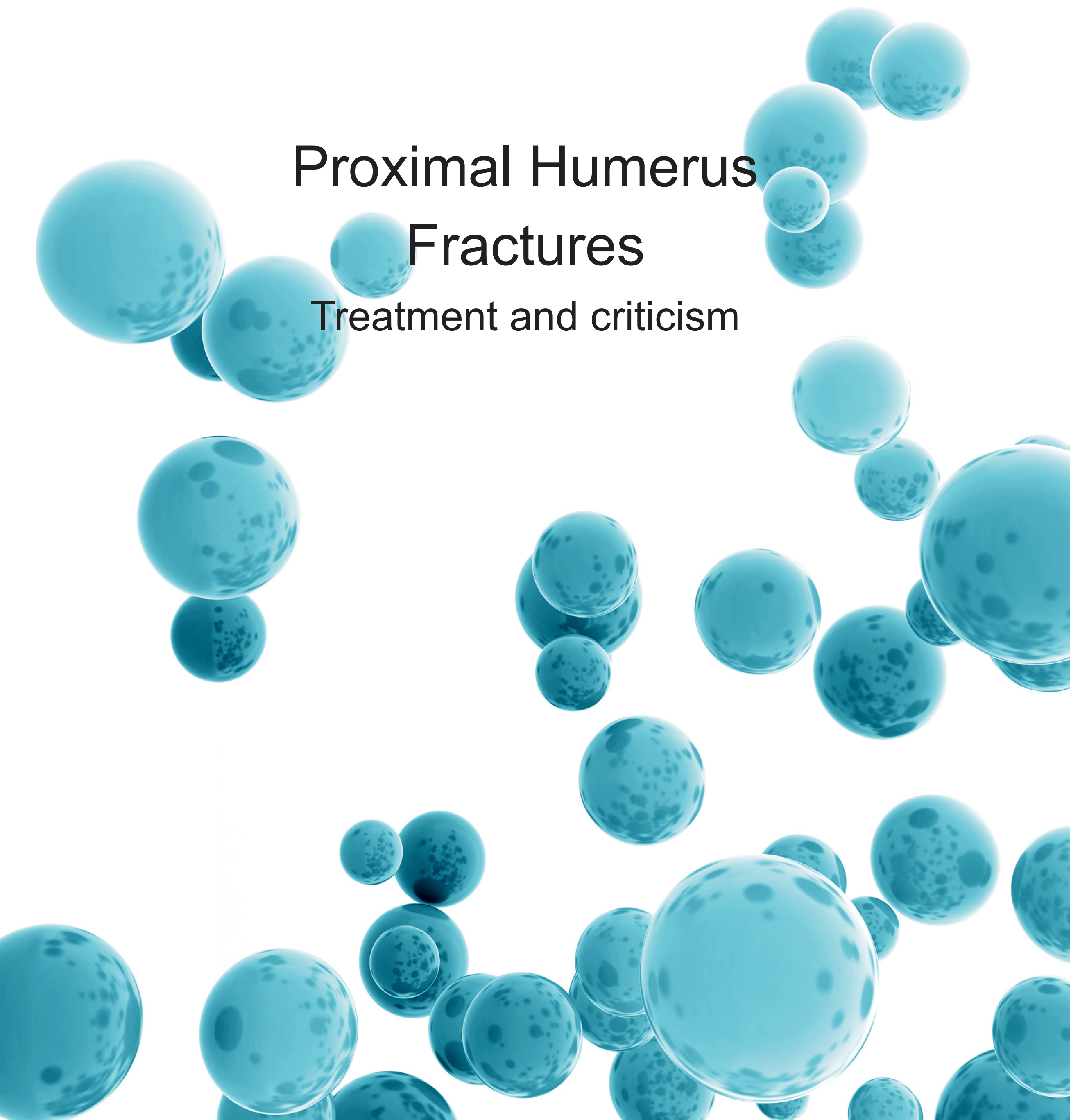
Acta Universitatis Tamperensis 2095

ANTTI LAUNONEN

Proximal Humerus Fractures

Treatment and criticism



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ACADEMIC DISSERTATION
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the Board of the School of Medicine of the University of Tampere,
for public discussion in the Jarmo Visakorpi auditorium
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on 30 October 2015, at 12 o'clock.

UNIVERSITY OF TAMPERE

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Dedicated to my mother, Aira Jokinen

ABSTRACT

In the aging population, the proximal humerus fracture is the third most common osteoporotic fracture type after hip and distal radius fractures, accounting for 4% of all fractures. More than 70% of the patients that present with proximal humerus fracture are over 60 years of age and 75% are women. The mechanism of low-energy injury in elderly patients is usually falling from standing height.

Approximately 85% of patients with a proximal humerus fracture are treated conservatively and will regain shoulder function without surgery. There were 2944 patients hospitalised due to proximal humerus fracture only in Finland in the year 2009. It can be estimated that the annual cost in Finland exceeds 70 million euros. Despite the expense of proximal humerus fractures, there is no clear evidence of the optimal and beneficial treatment.

After the introduction of locking plates in Finland in 2002, the incidence of plate fixation doubled between 2002 and 2009. Based on our survey, uniform lack of confidence regarding the best treatment was notable, and the need for more non-operative treatments over operative ones seemed important among trauma surgeons in Nordic countries and Estonia. Comparison of the locking plate with reverse prosthesis tended to favor reverse prosthesis in all countries except Estonia. We reviewed the currently available EBM literature and found no differences in functional outcomes between operative treatment with the tension band, locking plate or hemiarthroplasty and non-operative treatment. However, surgically treated patients exhibited high rates of complication (10% to 29%) and re-operation (16% to 30%).

