Fracture of the distal radius - outcome, primary surgery and treatment of malunion

Abramo, Antonio

2008

Contents

List of papers

This thesis is based on the following papers which will be referred to in the text by their Roman numerals:

I. Evaluation of a treatment protocol in distal radius fractures. A prospective study in 581 patients using DASH as outcome.
Abramo A, Kopylov P, Tägil M.
Acta Orthopaedica 2008; 79(3) in press

II. Open reduction and internal fixation versus closed reduction and external fixation in distal radial fractures. A randomized study in 50 patients.
Abramo A, Kopylov P, Geijer M, Tägil M.
Submitted

III. Osteotomy of dorsally displaced malunited fractures of the distal radius. No loss of radiographic correction during healing with a minimal invasive fixation technique and an injectable bone substitute.
Abramo A, Tägil M, Geijer M, Kopylov P.
Acta Orthopaedica 2008; 79(2): 262-268.

IV. Distal radius fracture malunion. Osteotomy using a fast remodeling bone substitute.
Abramo A, Geijer M, Kopylov P, Tägil M.
Submitted

Abbreviations and definitions

BMD – bone mineral density.

BMP – bone morphogenic protein.

Cerament® – a bone substitute consisting of 60% calciumsulphate and 40% calciumphosphate, designed to give a fast remodeling of the bone.

Colles fracture – eponym for extra articular dorsally displaced distal radius fracture.

CREF – closed reduction and external fixation.

CTS – carpal tunnel syndrome.

DASH – Disabilities of the Arm Shoulder and Hand – a validated scoring system for patient reported outcome in upper extremity disorders, consisting of 30 items, also translated to Swedish (Appendices 1 and 2).

DEXA – dual energy x-ray absorptiometry is a means of measuring bone mineral density (BMD). Two X-ray exposures with differing energy levels are centered at the patient's bones. The BMD can be determined from the absorption of each exposure by bone.

DBM – demineralised bone matrix.

DRF – distal radius fracture.

DRU-joint – distal radio ulnar joint.

Jamar – a dynamometer used to measure grip strength.

Likert scale – a rating scale in which raters express their opinions on a given subject by marking a box with a questionnaire item. Respondents specify their level of agreement to a statement usually on a 5 item scale.

Norian SRS® – a bone substitute consisting of calciumphosphate forming hydroxyapatite in situ, a substitute with a good compressive strength, but with slow resorption.

ORIF – open reduction and internal fixation

QuickDASH – short form of the DASH with 11 items (Appendix 3).

Responsiveness – the property of a questionnaire that yields different scores on repeated applications and a clinically relevant change has occurred.

ROM – range of motion.

RSD – reflex sympathetic dystrophy

TriMed® – a fragment specific fixation system for distal radius fractures consisting of pins and plates.

VAS – visual analogue scale, a 0–10 cm semiquantitative measurement of subjective parameters such as pain.

Thesis at a glance

I. Outcome of distal radius fractures measured with DASH

What is the patient-reported outcome in our distal radius fracture cohort with the current treatment protocol? Does a standardized treatment protocol give good and equal patient reported results after a fracture of the distal radius?

Patients: 581 consecutive patients with a fracture of the distal radius.

Methods: DASH questionnaire sent to the patients three and twelve months post injury.

Conclusion: With the current treatment protocol used in southern Sweden (Figure 18, see page 22) patients report a good outcome at one year, regardless of the initial severity of the fracture (Figure 1).

II. Open reduction and internal fixation (ORIF) versus closed reduction and external fixation (CREF) of distal radius fractures

Do the new open surgery techniques give a better result than the traditional external fixation?

Patients: 50 patients ranging in age from 18–65 years with an unstable distal radius fracture.

Methods: Randomization to either open reduction and internal fixation (ORIF) with the TriMed® system or to closed reduction and external fixation (CREF).

Conclusion: ORIF results in improved grip strength and a better range of motion (ROM) in forearm rotation when compared to CREF (Figure 2).

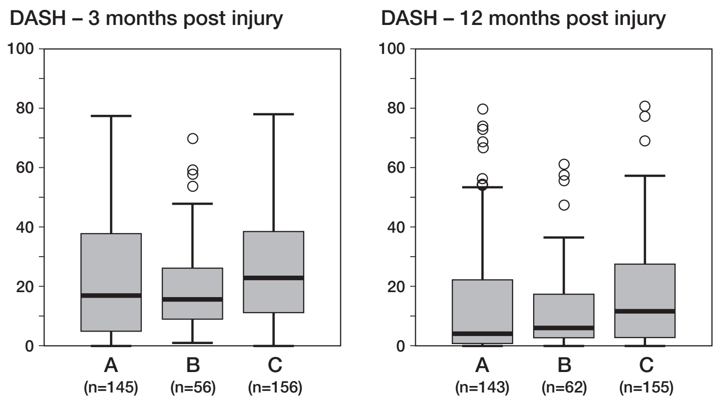

Figure 1. DASH scores for the three treatment types: A) Stable not reduced fractures, B) operated fractures, and C) primarily unstable/dislocated fractures but stable after closed reduction and treated with a cast. Circles represent outliers.

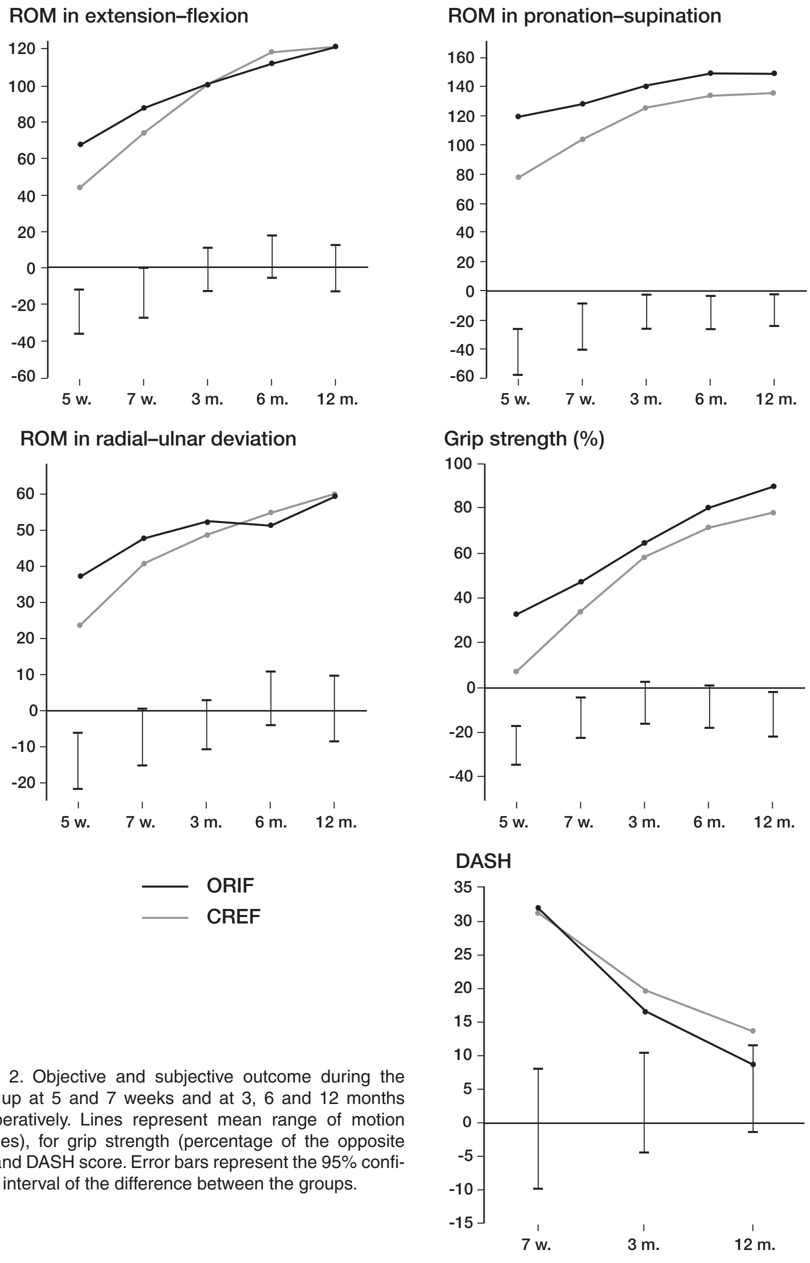

Figure 2. Objective and subjective outcome during the follow up at 5 and 7 weeks and at 3, 6 and 12 months postoperatively. Lines represent mean range of motion (degrees), for grip strength (percentage of the opposite side) and DASH score. Error bars represent the 95% confidence interval of the difference between the groups.

III. Treatment of a malunited fracture of the distal radius using a bone substitute instead of a bone graft

How well can we compensate a distal radius malunion with an osteotomy and can we use bone substitute as a safe and good alternative to bone graft?

Patients: 25 patients with a dorsally malunited distal radius fracture were followed prospectively.

Methods: The malunion was operated on with a distal radius osteotomy, using a fragment specific fixation (TriMed®) and filling the gap with the bone substitute Norian SRS®(Figure 3).

Conclusion: The range of motion and grip strength increases following an osteotomy and DASH scores decrease substantially. The operation can be performed as an outpatient procedure and donor site pain is avoided (Table 1).

IV. Treatment of a malunited fracture of the distal radius using fast resorbing bone substitute

Is a new fast resorbing bone substitute consisting of calcium phosphate and calcium sulphate a safe alternative when used as a gap filler in distal radius osteotomy?

Patients: 15 patients with a dorsally malunited distal radius fracture were followed prospectively.

Methods: A faster resorbing bone substitute Cerament® was used in distal radius osteotomies combined with a fragment specific fixation (TriMed®).

Conclusion: When Cerament® is used the gap heals (Figure 4). However, there is a tendency to lose radial height in some patients. A more rigid fixation would perhaps be preferable.

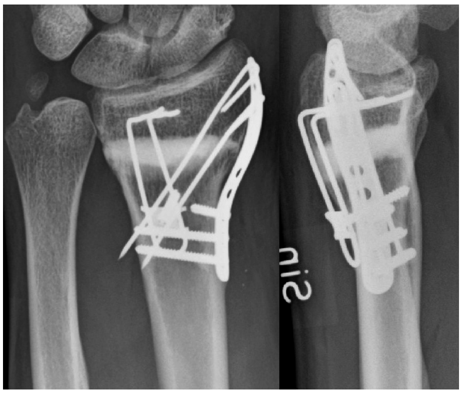

Figure 3. Osteotomy with TriMed® and Norian SRS® with the substitute still in place after four years.

Table 1. Results of osteotomy for malunion of distal radius fractures using TriMed® and Norian SRS®

	Preoperative mean (SD)	12 months [a] mean (SD)	P
Forearm rotation [b]	137 (32.8)	156 (25)	0.006
Extension/flexion [b]	103 (20.3)	120 (15.5)	<0.001
Grip strength [c]	62 (19)	82 (20)	<0.001
DASH	36 (16)	23 (19)	0.003

[a] or last follow up
[b] degrees
[c] percent of uninjured side

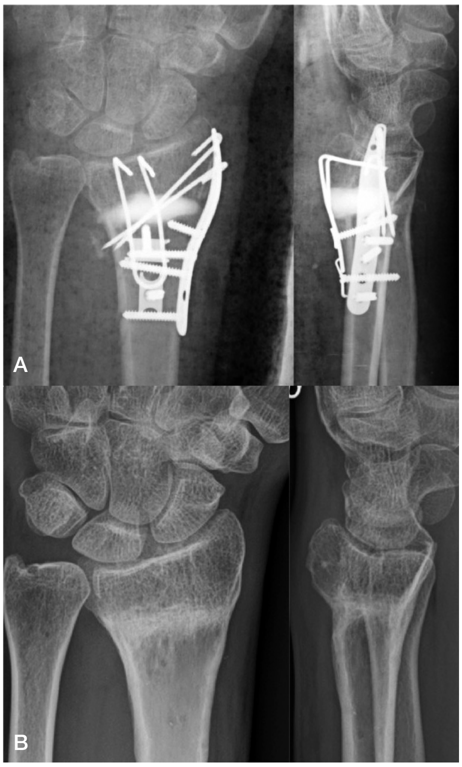

Figure 4. A) Osteotomy of the distal radius with TriMed® and Cerament® and B) healed osteotomy after 1 year with the fixation device removed.

Description of contributions

Paper I

Study design: Antonio Abramo, Magnus Tägil, Philippe Kopylov
Data collection: Antonio Abramo
Data analysis: Antonio Abramo, Magnus Tägil
Manuscript writing: Antonio Abramo, Magnus Tägil
Manuscript revision: Antonio Abramo, Magnus Tägil, Philippe Kopylov

Paper II

Study design: Antonio Abramo, Philippe Kopylov, Magnus Tägil
Data collection: Antonio Abramo, Mats Geijer
Data analysis: Antonio Abramo
Manuscript writing: Antonio Abramo
Manuscript revision: Antonio Abramo, Philippe Kopylov, Mats Geijer, Magnus Tägil

Paper III

Study design: Antonio Abramo, Philippe Kopylov, Magnus Tägil
Data collection: Antonio Abramo, Mats Geijer
Data analysis: Antonio Abramo, Magnus Tägil
Manuscript writing: Antonio Abramo, Magnus Tägil
Manuscript revision: Antonio Abramo, Philippe Kopylov, Mats Geijer, Magnus Tägil

Paper IV

Study design: Philippe Kopylov, Antonio Abramo
Data collection: Antonio Abramo, Mats Geijer
Data analysis: Antonio Abramo
Manuscript writing: Antonio Abramo
Manuscript revision: Antonio Abramo, Philippe Kopylov, Mats Geijer, Magnus Tägil

Introduction

Distal radius fracture then – historical background

Injuries to the distal forearm were described by Hippocrates as carpal dislocations. It was not until the eighteenth century that these were recognized as fractures, initially by Petit in 1705 who suggested that carpal dislocations, in some cases, could be fractures. Later in the same century Claude Pouteau (1783) stated carpal dislocations rather to be fractures at the distal end of the radius with a dorsal dislocation (Fernandez and Jupiter 1996). In 1814 Abraham Colles, the professor of anatomy, surgery and physiology at the Royal College of Surgeons in Ireland (Figure 5a), wrote his famous article and thereafter the fracture has been recognized as a common fracture. Besides describing the fracture that still today bears his name, Colles proposed a treatment and also predicted the outcome. However, at the start of the nineteenth century, French physicians under the lead of Guillaume Dupuytren (1777–1838), head of surgery at Hôtel-Dieu in Paris (Figure 5b) had the greater influence on distal radius fracture (DRF) treatment and also on the classification of fracture patterns, "*Usually fractures at the lower end of the radius are simple but sometimes they are comminuted*". In 1838 John Rhea Barton described the shearing fracture with an oblique fracture line from the articular margin, what is commonly called a Barton fracture (Barton 1838). The additional eponym Smith, which often parallels and complements the Barton fracture was described by R. W. Smith in 1847 as a palmar dislocated fracture but this had previously been described by Goyrand in 1832 (Fernandez and Jupiter 1996). Goyrand observed that most fractures are dorsally displaced but in some cases the displacement is in palmar direction. This fracture type is sometimes referred to as the Goyrand-Smith fracture.

During the late nineteenth century, anatomical dissections of cadaver specimens were used to relate the mechanism of injury to the fracture type. Treatment of the fracture was described by Colles, who suggested a double splint, also suggested by other surgeons during the nineteenth century. Today, the most common treatment for DRF remains a splint. A new era began in 1895 when Wilhelm Conrad Röntgen published his discovery for which he later received the first Nobel Prize in Physics. The use of x-rays to view and diagnose a DRF was presented to a meeting in New York in 1897 (Beck 1898) and today still plain radiographs are the most common method to diagnose and classify the fracture. With modern diagnostic tools such as conventional radiography and CT-scans, the treatment now can be customized, according to the fracture type. Splinting may still be the option

Figure 5. A) Abraham Colles (1773–1843) and Guillaume Dupuytren (1777–1838) two surgeons in the 19th century with a great impact on diagnostics and treatment of distal radius fractures.

Table 2. Incidence of distal radius fractures in the adult population of different countries

Author	Location	Population age	Incidence per 10000 Total	Men	Women
Alffram and Bauer 1962	Malmö (Se)	>20	19	~6	~33
Bengner and Johnell 1985	Malmö (Se)	>25	43	15	67
Solgaard and Petersen 1985	Frederiksborg (Dk)	>20	20	8	32
Robertsson et al. 1990	Reykjavik (Is)	>15	25		
Larsen and Lauritsen 1993	Odense (Dk)	>15	27	16	37
Hove et al. 1995	Bergen (No)	>20	38		
Hagino et al. 1999	Tottori (Jap)	>35		6	20
Melton et al. 1999	Rochester (MI)	>35	30	10	44
O'Neill et al. 2001	Manchester (UK)	>35		9	37
Court-Brown and Caesar 2006	Edinburgh (UK)	>12	20		
Brogren et al. 2007	Kristianstad (Se)	>18	26	12	39

for the simple fractures whereas surgical treatment is warranted when the fracture is comminuted and/or unstable.

A common fracture – epidemiological background

Distal radial fractures are common fractures accounting for about one-sixth of the fractures treated at emergency rooms (Fernandez and Jupiter 1996) or one-tenth of the total number of fractures in adults over 35 years (Melton et al. 1999). The incidence of DRF is approximately 19–43 per 10000 inhabitants annually (Table 2) with females outnumbering males in overall distribution 4:1. Compared to other fractures the distal radius fracture is one of the most common fractures with vertebral fractures, foot and toe fractures and hip fracture at a comparable incidence (Melton et al. 1999). Several epidemiologic studies have been performed and incidences vary according to country and region. In Sweden, the incidence in the city of Malmö had almost doubled from the 1950s to the 1980s. This change over time could not be explained by an increase in diagnosed DRF as the incidence of shaft fractures of the forearm remained the same (Bengner and Johnell 1985). The overall ageing of the population and an increased incidence of osteoporosis may offer an explanation. This trend can be reversed with community interventions which promote health-education programs that address dietary intake, physical activity, smoking habits and environmental risk factors for osteoporosis and falls. An intervention program as described has reduced the forearm fracture incidence in women over 40 years from 83/10000 to 46/10000 and in men over 40 years from 17/1000 to 7/10000 (Grahn Kronhed et al. 2005).

