AKTIVITETER

Uppskatta graden av svårighet du har upplevt när du har utfört vardagliga sysslor inom nedan listade områden under den gångna veckan genom att ringa in siffran som bäst beskriver din svårighet på en skala från noll (0) till tio (10). Med vardagliga sysslor menas sysslor som du utförde innan du fick problem med handleden. En nolla (0) betyder att du inte har upplevt någon svårighet och tio (10) betyder att det varit så svårt att du inte har kunnat utföra någon av dina vanliga sysslor inom detta område.

	Ingen svårighet										Omöjligt
2.7 Personlig vård (klä på sig, tvätta sig)	0	1	2	3	4	5	6	7	8	9	10
2.8 Hushållsarbete (tvätta, diska)	0	1	2	3	4	5	6	7	8	9	10
2.9 Arbete (ditt yrke eller vardagliga sysslor)	0	1	2	3	4	5	6	7	8	9	10
2.10 Fritidsaktiviteter, hobby	0	1	2	3	4	5	6	7	8	9	10

UTSEENDE – frivilligt

Hur viktigt är din hands utseende för dig? ☐ Mycket viktigt ☐ Ganska viktigt ☐ Inte alls viktigt

Gradera hur missnöjd du varit med din handled/hands utseende den senaste veckan

0	1	2	3	4	5	6	7	8	9	10
Inte alls										Helt och hållet

Övriga kommentarer?

Patient nr: Datum:

VAS (Visual Analog Scale)

Anvisningar: Frågorna nedan kommer att hjälpa oss att förstå hur stora svårigheter du haft med din handled den senaste veckan. Du kommer att få beskriva dina handledssymtom på en skala 0 – 10. Var snäll och svara på ALLA frågor. Om du inte utförde någon aktivitet, var snäll och UPPSKATTA den förväntade smärtan.

Ange ungefärlig smärta i din handled den SENASTE VECKAN genom att markera på linjen den plats som beskriver smärtnivån från 0 – 10, ”Ingen smärta” till ”Värsta tänkbara smärta”.

I VILA

I——————————————————————I
0 10
Ingen smärta Värsta tänkbara smärta

I AKTIVITET

Vid normal vardagsaktivitet, exempel matlagning, städning

I——————————————————————I
0 10
Ingen smärta Värsta tänkbara smärta

Patient nr: Datum:

VID LYFT AV ETT TUNGT FÖREMÅL

I——————————————————————I
0 10
Ingen smärta Värsta tänkbara smärta

NÄR DET ÄR SOM VÄRST

I——————————————————————I
0 10
Ingen smärta Värsta tänkbara smärta

HUR OFTA UPPLEVER DU SMÄRTA?

I——————————————————————I
0 10
Aldrig Alltid

Protokoll DRU-led

Herbert, Scheker, Eclypse, …….

Patient Nr:

KONTROLLER	DATUM	SIGNATUR	EXCEL DAT/SIGN
PREOP			
OP			
1. POSTOP 1-3 V			
2. 6 V			
3. 3 M			
4. 6 M			
5. 1 ÅR			
6. 2 ÅR			
7. 3 ÅR			
8. 5 ÅR			
9. 7 ÅR			
10. 10 ÅR			
11. 13 ÅR			
12. 16 ÅR			
13. 20 ÅR			

Hö / Vä Pat nr Datum

Preoperativ undersökning

RTG datum: DASH PRWE VAS

Ålder: Kön: M / K

Dominant hand: H / V Symtomgivande hand: H / V

Diagnos: RA / OA Skada: Skadetillfälle:

Annan indikation:

Sysselsättning: (Nuvarande/tidigare, utan förhinder, anpassade uppgifter) %

Arbetslös Ålders/avtalspension Sjukskriven/sjukpension %

Tidigare operationer i aktuell arm:

Dominerande besvär: (smärta, värk, instabilitet, svaghet, rörelseinskränkning…)

Kommentar: (utveckling, symtom, funktion)

8. DRUJ ARTHROPLASTY PROTOCOL: PREOPERATIVE EXAM (3/4)

Hö / Vä Pat nr Datum

”NÖJDHET” I----------I
Totalt missnöjd Maximalt nöjd

Mycket missnöjd, missnöjd, varken missnöjd eller nöjd, nöjd, mycket nöjd

ROM	Hö / Vä		Hö / Vä
Extension	/	Flexion	/
Supination	/	Pronation	/
Radialdeviation	/	Ulnardeviation	/

STYRKA		Hö / Vä
Grepp		/
Lyft	Neutralt	/
	Supination	/
	Pronation	/
Vridmoment	Supination	/
	Pronation	/

STABILITET (0-2) DRU Ballottement	Neutralt	/		
	Supination	/		
	Pronation	/		
SMÄRTA (0-3)	Kompression	/	Ballottement	/

KOMMENTAR, STATUS

8. DRUJ ARTHROPLASTY PROTOCOL: 1-YEAR FOLLOW-UP (4/4)

Hö / Vä Pat nr: Datum

Postoperativ kontroll 5 (1 år) RTG, VAS, PRWE, DASH

”NÖJDHET” I----------I
Totalt missnöjd Maximalt nöjd

Mycket missnöjd, missnöjd, varken missnöjd eller nöjd, nöjd, mycket nöjd

ROM	Hö / Vä		Hö / Vä
Extension	/	Flexion	/
Supination	/	Pronation	/
Radialdeviation	/	Ulnardeviation	/

STYRKA		Hö / Vä
Grepp		/
Lyft	Neutralt	/
	Supination	/
	Pronation	/
Vridmoment	Supination	/
	Pronation	/

STABILITET (0-2) DRU Ballottement	Neutralt	/		
	Supination	/		
	Pronation	/		
SMÄRTA (0-3)	Kompression	/	Ballottement	/

KOMMENTAR, förlopp / status (sår, svullnad, ömhet…)