Based on the current evidence based medicine literature, surgery should not be considered the gold standard when treating proximal humerus fractures. Nevertheless, because the superiority of single treatment has not been confirmed, the final decision should be made with the patient. Patients should be advised of the high rate of complications that is associated with choosing surgical treatment.

TIIVISTELMÄ

Ikääntyvässä populaatiossa olkaluun yläosan murtumat ovat kolmanneksi yleisin osteoporoottinen murtuma lonkka- ja rannemurtumien jälkeen, käsittäen 4 % kaikista murtumista. Olkaluun yläosan murtumapotilaista enemmän kuin 70 % on yli 60-vuotiaita ja 75 % on naisia. Ikääntyvillä matala-energinen vammamekanismi on yleisimmin kaatuminen.

85 % olkaluun yläosan murtuman saaneista potilaista hoidetaan konservatiivisesti ja olkapään toiminta palautuu ilman leikkaushoitoa. Suomessa vuonna 2009 hoidettiin 2944 potilasta sairaaloiden vuodeosastoilla olkaluun yläosan murtuman vuoksi. Arvioidut vuosikustannukset ylittävät 70 miljoonaa euroa. Korkeista hoitokustannuksista huolimatta tietoa parhaasta ja potilasta eniten hyödyttävästä hoidosta ei ole.

Vuoden 2002 lukkolevyjen markkinoille tulon jälkeen levytysten insidenssi on tuplaantunut, vuosien 2002 ja 2009 välillä. Kyselytutkimuksemme perusteella yhtenäinen konsensus parhaasta hoidosta puuttuu ja tarve hoitaa potilaita enemmän konservatiivisesti vaikutti tärkeältä vastaajillemme Pohjolassa ja Virossa. Verratessa lukkolevytystä käänteisproteesiin, jälkimmäistä suosittiin muissa maissa paitsi Virossa. Tutkimme ajankohtaisen EBM-kirjallisuuden, emmekä löytäneet eroavaisuutta toiminnallisessa lopputuloksessa verrattaessa konservatiivista hoitoa jännitesidokseen, lukkolevytykseen tai puoliproteesiin. Leikkaukselliseen hoitoon liittyi kuitenkin korkea komplikaatio- (10–29 %) ja uusintaoperaatio-riski (16–30 %).

Käytössä olevan EBM-kirjallisuuden valossa, leikkaushoitoa ei tulisi pitää kultaisena standardina hoidettaessa olkaluun yläosan murtumia. Koska yksikään hoitomuodoista ei ole osoitetusti paras, lopullinen hoitopäätös tulisi tehdä yhdessä potilaan kanssa. Potilasta tulee tässä yhteydessä informoida korkeista komplikaatioriskeistä leikkaushoidon yhteydessä.

CONTENTS

LIST OF ORIGINAL COMMUNICATIONS

This thesis is based on the original communications listed below. The publications are reprinted with permission from their copyright holder.

I. Launonen, A. P., V. Lepola, T. Flinkkila, N. Strandberg, J. Ojanpera, P. Rissanen, A. Malmivaara, V. M. Mattila, P. Elo, T. Viljakka and M. Laitinen (2012). "Conservative treatment, plate fixation, or prosthesis for proximal humeral fracture. A prospective randomized study." BMC Musculoskelet Disord. 13: 167.

II. Huttunen TT, Launonen AP, Pihlajamäki H, Kannus P, Mattila VM. (2012). Trends in the surgical treatment of proximal humeral fractures—a nationwide 23-year study in Finland. BMC Musculoskelet Disord. 2012 Dec 29; 13: 261.

III. Launonen, A. P., V. Lepola, T. Flinkkila, M. Laitinen, M. Paavola and A. Malmivaara (2015). "Treatment of proximal humerus fractures in the elderly." Acta Orthop. 86(3): 280.

IV. Launonen, A. P., V. Lepola, A. Saranko, T. Flinkkila, M. Laitinen and V. M. Mattila (2015). "Epidemiology of proximal humerus fractures." Arch Osteoporos 10(1): 209.

V. Launonen AP, Lepola V, Laitinen M, Mattila VM. Proximal humerus fractures – Does the treatment policies differ in three Nordic countries and Estonia? A cross-sectional questionnaire-based study. Submitted to Scandinavian Journal of Surgery.

ABBREVIATIONS

15D	Health Related Quality of Life outcome measure
AO	Arbeitsgemeinschaft für Osteosynthesefragen
CRF	Case Report Form
CT	Computed Tomography
DASH	Disabilities of the Arm, Shoulder and Hand
EQ-5D	EuroQol, Health Related Quality of Life outcome measure
HA	Hemi-arthroplasty, Hemi-prosthesis
HRQoL	Health Related Quality of Life
m.	Musculus – muscle
MCID	Minimal clinically important difference
NHDR	Finnish national hospital discharge register
n.	Nervus – nerve
OSS	Oxford Shoulder Score
ORIF	Open reduction and internal fixation
PROM	Patient-reported outcome measure
RCT	Randomized Clinical Trial
ROM	Range of Motion
RSA	Reverse prosthesis
SD	Standard deviation
VAS	Visual Analogue Scale

1 INTRODUCTION

In the aging population, the proximal humerus fracture is the third most common osteoporotic fracture type after hip and distal radius fractures, accounting for 4% of all fractures (Seeley, Browner et al. 1991, Lauritzen, Schwarz et al. 1993, Court-Brown and Caesar 2006). More than 70% of the patients that present with proximal humerus fracture are over 60 years of age and 75% are women (Kristiansen, Barfod et al. 1987). The mechanism of low-energy injury in elderly patients is usually falling from standing height (Panula, Pihlajamaki et al. 2011). A comprehensive hospital discharge-based study demonstrated an increase in annual hospitalization due to fracture of 13% per year over the past 33 years. The incidence reached 105 per 100,000 person-years in the year 2002 (Palvanen, Kannus et al. 2006). If this trend were to continue, the fracture rate would triple over the next three decades.