With increasing age DRF, as well as fractures in general, tend to be more common. The DRF is most common among older women with an incidence of 60–120 per 10000 inhabitants annually (Alffram and Bauer 1962; Bengner and Johnell 1985; Brogren et al. 2007) (Figure 6). Over the last decades there has been an increase in incidence especially in the age group greater than 60 years. The higher incidence among older women could be explained by the increasing incidence of osteoporosis. Bone mineral density (BMD) is measured by DEXA scans and expressed as ‘‘T-score standard deviations’’ (SD) compared to a reference group of young sex-matched adults. By definition a T-score of -2.5 SD represents osteoporosis and a T-score between -2.5 and -1 represents osteopenia. A T-score > -1 is considered normal (WHO 2000). A screening of patients with wrist fractures between the ages of 50–75 years revealed that only 19% had normal BMD in the hip and vertebrae (Åstrand et al. 2006). In another study 85% of the women between the ages 55–79 years had a low BMD with a T score of less than -1 (Hegeman et al. 2004). A low BMD indicates a higher risk for hip fractures (Cummings et al. 1993). The occurrence of a DRF can be used as a predictor for a later hip fracture. In a Swedish study an overall relative risk to sustain a hip fracture after a previous DRF was 1.54 for women and 2.27 for men (Mallmin et al.

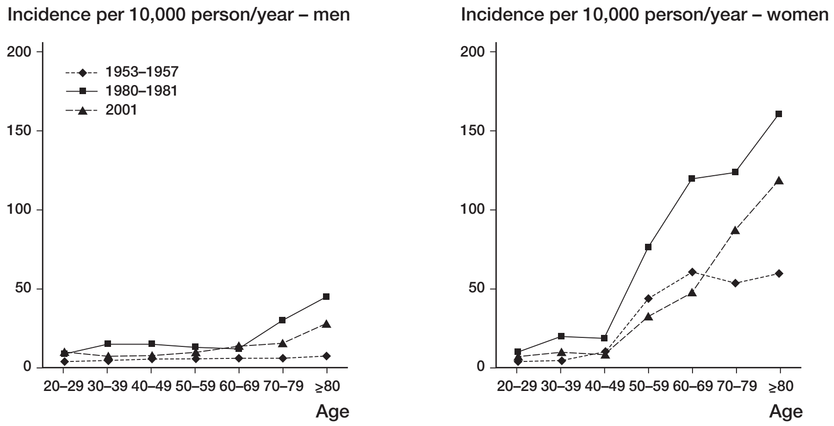

Figure 5. Age specific incidences in different decades in the Scania region. Incidence per 10000 person/year in 10 year age-groups in Malmö 1953–1957 (Alffram and Bauer 1962), in Malmö 1980–1981 (Bengner and Johnell 1985) and in Hässleholm–Kristianstad 2001 (Brogren et al. 2007).

1993) and in an American study the relative risk for a hip fracture was 1.4 for women and 2.7 for men. The risk to have a later vertebral facture was shown to be even higher with a 5.2-fold increase in risk among women and a 10.7-fold increase among men following a first distal forearm fracture (Cuddihy et al. 1999). Although the fracture is most common in older women, also men have DRF with increasing incidence in the ages over 60 years. DEXA-screening reveals that also men have osteoporosis to a large extent with increasing incidence with increasing age (Tuck et al. 2002; Åstrand et al. 2006).

For DRF in younger patients the proportions of men and women are equal. These fractures are often the result of a high energy trauma and should therfore be treated differently than the osteoporotic fractures (Lindau et al. 1999). The fractures in younger patients are more often intra-articular and associated with a high incidence of ligamentous injuries (Lindau et al. 1997) with the sacpholunate ligament being the most commonly injured (Forward et al. 2007).

As the fracture is so common, it imposes large costs to society. In the UK, 1997, each fracture was estimated at 325£ (425€) in direct costs prior to discharge (Kakarlapudi et al. 2000). In France 2005, the cost for in-patient treatment for a DRF was calculated in the range between 2,363 and 2,574€ (Maravic et al. 2005). In Rochester, USA the calculated cost for the year following a DRF due to a moderate trauma was 1628$ (1050€) (Melton et al. 2003). In Sweden, the costs in the year following the fracture were 2147€, including both direct and indirect costs (Borgström et al. 2006) resulting in an annual cost to the country of about 50 million Euro for the adult (7,26 million persons) population (November 2007). However, costs for fractures after the first year, such as costs for surgery of malunions, are not taken to account.

With an increasing proportion of elderly people, not only in the western communities but also in the developing countries, the DRF remains an important and increasing economical problem that has to be assessed. However, not only the costs of the fracture are of importance, but also the outcome and disability from the patients' perspective and therefore reliable objective measurements are of importance.

How to measure the final results – clinical assessment, radiographs and outcome instruments (Figure 7)

Outcome is what we percieve as the final result of a fracture and can be difficult to define and measure. Various modalities have to be considered, such as the subjective, objective and economical outcome; a broad view which incorporates pain, range of

Figure 7. To measure the final results

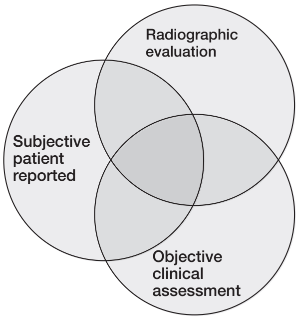

Figure 8. Three ways to define outcome in distal radius fractures. In the middle we might be able to get a more comprehensive picture of the outcome.

motion and cosmetic appearance was suggested by Colles as *"One consolation only remains, that the limb will at some remote period again enjoy perfect freedom in all of its motions and be completely exempt from pain: the deformity, however, will remain undiminished through life"*. This description of the outcome following a DRF is still valid today as found and described by Kopylov et al. (1993) in a 30 year follow up of 76 patients with most patients experiencing a good longterm outcome. In a shorter perspective it is somewhat different. Most fractures do heal and function is restored almost completely after one year but 16% of patients has been shown to suffer from residual symptoms such as nerve symptoms, pain and disability (MacDermid et al. 2003). The outcome thus can be described differently and restitution be more or less complete. To fully evaluate any diagnosis or treatment option, we believe both subjective parameters from the patient's perspective as well as objective clinical assessment and radiographic examination are of interest and should be used (Figure 8).

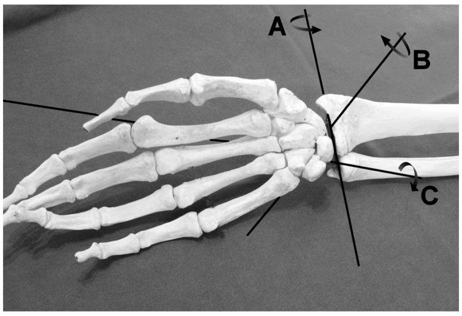

Figure 9. The axes of rotation in and around the wrist joint: A) extension/flexion of the wrist, B) radial/ulnar deviation of the wrist and C) forearm rotation (pronation/supination) around the head of the ulna.

Figure 10. The Jamar dynamometer. The width of the grip is adjusted in five steps. Step 2 is the commonly used size.

Objective clinical assessment

In the four studies in this thesis various objective parameters have been used. In **Paper II and III**, the range of motion was measured in the three axes of rotation around the wrist joint. Extension and flexion as well as radial and ulnar deviation take place in the radiocarpal joint and were measured and expressed as one parameter as these could be regarded as one motion around the radio-ulnar and dorso-volar axis. Forearm rotation takes place in the distal and proximal radio-ulnar joints around the longitudinal axis (Figure 9). Grip strength, the next objective clinical parameter of interest, was measured with the Jamar dynamometer (Figure 10), expressed in kg and related to the strength of the contralateral hand. In our studies, grip strength was calculated as a mean of three repeated measurements according to the method of Ashford et al. (1996) but one maximal test has been shown to be as reliable as the average value of three trials (Coldham et al. 2006). Grip strength in an older population has been shown to correlate well to the health related quality of life measured by the SF-36 (Sayer et al. 2006). Normative values for the grip strength exist for both the younger population under 65 years (Hanten et al. 1999) and for the older population over 60 years (Desrosiers et al. 1995). A decrease in grip strength has been shown with increasing age (Hanten et al. 1999). In **Papers II–IV** grip strength was expressed as a percentage of the contralateral side.

Radiographs

As previously noted, radiographs were first used for examination of DRF at the end of the nineteenth century. Since then, radiographic examination has improved technically and forms a basis of classification and outcome. However, it has in some studies been shown to correlate poorly with final clinical outcome (Altissimi et al. 1986; Tsukazaki et al. 1993; Flinkkilä et al. 1998; Anzarut et al. 2004) and the inter-observer reliability and intra-observer reproducibility of different radiographic classifications is low (Andersen et al. 1996). In some studies, however, an association has been shown between the initial radiographs and the final radiographic outcome. Lafontaine et al. (1989) created an instability index incorporating an increased number of instability factors on the initial radiograph, i.e., dorsal angulation more than 20°, dorsal comminution, intra-articular radiocarpal fracture and associated ulnar fracture and an age over 60 years were all correlated to worse radiographic outcome. Mackenney et al. (2006) demonstrated that ulnar variance, metaphyseal comminution and patient age were predictors for the radiographic outcome, as was the dorsal angulation as a predictor in primary displaced fractures. In a recent study, the radiographic appearance in the initial radiograph, radial shortening ≥ 2mm, dorsal angulation >15 degrees, and radial angulation >10 degrees were each significantly associated with a poorer DASH score (Wilcke et al. 2007). This brings us to the third cornerstone in assessing outcome in DRF, the patient's perspective.

Subjective parameters

Colles considered that apart from range of motion, relief of pain which can be regarded as a subjective parameter, is an important outcome measure. In recent years there has been interest in the development of patient related outcome scores – generic, region specific and organ or joint specific. In the early years of health measurement, generic tools measuring the general health or health related quality of life were dominating and one of the first was the sickness impact profile (Gilson et al. 1975). Other generic outcome scores which became widely used in the orthopedic literature are the Nottingham Health Profile (Wiklund and Dimenas 1990) and the SF -36 (Sullivan et al. 1995; Sullivan and Karlsson 1998). The latter is today the most frequently used and measure health in 8 domains; physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional and mental health. EQ-5D (Burström et al. 2001), another generic and short-form tool designed to measure general health. It calculates a utility score using population-assigned weights and can be expressed as a utility value ranging from -0.59 to 1. These generic instruments all measure general health and are valuable in covering general health issues such as diabetes, heart disease or other combined conditions but are less sensitive to small changes in various disorders such as orthopedic conditions (Hawker et al. 1995).

In order to try to catch smaller but clinically important changes in a particular disorder such as distal radius fractures, we have used a region specific outcome scoring system, the DASH (Appendix 1), which is one of the most commonly used region specific scoring systems for the upper extremity. DASH is an abbreviation for Disabilities of the Arm Shoulder and Hand, initially published, and later corrected, as the Disabilities of the Arm, Shoulder and Head (Hudak et al. 1996). DASH is a self-administered questionnaire developed by the AAOS and the Institute for Work & Health in Canada (http://www.dash.iwh.on.ca/). DASH has been translated and validated in Swedish (Atroshi et al. 2000) (Appendix 2) and validated for general use in upper extremity disorders but not specifically for distal radius fractures. The questionnaire consists of 30 items pertaining to difficulties to perform physical activities (21 questions), symptom severity (five questions) and the effect of the injury on social activities, self-image, work and sleep (four questions). Each question has five response options. A score is calculated and the disability of the patient is expressed on a scale from 0 to 100, with 100 being the worst result. A minimum of 27 items must be answered for the result to be valid and in order to calculate the DASH score. A change in mean DASH score of 10 points after an intervention such as surgery is considered as minimally important change (Gummesson et al. 2003). During the time of our studies a shorter form, QuickDASH (Appendix 3), consisting of eleven questions from the original DASH was developed and validated (Beaton et al. 2005). It was later translated to and validated in Swedish and has been shown to correlate excellently with the standard DASH (Gummesson et al. 2006).

Even more specific are the disease or site-specific outcome instruments. The carpal tunnel syndrome (CTS) instrument, translated into Swedish (Atroshi et al. 1998) and the SPADI (Shoulder Pain and Disability Index) (MacDermid et al. 2006) are examples of validated scoring systems for the upper extremity. For the wrist, a joint-specific outcome instrument for wrist injuries and disorders exists – the Patient Rated Wrist Evaluation (PRWE) which has a somewhat higher specificity than the DASH (MacDermid et al. 2000), but it has not yet been translated to Swedish.

How to treat – conservative and surgical treatment of distal radius fractures

Closed reduction

Colles described a method for closed reduction and also suggested a tin splint for stabilizing the fracture. Other surgeons such as Dupuytren (1847) described their methods for reducing the fracture and the method of immobilization: *"I apply the usual apparatus for fractures of the forearm – that is to say a bandage for the hand, two graduated compresses on the anterior surface of the forearm and two on the posterior and over these two broad splints"* (Fernandez and Jupiter 1996). Closed reduction and splinting is still today the most commonly used method of treatment in the DRF. The type of splinting is of importance as is the position to immobilize. In supination there is less likelihood of redislocation (Wahlström 1982).

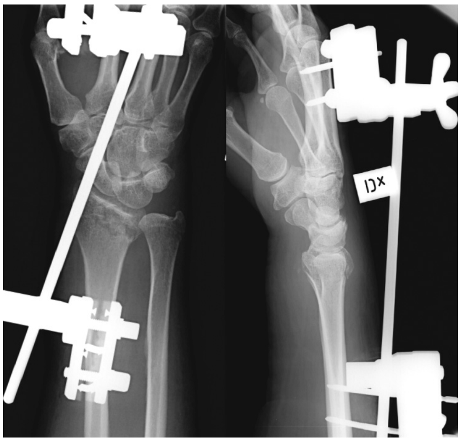

Figure 11. The external fixator.

In the Cochrane data base report on closed reduction methods, only three randomized or quasi-randomized studies were found including 404 patients (Handoll and Madhok 2003). Many methods of closed reduction have been developed during the years but there is no evidence based on randomized studies to support the choice of a closed reduction method. Handoll and Madok found more studies (33), when also systematically evaluating non-randomized reports of methods of closed reduction. Even in this study, there is no robust evidence to support any treatment in favor to another and the authors simply recommend the use of a method with which the practitioner is familiar (Handoll and Madhok 2002). In many cases conservative treatment, however, is not enough and especially for primarily or secondarily unstable fractures, surgical options are needed. Different surgical treatments are available, in **Paper II** we have focused on two types: external fixation of the bridging type and internal fixation with a fragment specific system, TriMed®.

Surgery – closed techniques

External fixation (Figure 11)

External fixation of DRF has been in use for more than three decades (Jakob 1994). In Sweden, it is considered to be the standard method for operative treatment of the fracture and for this reason it was chosen as the method to which to compare the newer methods with in **Paper II**. External fixation uses ligamentotaxis to both reduce as well as to keep the fracture in position during healing (Cooney et al. 1979). Better results have been presented with the external fixation than with a below elbow cast evaluated at 2.5 years post fracture, but the external fixation was noted as having more complications (Solgaard 1989). The external fixator can be used also for complex and intra-articular fractures (McKenna et al. 2000). The recommended time for immobilization varies, ranging from 4 weeks (Svensson et al. 2000) to 6 weeks (Gausepohl et al. 2000) and even up to at least 8 weeks (Prince and Worlock 1988). In general, long immobilization time increases the risk for reflex sympathetic dystrophy (RSD) (Gausepohl et al. 2000). At the Department of Orthopedics in Lund where our studies took place, a 5 weeks immobilization period with the fixator was the aim. The traction of the wrist ligaments may cause stiffness and therefore dynamic fixation with an articulated device (Agee 1993; Pennig 1993; Pennig et al. 1994; Pennig and Gausepohl 1996) or non-bridging fixation has been proposed with better results reported than for traditional bridging technique (McQueen 1998). A recent randomized study was unable to find any difference between the bridging and the non-bridging external fixator in regard to clinical results in elderly patients (Atroshi et al. 2006).

Pinning

Other closed reduction techniques includes fixation of the fracture by pinning. Various techniques have been described such as intrafocal pinning (Kapandji 1987), intrafocal intramedullary pinning (Walton et al. 2001) or pinning in combination with external fixation (Trumble et al. 1998). In some studies pinning resulted in a large number of malunions (Oskam et al. 1997), whereas other authors report satisfying results with the technique (Harley et al. 2004). In the Cochrane report on percutaneuos pinning of DRF it is stated that the high rate of complications casts some doubt on their general use (Handoll et al. 2007). The volar locking plate technique is the dominating trend for fixation of distal radius fracture in recent years (see below). Compared to this, intrafocal pinning was in one comparative study shown to be inferior (Oshige et al. 2007). In another study in extra-articular fractures in patients over 60 years pinning was found to provide only a marginal improvement in the radiological parameters compared with immobilisation in a cast alone (Azzopardi et al. 2005).

Plates

For volarly dislocated fractures especially of the Barton or Smith type, a volar plate is preferably used (Keating et al. 1994). For other types of DRF, other techniques have been considered. Standard AO-plates and screws can be used with good results, however, to get a good stability, usually two or more columns of the radial cortex has to be fixated to achieve good results (Jakob et al. 2000; Rikli and Regazzoni 2000). With the introduction of implants designed specifically for the distal radius, the open technique has become increasingly popular. The Pi plate, named after its shape like the Greek symbol π, is designed to fit on the dorsal side of the radial metaphysis. Good results have been reported (Rozental et al. 2003; Krukhaug and Hove 2004) but interference with the extensor tendons and high complication rates have been noted (Rozental et al. 2003; Grewal et al. 2005). This has made a change in design of the plate necessary.

TriMed®

The TriMed® is a fragment specific system addressing the radial and ulnar columns separately as well as single fracture fragments both dorsally and at the volar rim by a combination of plates, pins and screws. It is primarily based on pinning of the fracture but since additional stability is needed to prevent the pins from bending or the fragments from sliding on the pins, a stabilizing plate to secure the pins has been added. In addition, wire forms to support the subchondral bone or small fragments can be used. The system is low profile and offers good stability (Konrath and Bahler 2002; Benson et al. 2006; Schnall et al. 2006; Gerostathopoulos et al. 2007) (Figure 12). The TriMed® pins and plates are used in **Paper II** in a comparison with bridging external fixation and in **Papers III** and **IV** as a fixation device for patients undergoing an osteotomy. The fracture is approached through a radial incision through the first extensor compartment for placement of the pins and fixation with a radial pin plate and secondly through a second incision through the fourth compartment for fixa-

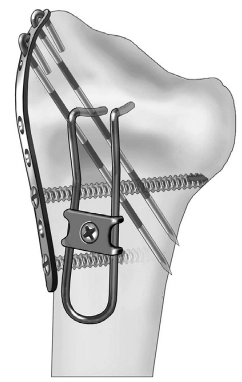

Figure 12. The TriMed® fragment specific wrist fixation system with a radial pin plate with pins and screws and a dorsal buttress pin with a washer and screw.