Approximately 85% of patients with a proximal humerus fractures are non-dislocated and are treated conservatively. Patients will regain satisfactory shoulder function for his/her needs without surgery (Bell, Leung et al. 2011). There were 2944 patients hospitalised due to proximal humerus fracture only in Finland in the year 2009 (Huttunen, Launonen et al. 2012). According to a study from Norway, the cost of single patient treated in hospital is 23 953€ (Fjalestad, Hole et al. 2010). Although treatment costs are not directly generalizable to other nations, it can be estimated that the annual cost in Finland exceeds 70 million euros. Despite the expense of proximal humerus fractures, there is no clear evidence of the optimal and beneficial treatment (Handoll, Ollivere et al. 2012). Interestingly, after introducing new implants for the surgical treatment of proximal humerus fractures at the beginning of the 2000s, surgical treatment has multiplied in a short period of time without any evidence that it produces superior outcomes (Huttunen, Launonen et al. 2012). To date, some studies have been published concerning the usefulness and effectiveness of different treatment methods. However, the quality of these studies has been moderate at best, and more often poor (Lanting, MacDermid et al. 2008). Some high-quality, randomized, controlled trials (RCT) comparing non-surgical to surgical treatment have been published since the latest Cochrane review from 2012 (Boons, Goosen et al. 2012, Fjalestad, Hole et al. 2012, Handoll, Ollivere et al. 2012). However, a meta-analysis or review completing the knowledge has not yet been carried out.

Numerous difficulties underlie the treatment of this common fracture. One basic reason is an insufficient and unreproducible fracture classifications. In Finland, the most commonly used classifications are Neer and AO/OTA classifications (Arbeitsgemeinschaft für Osteosynthesefragen/American Orthopaedic Trauma Association) (Neer 1970). However, recent studies have provided no clear answer regarding whether one classification system is superior and which of the classifications are better, as results can not be reproduced between researchers, or even by a single researcher (Brorson, Bagger et al. 2009). One major flaw is that the aforementioned classifications do not generally predict outcome. (Gerber, Werner et al. 2004.)

Another challenge is interpreting the outcome of treatment. It is not known how a satisfactory result should be measured. For example, do we declare a good result when the range of motion (ROM) is full but the patient is suffering severe pain, or on the contrary, when there is no movement but also no pain? The need for reasonable outcome measures in different age groups is apparent when evaluating the treatment. One point worth noting is that the interpretations of outcomes differ regarding working-age patients versus elderly patients. Unfortunately, ROM has been the most common outcome measure in previous studies; however, as discussed, it is a relatively poor surrogate predictor of functional outcome because it depicts only function, and not the strength, pain, or satisfaction of the patient (Lanting, MacDermid et al. 2008).

The third (and possibly the most important) reason for the lack of consensus is methodology. RCT is the gold standard in modern trials. Most previous studies on proximal humerus fractures are based on case series and cohort studies. Unfortunately, much of the effort has been invested in case reports, retrospective series, and uncontrolled cohort studies; as a result, we are unable to compare different treatments without significant bias. Even when an RCT is done well, the reporting may include flaws that lead to a high risk of bias (Furlan, Pennick et al. 2009).

The fourth reason might be the implementation of the study results in the context of clinical work. Traditions and beliefs also guide us in orthopaedics, and dramatic changes in treatment policies may be slow despite the need for them. Change of resistance against new methods has not been studied in orthopaedics; however, sometimes adopting new treatment methods is successful. For example, regarding the treatment of achilles tendon ruptures (Huttunen, Kannus et al. 2014), new high-quality studies have demonstrated the superiority of non-surgical treatment; as a result, the incidence of surgery has decreased.

2 REVIEW OF LITERATURE

2.1 Anatomy

The shoulder joint is the most mobile and unstable joint of the body (Fig. 1). The humerus articulates with the hemispheric surface to the glenoid cavity of the scapula. One-third of the total ROM is attained by scapular movement, and two-thirds is attained from the glenohumeral joint itself. Movements of the humerus are managed mainly with shoulder girdle muscles (musculus, m.): m. subscapularis, m. supraspinatus, m. infraspinatus, and m. teres minor. M. subscapularis attaches to the tuberculum minus, and the rest of the muscles attach to the tuberculum majus. Tendinous parts of the muscles form the rotator cuff. The tendinous and bony parts of the shoulder are enveloped by the deltoid muscle, which functions synergistically with the abovementioned muscles to create the full arch of movement. Humeral adductors m. latissimus dorsi and m. pectoralis attach to the upper third of the humerus.

Rotational movements of the humerus mainly arise from the muscles of the rotator cuff: m. subscapularis functions as the inner rotator, m. infraspinatus and teres minor are the outer rotators, and m. supraspinatus functions as the abductor. M. latissimus dorsi and m. pectoralis major are adductors of the limb. In order to abduct the humerus,

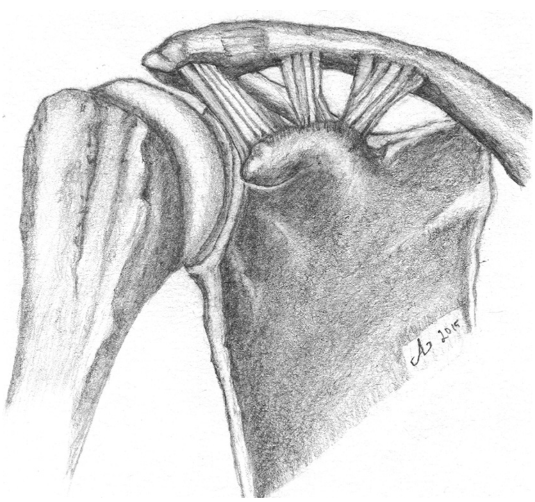

Figure 1. Shoulder bony anatomy, anterior view.

m. supraspinatus activates the rising humerus for the first third of the movement arch. After the first activation, the deltoid muscle takes the main activation through the second third of the arch. The final third of the movement is conducted purely from scapular rotation.

Blood flow in the proximal part of the humerus arises mainly from two arteries: the arteria (artery, a.) circumflexa posterior and anterior. The nervus (nerve, n.) axillaris divides from the upper trunk of the plexus and travels through quadrangular space from posterior to anterior, branching off to m. teres minor, and travels on the inner fascia of the deltoid muscle to muscle itself. N. suprascapularis arises from the upper trunk of the plexus, travels through the scapular notch in the anterior to posterior direction, and branches to the m. supraspinatus and m. infraspinatus. Innervation to m. subscapularis arises from the posterior cord of the plexus and along the nn. supra- and infrascapular.

2.2 Incidence

Taking into account the number of proximal humerus fracture patients seen in the everyday practice of physicians each year, epidemiology regarding proximal humerus fracture is surprisingly poorly known. Only a few population-based studies exist that include both inpatient and outpatient treatment (Rose, Melton et al. 1982, Kristiansen, Barfod et al. 1987, Court-Brown, Garg et al. 2001). In Rochester, Minnesota, USA unadjusted incidences for men and women were 30 and 71 per 100,000 person-years, respectively, between 1965–1974 (Rose, Melton et al. 1982). In a 1983 study conducted in Copenhagen, Denmark, the unadjusted incidences for men and women were 48 and 142 per 100,000 person-years (Kristiansen, Barfod et al. 1987). A study conducted in Edinburgh, Scotland from 1992 to 1996 did not calculate the total incidences; however, the highest age-specific figures in that study were observed among 80- to 89-year-olds: 109 and 260 per 100,000 person-years for men and women, respectively (Court-Brown, Garg et al. 2001).

It must be noted that unadjusted incidences are not transferrable to another population, or to another time span in the same geographical area. The fracture rate with the certain risk population must be adjusted to take into account the population structure. For example, after the ratio of women to men and age structures have been adjusted regarding the regional risk population, the age- and sex-adjusted incidences can be compared with those from another region and population.

When interpreting the incidence figures from different studies, one must note the methodology that is used for data collection. When the data are derived from a hospital discharge register, as in the study by Palvanen et al. (Palvanen, Kannus et al.

2006, Palvanen, Kannus et al. 2010), the total incidence rate is underestimated, because discharge registers include only hospitalized patients, and thus exclude patients treated in emergency departments. In addition, a great number of proximal humerus fractures in Nordic countries are treated in the outpatient setting at local healthcare centers, and these patients are not included in the hospital discharge registers.

2.3 Risk factors

Court-Brown et al. published a large follow-up study on the epidemiology of proximal humerus fractures. They found out that the majority (90%) of simple low-energy traumas by falling occurred for patients aged 60 years and older, and that the severity of the fracture increases with age. This suggests the osteopenic or osteoporotic nature of the proximal humerus fracture (Court-Brown, Garg et al. 2001). Rotator cuff ruptures are mostly degenerative in nature and are part of normal ageing. A recent report notes that degenerative rotator cuff rupture patients have low mineral density of the proximal humerus; thus, the presence of rotator cuff rupture is ostensibly a risk factor for fracture as a result of falling (Oh, Song et al. 2014).

It has been suggested that the most significant risk factors of proximal humerus fractures are age and sex (Palvanen, Kannus et al. 2006). Fracture appears to be most common for elderly women, while falls from standing height seem to describe most of the accidents. Reasons for falling vary, and include poor vision, poor lighting conditions, fatigue, and fragility. Some studies have shown that the rates of other osteoporotic fractures increase during winter (Flinkkila, Sirnio et al. 2011).

2.4 Fracture Classification

The first written record of proximal humerus fractures was found on the Edwin Smith papyrus, dating to ca. 1600 BCE. Three proximal humerus fracture cases were described, and were treated with traction reduction and bandaging (Breasted 1930, Allen 2005). In the 19th century, several classifications and mainly bandaging or traction treatments were introduced, with inevitable hopeless results (Liston 1838, Stimson 1899, van Assen J 1948, Brorson 2011). The modern classification systems evolved only after invention of x-rays.

There are mainly two international x-ray–based fracture classification systems in current use: the *Arbeitsgemeinschaft für Osteosynthesefragen* [Association for the Study of Internal Fixation]/Orthopaedic Trauma Association (AO/OTA) and Neer classifications (Neer 1970, Helfet, Haas et al. 2003). There are other less often used classifications (e.g., Codman-Hertel and Resch) that have not gained popularity outside German-speaking countries (Resch 2003, Hertel 2005).

In 1934, Ernest Amory Codman introduced a 4-part fracture classification that was developed further by Charles Neer in 1970, with improved regard to fracture dislocation and blood flow. This is known as Neer's classification. (Codman 1934, Neer 1970.) The AO/OTA classification system for long bones was initially proposed by Maurice Müller and coworkers in 1987, and was originally known as the Müller/AO classification system; regular updates have been published. (M.E. Muller 1990.) The AO/OTA classification system was intended to improve upon the Neer classification system; however, as it subdivides fractures into 27 patterns, its use is generally considered too time-consuming and complicated for use in clinical work.