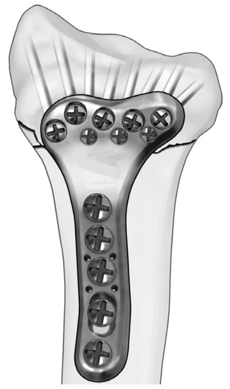

Figure 14. Volar locking plates for distal radius fractures have become increasingly popular in the last years.

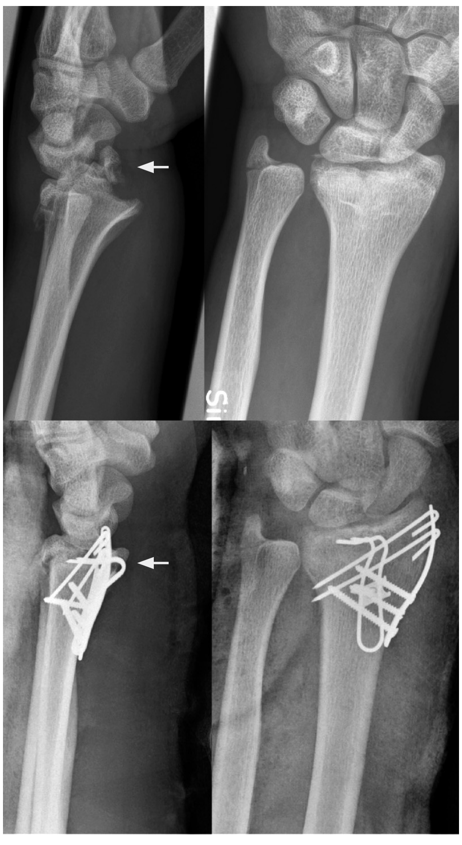

Figure 13. Volar buttress pin for fixation of small volar fragments. Patient case with a severely dislocated volar rim (arrow) fracture of the radius.

tion with wire forms, buttress pins and ulnar pin plate. A volar approach can also be performed to secure the fracture with a volar buttress pin (Figure 13). The surgical approach is determined by the type of fracture and the type of fixation needed to address the fragments.

Volar locking plates (Figure 14)

The newest concept, the volar locking plates with angle stable screws or pegs is becoming widely used as it offers stability and a safe approach to the fracture. The fracture is approached from the volar side using the Henry approach just radially to the flexor carpi radials, ulnarly to the radial artery. This offers an easy access to the volar part of the radius. The volar locking plate has, in biomechanical testing, been shown to be sufficiently stable for fixation of the dorsally comminuted fracture (Osada et al. 2003; Osada et al. 2004; Koh et al. 2006; Willis et al. 2006) and has been shown to offer equivalent stability when compared to the TriMed® fragment specific fixation (Taylor et al. 2006). The best stability is provided by a combination of a volar locking plate with the fragment specific system (Grindel et al. 2007). Good clinical results have reported in a few case series (Musgrave and Idler 2005; Gruber et al. 2006). Complications such as tendon ruptures have been reported (Benson et al. 2006; Arora et al. 2007; Klug et al. 2007). No randomized study has been published yet comparing this concept to conventional DRF fixation in a clinical setting.

To fill the gaps – the use of bone grafts and bone substitutes

After open reduction a void is commonly seen in the metaphysis and the fixation needs to be combined with a bone graft or bone substitute to fill the gap caused by the impacted osteoporotic bone (Figure 15).

Bone grafts

The most common bone graft is an autograft, often from the iliac crest. An autograft has the advantage of being both osteoconductive (allows bone to grow into it) as well as osteoinductive (induces formation of new bone). The major disadvantage is the limited amount of bone available and postoperative morbidity from the donor site. Complications can occur such as minor infections or seromas in 10% and even major complications requiring hospitalization in 6% of patients (Arrington et al. 1996). At discharge nearly all patients, not surprising, complain of pain at the harvest site (Sasso et al. 2005). More troublesome is the persisting pain over 6 months in 26–41% of patients (Heary et al. 2002; Silber et al. 2003; Sasso et al. 2005).

Therefore there is a need for an alternative to autograft. Allograft has been used widely and is the standard choice in hip revision surgery impacted into the cavity (Tägil and Aspenberg 1998).

However, the risk of transmitting viral or today unknown diseases have made the use of human and even animal grafts less attractive (Larsson and Berg 2005). The need for alternatives to bone grafts have therefore arisen and various substitutes have been developed.

Bone substitutes

Synthetic bone substitutes have the advantage of comparable mechanical properties while diminishing the risk for transmittal of diseases. *Calcium sulphate* (plaster of Paris) was commonly used since the late 19th century but has the disadvantage of having poor mechanical resistance and fast resorption rate (Larsson and Berg 2005). It resorbs by dissolution during a period of approximately four to six weeks (Nilsson 2003; Stubbs et al. 2004) and complete resorption has been noted in dogs after 13 weeks (Turner et al. 2003). An advantage of a material resorbing by dissolution is its ability to act as a drug carrier. However, in a clinical setting with fracture treatment or healing of an osteotomy a short resorption time could be a drawback when ingrowth of bone and bony healing might not be completed before the material has lost its strength. Therefore slowly resorbing and stronger substitutes have been developed.

Figure 15. In osteoporotic fractures there is sometimes a loss of bone which has to be replaced. The same applies to distal radius osteotomies where there is a gap that preferably is filled with bone or bone substitute.

To mimic bone various bone substitutes using *calcium phosphate*, the major mineral component of bone, have been developed. It is used as *hydroxyapatite* $Ca_{10}(PO_4)_6\,(OH)_2$, which is poorly soluble and as *tricalcium phosphate* $Ca_3(PO_4)_2$, which is relatively soluble, or a combination of both. These substitutes can be obtained in granules or monoblocks but to facilitate minimal invasive surgery injectable substitutes have been developed. In **Paper III** an injectable calcium phosphate consisting of a powder of tricalcium sulphate, calcium carbonate and monocalcium phosphate monohydrate is mixed with a sodium phosphate solution and forms a hydroxyapatite (dahlite) in vivo, Norian SRS® (Kopylov et al. 1996; Kopylov 2001; Cassidy et al. 2003), has been used. In **Paper IV**, a mixture of hydroxyapatite and calcium sulphate, Cerament®, (Nilsson et al. 2004) has been used. This material consists of 40% hydroxyapatite and 60% calcium sulphate, which has proven to be the strongest mixture with a compressive strength up to 35–50 MPa, comparable to trabecular bone (Nilsson 2003). By incorporating calcium sulphate into the hydroxyapatite, macroporosity is obtained allowing bone ingrowth. All the above mentioned

Table 3. Proprieties of different types of bonegrafts and bone substitutes (modified from Giannoudis et al. 2005)

Type	Osteo-conduction	Osteo-induction	Advantages	Disadvantages
Autograft	++	++	Gold standard	Donor site pain
Allograft	++	+	Good availability	Infection risk
Demineralized bone	+	+	Osteoinductive	Infection risk
Calcium sulphate	+	-	Cheap	Limited period of structural support
TCP, hydroxyapatite	+	-	Good structural support	Expensive
Composite [a]	++	++	Close to gold standard	Expensive

[a] Substitute with addition of osteoinductive factors as bone morphogenic proteins or bone marrow

types of bone substitutes are highly biocompatible but have no osteoinductive properties in contrast to bone graft. This can, however, be dealt with when designing composite grafts, combining bone substitute either with substances increasing ingrowth such as osteogenic proteins (BMP) or bone marrow aspirate or substances reducing resorption such as bisphosphonates.

When initial treatment fails – malunion and distal radius osteotomies

In spite of advances in the treatment of DRF, malunion is one of the most common complications. Malunion is a major cause for residual symptoms and appears in about 5% of fractures (Cooney et al. 1980). The patient suffers from decreased range of motion and pain, especially at the ulnar side of the wrist. The cause for the symptoms is the malunion resulting in an incongruency of the distal radio ulnar joint (af Ekenstam et al. 1985; Bronstein et al. 1997). Apart for the symptoms above these patients suffer from decreased grip strength and also a poor cosmetic appearance.

Osteotomy

The common treatment option for malunions is an osteotomy of the distal radius and this has been in use for many years. A volar approach for the dorsally malunited DRF is today an increasingly popular choice since the volar locking plate gain in popularity as the fixation of choice for DRF. The technique was previously described by Lanz (Lanz and Kron 1976) but as the paper was written in German the technique never became popular in non-German speaking countries. The technique with dorsal approach for dorsally malunited fractures and a volar approach for volar malunions became popularized by Fernandez (1982) who, in the early eighties, could show good results. Others have followed but the technique has basically remained the same although various fixation types have been advocated (Table 4 and Figure 16).

The healed fracture is cut at the fracture site and a correction of the length and/or angle is done using an opening wedge technique. In some cases when there is an operation performed at the ulna, such as a Darrach (ulna head resection) or a Kapandji-Sauvee (arthrodesis of the DRU-joint and osteotomi of the ulnar neck), a closing wedge can be used (Van Cauwelaert de Wyels and De Smet 2003). Sometimes the osteotomy of the radius is combined with a shortening osteotomy of the ulna (Flinkkilä et al. 2000).

An opening wedge osteotomy is a common and logic solution for dorsally malunited fractures and fixation is commonly achieved with a dorsal plate but other techniques have been used (Table 4). **Paper III** describes a novel technique developed in Lund using a fragment specific system for the fixation of the osteotomy allowing adjustment in the amount of radial lengthening an angulation even after a substantial part of then hardware has been put in place. Even for volarly displaced fractures the opening wedge osteotomy can be an alternative (Fernandez 1982; Shea et al. 1997) and also for intra-articular malunited fractures, an intra-articular osteotomy can be performed (Ring et al. 2005). An iliac crest bone graft is often used to fill the

Table 4. Different fixations and grafting techniques used in osteotomy for malunited distal radius fractures

Author	Number of patients	Fixation	Graft
Fernandez 1982	20	Dorsal plate (Colles) Volar plate (Smith)	Corticocancellous
af Ekenstam et al. 1985	39	Dorsal plate	Corticocancellous
Hove and Mölster 1994	16	Dorsal plate	Corticocancellous
Arslan et al. 2003	9	External fixator	Callus distraction
Pennig et al. 2000	14	External fixator	Callus distraction (8), corticocancellous
Krukhaug and Hove 2007	33	Dorsal plate	Corticocancellous
Ring et al. 2002	20	Dorsal plate	Corticocancellous (10), cancellous
Flinkkilä et al. 2000	45	Compression plate (41 cases), K-wire, rod, external fixation	Corticocancellous
Prommersberger et al. 2002	29	Volar plate	Corticocancellous
Van Cauwelaert de Wyels and De Smet 2003	21	K-wires or T-plate	Corticocancellous
Luchetti 2004	6	Pinning	Norian SRS®
Lozano-Calderon et al. 2007	6	Volar locking plate	Norian SRS®

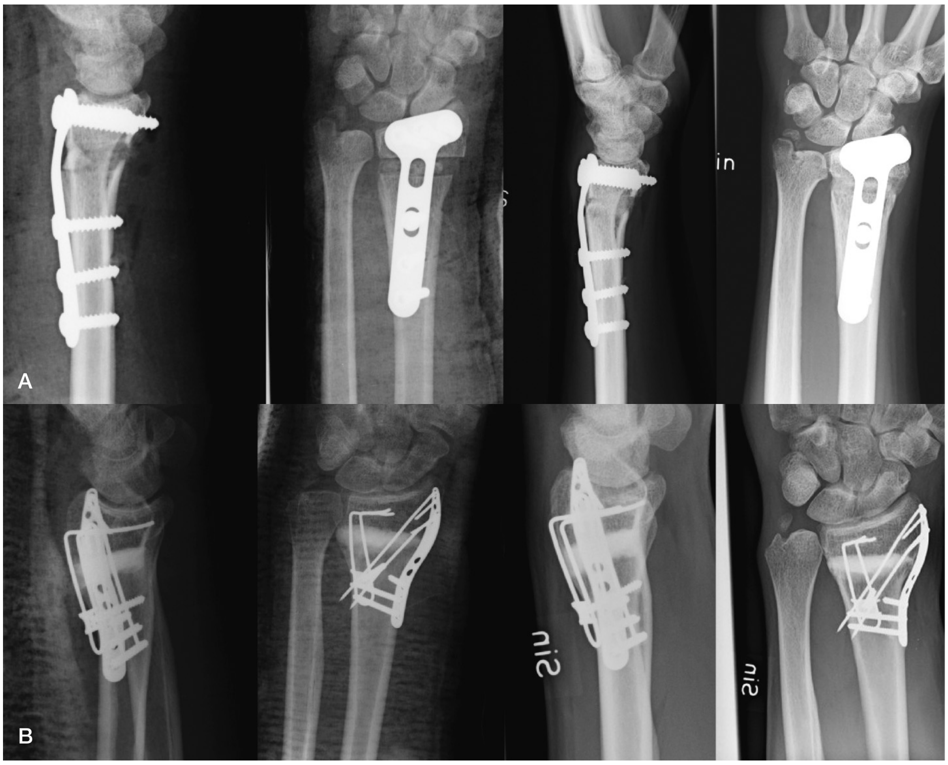

Figure 16. A malunited fracture of the distal radius can be treated with an osteotomy. Two types of fixation and two types of gap fillers are shown. A) Dorsal plate with iliac crest bone graft postoperatively and after 1 year. B) TriMed® fragment specific wrist fixation with Norian SRS® bone substitute postoperatively and after 4 years.

gap, either as a single block of cortico-cancellous bone or as a non-structural cancellous graft (Ring et al. 2002). The drawback of this is donor site problems. A few reports have been written on the use of bone substitute for distal radius osteotomies but mainly in small series (Luchetti 2004; Lozano-Calderon et al. 2007).

Aims of the study

The general aim of this study was to investigate the outcome of DRF in three different perspectives. Our first aim was to examine the patient reported outcome in a large population based cohort and relate the outcome to different treatments based on the treatment protocol used in the south of Sweden. Secondly, in a smaller series we aimed to study two different surgical options for unstable distal radial fractures which require surgery. Finally, we were interested in finding new treatment options for those patients with fractures healed with malunion. Prior to starting the study the following questions were asked:

- Is a standardized treatment program a tool to treat DRF giving a good patient reported outcome, regardless of the severity of the injury?
- Can the DASH questionnaire be used as outcome measure in DRF to monitor large cohorts?
- Do more complex and more technically demanding open reduction and internal fixation produce a better result in treating DRF than traditional external fixation?
- Is an osteotomy of the distal radius an effective treatment to reduce pain and to give better function when a distal radial fracture has healed with malunion?
- For malunited DRF – is the use of a bone substitute a safe alternative to bone grafting when filling the gap during an osteotomy?
- Is a fast resorbing bone substitute a safe alternative offering the same stability as Norian SRS® and is the bony healing better after osteotomy of malunited DRF?

Summary of papers with focus on material and results

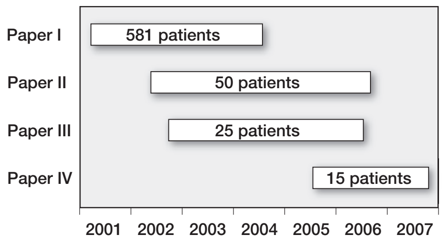

Figure 17. Timeline and patients in the four studies.

Paper I. Evaluation of a treatment protocol in distal radius fractures. A prospective study in 581 patients using DASH as outcome

Patients: 581 patients (77% women) with 584 DRF were followed between September 2001 and August 2003. The mean age was 60 (19–93) years. The follow-up period was one year. 63 patients were excluded and the remaining 518 patients had a mean age of 60 (19–93) years. 398 were female (mean age 63 years, 19–93) and 120 were male (mean age 50 years, 19–92). 206 had fractured their right wrist, 309 their left and 3 had bilateral fractures.

Methods: The patients were divided in three treatment groups according to a standardized treatment program used in the southern region of Sweden (Figure 18). We used a short arm cast for stable fractures and for fractures that could be treated with closed reduction under local anesthesia. Unstable fractures were operated on either with closed reduction and external fixation or open reduction and internal fixation. All patients treated conservatively were reassessed at one week after the fracture and reexamined radiographically. Redislocated fractures underwent surgery. A validated outcome instrument, (DASH – Disabilities of the Arm, Shoulder and Hand) was distributed to all patients at three and twelve months post-fracture. A score is calculated between 0–100 with the higher value being the worst. A control group of 109 healthy age and gender matched subjects also received the questionnaire and 75 of the 109 persons responded (69%).

Results: 75% of the patients returned the questionnaire at 3 and 12 months. The median DASH score for the entire group was 18 at three months and 7 at 12 months. In the older "osteoporotic" age group defined as men aged 60 and older and women aged 50 and older based on the increasing incidence of osteoporosis in the older groups. (Lindau 2000), DASH scores were 23 and 9 respectively and in the younger age group 12 and 5. There was no difference in DASH score between fractures of the left compared to the right wrist. At three months, the median DASH score was 16 in the non-operated group, 14 in external fixation, 15 in volar plate and 16 in the TriMed® group. At 12 months the scores were 6 in the non-operated group, 7 in external fixation, 4 in volar plate and 7 in the TriMed® group. Patients with non-reduced fractures treated with a cast had a score of 16 at 3 months and 4 at 12 months. Patients with reduced fractures treated with closed reduction and casting recorded 18 and 12 and the primarily operated group 14 and 5 at 3 and 12 months, respectively.

Paper II. Open reduction and internal fixation versus closed reduction and external fixation in distal radial fractures, a randomized study in 50 patients

Patients: 50 patients (36 women and 14 men with a mean age of 48 years) with an unstable distal radial fracture were included and randomized to treatment with either open reduction and internal fixation (ORIF), or closed reduction and external fixation (CREF). Inclusion criteria were patients aged 18–65 with fractures which *after* the primary reduction were incongruent in the radiocarpal or distal radioulnar joint and/or showed an axial compression of more than 2 mm and/or a dorsal compression of more than 20°. 24 were randomized to CREF and 26 to ORIF.

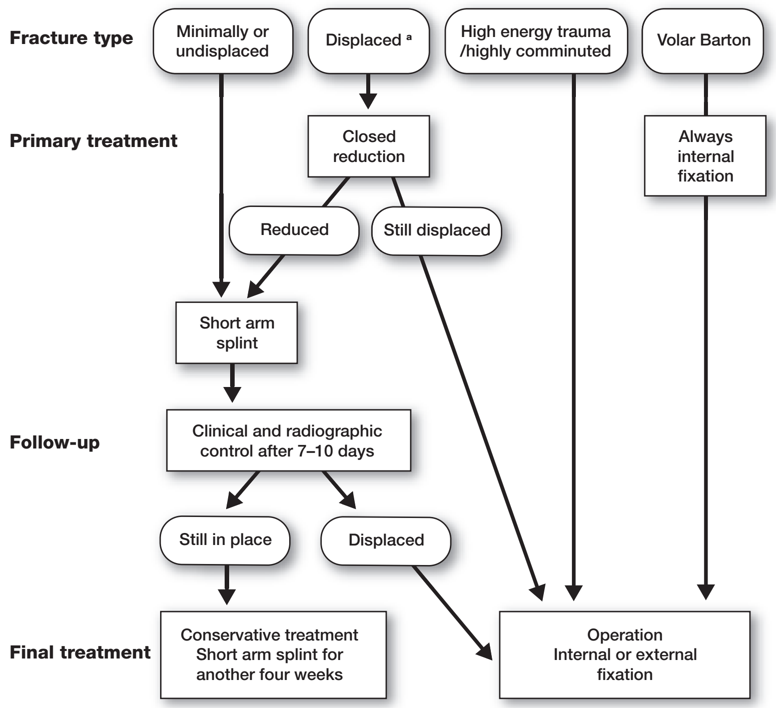

Figure 18. The treatment protocol for distal radius fractures. When selecting different treatments the patients' age and demands also have to be accounted for.
[a] Displaced = dorsal angulation >10° and/or ulna+ >2 mm and/or volar angulation > 25°.

Methods: Randomization was done by sealed envelopes opened at the day of surgery. All patients were followed at two, five and seven weeks and three, six and twelve months postoperatively. A registration of complications was made by a hand surgeon at each visit. Grip strength, range of motion and sensibility were recorded by a physiotherapist at all visits. Lateral and AP radiographs were taken. Dorsal angulation, ulnar variance and radial inclination were also measured (van der Linden and Ericson 1981; Mann et al. 1992). Subjective outcome was evaluated using the DASH score.

Operative technique

For the open group the TriMed® fragment specific system was used. The fracture was reduced and pins introduced at the tip of the radial styloid, and secured by a pin-plate threaded onto the styloid pins on the radial side of the radius and secured by 3–5 screws. Buttress pins, wire forms and/or an ulnar pin-plate were introduced for additional stability. When deemed necessary, Norian SRS® was used in the void to add stability. Postoperatively, the patients were treated with a forearm plaster cast for two weeks and thereafter active mobilization commenced.

The external fixator, pins were inserted into the second metacarpal and into the radius proximally to the fracture with careful control of the radial nerve and extensor tendons. Clamps were attached to the pins and the fracture was reduced and fixated with a rod between the clamps. In comminuted fractures with a bony defect, and when additional stability was desired, K-wires and/or a bone graft substitute, Norian SRS® was used. The fixator was removed after 5–6 weeks.

Results: 51 postoperative complications were reported in 34 patients (Table 5).

At initial follow up at 5 weeks postoperatively, range of motion in extension/flexion, forearm rotation (supination/pronation) and radial/ulnar

Table 5. Complications by group and severity

Complications	CREF	ORIF	total	P-value [a]
Minor [b]				
Postoperative CTS	3	1	4	
Skin adherences	4		4	
Mb de Quervain		1	1	
Radial neurapraxia	2	10	12	
Adherent tendon		1	1	
Prolonged postop. pain	4		4	
Pin tract infection	2		2	
	15	13	28	0.4
Moderate [c]				
Postoperative CTS	4		4	
Skin adherences	1		1	
Malunion	1		1	
Radial neurapraxia		1	1	
Adherent tendon	1	1		
APL dislocation		1	1	
Radial pin irritation		3	3	
Pin tract infection	1		1	
	7	6	13	0.8
Major [d]				
Fractured metacarpal	1		1	
Malunion	5	1	6	
RSD	2	1	3	
	8	2	10	0.04

[a] Fisher's exact test
[b] Transient problems in no need of interventions.
[c] Complication in need of further intervention such as surgery or antibiotic treatment but not inflicting the final outcome, or malunions treated conservatively.
[d] Severe complications inflicting the final outcome and in need of surgical or other intervention.

deviation as well as grip strength were all significantly better in the ORIF group. Forearm rotation remained significantly better for the ORIF group, compared to CREF, at all time points. Range of motion in extension/flexion was better at the 7 week visit but not thereafter. Grip strength was significantly better for the ORIF group, compared to CREF, at the first two examinations at 5 and 7 weeks and at the final visit at one year (Table 6).

Paper III. Osteotomy of dorsally displaced malunited fractures of the distal radius. No loss of radiographic correction during healing with a minimal invasive fixation technique and an injectable bone substitute

Patients: 25 consecutive patients with a dorsal malunion following DRF underwent an osteotomy between November 2002 and October 2005. The patients were followed prospectively for a minimum of one year. The mean age in the study group was 52 (25–74) years and 9 patients were men and 16 women.

Methods: An occupational therapist interviewed and examined the patients preoperatively and at 3

Table 6. Results of the two study groups early (7 weeks) and late (12 months)

	CREF		ORIF		95% CI of	
	n	mean (SD)	n	mean (SD)	the difference	P-value [a]
Extension / flexion						
7 weeks	23	74 (24)	26	88 (23)	-27 to -0	0.05
12 months	21	122 (22)	25	122 (20)	-13 to 13	1
Forearm rotation						
7 weeks	23	104 (29)	26	129 (26)	-41 to -9	0.003
12 months	21	136 (20)	25	149 (15)	-24 to -3	0.02
Radial/ulnar deviation						
7 weeks	23	41 (11)	26	48 (16)	-15 to 1	0.07
12 months	21	61 (19)	25	60 (12)	-8 to 10	0.9
Grip strength (%)						
7 weeks	23	34 (13)	25	47 (17)	-22 to -4	0.005
12 months	21	78 (17)	25	90 (16)	-22 to -2	0.02
DASH						
7 weeks	23	31 (16)	25	32 (14)		0.5
12 months	21	14 (13)	25	9 (9)		0.2

[a] P-value comparing range of movement and grip strength (Students T-test) and DASH (Mann-Whitney U-test).

Figure 19. Materials used for the radius osteotomy: A) buttress pin, B) radial pin plate. Pre- and postoperative AP and lateral radiograph.

and 12 months postoperatively. Range of motion and grip strength were measured. The patients rated their pain at activity and at rest on a 10 cm Visual Analog Scale (VAS) and the functional outcome was evaluated using the Swedish version of the DASH.

Preoperatively, the patients noted their expectations of the outcome of the surgery in a 5 graded Likert scale in terms of pain, function, mobility and cosmetic appearance.

Radiographs were performed preoperatively, postoperatively and at follow up at 1 year.

Operative technique

All osteotomies were operated using the TriMed® system as fixation and Norian SRS® as the gap filler. The TriMed® system is a fragment specific fixation device for DRF consisting of plates and pins. In the current osteotomy technique a radial pin plate and a dorsal buttress pin were used (Figures 19 and 20). Norian SRS® (Synthes GmbH, Switzerland) is a non- or slowly resorbing bone substitute and consists of calcium phosphate. It is mixed to a paste suitable for injection into the gap and sets to carbonated hydroxyapatite after 10 minutes in situ. The resistance to compressive forces exceeds

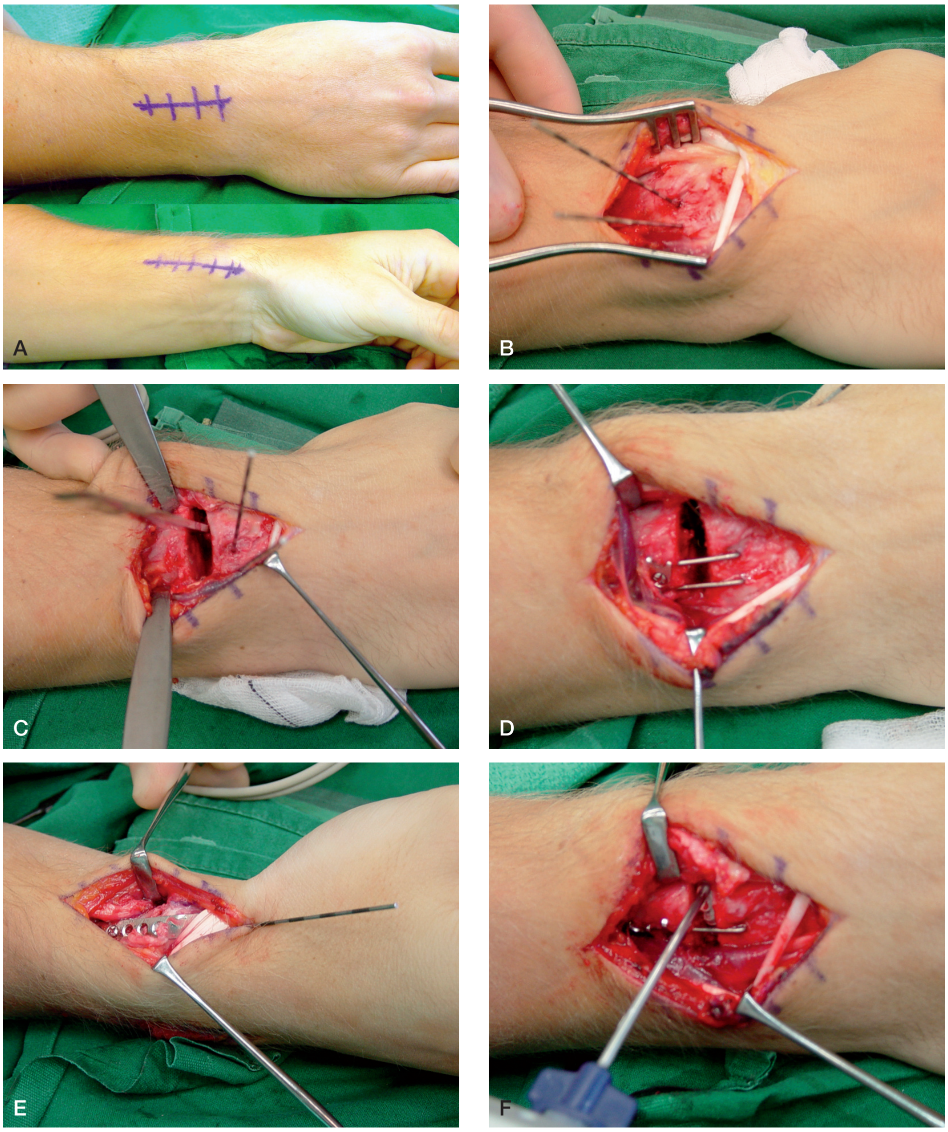

Figure 19. A. The operation was carried out with the arm in a prone position. 2 short incisions were made, one radially through the first extensor compartment and a second dorsal incision through the fourth compartment. B. The joint line was marked with 2 parallel pins into the distal radius and the holes were later used for the dorsal buttress pin. C. The osteotomy was then performed with an oscillating saw and the malposition reduced. A temporary fixation was achieved by a pin driven through the radial styloid and into the radius, proximal to the osteotomy, thereby bridging the osteotomy. D. When optimal positioning was accomplished, the fixation was secured by the dorsal buttress pin and the radial pin plate (E). F. Norian SRS was injected into the bone defect and left to harden as the extensor retinaculum and skin were closed.

10 MPa initially and increases to 55 MPa after 12 hours (Kopylov 2001), which is superior to cancellous bone but inferior to cortical bone.

Results: All but one patient were admitted as outpatients and 18/25 patients could return home the same day, the others returned home the following morning. The mean axial shortening preoperatively was 4.0 mm, and decreased to 2.7 mm postoperatively and 2.6 mm at the final follow up. The mean radial inclination was 20° preoperatively, 21° postoperatively and 22° at the final follow up. Dorsal angulation was 16° preoperatively, -0.1° postoperatively and -0.5° at the final follow up. At 1 year postoperatively, the range of motion was increased compared to preoperatively; in forearm rotation (supination/pronation) from 137° to 155°, in flexion/extension from 103° to 120° and in radial/ulnar deviation from 32° to 43°. Grip strength increased from 62% of the uninjured side to 82%. The mean DASH score decreased from 36 to 23. Pain at rest as measured on a VAS scale decreased from 3.9 to 2.0 cm and pain at activity from 6.3 to 3.7 cm.

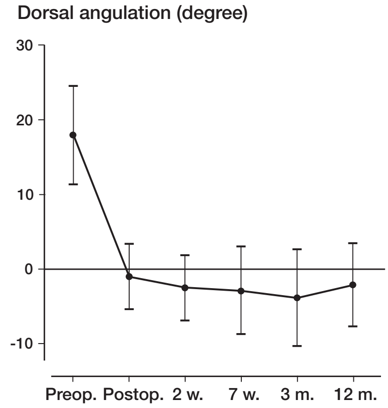

Figure 21. Radiographic findings at different times for osteotomies with the TriMed® system and Cerament® bone substitute. Error bars represent 95% confidence interval.

Paper IV. Osteotomy of malunited distal radius fractures using a remodeling bone substitute

Patients: 15 consecutive patients with a dorsal malunion following a DRF were included and underwent an osteotomy with Cerament® as gap filler. They were operated on between October 2005 and November 2006. The mean age was 50 (27–71) years and there were 10 women and 5 men.

Methods: The patients were followed for one year with clinical assessment, radiographs and DASH. The operative technique was similar to study III, only the type of injected bone substitute differed. The Cerament® bone substitute consists of 40% hydroxyapatite and 60% calcium sulphate. This ratio gives the mixture a compressive strength of 35–50 MPa comparable to trabecular bone. The Cerament® powder was mixed with Omnipaque™ (iohexol), a low osmolar, nonionic, iodinated contrast agent to form an injectable paste. The working time and injectability of the substance is 7 minutes using a 16G cannula and the final setting time is 25 minutes. The setting temperature is 39° C. The calcium sulphate dissolves in approximately 6–12 weeks allowing ingrowth of bone and fast remodeling, compared to a pure hydroxyapatite bone substitute. The osteotomy was secured by the TriMed® system.

Results: 11/15 patients could be treated as outpatients, the remaining four returned home the morning after. Radiographically, all the osteotomies healed. The mean ulnar variance for the whole group was +2.4 (0-9.2) mm preoperatively, +1.9 (-1.0–7.8) mm immediately postoperatively and +2.6 (-0.6–9.4) mm at the final follow up. These changes were statistically not significant. The mean radial inclination was 19° (9–30) preoperatively, 23° (15–31) postoperatively and 24° (18–33) at one year. The mean dorsal angulation was 18 (-9–38) preoperatively, -1.1° (-15–12) postoperatively and -2° (-19–17) at the final follow up (Figure 21). In four patients, there was a greater than 1 mm loss of ulnar variance correction from immediately postoperatively to the one year follow-up. Grip strength increased from 61% (28–93%) of the uninjured side preoperatively to 85% (58–109%, $P < 0.001$) at one year. The preoperative pain at rest as measured on a visual analogue scale (0–10 cm) was 5.5 (3–10) preoperatively and 2.4 (1–6) at one year ($P < 0.001$). The mean DASH score was 37 (22–61) preoperatively and 20 (2–49) at one year ($P = 0.003$).

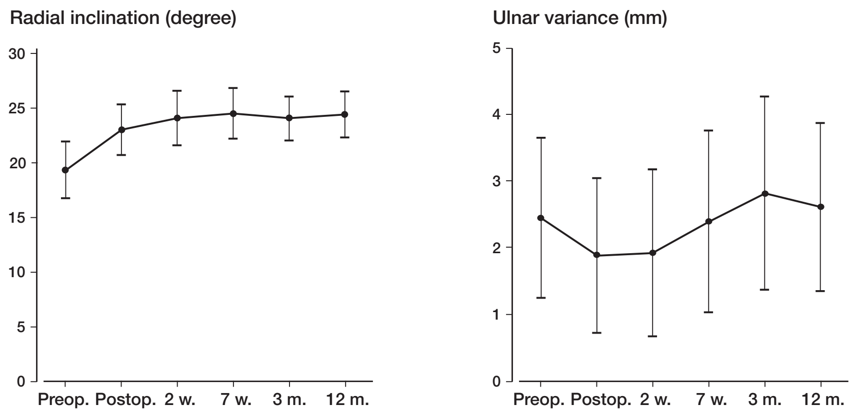

Figure 21. continued.

Discussion

A standardized treatment program

Although radiographs have been shown to have a poor predictive value for DRF (Altissimi et al. 1986; Tsukazaki et al. 1993; Flinkkilä et al. 1998; Anzarut et al. 2004) there is today some evidence to support that the initial dislocation of the fracture can be a predictor of instability (Lafontaine et al. 1989; Altissimi et al. 1994; Leone et al. 2004) and outcome (Wilcke et al. 2007). However, in older patients the fracture can heal with a malunion and yet an acceptable final function can be achieved (Dayican et al. 2003). A treatment program, based on the radiographic appearance but taking into account the age and demands of the patients when selecting the proper treatment was developed by the "Consensus group for distal radius fractures in southern Sweden", consisting of dedicated surgeons from the orthopedic and hand surgery departments at the hospitals in the southern part of Sweden, and used in **Paper I**. In this paper we prospectively registered the outcome of DRF using a subjective outcome, the validated DASH, as the only outcome parameter. The treatment program is meant to be used as a guideline for treatment; therefore a strict compliance to the program is not expected. Even with these limitations, the patients in this study reach the same level of disability as measured with the DASH, regardless of the initial appearance and treatment of the fractures. The interpretation could be that the treatment program helps to select the optimal treatment, limitations do however exist. Many fractures redislocate at follow up but are not always operated on as some patients, mostly elderly, decline an operation although the fractures radiographic appearance meets the criteria for surgery. By speculation, this is reflected in the slightly higher score in patients with unstable fractures treated with closed reduction and a cast.