2.4.1 Neer classification system

In clinical practice in Finland, the widely used classification system for proximal humerus fractures is Neer's 6-phase classification system. This system divides the proximal humerus into four parts: shaft, tuberculum majus, tuberculum minus, and articular surface (Fig. 2).

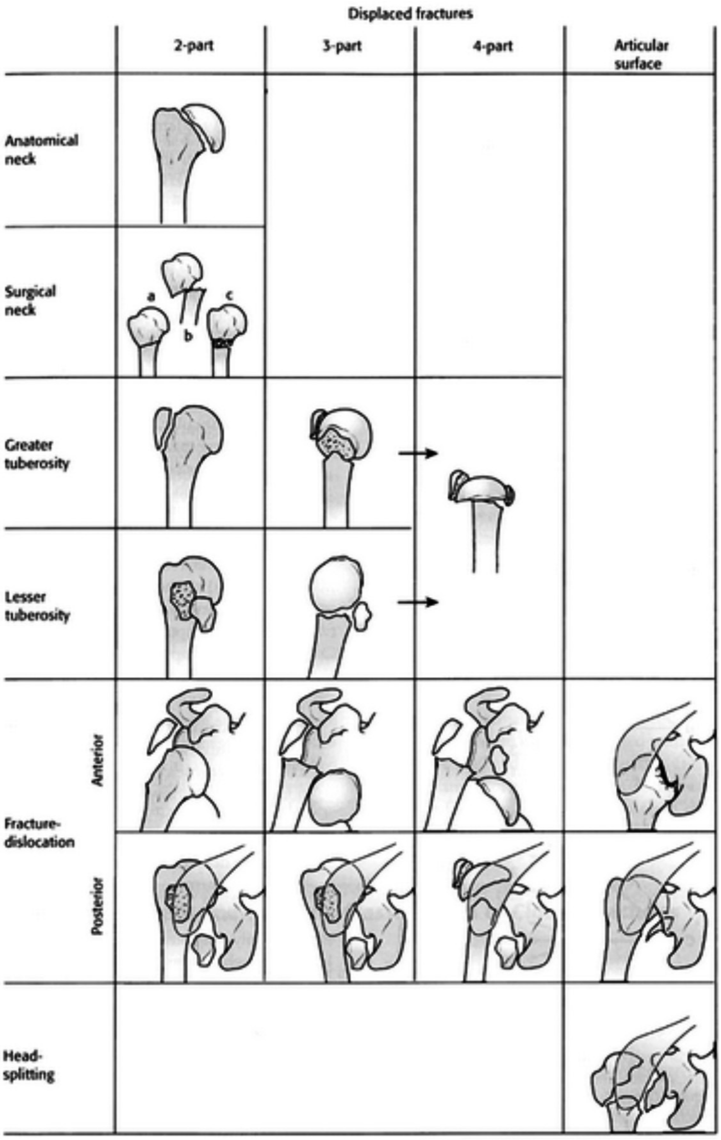

Figure 2. Neer Classification.
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A 1-part fracture is an undisplaced fracture, in which any of the four aforementioned parts are dislocated <1 cm or angulated <45 degrees in relation to the other parts.

A 2-part fracture is a fracture in which any of the four aforementioned parts are displaced >1 cm or angulated >45 degrees in relation to the other parts.

In a 3-part fracture, three of the aforementioned parts are displaced in relation to each other.

In a 4-part fracture, all four parts are displaced in relation to the other parts.

In addition to these classes, fracture dislocation and head splitting fracture form a category of their own.

2.4.2 AO classification system

The Müller/AO classification system was created for standardization purposes, with defined terms of fracture description. Each bone and bone segment (proximal, diaphyseal, distal, or malleolar) is typed in three categories (A–C), further subdivided into three groups, and again into three subgroups (Fig. 3).

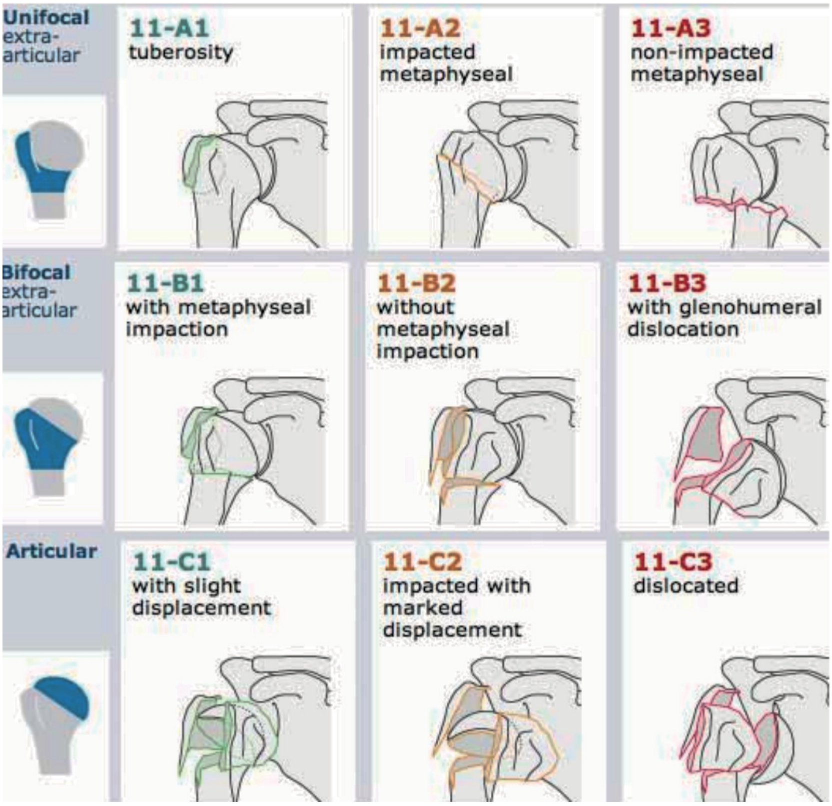

Figure 3. Humerus AO/OTA Classification.
Reprinted with permission.