Although by no means being normalized, most patients reach an acceptable level of disability after three months but an improvement is still seen 3 to 12 months post injury. Other authors have reported the same pattern for patient related problems such as pain in the first year after the fracture (MacDermid et al. 2003). The mean final DASH score in our study was 16 which is in accordance with other studies evaluating both conservative and surgical treatment (Table 7). In our series, different surgical interventions were compared but we were unable to show statistically significant differences between external fixation, internal fixation with the TriMed® system and internal fixation with a volar plate for volar fractures. No other studies comparing surgical techniques using the DASH have to our knowledge been able to show differences in outcome (Wright et al. 2005; Atroshi et al. 2006; Ruch and Papadonikolakis 2006). The use of DASH as a patient administered, surgeon independent, single outcome measure is an attractive way to collect outcome data both in smaller randomized studies as well as in a large cohort of patients, thus eliminating the need for repeated visits. Responsiveness in previous studies presented as the effect size (Kazis et al. 1989) (mean score change divided by the standard deviation of the initial score) has previously been shown to be good.

The DASH questionnaire as an outcome measure in DRF

In our study it was difficult to acquire a valid baseline DASH data. Some patients reported the pre-fracture data as intended but many instead described their immediate post-fracture data, in spite of the written instructions, thus making these data unusable. Using the 3 months result as a baseline and comparing them to the 12 months result the effect size is only moderate (0.37) for the DASH in our study. MacDermid et al. (2000) compared a baseline DASH for DRF to the final result at six months and got a large effect size (2.32), found also by us when we compared the results for the fracture cohort three months after a fracture to an uninjured group (1.12). The low effect size found in our study between the 3 months and 12 months is

Table 7. Mean DASH scores for distal radius fractures for different treatments, conservative, external fixation and open surgical fixation

Author	Treatment	Number of patients	Mean follow up, months	DASH
Wolfe et al. 1999	External fixation	21	35	90.3 [f]
Konrath and Bahler 2002	TriMed®	25	29	17
Rozental et al. 2003	Dorsal plate	28	21	14.5
Ruch et al. 2004	External fixation [a]	15	12	19
	External fixation [b]	15	12	11
Krukhaug and Hove 2004	Pi-plate	29	23	7.8 [g]
Wright et al. 2005	External fixation	11	47	15
	Volar plate	22	17	16
Rikli et al. 2005	Dorsal plate	25	>12	7.2
Ruch and Papadonikolakis 2006	Volar plate	14	22	12
	Dorsal plate	20	21	11
Atroshi et al. 2006	External fixation [c]	19	12	11
	External fixation [d]	19	12	7
Gruber et al. 2006	Volar plate	102	15.6	8
Jaremko et al. 2007	Cast	74	6	24
Westphal 2007	Mixed [e]	72	12	13.2
Forward et al. 2007	Mixed [e]	123	>72	12
Murakami et al. 2007	Volar plate	24	>5	9.9
Arora et al. 2007	Volar plate	114	>12	13
Wilcke et al. 2007	Mixed [e]	78	22	13
Paper I	Mixed [e]	518	12	15.9

[a] Fluoroscopic assistance
[b] Arthroscopic assistance
[c] Bridging
[d] Non-bridging
[e] A mix of different treatments both surgical and conservative
[f] Inverted score
[g] Median score

similar to MacDermid who reported an effect size of 0.44 between the 3 and 6 months after a DRF. The standard DASH with 30 items is sometimes difficult for patients to answer, especially for elderly patients. We had a higher frequency of unusable DASH forms (i.e. with more than three items unanswered) in the older group than in the younger patients. A new shorter version of the DASH (QuickDASH) has been developed and has been shown to correlate to the full DASH (Gummesson et al. 2006). This new questionnaire could be an alternative and we also found an excellent correlation between the two instruments. (Figure 22).

In **Paper I,** DASH was used to monitor a large group of patients and the only predictor of outcome measured with DASH was age. The DASH score was not correlated with any other outcome which is a limitation. This was, however, to reduce the work load and allow a quality system within the everyday clinical setting. Further studies could and have been initiated to more accurately evaluate the radiographic and clinical objective outcomes in subgroups of the larger cohort. A correlation to radiographic and objective outcome has been found in smaller series and the DASH has been shown to correlate to reduced grip strength, extension and ulnar deviation (Wilcke et al. 2007). In the same study radial shortening $\geq$ 2 mm, dorsal angulation >15 degrees, and radial angulation >10 degrees were associated with a poorer DASH score but there was no linear correlation between radiographic parameters and the DASH. In this first cohort study no difference was found between the two major types of operation; open reduction and internal fixation with the TriMed® system versus closed reduction and external fixation, but patients were selected for each operation according to the severity of type fracture. To determine which of

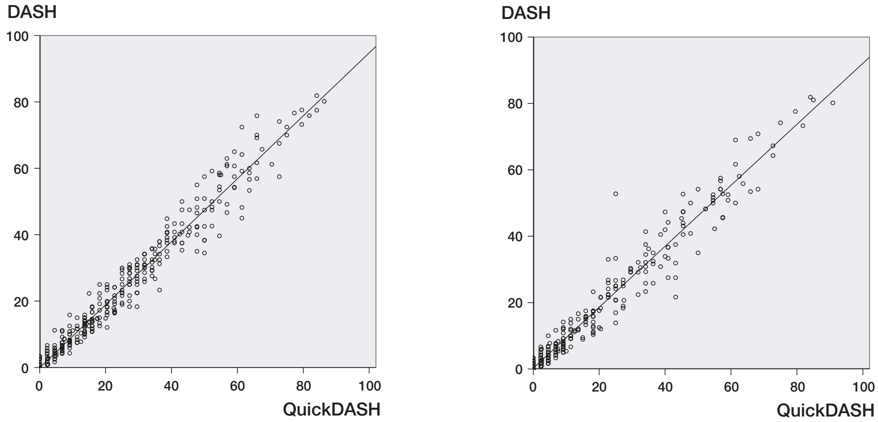

Figure 22. Correlations between the full 30-item DASH score on the y-axis and the 11 item Quick DASH on the x-axis at 3 months to the left (Spearman correlation 0.98, P<0.001) and at 1 year to the right (Spearman correlation 0.97, P< 0.001).

these two surgical techniques gives the best result, a randomized study was performed.

Two different surgical techniques for unstable fractures

Although there are a large number of studies on DRF there is, maybe somewhat surprising, no robust evidence to support the selection of one surgical treatment over the other. This has been reported both in large meta analyses (Paksima et al. 2004; Margaliot et al. 2005) and in the Cochrane reports (Handoll and Madhok 2003). Although no solid evidence exists, we believe that new concepts, such as the TriMed® system or the increasingly popular volar angle-stabile plates, represent improved treatment options for unstable DRF. These methods provide us an opportunity to fix the fragments in an optimal, preferably anatomical position. In **Paper II,** therefore a subgroup of all DRF was studied and patients with the most complex and unstable fractures were randomized to either closed or open surgery. We recorded a quite high complication rate, but most complications were minor and transient in both groups. There was a tendency towards more clinical malunions eligible for secondary surgery in the external fixation group (6), than in the internal fixation group (1). This finding is similar to another randomized study comparing open to closed surgery with 8 of 88 patients in the indirect reduction group having to cross over to the open reduction group, compared to one cross over in the open group (Kreder et al. 2005). In contrast to our study they concluded that they had better results after external fixation. However, 25% of the patients were lost to follow up and all patients in the open group underwent an arthrotomy which hardly would be necessary in the majority of the operations. Arthrotomy was not performed in any of the patients in our study. Two other randomized studies have been performed comparing open with closed surgery. Kapoor et al. (2000) compared cast fixation, external fixation and internal fixation and concluded that surgery was a better option than fixation in a cast for intraarticular fractures and that open reduction and internal fixation gave a better radiographic anatomical result if there was an articular step of 2mm or more. If the fracture was very comminuted the external fixator was found to be preferable. Regarding the functional outcome, it is unclear whether either of the two surgical techniques provides a better outcome than the other. Grewal et al. (2005) compared open surgery with dorsal plating using the Pi-plate and compared it to mini open surgery and external fixation. No differences in DASH scores were found, but maybe, as expected, a higher complication rate in the dorsal plate group. The Pi-plate has been shown to have a high complication rate, especially with problems involving the extensor tendons (Rozental et al. 2003; Khanduja et al. 2005).

A high rate of complications with external fixation has been reported earlier (Anderson et al. 2004; Capo et al. 2006). A high rate of radiographic malunion has also been reported with external fixation (McQueen 1998). Often, malunion does not correlate with clinical problems but a correlation between malunion and functional outcome has been reported (McQueen et al. 1992). Kreder et al. (2005) found the same rate of complications in the open group as well as in the closed group and also that a step-off in the joint surface correlated to a higher frequency of posttraumatic osteoarthritis. In 30-year follow up after DRF an incongruity of more than 1 mm after reduction lead to a significantly higher proportion of patients developing degeneration in both radiocarpal and distal radio-ulnar joints. The degeneration of the distal radioulnar joint did not correlate with more complaints such as pain, but degenerative changes in the radio-carpal joint correlated to more complaints (Kopylov et al. 1993). Thus, to obtain an optimal result, it is important to achieve as good fracture alignment as possible. We believe that our study supports the statement that this is best done by open reduction and internal fixation at least in comminuted intra-articular fractures and fractures with high risk of instability. In our study we had better functional results in the internal fixation group regarding both grip strength and forearm rotation. These differences have not been observed in other studies (McQueen et al. 1996; Westphal et al. 2005) or mentioned in the Cochrane report (Handoll and Madhok 2003). We found, however, no difference in the subjective outcome as measured with the DASH which could mean either that there is no difference or that our outcome instrument is to blunt to find it. The results in the open group had a much narrower range suggesting that the results in this group were more consistent (Figure 23) and the extreme bad results can be avoided. As the DASH score for most patients with a DRF are normalized at the floor of the scale it might be difficult to find any significant differences when comparing two similar groups and a larger number of patients are needed. In conclusion, complications do occur and one complication, malunion and especially the treatment thereof, has been the focus in the last two papers.

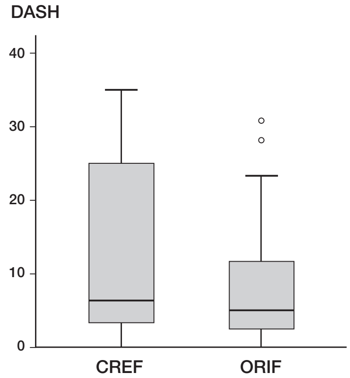

Figure 23. DASH score at 12 months postoperative. Boxes represent quartiles, middle line median, low and high lines min. and max. Circles represent outliers.

Osteotomy of the distal radius to treat malunion

In our study, as in previous studies, osteotomy has proven effective to restore function in a malunited DRF. In comparison to other studies our results are comparable but only a few studies report preoperative data on subjective parameters (Fernandez 1982; af Ekenstam et al. 1985; Ring et al. 2002; Van Cauwelaert de Wyels and De Smet 2003; Luchetti 2004; Krukhaug and Hove 2007) and none uses preoperative DASH making a complete comparison difficult (Table 8). Only one study is stated to be performed with a prospective protocol (Luchetti 2004). In many series, the osteotomy is combined with an ulnar procedure (Fernandez 1982; Oskam et al. 1996; Flinkkilä et al. 2000; Van Cauwelaert de Wyels and De Smet 2003). In our studies this was the case in three patients, two in **Paper III** and one in **Paper IV.** We found a significant decrease in DASH score for the operated patients as well as an increase in grip strength and a decrease in pain. In **Paper III** we found an increased range of motion in forearm rotation, radial/ulnar deviation and in extension/flexion. In **Paper IV** range of motion was not assessed at follow up as this was not part of the protocol. The study was primarily intended to evaluate the feasibility of the new bone substitute (Cerament®). The rationale for using bone substitute was to eliminate the problems, mainly pain, associated with iliac crest bone harvesting. In the

Table 8. Pre- and postoperative measures in different studies on osteotomy for malunited distal radius fractures

Author	n	Type [a]	Grip strength [b]		Forearm rotation		Extension/flexion		DASH	
			Pre.	Post.	Pre.	Post.	Pre.	Post.	Pre.	Post.
Fernandez 1982	20	R	36	74	125	159	80	108	-	-
af Ekenstam et al. 1985	39	R	57	85	123	imp.[c]	96	imp.[c]	-	-
Hove and Mölster 1994	16	R	-	-	-	164	-	119	-	-
Flinkkilä et al. 2000	45	R	-	83	-	173	-	123	-	-
Prommersberger et al. 2002	29	R	20 kg	40 kg	170	170	70	100	-	-
Ring et al. 2002 [d]	10	R	48	73	95	138	76	98	-	-
Ring et al. 2002 [e]	10	R	42	66	113	153	86	132	-	-
Arslan et al. 2003	9	R	-	-	42	105	73	93	-	-
Van Cauwelaert de Wyels and De Smet 2003 [f]	15	R	-	-	131	147	88	106	-	33
Van Cauwelaert de Wyels and De Smet 2003 [g]	6	R			76	149	75	102	-	26
Luchetti 2004	6	P	49	107	116	157	75	110	-	-
Krukhaug and Hove 2007	33	R	-	82	145	180	85	125	-	21
Lozano-Calderon et al. 2007	6	R	-	88	-	161	-	97	-	28
Paper III	25	P	62	82	137	156	103	120	36	21
Paper IV	15	P	61	85	-	-	-	-	37	20

[a] R – retrospective; P – prospective
[b] Grip strength expressed as a percentage of the healthy side except when stated otherwise
[c] Improvement in forearm rotation in 24/37 patients with 25–140° and in extension/flexion in 17/37 patients with 20–70°
[d] Structural graft
[e] Cancellous graft
[f] Colles type
[g] Smith type

short perspective spinal fusion studies, focusing on donor site problems report incidences ranging from 16% to 99%, and persisting pain for more than 6 months in 26 to 41% (Heary et al. 2002; Silber et al. 2003; Sasso et al. 2005). Donor site complications apart from pain are reported. Major complications, defined as patients needing a major change in treatment, prolonged hospitalization or reoperation were reported in 24 of 414 patients and minor complications such as superficial infections, seromas or minor hematomas in 41 patients (Arrington et al. 1996). These problems are completely avoided by the use of a bone substitute. The osteotomy could be performed as an outpatient procedure in 29 of the 40 patients in both our studies.

The use of a bone substitute as an alternative to bone graft performing an osteotomy

For both bone substitutes there was a substantial improvement in patient reported score (DASH) as well as objective parameters whereas the radiographic parameters were more complex. Regarding dorsal angulation there was an improvement in both groups bringing the volar inclination angle almost back to normal. The ulnar variance was, however, not corrected to normal at surgery. With Cerament®, the final ulnar variance deteriorated in some patients during healing and was identical for the group at 12 months compared to preoperative. Radiographically, it is difficult to classify the ulnar variance as the radiographic projections are not identical at different time-points. It has been shown that measuring the ulnar variance and radial length is associated with a high rate of error and the result is influenced by ulnar and palmar tilt and, to be more consistent, an increased number of reference points are needed (Bilic et al. 1995). This makes adequate radiographic projections even more important. In our studies the palmar edge of the ulnar notch was used. Radiographic shortcomings were however not reflected in the final objective and subjective outcome. The cause for this might be the quite small to moderate initial ulnar variance in the series at start (4.0 mm and 2.4 mm, respectively). A ulnar shortening of more than 2 mm has

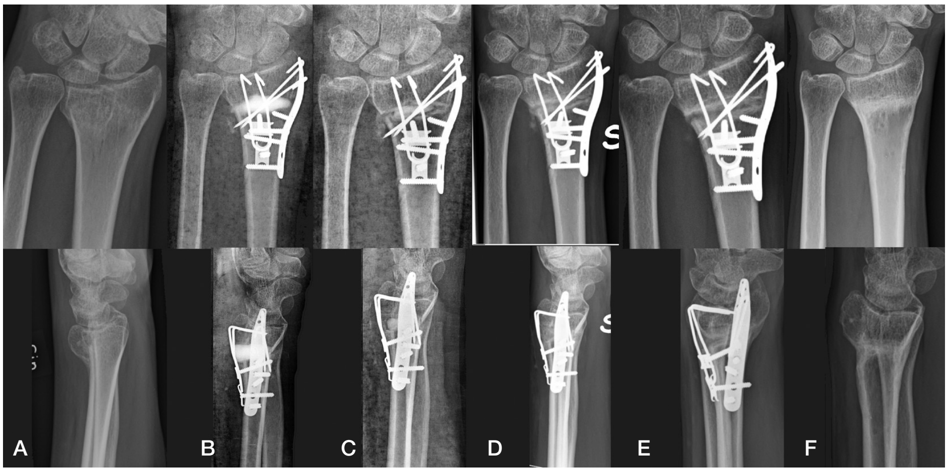

Figure 24. Patient case of an osteotomy of the distal radius. A-P an lateral radiographs A) preoperatively, B) postoperative, C) at 2 weeks, D) at seven weeks, E) at 3 months and F) at one year postoperatively showing resorption of the Cerament® and finally bony healing at one year with the fixation device removed.

been shown to correlate to poorer outcome (Wilcke et al. 2007).

The fast resorbing bone substitute as an alternative

Two different bone substitutes were used and compared. In **Paper III** the slow or non resorbing Norian SRS® was used and was proven to offer a stabile alternative to bone graft. The bone substitute however remains in place for a long time and therefore a faster resorbing material has been developed. In **Paper IV** this faster resorbing bone substitute provided equally good clinical results to those shown in Paper III with a substantial improvement in grip strength as well as improvement in the DASH score from 37 to 20. The fast resorbing bone substitute was not associated with any complications but a few patients showed a recurrence of the ulnar variance during healing. However, as mentioned previously the measuring of ulnar variance is associated with a high degree of error (Bilic et al. 1995). The bone substitute remodeled completely into bone during the first year (Figure 24) but perhaps a more stabile fixation is preferred. A fast remodeling substitute is an interesting alternative also in other types of surgery where a dense deposit of substitute can compromise future surgery such as in tibial plateau fractures where a secondary procedure with a knee arthroplasty might be needed.

Conclusions

- A standardized treatment protocol seems to be a good tool for selecting patients with DRF for proper treatment, but further studies are needed to asses the patients with poor outcome. Most patients treated for a distal radius fracture have an almost, but not fully, normalized function after one year.
- DASH can be used as an outcome measure for DRF, especially for measuring an event such as a fracture or an operation, but it is less sensitive for small differences between groups regarding treatment.
- An open technique for surgical treatment of DRF using the TriMed® system gives a better result regarding grip strength and range of motion in forearm rotation in the short term and after one year, compared to the closed technique with external fixation.
- An osteotomy of the distal radius after a malunion, restores function, relieves pain and increases range of motion and grip strength.
- The osteotomy can be performed avoiding graft donor site morbidity as an outpatient procedure using a bone substitute instead of a bone graft.
- The use of a faster resorbing bone substitute, Cerament®, results in a good bony healing and gives good clinical results but in combination with the TriMed® system there is some loss of radiographic correction.

Future perspectives

Although considered as the highest level of evidence based medicine, the randomized study has shortcomings. In the clinical surgical setting, the studies are difficult to perform and are rarely supported by the industry in contrast to drug testing. Therefore, studies of sufficient quality are lacking particularly in important broad diagnoses such as the DRF. The randomized studies most often are limited in size and large differences are necessary to show statistically significant differences. Small but important differences like reoperation rate or malunion rate will easily be missed and parameters which are less important but easier to exactly measure are wrongly focused on. Studies in larger non-randomized cohorts of distal radius fractures therefore are needed to complement the more specified randomized studies. It is important for us clinicians to learn how a consensus treatment protocol or guidelines work in the everyday clinical setting away from the artificial conditions of a randomized study.

After finishing this work, we no longer look upon the DRF as a homogenous entity but instead as a rather heterogenic group. In Lund our registration is still ongoing and the prospective follow up of the DRF with the DASH will allow us to pick out smaller groups, analyze the result and perhaps change the treatment for that specific group. Ideally, the registry works as a hypothesis generating tool for selection of randomized studies as the next step. To this date another 1200 patients have been sent the questionnaire giving a total of about 1500–1800 patients. A collection of data is done to correlate the DASH with ability to cope with pain. A subgroup analysis of all patients operated on with the TriMed® system is planned as well as a specific analysis of the patients with poor DASH results. A tendency of the secondarily unstable fractures to have a worse subjective outcome also warrants a further analysis. More predictors for future instability and final outcome of DRF are needed and would be an invaluable asset in designing future treatment programs. Another randomized study has been initiated comparing external fixation to the currently dominating volar locking plate.

The growing market of new bone substitute materials with new designs and the possibility to act as a drug carrier will give us an opportunity to incorporate osteoinductive proteins making it possible to speed up bony ingrowth. It might then be possible to completely avoid autologous bone graft with harvesting site problems and also avoid allograft, thereby avoiding the risk of transmitting diseases.

Summary

Distal radius fractures (DRF) are most often treated non-operatively but sometimes surgically when classified unstable. Based on the literature, a consensus protocol for treatment has been developed in the south Swedish region to aid clinicians in decision-making. In **Paper I** we prospectively evaluated the results of this protocol using a validated outcome instrument (DASH) in a large consecutive and population-based series of 581 unselected patients.

Age, sex, fracture side, and type of treatment were registered. The subjective outcome was measured by DASH. 75% of the patients returned the questionnaire. At 3 months after the fracture the median DASH score was 18 and at 12 months 7. A good final subjective result was achieved with the proposed protocol regardless of initial severity and treatment of the fracture as indicated by a low median DASH score in all groups at final follow up at 1 year after the fracture. However, primarily reduced, non-operated fractures, had a worse score (12) than non-displaced (4), or operated fractures (6). Age was the only other predictor, older patients having a worse score. No differences in DASH were seen for different operative techniques. An excellent correlation was found between the short version 11-item QuickDASH questionnaire and the full 30-item DASH both at 3 months (r = 0.98) and at 1 year (r = 0.97) (P< 0.001 for both). In **Paper II** we compared two techniques for surgical treatment of DRF. 50 patients with an unstable or complex DRF were randomized to either closed reduction and external fixation, or open reduction and internal fixation using the TriMed® system. The patients were followed prospectively for one year with objective clinical assessment, subjective outcome using DASH and radiographic examination. Pronation/supination and grip strength were better in the internal fixation group (150° ±15° and 90% ±16% of the uninjured side) at one year compared to the external fixation group (136° ±20° and 78% ±17%). There were no differences in DASH scores or in radiographic parameters. Five patients in the external fixation group were reoperated for malunion compared to one in the internal fixation group. In conclusion, internal fixation gives a better grip strength and a better range of motion and tends to have fewer major complications and malunions than external fixation.

In the last two papers, malunions of the fracture were the focus and the treatment with an osteotomy of the distal radius with bone substitute to fill the gap instead of autologous iliac crest bone graft was evaluated. Bone grafting from the iliac crest, which is the most common source for grafting in malunited distal radius fractures, is associated with donor site morbidity. In **Paper III** we investigated function in patients following an osteotomy and used a slow-resorbing bone substitute (Norian SRS®) in combination with a minimal invasive fixation technique. Norian SRS® is an injectable calcium phosphate paste which hardens in situ to form a hydroxyapatite mimicking the mineral phase of bone. It has a compressive strength comparable or even stronger than cancellous bone.

25 consecutive patients with a dorsal malunion following a distal radius fracture underwent an osteotomy. A TriMed® buttress pin and a radial pin plate were used for fixation and Norian SRS® as bone substitute. The patients were followed for a minimum of one year and range of motion (ROM), grip strength, DASH scores, and the radiographic correction were measured.

We were able to improve forearm rotation from 137° to 155°, flexion/extension from 102° to 120° and radioulnar deviation from 32° to 43°. Grip strength increased from 62 % of the contralateral hand to 82%. DASH scores decreased from 36 to 23. Radiographically all osteotomies but one healed. The achieved radiographic correction was consistent over the first year but the resorption was slow and the time to remodel was long. In **Paper IV** a novel bone substitute (Cerament®) was used with a faster resorbing mixture of calcium phosphate and calcium sulphate. Cerament® consists of 40% calcium phosphate and 60% calcium sulphate. The calcium sulphate which is equivalent to

plaster of Paris dissolves in 6–12 weeks allowing bone to grow in to the gap.

Fifteen consecutive patients, 4 males and 11 females with a mean age of 52 (27–71) years were included. All patients had a radiographic and clinically manifesting malunion after a DRF and underwent an osteotomy between October 2005 and November 2006. The same technique for fixation of the osteotomy was used as in **Paper III** but this time with Cerament® as bone substitute. The patients were followed for one year and grip strength, DASH scores, radiographic correction, healing and resorption rate were measured.

Grip strength increased from 61% of the contralateral hand to 85%. DASH scores decreased from 37 to 24. Radiographically all osteotomies healed. A fast resorption of the bone substitute was noticed but also an increase of ulnar variance from 1.8 mm immediately postoperatively to 2.6 mm at final follow up.

Osteotomy of the distal radius is an effective way to increase range of motion and grip strength after a malunited fracture. Patient satisfaction is high and subjective results measured with DASH are good. Using a bone substitute, the operation can be performed as an outpatient procedure and donor site pain avoided. In **Paper III** the radiographic correction remained during the healing period but in **Paper IV** the bone substitute was rapidly resorbed and replaced by bone, but a small loss of the achieved radiographic correction was noted in a few patients during osteotomy healing. Perhaps a more rigid fixation is needed for this kind of bone substitute.

Summary in Swedish – Sammanfattning på svenska

Distala radiusfrakturer. Patientupplevt resultat, kirurgisk behandling och behandling av felläkta frakturer

Distal radiusfraktur (handledsfraktur eller strålbensbrott) är en av våra vanligaste frakturer och så många som var sjätte patient som uppsöker en akutmottagning på grund av en fraktur har en handledsfraktur. Varje år drabbas upp emot 22000 svenskar i åldern över 18 år av denna vanliga fraktur med en i Sverige årlig kostnad för samhället på c:a en halv miljard kr.

De flesta patienterna är kvinnor och de har ofta en underliggande benskörhet (osteoporos). Frakturen beskrevs första gången på 1700-talet och sedan dess har olika behandlingar använts. Än idag är den valigaste behandlingen gipsförband. En del av patienterna behöver dock opereras och man har sedan början av 1900-talet använt sig av kirurgi i behandlingen av dessa frakturer. Ett flertal olika operationsmetoder har föreslagits men trots att så lång tid förflutit vet man ännu idag inte vilket operationsmetod som lämpar sig bäst. På senare år har dock utvecklingen gått mot mer avancerad kirurgi med ambitionen att kunna uppnå bästa möjliga frakturläge. Trots modern behandlig drabbas en del av patienterna av en felläkt fraktur. Sedan 1970-talet har man i dessa fall operativt kunnat återställa strålbenets normala läge med en vinklingsoperation, en så kallad osteotomi.

Syfte med denna avhandling är dels att kartlägga hur patienterna mår ett år efter skadan och samtidigt utvärdera det vårdprogram för radiusfrakturer som utarbetats i södra sjukvårdsregionen. Vi vill också ta reda på om modern avancerad kirurgi lämpar sig bättre för behandling av svåra frakturer än traditionell kirurgisk teknik och dessutom utprova ny teknik för behandling av de frakturer som läkt i ett felaktigt läge med följdbesvär.

I **delarbete I** har vi följt 581 patienter under ett år med en hälsoenkät (DASH) som kan mäta skadans inverkan på armfunktionen. Funktionsinskränkningen har ställts i relation till vilken typ av behandling man fått. Vi fann att såväl patienter med svåra operationskrävande skador, patienter med mindre svåra frakturer men som behövde dras rätt och patienter med enkla frakturer eller sprickor fick ett slutresultat efter ett år som låg nära en normal funktion. Många var dock inte helt återställda. Vi fann samtidigt att man efter tre månader hade en märkbar funktionsinskränkning men att detta bättrades fram till ett år efter skadan. I **delarbete II** har vi jämfört två olika operationsmetoder för distala radiusfrakturer som används i de fall då akut operation har varit nödvändig. Vid avancerad öppen kirurgi, då man öppnar in till benet och lägger frakturfragmenten (benbitarna) på plats och fixerar med metallplattor, skruvar och stift direkt på benet jämfördes med traditionell sluten behandling (drag i armen och manipulation av frakturfragmenten) utan att öppna huden och fixation av frakturen med en yttre ram. Det visade sig att en avancerad teknik gav ett bättre rörelseomfång i handleden och en bättre greppstyrka både tidigt (sju veckor) efter operationen men även ett år efter operationen. I **delstudie III** och **IV** utvärderades ett nytt sätt att operera frakturer som läkt i ett felaktigt läge, huvudsakligen med en vinkling men också med en förkortning av benet. Patienter med felläkt fraktur besväras ofta av smärtor i handleden och ett försämrat rörelseomfång och handleden kan se snedställd ut. Behandlingen för dessa patienter har varit att man sågar upp brottet och återställer strålbenets normala läge. Det nya brottet fixeras med en metallplatta. Spalten som bildas har man tidigare fyll med ben som tagits från höfbenskammen. Denna behandling kan dock vara smärtsam och besvär från höftbenskammen har i många fall setts lång tid efter operationen. Vi presenterar här ett nytt material att fylla spalten med en konstgjord benmassa. Eftersom man inte har tagit ben från höftbenskammen har operationerna i de flesta fall kunnat utföras i armbedövning och utan att patienten behövt sövas och behandlingen har i de flesta fall kunnat utföras polikliniskt. I de två studierna har 29 av 40 patienter kunnat komma hem samma dag som operationen har utförts. **Delarbete III** används ett material (Norian SRS®) som är stabilt, men som stannar kvar i benet under många år även efter att benläkning har skett. Det har använts tillsammans med små plattor stift och skruvar av samma typ som i delarbete II. Det visade sig att patienterna förbättrades avsevärt vad gäller smärta, rörelseomfång, greppstyrka och funktion. Det visade sig också vara stabilt och frakturens läge på röntgenbilder ändrades inte under läkning. I **delarbete IV** har vi använt ett nytt benersättningsmedel (Cerament®) som tas upp av kroppen snabbare och helt ersätts med ben. Vi fann att resultaten var bra men att stabiliteten blev något sämre med en ändring av frakturens läge under läkningen för ett fåtal patienter. Detta påverkade dock inte resultaten vad avser greppstyrka, smärta och funktion. Strålbenet kunde med detta nya material läka på ett mer naturligt sett eftersom detta benersättningsmedel helt ersattes med naturligt ben men en stabilare fixation kan behövas.

Acknowledgements

I would like to express my gratitude to the following persons:

Magnus Tägil – my friend and supervisor for excellent support and constructive criticism – without him pushing me this work would not have been finished. *"Always two there are, a master and an apprentice"*, /master Yoda; Star Wars episode I

Philippe Kopylov my friend, co-author and mentor who taught me almost all I know about hand surgery and especially how to treat DRF,

all *patients* participating in the studies thanks to whom this thesis could be conducted

physical therapist *Kerstin Runnquist,* and occupational therapists *Margareta Wollmark and Ulrika Wijk* for excellent help in assessing the patients,

Mats Geijer my co-author for fast and precise radiographic assistance,

my collegues at the Hand unit *Marianne Arner, Jörgen Åstrand, Ante Mrkonjic, and Annika Widerberg* for help in recruiting and in the follow up of the patients,

secretary *Ewa Persson* for keeping track of the patients,

Kaj Knutson for typesetting the thesis,

Rolf Önnerfelt and *Karl-Göran Thorngren* for valuable advice,

Joan Tornquist for language correction,

friends and colleagues at the eighth floor and especially to my roommate at the department *Ulrik Hansson* for valuable advice and a fruitful competition to the dissertation finish line and I congratulate him for finishing first,

my parents *Lisbeth* and *Andrea Abramo* for their never-ending support and help,

and last but not least to my wife *Lotta* for her love and support and for always being there and to my children *Casper, Malla and Edith* the joys of my life making it all worthwhile.

The project was supported by Region Skåne, Lund University Hospital, the Swedish Medical Research Council (project 09509), Alfred Österlund, Greta and Johan Kock and Maggie Stephens foundations, Stiftelsen för bistånd åt rörelsehindrade i Skåne and the Faculty of Medicine, Lund University.

Appendix 1 – English version of the DASH

DISABILITIES OF THE ARM, SHOULDER AND HAND

Please rate your ability to do the following activities in the last week by circling the number below the appropriate response.

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	UNABLE
1. Open a tight or new jar.	1	2	3	4	5
2. Write.	1	2	3	4	5
3. Turn a key.	1	2	3	4	5
4. Prepare a meal.	1	2	3	4	5
5. Push open a heavy door.	1	2	3	4	5
6. Place an object on a shelf above your head.	1	2	3	4	5
7. Do heavy household chores (e.g., wash walls, wash floors).	1	2	3	4	5
8. Garden or do yard work.	1	2	3	4	5
9. Make a bed.	1	2	3	4	5
10. Carry a shopping bag or briefcase.	1	2	3	4	5
11. Carry a heavy object (over 10 lbs).	1	2	3	4	5
12. Change a lightbulb overhead.	1	2	3	4	5
13. Wash or blow dry your hair.	1	2	3	4	5
14. Wash your back.	1	2	3	4	5
15. Put on a pullover sweater.	1	2	3	4	5
16. Use a knife to cut food.	1	2	3	4	5
17. Recreational activities which require little effort (e.g., cardplaying, knitting, etc.).	1	2	3	4	5
18. Recreational activities in which you take some force or impact through your arm, shoulder or hand (e.g., golf, hammering, tennis, etc.).	1	2	3	4	5
19. Recreational activities in which you move your arm freely (e.g., playing frisbee, badminton, etc.).	1	2	3	4	5
20. Manage transportation needs (getting from one place to another).	1	2	3	4	5
21. Sexual activities.	1	2	3	4	5

DISABILITIES OF THE ARM, SHOULDER AND HAND

	NOT AT ALL	SLIGHTLY	MODERATELY	QUITE A BIT	EXTREMELY
22. During the past week, to what extent has your arm, shoulder or hand problem interfered with your normal social activities with family, friends, neighbours or groups? (circle number)	1	2	3	4	5

	NOT LIMITED AT ALL	SLIGHTLY LIMITED	MODERATELY LIMITED	VERY LIMITED	UNABLE
23. During the past week, were you limited in your work or other regular daily activities as a result of your arm, shoulder or hand problem? (circle number)	1	2	3	4	5

Please rate the severity of the following symptoms in the last week. (circle number)

	NONE	MILD	MODERATE	SEVERE	EXTREME
24. Arm, shoulder or hand pain.	1	2	3	4	5
25. Arm, shoulder or hand pain when you performed any specific activity.	1	2	3	4	5
26. Tingling (pins and needles) in your arm, shoulder or hand.	1	2	3	4	5
27. Weakness in your arm, shoulder or hand.	1	2	3	4	5
28. Stiffness in your arm, shoulder or hand.	1	2	3	4	5

	NO DIFFICULTY	MILD DIFFICULTY	MODERATE DIFFICULTY	SEVERE DIFFICULTY	SO MUCH DIFFICULTY THAT I CAN'T SLEEP
29. During the past week, how much difficulty have you had sleeping because of the pain in your arm, shoulder or hand? (circle number)	1	2	3	4	5

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	AGREE	STRONGLY AGREE
30. I feel less capable, less confident or less useful because of my arm, shoulder or hand problem. (circle number)	1	2	3	4	5

DASH DISABILITY/SYMPTOM SCORE $= \left[\frac{(\text{sum of n responses})}{n} - 1\right] \times 25$, where n is equal to the number of completed responses.

A DASH score may not be calculated if there are greater than 3 missing items.

Appendix 2 – Swedish version of the DASH

Hälsoenkät (arm/axel/hand)

Denna enkät berör Dina symptom och Din förmåga att utföra vissa aktiviteter.
Svara på varje fråga, baserat på hur Du har mått den senaste veckan, genom att kryssa för ett svarsalternativ för varje fråga.

Om det är någon aktivitet Du inte har utfört den senaste veckan får Du kryssa för det svar som Du bedömer stämmer bäst om Du hade utfört aktiviteten.
Det har ingen betydelse vilken arm eller hand Du använder för att utföra aktiviteten. Svara baserat på Din förmåga oavsett hur Du utför uppgiften.