Humerus is designated as bone number 1, and the proximal part of the arm is also designated as 1; hence, the proximal humerus has bone segment is designated as 11. Fracture type A is extra-articular, type B partially intra-articular, and type C is intra-articular. Each of these types has three groups and three subgroups according to the severity of the fracture. The two ends of a proximal humerus fracture are classified as 11 A1.1 (mildest fracture) and 11 AC3.3 (most severe fracture). This system leads to

27 subgroups for each fracture pattern. This detailed description is rarely needed for clinical use.

2.4.3 Hertel and Resch classification systems

Hertel refined the original Codman classification to a so-called binary or lego description system. It is easy to use and understandable, but does not account for the varus- and valgus-type fractures (Resch 2011). Resch or HCTS (head/calcar/tuberosities/shaft) classification also includes these types of fractures.

2.4.4 Reliability of classification systems

At its best, the Neer classification system achieved an inter-observer mean kappa value of 0.48 with 4-part fractures. Another inter-observer study that used Codman-Hertel classification and plain x-rays achieved a kappa value of 0.44. These results reflect the low level of agreement among doctors when classifying fractures, regardless of the classification system used (Brorson, Bagger et al. 2009, Majed, Macleod et al. 2011). However, systematic training regarding classification increases the prediction value and agreement of classifications (Brorson, Bagger et al. 2002). Computed tomography (CT) and 3-dimentional CT seemed not to contribute more to the classification of displaced fractures (Sjoden, Movin et al. 1999, Berkes, Dines et al. 2014), although they may be valuable in pre-operative planning.

2.4.5 Functional outcome and classifications

Canbora et al. demonstrated a negative correlation between function and the initial amount of bone fragmentation (Canbora, Kose et al. 2013). However, some reports suggest that fracture classification does not affect the end result (Bjorkenheim, Pajarinen et al. 2004). Other reports claim that increased age is associated with poor outcome (Court-Brown and McQueen 2004). In conclusion, classification of any type does not appear to reliably predict the clinical outcome of a distinct fracture (Gerber, Werner et al. 2004).

2.5 Outcome measures

Ernest Amory Codman introduced the need for post-treatment control and evaluation for treatment in the early 1900s under "end result" system (Brand 2009). The idea was finally adopted generally, but it took over 80 years before the first real numeral outcome scoring system for the shoulder, the Constant-Murley score, was invented. Previously, fracture union, physician satisfaction, patient satisfaction, and ROM were considered acceptable outcomes.

Bony union of a fracture has been widely used as an outcome in traumatology. Similarly, bony non-union (unconsolidated fracture) has been categorized as a complication of treatment and is considered a failure. Historically, fracture union was used as the only outcome measure of treatment; however, it was later shown that various parameters affect patient-reported outcome measures (PROMs) (Broadbent, Will et al. 2010).

Pain is generally a marker of pathology in organisms. Continuous pain after trauma and surgery is known to decrease one's quality of life (Brinker, Hanus et al. 2013). The best, validated, and easiest way to measure pain in clinical use is the visual analog scale (VAS) (Huskisson 1974). The VAS is numbered from 0 to 100 on a millimeter scale; 0 stands for pain-free sensation and 100 represents the worst pain imagined.

Before the Constant score was introduced and popularized, ROM and pain were considered the most important outcome measures in proximal humerus fractures (Edelson, Safuri et al. 2008). From the patient's point of view, shoulder ROM could be seen as a surrogate variable of activity level. However, ROM must be interpreted with caution, because ROM measures only the degree of motion and ignores the satisfaction of the patient. Although ROM may be a more suitable outcome measure for younger patients, it is known to be insufficient regarding fragility fractures and elderly patients. For elderly patients, painless motion regardless of range and the overall ability to cope with daily activities are essential. Several PROMs can be used to obtain this information from patients with proximal humerus fracture. These outcome measures can be divided into two categories: measures of health-related quality of life (HRQoL) and fracture/shoulder-specific outcome measures.

In order to compare different treatments, the minimal clinically important difference (MCID) should be known. Previously, statistical significance has been considered powerful enough evidence to support further decision-making when choosing between treatments. However, it has recently become clear that statistical significance is not enough (Leopold 2013). MCID stands for the minimal change that a patient subjectively notices as a shift to better or worse. For example, the MCIDs for the Disabilities of the Arm, Shoulder and Hand (Dash, Sanda et al.) score and for the

Constant score are each 10 points (Kukkonen, Kauko et al. 2013, Sorensen, Howard et al. 2013). MCID for VAS in rotator cuff disease has been defined as 14 mm (Tashjian, Deloach et al. 2009).

In order to compare different outcome measures, each must be translated into different languages and validated in different regions. For example, some shoulder-specific outcome measures have been translated into Finnish and culturally adopted in Finland.

2.5.1 HRQoL measures

HRQoL measures are assessments of wellbeing in certain populations. The validated questionnaires are multidimensional and take into account different aspects of physical, social, emotional, and cognitive differences. They result in a numerical figure, which can be compared with a reference population or the patient's own results in time. Thus, after an event of proximal humerus fracture, its association with an individual's wellbeing can be determined (WHOQOL 1998).