	Ingen svårighet	Viss svårighet	Måttlig svårighet	Stor svårighet	Omöjligt att göra
1. Öppna en ny burk, eller hårt sittande lock	☐	☐	☐	☐	☐
2. 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 portfölj	☐	☐	☐	☐	☐
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 liten 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. Friritidsaktiviteter där Du rör på armen fritt (t ex spela badminton, simma, gympa)	☐	☐	☐	☐	☐
20. Färdas från en plats till en annan	☐	☐	☐	☐	☐
21. Sexuella aktiviteter	☐	☐	☐	☐	☐

DASH svensk v 2.0, Gummesson/Atroshi

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 vilken utsträckning** har Dina arm-, axel- eller handproblem stört Ditt vanliga arbete eller andra dagliga aktiviteter?

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

Ange svårighetsgraden på Dina symtom 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 handproblem.

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

Appendix 3 – Swedish version of the QuickDASH

Hälsoenkät (arm/axel/hand)

Denna enkät berör Dina symtom och Din förmåga att utföra vissa aktiviteter.
Svara på **varje fråga**, baserat på hur Du har mått **den senaste veckan**, genom att kryssa för ett svarsalternativ för varje fråga.
Om det är någon aktivitet Du inte har utfört den senaste veckan får Du kryssa för det svar som Du bedömer **stämmer bäst** om Du hade utfört aktiviteten.
Det har ingen betydelse vilken arm eller hand Du använder för att utföra aktiviteten. Svara baserat på Din förmåga oavsett hur Du utför uppgiften.

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

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

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

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

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

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

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

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

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

References

af Ekenstam, F., Hagert, C. G., Engkvist, O., Tornvall, A. H., Wilbrand, H. (1985). Corrective osteotomy of malunited fractures of the distal end of the radius. Scand J Plast Reconstr Surg 19; 2: 175-87.

Agee, J. M. (1993). External fixation. Technical advances based upon multiplanar ligamentotaxis. Orthop Clin North Am 24; 2: 265-74.

Alffram, P. A., Bauer, G. C. (1962). Epidemiology of fractures of the forearm. A biomechanical investigation of bone strength. J Bone Joint Surg Am 44-A: 105-14.

Altissimi, M., Antenucci, R., Fiacca, C., Mancini, G. B. (1986). Long-term results of conservative treatment of fractures of the distal radius. Clin Orthop Relat Res206: 202-10.

Altissimi, M., Mancini, G. B., Azzara, A., Ciaffoloni, E. (1994). Early and late displacement of fractures of the distal radius. The prediction of instability. Int Orthop 18; 2: 61-5.

Andersen, D. J., Blair, W. F., Steyers, C. M., Jr., Adams, B. D., el-Khouri, G. Y., Brandser, E. A. (1996). Classification of distal radius fractures: an analysis of interobserver reliability and intraobserver reproducibility. J Hand Surg [Am] 21; 4: 574-82.

Anderson, J. T., Lucas, G. L., Buhr, B. R. (2004). Complications of treating distal radius fractures with external fixation: a community experience. Iowa Orthop J 24: 53-9.

Anzarut, A., Johnson, J. A., Rowe, B. H., Lambert, R. G., Blitz, S., Majumdar, S. R. (2004). Radiologic and patient-reported functional outcomes in an elderly cohort with conservatively treated distal radius fractures. J Hand Surg [Am] 29; 6: 1121-7.

Arora, R., Lutz, M., Hennerbichler, A., Krappinger, D., Espen, D., Gabl, M. (2007). Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate. J Orthop Trauma 21; 5: 316-22.

Arrington, E. D., Smith, W. J., Chambers, H. G., Bucknell, A. L., Davino, N. A. (1996). Complications of iliac crest bone graft harvesting. Clin Orthop Relat Res329: 300-9.

Arslan, H., Subasi, M., Kesemenli, C., Kapukaya, A., Necmioglu, S. (2003). Distraction osteotomy for malunion of the distal end of the radius with radial shortening. Acta Orthop Belg 69; 1: 23-8.

Ashford, R. F., Nagelburg, S., Adkins, R. (1996). Sensitivity of the Jamar Dynamometer in detecting submaximal grip effort. J Hand Surg [Am] 21; 3: 402-5.

Atroshi, I., Brogren, E., Larsson, G. U., Kloow, J., Hofer, M., Berggren, A. M. (2006). Wrist-bridging versus non-bridging external fixation for displaced distal radius fractures: a randomized assessor-blind clinical trial of 38 patients followed for 1 year. Acta Orthop 77; 3: 445-53.

Atroshi, I., Gummesson, C., Andersson, B., Dahlgren, E., Johansson, A. (2000). The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: reliability and validity of the Swedish version evaluated in 176 patients. Acta Orthop Scand 71; 6: 613-8.

Atroshi, I., Johnsson, R., Sprinchorn, A. (1998). Self-administered outcome instrument in carpal tunnel syndrome. Reliability, validity and responsiveness evaluated in 102 patients. Acta Orthop Scand 69; 1: 82-8.

Azzopardi, T., Ehrendorfer, S., Coulton, T., Abela, M. (2005). Unstable extra-articular fractures of the distal radius: a prospective, randomised study of immobilisation in a cast versus supplementary percutaneous pinning. J Bone Joint Surg Br 87; 6: 837-40.

Barton, J. (1838). Views and treatment of an important injury of the wrist Medical Examiner 1: 365-368.

Beaton, D. E., Wright, J. G., Katz, J. N. (2005). Development of the QuickDASH: comparison of three item-reduction approaches. J Bone Joint Surg Am 87; 5: 1038-46.

Beck, C. (1898). Colles' fracture and the Roentgen-rays. Med news 72: 230.

Bengner, U., Johnell, O. (1985). Increasing incidence of forearm fractures. A comparison of epidemiologic patterns 25 years apart. Acta Orthop Scand 56; 2: 158-60.

Benson, E. C., DeCarvalho, A., Mikola, E. A., Veitch, J. M., Moneim, M. S. (2006). Two potential causes of EPL rupture after distal radius volar plate fixation. Clin Orthop Relat Res 451: 218-22.

Benson, L. S., Minihane, K. P., Stern, L. D., Eller, E., Seshadri, R. (2006). The outcome of intra-articular distal radius fractures treated with fragment-specific fixation. J Hand Surg [Am] 31; 8: 1333-9.

Bilic, R., Ruzic, L., Zdravkovic, V., Boljevic, Z., Kovjanic, J. (1995). Reliability of different methods of determination of radial shortening. Influence of ulnar and palmar tilt. J Hand Surg [Br] 20; 1: 97-101.

Borgström, F., Zethraeus, N., Johnell, O., Lidgren, L., Ponzer, S., Svensson, O., Abdon, P., Ornstein, E., Lunsjö, K., Thorngren, K. G., Sernbo, I., Rehnberg, C., Jonsson, B. (2006). Costs and quality of life associated with osteoporosis-related fractures in Sweden. Osteoporos Int 17; 5: 637-50.

Brogren, E., Petranek, M., Atroshi, I. (2007). Incidence and characteristics of distal radius fractures in a southern Swedish region. BMC Musculoskelet Disord 8: 48.

Bronstein, A. J., Trumble, T. E., Tencer, A. F. (1997). The effects of distal radius fracture malalignment on forearm rotation: a cadaveric study. J Hand Surg [Am] 22; 2: 258-62.

Burström, K., Johannesson, M., Diderichsen, F. (2001). Swedish population health-related quality of life results using the EQ-5D. Qual Life Res 10; 7: 621-35.

Capo, J. T., Swan, K. G., Jr., Tan, V. (2006). External fixation techniques for distal radius fractures. Clin Orthop Relat Res 445: 30-41.

Cassidy, C., Jupiter, J. B., Cohen, M., Delli-Santi, M., Fennell, C., Leinberry, C., Husband, J., Ladd, A., Seitz, W. R., Constanz, B. (2003). Norian SRS cement compared with conventional fixation in distal radial fractures. A randomized study. J Bone Joint Surg Am 85-A; 11: 2127-37.

Coldham, F., Lewis, J., Lee, H. (2006). The reliability of one vs. three grip trials in symptomatic and asymptomatic subjects. J Hand Ther 19; 3: 318-26; quiz 327.

Cooney, W. P., 3rd, Dobyns, J. H.Linscheid, R. L. (1980). Complications of Colles' fractures. J Bone Joint Surg Am 62; 4: 613-9.

Cooney, W. P., 3rd, Linscheid, R. L., Dobyns, J. H. (1979). External pin fixation for unstable Colles' fractures. J Bone Joint Surg Am 61; 6A: 840-5.

Court-Brown, C. M., Caesar, B. (2006). Epidemiology of adult fractures: A review. Injury 37; 8: 691-7.

Cuddihy, M. T., Gabriel, S. E., Crowson, C. S., O'Fallon, W. M., Melton, L. J., 3rd (1999). Forearm fractures as predictors of subsequent osteoporotic fractures. Osteoporos Int 9; 6: 469-75.

Cummings, S. R., Black, D. M., Nevitt, M. C., Browner, W., Cauley, J., Ensrud, K., Genant, H. K., Palermo, L., Scott, J., Vogt, T. M. (1993). Bone density at various sites for prediction of hip fractures. The Study of Osteoporotic Fractures Research Group. Lancet 341; 8837: 72-5.

Dayican, A., Unal, V. S., Ozkurt, B., Portakal, S., Nuhoglu, E., Tumoz, M. A. (2003). Conservative treatment in intra-articular fractures of the distal radius: a study on the functional and anatomic outcome in elderly patients. Yonsei Med J 44; 5: 836-40.

Desrosiers, J., Bravo, G., Hebert, R., Dutil, E. (1995). Normative data for grip strength of elderly men and women. Am J Occup Ther 49; 7: 637-44.

Fernandez, D. L. (1982). Correction of post-traumatic wrist deformity in adults by osteotomy, bone-grafting, and internal fixation. J Bone Joint Surg Am 64; 8: 1164-78.

Fernandez, D. L. ,Jupiter, J. (1996). Epidemiology, mechanism, classification. Fractures of the distal radius. A practical approach to management. New York, Springer Verlag: 24-6.

Fernandez, D. L., Jupiter, J. (1996). Fracture of the Distal End of the Radius: Historical Perspective. Fractures of the distal radius. A practical approach to management. New York, Springer Verlag: 2-21.

Flinkkilä, T., Raatikainen, T.Hämäläinen, M. (1998). AO and Frykman's classifications of Colles' fracture. No prognostic value in 652 patients evaluated after 5 years. Acta Orthop Scand 69; 1: 77-81.

Flinkkilä, T., Raatikainen, T., Kaarela, O., Hämäläinen, M. (2000). Corrective osteotomy for malunion of the distal radius. Arch Orthop Trauma Surg 120; 1-2: 23-6.

Forward, D. P., Lindau, T. R., Melsom, D. S. (2007). Intercarpal ligament injuries associated with fractures of the distal part of the radius. J Bone Joint Surg Am 89; 11: 2334-40.

Forward, D. P., Sithole, J. S., Davis, T. R. (2007). The internal consistency and validity of the Patient Evaluation Measure for outcomes assessment in distal radius fractures. J Hand Surg Eur Vol 32; 3: 262-7.

Gausepohl, T., Pennig, D., Mader, K. (2000). Principles of external fixation and supplementary techniques in distal radius fractures. Injury 31 Suppl 1: 56-70.

Gerostathopoulos, N., Kalliakmanis, A., Fandridis, E., Georgoulis, S. (2007). Trimed fixation system for displaced fractures of the distal radius. J Trauma 62; 4: 913-8.

Giannoudis, P. V., Dinopoulos, H.Tsiridis, E. (2005). Bone substitutes: an update. Injury 36 Suppl 3: S20-7.

Gilson, B. S., Gilson, J. S., Bergner, M., Bobbit, R. A., Kressel, S., Pollard, W. E., Vesselago, M. (1975). The sickness impact profile. Development of an outcome measure of health care. Am J Public Health 65; 12: 1304-10.

Grahn Kronhed, A. C., Blomberg, C., Karlsson, N., Löfman, O., Timpka, T., Möller, M. (2005). Impact of a community-based osteoporosis and fall prevention program on fracture incidence. Osteoporos Int 16; 6: 700-6.

Grewal, R., Perey, B., Wilmink, M., Stothers, K. (2005). A randomized prospective study on the treatment of intra-articular distal radius fractures: open reduction and internal fixation with dorsal plating versus mini open reduction, percutaneous fixation, and external fixation. J Hand Surg [Am] 30; 4: 764-72.

Grindel, S. I., Wang, M., Gerlach, M., McGrady, L. M., Brown, S. (2007). Biomechanical comparison of fixed-angle volar plate versus fixed-angle volar plate plus fragment-specific fixation in a cadaveric distal radius fracture model. J Hand Surg [Am] 32; 2: 194-9.

Gruber, G., Bernhardt, G. A., Kohler, G., Gruber, K. (2006). Surgical treatment of distal radius fractures with an angle fixed bar palmar plating system: a single center study of 102 patients over a 2-year period. Arch Orthop Trauma Surg 126; 10: 680-5.

Gummesson, C., Atroshi, I., Ekdahl, C. (2003). The disabilities of the arm, shoulder and hand (DASH) outcome questionnaire: longitudinal construct validity and measuring self-rated health change after surgery. BMC Musculoskelet Disord 4; 1: 11.

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

Hagino, H., Yamamoto, K., Ohshiro, H., Nakamura, T., Kishimoto, H., Nose, T. (1999). Changing incidence of hip, distal radius, and proximal humerus fractures in Tottori Prefecture, Japan. Bone 24; 3: 265-70.

Handoll, H. H., Madhok, R. (2002). Conservative interventions for treating distal radial fractures in adults. Cochrane Database Syst Rev2: CD000314.

Handoll, H. H., Madhok, R. (2003). Closed reduction methods for treating distal radial fractures in adults. Cochrane Database Syst Rev1: CD003763.

Handoll, H. H., Madhok, R. (2003). Surgical interventions for treating distal radial fractures in adults. Cochrane Database Syst Rev3: CD003209.

Handoll, H. H., Vaghela, M. V., Madhok, R. (2007). Percutaneous pinning for treating distal radial fractures in adults. Cochrane Database Syst Rev3: CD006080.

Hanten, W. P., Chen, W. Y., Austin, A. A., Brooks, R. E., Carter, H. C., Law, C. A., Morgan, M. K., Sanders, D. J., Swan, C. A., Vanderslice, A. L. (1999). Maximum grip strength in normal subjects from 20 to 64 years of age. J Hand Ther 12; 3: 193-200.

Harley, B. J., Scharfenberger, A., Beaupre, L. A., Jomha, N., Weber, D. W. (2004). Augmented external fixation versus percutaneous pinning and casting for unstable fractures of the distal radius--a prospective randomized trial. J Hand Surg [Am] 29; 5: 815-24.

Hawker, G., Melfi, C., Paul, J., Green, R.Bombardier, C. (1995). Comparison of a generic (SF-36) and a disease specific (WOMAC) (Western Ontario and McMaster Universities Osteoarthritis Index) instrument in the measurement of outcomes after knee replacement surgery. J Rheumatol 22; 6: 1193-6.

Heary, R. F., Schlenk, R. P., Sacchieri, T. A., Barone, D., Brotea, C. (2002). Persistent iliac crest donor site pain: independent outcome assessment. Neurosurgery 50; 3: 510-6; discussion 516-7.

Hegeman, J. H., Oskam, J., van der Palen, J., Ten Duis, H. J., Vierhout, P. A. (2004). The distal radial fracture in elderly women and the bone mineral density of the lumbar spine and hip. J Hand Surg [Br] 29; 5: 473-6.

Hove, L. M., Fjeldsgaard, K., Reitan, R., Skjeie, R., Sörensen, F. K. (1995). Fractures of the distal radius in a Norwegian city. Scand J Plast Reconstr Surg Hand Surg 29; 3: 263-7.

Hove, L. M., Mölster, A. O. (1994). Surgery for posttraumatic wrist deformity. Radial osteotomy and/or ulnar shortening in 16 Colles' fractures. Acta Orthop Scand 65; 4: 434-8.

Hudak, P. L., Amadio, P. C., Bombardier, C. (1996). Development of an upper extremity outcome measure: the DASH (disabilities of the arm, shoulder and hand) [corrected]. The Upper Extremity Collaborative Group (UECG). Am J Ind Med 29; 6: 602-8.

Jakob, M., Rikli, D. A., Regazzoni, P. (2000). Fractures of the distal radius treated by internal fixation and early function. A prospective study of 73 consecutive patients. J Bone Joint Surg Br 82; 3: 340-4.

Jakob, R. P. (1994). Development of the small AO fixator to the current set. Injury 25 Suppl 4: S-D26-7.

Jaremko, J. L., Lambert, R. G., Rowe, B. H., Johnson, J. A., Majumdar, S. R. (2007). Do radiographic indices of distal radius fracture reduction predict outcomes in older adults receiving conservative treatment? Clin Radiol 62; 1: 65-72.

Kakarlapudi, T. K., Santini, A., Shahane, S. A., Douglas, D. (2000). The cost of treatment of distal radial fractures. Injury 31; 4: 229-32.

Kapandji, A. (1987). [Intra-focal pinning of fractures of the distal end of the radius 10 years later]. Ann Chir Main 6; 1: 57-63.

Kapoor, H., Agarwal, A., Dhaon, B. K. (2000). Displaced intra-articular fractures of distal radius: a comparative evaluation of results following closed reduction, external fixation and open reduction with internal fixation. Injury 31; 2: 75-9.

Kazis, L. E., Anderson, J. J., Meenan, R. F. (1989). Effect sizes for interpreting changes in health status. Med Care 27; 3 Suppl: S178-89.

Keating, J. F., Court-Brown, C. M., McQueen, M. M. (1994). Internal fixation of volar-displaced distal radial fractures. J Bone Joint Surg Br 76; 3: 401-5.

Khanduja, V., Ng, L., Dannawi, Z., Heras, L. (2005). Complications and functional outcome following fixation of complex, intra-articular fractures of the distal radius with the AO Pi-Plate. Acta Orthop Belg 71; 6: 672-7.

Klug, R. A., Press, C. M.Gonzalez, M. H. (2007). Rupture of the flexor pollicis longus tendon after volar fixed-angle plating of a distal radius fracture: a case report. J Hand Surg [Am] 32; 7: 984-8.

Koh, S., Morris, R. P., Patterson, R. M., Kearney, J. P., Buford, W. L., Jr., Viegas, S. F. (2006). Volar fixation for dorsally angulated extra-articular fractures of the distal radius: a biomechanical study. J Hand Surg [Am] 31; 5: 771-9.

Konrath, G. A., Bahler, S. (2002). Open reduction and internal fixation of unstable distal radius fractures: results using the trimed fixation system. J Orthop Trauma 16; 8: 578-85.

Kopylov, P. (2001). Injectable calcium phosphate bone substitute in distal radial fractures. Department of Orthopaedics. Lund, Lund University. Thesis.

Kopylov, P., Johnell, O., Redlund-Johnell, I., Bengner, U. (1993). Fractures of the distal end of the radius in young adults: a 30-year follow-up. J Hand Surg [Br] 18; 1: 45-9.

Kopylov, P., Jonsson, K., Thorngren, K. G., Aspenberg, P. (1996). Injectable calcium phosphate in the treatment of distal radial fractures. J Hand Surg [Br] 21; 6: 768-71.

Kreder, H. J., Hanel, D. P., Agel, J., McKee, M., Schemitsch, E. H., Trumble, T. E., Stephen, D. (2005). Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal radius: a randomised, controlled trial. J Bone Joint Surg Br 87; 6: 829-36.

Krukhaug, Y., Hove, L. (2004). Experience with the AO Piplate for displaced intra-articular fractures of the distal radius. Scand J Plast Reconstr Surg Hand Surg 38; 5: 293-6.

Krukhaug, Y., Hove, L. M. (2007). Corrective osteotomy for malunited extra-articular fractures of the distal radius: A follow-up study of 33 patients. Scand J Plast Reconstr Surg Hand Surg: 1-7.

Lafontaine, M., Hardy, D., Delince, P. (1989). Stability assessment of distal radius fractures. Injury 20; 4: 208-10.

Lanz, U., Kron, W. (1976). [A new technic for the correction of malunited distal radius fractures]. Handchirurgie 8; 4: 203-6.

Larsen, C. F., Lauritsen, J. (1993). Epidemiology of acute wrist trauma. Int J Epidemiol 22; 5: 911-6.

Larsson, S., Berg, P. (2005). Bensubstitut inom ortopedisk kirurgi. Finska Läkaresällskapeets Handlingar 165; 2: 41-48.

Leone, J., Bhandari, M., Adili, A., McKenzie, S., Moro, J. K., Dunlop, R. B. (2004). Predictors of early and late instability following conservative treatment of extra-articular distal radius fractures. Arch Orthop Trauma Surg 124; 1: 38-41.

Lindau, T. (2000). Distal radial fractures and effects of associated ligament injuries. Department of orthopaedics. Lund, Lund University Thesis.

Lindau, T., Arner, M., Hagberg, L. (1997). Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg [Br] 22; 5: 638-43.

Lindau, T., Aspenberg, P., Arner, M., Redlundh-Johnell, I., Hagberg, L. (1999). Fractures of the distal forearm in young adults. An epidemiologic description of 341 patients. Acta Orthop Scand 70; 2: 124-8.

Lozano-Calderon, S., Moore, M., Liebman, M., Jupiter, J. B. (2007). Distal radius osteotomy in the elderly patient using angular stable implants and Norian bone cement. J Hand Surg [Am] 32; 7: 976-83.

Luchetti, R. (2004). Corrective osteotomy of malunited distal radius fractures using carbonated hydroxyapatite as an alternative to autogenous bone grafting. J Hand Surg [Am] 29; 5: 825-34.

MacDermid, J. C., Richards, R. S., Donner, A., Bellamy, N., Roth, J. H. (2000). Responsiveness of the short form-36, disability of the arm, shoulder, and hand questionnaire, patient-rated wrist evaluation, and physical impairment measurements in evaluating recovery after a distal radius fracture. J Hand Surg [Am] 25; 2: 330-40.

MacDermid, J. C., Roth, J. H., Richards, R. S. (2003). Pain and disability reported in the year following a distal radius fracture: a cohort study. BMC Musculoskelet Disord 4; 1: 24.

Macdermid, J. C., Solomon, P., Prkachin, K. (2006). The Shoulder Pain and Disability Index demonstrates factor, construct and longitudinal validity. BMC Musculoskelet Disord 7; 1: 12.

Mackenney, P. J., McQueen, M. M., Elton, R. (2006). Prediction of instability in distal radial fractures. J Bone Joint Surg Am 88; 9: 1944-51.

Mallmin, H., Ljunghall, S., Persson, I., Naessen, T., Krusemo, U. B., Bergstrom, R. (1993). Fracture of the distal forearm as a forecaster of subsequent hip fracture: a population-based cohort study with 24 years of follow-up. Calcif Tissue Int 52; 4: 269-72.

Mann, F. A., Wilson, A. J., Gilula, L. A. (1992). Radiographic evaluation of the wrist: what does the hand surgeon want to know? Radiology 184; 1: 15-24.

Maravic, M., Le Bihan, C., Landais, P., Fardellone, P. (2005). Incidence and cost of osteoporotic fractures in France during 2001. A methodological approach by the national hospital database. Osteoporos Int 16; 12: 1475-80.

Margaliot, Z., Haase, S. C., Kotsis, S. V., Kim, H. M., Chung, K. C. (2005). A meta-analysis of outcomes of external fixation versus plate osteosynthesis for unstable distal radius fractures. J Hand Surg [Am] 30; 6: 1185-99.

McKenna, J., Harte, M., Lunn, J., O'Bierne, J. (2000). External fixation of distal radial fractures. Injury 31; 8: 613-6.

McQueen, M. M. (1998). Redisplaced unstable fractures of the distal radius. A randomised, prospective study of bridging versus non-bridging external fixation. J Bone Joint Surg Br 80; 4: 665-9.

McQueen, M. M., Hajducka, C., Court-Brown, C. M. (1996). Redisplaced unstable fractures of the distal radius: a prospective randomised comparison of four methods of treatment. J Bone Joint Surg Br 78; 3: 404-9.

McQueen, M. M., Michie, M., Court-Brown, C. M. (1992). Hand and wrist function after external fixation of unstable distal radial fractures. Clin Orthop285: 200-4.

Melton, L. J., 3rd, Crowson, C. S., O'Fallon, W. M. (1999). Fracture incidence in Olmsted County, Minnesota: comparison of urban with rural rates and changes in urban rates over time. Osteoporos Int 9; 1: 29-37.

Melton, L. J., 3rd, Gabriel, S. E., Crowson, C. S., Tosteson, A. N., Johnell, O., Kanis, J. A. (2003). Cost-equivalence of different osteoporotic fractures. Osteoporos Int 14; 5: 383-8.

Murakami, K., Abe, Y., Takahashi, K. (2007). Surgical treatment of unstable distal radius fractures with volar locking plates. J Orthop Sci 12; 2: 134-40.

Musgrave, D. S.Idler, R. S. (2005). Volar fixation of dorsally displaced distal radius fractures using the 2.4-mm locking compression plates. J Hand Surg [Am] 30; 4: 743-9.

Nilsson, M. (2003). Injectable calcium sulphate and calcium phosphate bone substitutes. Department of Orthopaedics Lund, Lund University. Thesis.

Nilsson, M., Wang, J. S., Wielanek, L., Tanner, K. E., Lidgren, L. (2004). Biodegradation and biocompatability of a calcium sulphate-hydroxyapatite bone substitute. J Bone Joint Surg Br 86; 1: 120-5.

O'Neill, T. W., Cooper, C., Finn, J. D., Lunt, M., Purdie, D., Reid, D. M., Rowe, R., Woolf, A. D., Wallace, W. A. (2001). Incidence of distal forearm fracture in British men and women. Osteoporos Int 12; 7: 555-8.

Osada, D., Fujita, S., Tamai, K., Iwamoto, A., Tomizawa, K., Saotome, K. (2004). Biomechanics in uniaxial compression of three distal radius volar plates. J Hand Surg [Am] 29; 3: 446-51.

Osada, D., Viegas, S. F., Shah, M. A., Morris, R. P., Patterson, R. M. (2003). Comparison of different distal radius dorsal and volar fracture fixation plates: a biomechanical study. J Hand Surg [Am] 28; 1: 94-104.

Oshige, T., Sakai, A., Zenke, Y., Moritani, S., Nakamura, T. (2007). A comparative study of clinical and radiological outcomes of dorsally angulated, unstable distal radius fractures in elderly patients: intrafocal pinning versus volar locking plating. J Hand Surg [Am] 32; 9: 1385-92.

Oskam, J., Bongers, K. M., Karthaus, A. J., Frima, A. J., Klasen, H. J. (1996). Corrective osteotomy for malunion of the distal radius: the effect of concomitant ulnar shortening osteotomy. Arch Orthop Trauma Surg 115; 3-4: 219-22.

Oskam, J., Kingma, J., Bart, J., Klasen, H. J. (1997). K-wire fixation for redislocated Colles' fractures. Malunion in 8/21 cases. Acta Orthop Scand 68; 3: 259-61.

Paksima, N., Panchal, A., Posner, M. A., Green, S. M., Mehiman, C. T., Hiebert, R. (2004). A meta-analysis of the literature on distal radius fractures: review of 615 articles. Bull Hosp Jt Dis 62; 1-2: 40-6.

Pennig, D.Gausepohl, T. (1996). External fixation of the wrist. Injury 27; 1: 1-15.

Pennig, D., Gausepohl, T., Lukosch, R. (1994). [Use of a fixation pin for fragment stabilization in hand surgery]. Handchir Mikrochir Plast Chir 26; 5: 270-4.

Pennig, D., Gausepohl, T., Mader, K. (2000). Corrective osteotomies in malunited distal radius fractures: external fixation as one stage and hemicallotasis procedures. Injury 31 Suppl 1: 78-91.

Pennig, D. W. (1993). Dynamic external fixation of distal radius fractures. Hand Clin 9; 4: 587-602.

Prince, H., Worlock, P. (1988). The small AO external fixator in the treatment of unstable distal forearm fractures. J Hand Surg [Br] 13; 3: 294-7.

Prommersberger, K. J., Van Schoonhoven, J., Lanz, U. B. (2002). Outcome after corrective osteotomy for malunited fractures of the distal end of the radius. J Hand Surg [Br] 27; 1: 55-60.

Rikli, D. A., Businger, A., Babst, R. (2005). Dorsal double-plate fixation of the distal radius. Oper Orthop Traumatol 17; 6: 624-40.

Rikli, D. A.Regazzoni, P. (2000). The double plating technique for distal radius fractures. Tech Hand Up Extrem Surg 4; 2: 107-14.

Ring, D., Prommersberger, K. J., Gonzalez del Pino, J., Capomassi, M., Slullitel, M., Jupiter, J. B. (2005). Corrective osteotomy for intra-articular malunion of the distal part of the radius. J Bone Joint Surg Am 87; 7: 1503-9.

Ring, D., Roberge, C., Morgan, T., Jupiter, J. B. (2002). Osteotomy for malunited fractures of the distal radius: a comparison of structural and nonstructural autogenous bone grafts. J Hand Surg [Am] 27; 2: 216-22.

Robertsson, G. O., Jonsson, G. T., Sigurjonsson, K. (1990). Epidemiology of distal radius fractures in Iceland in 1985. Acta Orthop Scand 61; 5: 457-9.

Rozental, T. D., Beredjiklian, P. K., Bozentka, D. J. (2003). Functional outcome and complications following two types of dorsal plating for unstable fractures of the distal part of the radius. J Bone Joint Surg Am 85-A; 10: 1956-60.

Ruch, D. S., Papadonikolakis, A. (2006). Volar versus dorsal plating in the management of intra-articular distal radius fractures. J Hand Surg [Am] 31; 1: 9-16.

Ruch, D. S., Vallee, J., Poehling, G. G., Smith, B. P., Kuzma, G. R. (2004). Arthroscopic reduction versus fluoroscopic reduction in the management of intra-articular distal radius fractures. Arthroscopy 20; 3: 225-30.

Sasso, R. C., LeHuec, J. C., Shaffrey, C. (2005). Iliac crest bone graft donor site pain after anterior lumbar interbody fusion: a prospective patient satisfaction outcome assessment. J Spinal Disord Tech 18 Suppl: S77-81.

Sayer, A. A., Syddall, H. E., Martin, H. J., Dennison, E. M., Roberts, H. C., Cooper, C. (2006). Is grip strength associated with health-related quality of life? Findings from the Hertfordshire Cohort Study. Age Ageing 35; 4: 409-15.

Schnall, S. B., Kim, B. J., Abramo, A., Kopylov, P. (2006). Fixation of distal radius fractures using a fragment-specific system. Clin Orthop Relat Res 445: 51-7.

Shea, K., Fernandez, D. L., Jupiter, J. B., Martin, C., Jr. (1997). Corrective osteotomy for malunited, volarly displaced fractures of the distal end of the radius. J Bone Joint Surg Am 79; 12: 1816-26.

Silber, J. S., Anderson, D. G., Daffner, S. D., Brislin, B. T., Leland, J. M., Hilibrand, A. S., Vaccaro, A. R.Albert, T. J. (2003). Donor site morbidity after anterior iliac crest bone harvest for single-level anterior cervical discectomy and fusion. Spine 28; 2: 134-9.

Solgaard, S. (1989). External fixation or a cast for Colles' fracture. Acta Orthop Scand 60; 4: 387-91.

Solgaard, S., Petersen, V. S. (1985). Epidemiology of distal radius fractures. Acta Orthop Scand 56; 5: 391-3.

Stubbs, D., Deakin, M., Chapman-Sheath, P., Bruce, W., Debes, J., Gillies, R. M., Walsh, W. R. (2004). In vivo evaluation of resorbable bone graft substitutes in a rabbit tibial defect model. Biomaterials 25; 20: 5037-44.

Sullivan, M., Karlsson, J. (1998). The Swedish SF-36 Health Survey III. Evaluation of criterion-based validity: results from normative population. J Clin Epidemiol 51; 11: 1105-13.

Sullivan, M., Karlsson, J., Ware, J. E., Jr. (1995). The Swedish SF-36 Health Survey--I. Evaluation of data quality, scaling assumptions, reliability and construct validity across general populations in Sweden. Soc Sci Med 41; 10: 1349-58.

Svensson, O., Ahrengart, L., Ekholm, C., Andersson, G. L., Höglund, M., Jonsson, U., Juhlin, L., Kopylov, P., Lagerström, C., Lundborg, G., Made, C., Mallmin, H., Raf, L., Törnkvist, H. (2000). [Malpractice in connection with radius fractures must be reduced. Clear guidelines for treatment and follow-up are required]. Läkartidningen 97; 15: 1800-4, 1807-9.

Taylor, K. F., Parks, B. G., Segalman, K. A. (2006). Biomechanical stability of a fixed-angle volar plate versus fragment-specific fixation system: cyclic testing in a c2-type distal radius cadaver fracture model. J Hand Surg [Am] 31; 3: 373-81.

Trumble, T. E., Wagner, W., Hanel, D. P., Vedder, N. B., Gilbert, M. (1998). Intrafocal (Kapandji) pinning of distal radius fractures with and without external fixation. J Hand Surg [Am] 23; 3: 381-94.

Tsukazaki, T., Takagi, K., Iwasaki, K. (1993). Poor correlation between functional results and radiographic findings in Colles' fracture. J Hand Surg [Br] 18; 5: 588-91.

Tuck, S. P., Raj, N., Summers, G. D. (2002). Is distal forearm fracture in men due to osteoporosis? Osteoporos Int 13; 8: 630-6.

Turner, T. M., Urban, R. M., Gitelis, S., Haggard, W. O., Richelsoph, K. (2003). Resorption evaluation of a large bolus of calcium sulfate in a canine medullary defect. Orthopedics 26; 5 Suppl: s577-9.

Tägil, M., Aspenberg, P. (1998). Impaction of cancellous bone grafts impairs osteoconduction in titanium chambers. Clin Orthop352: 231-8.

Wahlström, O. (1982). Treatment of Colles' fracture. A prospective comparison of three different positions of immobilization. Acta Orthop Scand 53; 2: 225-8.

Walton, N. P., Brammar, T. J., Hutchinson, J., Raj, D., Coleman, N. P. (2001). Treatment of unstable distal radial fractures by intrafocal, intramedullary K-wires. Injury 32; 5: 383-9.

Van Cauwelaert de Wyels, J., De Smet, L. (2003). Corrective osteotomy for malunion of the distal radius in young and middle-aged patients: an outcome study. Chir Main 22; 2: 84-9.

van der Linden, W., Ericson, R. (1981). Colles' fracture. How should its displacement be measured and how should it be immobilized? J Bone Joint Surg Am 63; 8: 1285-8.

Westphal, T. (2007). [Reliability and responsiveness of the German version of the Disabilities of the Arm, Shoulder and Hand questionnaire (DASH).]. Unfallchirurg 110; 6: 548-52.

Westphal, T., Piatek, S., Schubert, S., Winckler, S. (2005). Outcome after surgery of distal radius fractures: no differences between external fixation and ORIF. Arch Orthop Trauma Surg: 1-8.

WHO (2000). Prevention and management of osteoporosis: report of a WHO scientific group. WHO technical report series 921. Geneva, Switzerland, Scientific Group on the Prevention and Management of Osteoporosis.

Wiklund, I., Dimenas, E. (1990). [The Swedish version of the Nottingham Health Profile. A questionnaire for the measurement of health-related quality of life]. Läkartidningen 87; 18: 1575-6.

Wilcke, M. K., Abbaszadegan, H., Adolphson, P. Y. (2007). Patient-perceived Outcome after Displaced Distal Radius Fractures A Comparison between Radiological Parameters, Objective Physical Variables, and the DASH Score. J Hand Ther 20; 4: 290-9.

Willis, A. A., Kutsumi, K., Zobitz, M. E., Cooney, W. P., 3rd (2006). Internal fixation of dorsally displaced fractures of the distal part of the radius. A biomechanical analysis of volar plate fracture stability. J Bone Joint Surg Am 88; 11: 2411-7.

Wolfe, S. W., Pike, L., Slade, J. F., 3rd, Katz, L. D. (1999). Augmentation of distal radius fracture fixation with coralline hydroxyapatite bone graft substitute. J Hand Surg [Am] 24; 4: 816-27.

Wright, T. W., Horodyski, M., Smith, D. W. (2005). Functional outcome of unstable distal radius fractures: ORIF with a volar fixed-angle tine plate versus external fixation. J Hand Surg [Am] 30; 2: 289-99.

Åstrand, J., Thorngren, K. G., Tägil, M. (2006). One fracture is enough! Experience with a prospective and consecutive osteoporosis screening program with 239 fracture patients. Acta Orthop 77; 1: 3-8.