The EuroQol (EQ-5D) and 15D are generic HRQoL measurement tools that are widely used in the context of proximal humerus fractures. However, the assessment of HRQoL with the EQ-5D in patients with a proximal humeral fracture is questionable. Although Olerud et al. reported that EQ-5D exhibited good responsiveness (Olerud, Tidermark et al. 2011), two other studies found a significant ceiling effect that limits the reliability of this instrument (Slobogean, Noonan et al. 2010, Skare, Liavaag et al. 2013). There are no reports of 15D regarding proximal humerus fractures; however, it has shown a good responsiveness with respect to fragility wrist and hip fractures (Rohde, Moum et al. 2012).

The ceiling effect represents a data-gathering problem possessed by certain instruments. Bunching of scores at the upper limit (ceiling) diminishes sensitivity, and makes it more difficult to spot differences (Cramer 2005). In practice, the problem occurs when a patient has high initial scores; because the "ceiling" is close, the amount that possible scores can increase is limited. The floor effect is similar to the ceiling effect, with the bunching occurring at the lower limit.

2.5.2 Shoulder-specific outcomes

2.5.2.1 The Constant Score

Cristopher Constant's university thesis about a functional assessment scoring system became available in 1986 (Constant 1986). This scoring system is now known and widely used as the Constant-Murley score (Constant score, CS). Constant developed the scoring system during a 5-year period with the assistance of Alan Murley (Constant, Gerber et al. 2008).

The Constant-Murley Score is considered a benchmark of outcome measures with respect to the shoulder. It has both objective and subjective aspects, which are taken into account in the result (Fig. 4). Because the Constant is labor consuming and subjective questionnaires have been shown to correlate between each other, subjective questionnaires are currently preferred over the Constant (Baker, Nanda et al. 2008). The Constant score ranges from 0–100, where 0 represents a missing upper extremity and 100 represents a perfect, normally functioning and pain-free extremity. The MCID is 10.4 points (Kukkonen, Kauko et al. 2013).

OUT-PATIENT CLINIC **SHOULDER UNIT**

CONSTANT SCORE

Patient's Details

Operation/Diagnosis: **Date:**________

Side: R L

Examination: Pre-op
3 months 6months
1 year 2 years ___ years

A.- Pain (/15): Average (1 + 2) [ ] A

1. Do you have pain in your shoulder (normal activities)?
   No =15 pts, Mild pain = 10 pts, Moderate = 5 pts, Severe or permanent = 0. ____

2. Linear scale:
   If "0" means no pain and "15" is the maximum pain you can experience, please circle where is the level of pain of your shoulder. (Points given are inverse to the scale. E.g. level 5 in the scale means 10 points)

Level of pain:	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Points:	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

____

B.- Activities of daily living (/20) Total (1 + 2 + 3 + 4) [ ] B

1. Is your occupation or daily living limited by your shoulder?
   No = 4, Moderate limitation = 2, Severe limitation = 0 ____
2. Are your leisure and recreational activities limited by your shoulder?
   No = 4, Moderate limitation = 2, Severe limitation = 0 ____
3. Is your night sleep disturbed by your shoulder?
   No = 2, Sometimes = 1, Yes = 0 ____
4. State to what level you can use your arm for painless, reasonably activities.
   Waist = 2, Xiphoid (sternum) = 4, Neck = 6, Head = 8, Above head = 10 ____

C.- Range of movement (leave this for the doctor or physiotherapist) **(/40):** Total (1 + 2 + 3 + 4) [ ] C

1.- FWD Flexion: ____
- 0 - 30 0 pts
- 31 -60 2 pts
- 61 - 90 4 pts
- 91 - 120 6 pts
- 121- 150 8 pts
- >150 10 pts

2.- Abduction: ____
- 0 - 30
- 31 - 60
- 61 - 90
- 91 - 120
- 121 - 150
- >150

3.- External Rotation: ____
- Hand behind head & elbow forward 2
- Hand behind head & elbow back 4
- Hand above head & elbow forward 6
- Hand above head & elbow back 8
- Full elevation of arm 10

4.- Internal Rotation: (Dorsum hand to) ____
- Thigh 0
- Buttock 2
- SI joint 4
- Waist 6
- T12 8
- Between shoulder blades 10

D.- Power (/25): Points: average (kg) x 2 = [ ] D

First pull: Second pull: Third pull: Fourth pull: Fifth pull:
Average pulls:

TOTAL (/100): A + B + C+ D [ ]

Figure 4. The Constant-Murley scoring questionnaire

2.5.2.2 The DASH Questionnaire

The Disabilities of the Arm, Shoulder and Hand (Hudak, Amadio et al. 1996) questionnaire and the Oxford Shoulder Score questionnaire (Dawson, Fitzpatrick et al. 1996) are two purely subjective instruments that attempt to categorize patient function and satisfaction through applying culturally adopted and transferrable (validated) questions over a period of time. The DASH has 30 mandatory and 8 additional questions that cover different areas of life, which are graded from 1 (normal use of the limb) to 5 (not functioning) over the specific task. The outcome scale is from 0–100, with 0 representing the normally functioning and pain-free usage of the extremity and 100 representing a missing limb (Hudak, Amadio et al. 1996). The DASH score has been validated in Finnish, and the MCID is 10 points (Franchignoni, Vercelli et al. 2014).

Because DASH is time-consuming and may be complicated to fill (especially for elderly patients), the quick-DASH has been created. It includes only 11 questions, which are also included in the original DASH (Beaton, Wright et al. 2005).

2.5.2.3 The OSS

The Oxford Shoulder Score is a subjective, shoulder-specific score specifically for use in the context of shoulder pathologies. It includes 12 questions on coping with daily activities. Unfortunately, its scaling has been changed, and a direct and uniform comparison between the two versions is not possible. MCID has not been assessed, and Finnish language validation has not been completed (Dawson, Fitzpatrick et al. 1996).

2.5.2.4 The UCLA Questionnaire

The University of California Los Angeles questionnaire represents a subjective shoulder score that ranges from 0 to 35, where 0 represents the worst and 35 the best result. MCID has not been assessed, and Finnish language validation has not been completed (Amstutz, Sew Hoy et al. 1981).

2.5.2.5 The ASES Questionnaire

The American Shoulder and Elbow Surgeons (Pakos, Nearchou et al.) outcome is a 10-point questionnaire used to assess pain, subjective instability, and abilities for daily living. Its scale ranges from 0 to 100, where 100 is the best result. Although the score is easy to use, the MCID has not been assessed, and Finnish language validation has not been completed (Richards, An et al. 1994).

2.5.2.6 The SST

The Simple Shoulder Test (SST) contains 12 questions with yes/no answers. Each yes is given 1 point. All points are added, and the result may be compared. Scale ranges from 0 to 12, where 0 is the worst and 12 is the best result (L'Insalata, Warren et al. 1997). The MCID is 2 points; Finnish language validation has not been completed (Tashjian, Deloach et al. 2010).

2.6 Treatment options for a proximal humerus fracture

There are numerous publications concerning the treatment of proximal humeral fractures. A Medline search using the keywords "treatment proximal humerus fracture" yielded 1529 abstracts on 8 March 2015. Reports exhibit a great variety of treatment methods and results. The majority of the studies are retrospective and not comparative. A review article by Lanting and coworkers published in 2008 included 66 publications on proximal humerus fracture treatment before 2004 (Lanting, MacDermid et al. 2008). Only two of them were RCTs that compared operative and non-operative treatment (Kristiansen and Kofoed 1988, Zyto, Ahrengart et al. 1997). Several different operative methods have been published that describe one method or a combination of different methods (e.g., external fixation or external fixation with k-wires). However, these are mostly case reports or small patient series.

2.6.1 Non-operative treatment

Court-Brown and his workgroup published retrospective analysis of impacted varus fracture in 2004 treated non-operatively. They included 99 patients with 1 year follow-up. 79% had good or excellent result according to Neer score. In another publication from same workgroup researchers noted increase of age and degree of displacement affected negatively the outcome. (Court-Brown, Cattermole et al. 2002, Court-Brown and McQueen 2004.)

In 2009, Hanson published his case series study with 160 non-operatively treated patients (mean age 63 years); 77.5% came to a follow-up visit. More than one-half of the patients had a 2-part (38%) or 3-part (14%) fracture based on x-rays. After a 12-month follow-up period, the difference in the end result compared with the healthy side was 8.2 points when measured with the Constant-Murley score and 10.2 points when measured with the DASH score. The Constant results are below MCID and DASH is just over it. The risk of non-union was 7%, and was 5.5-fold greater for smokers than for non-smokers (Hanson, Neidenbach et al. 2009).

In 2005, Fjalestad published a retrospective comparative study in which 70 patients (mean age 71 years) admitted to Aker university hospital were treated and followed. Fifteen patients were treated with surgery and 55 patients were treated non-operatively. Follow-up was a minimum of 10 months. They used Rowe score to evaluate outcomes: the non-operative group achieved 64% of total score, and the surgical group had 38% of the maximum score. The difference between treatment groups was statistically significant (Fjalestad, Stromsoe et al. 2005), although treatment groups were not comparable.

2.6.2 External fixation

Kristiansen and Kofoed from Denmark published the first randomized study to address proximal humerus fractures as early as 1988. A consecutive series of 31 patients (age range 30 to 91 years) with displaced 2- to 4-part fractures were randomly treated either with closed reduction (n=15, median age 72 years) or Hoffman's external fixator (n=16, median age 66 years). The follow-up time was 1 year. They found that overall, external fixation produced superior outcomes to closed reduction. Unfortunately, the outcome score was old-fashioned (Neer score), and so it is not possible to compare these results with more modern studies. Although the methodology of this study was modern, the group sizes were too small to produce adequate statistical power (Kristiansen and Kofoed 1988). There is only one other published report about external fixation. The same authors presented the surgical technique and reported their preliminary results with a small pilot group (Kristiansen and Kofoed 1987).

2.6.3 Tension band

Darder and co-workers presented 33 patients with 7 years of follow-up after 4-part fractures with open reduction and internal fixation (ORIF) with k-wires and tension band. Results were excellent and satisfactory in 21 cases (64%). Non-satisfactory or poor results were noted with 12 cases. Avascular necrosis was noted in 27% of patients (Darder, Darder et al. 1993).

In 1997 Zyto et al. published an RCT about the treatment of proximal humerus fractures with tension bands. Forty patients with 3- or 4-part fractures were randomized to two treatment groups: non-operative or operative treatment with tension band osteosynthesis. After 1 year of follow-up, the Constant score was 60 in the tension band group and 65 in the non-operative group. The difference was not statistically or clinically significant. Eight (20%) complications were reported (Zyto, Ahrengart et al. 1997).

2.6.4 Helix wire

Helix wire was introduced as a minimally invasive instrument. Titanium helical wire was inserted via diaphysis and the fracture was "screwed" to stable. Some primary reports were positive, with good to excellent results in case of 2- and 3-part fractures (Gorschewsky, Puetz et al. 2005, Krause, Gathmann et al. 2008). However, there is a widespread understanding that this technique produces poor results—it is associated with primary failure and non-union rates of up to 47% (Raissadat, Struben et al. 2004, Khan 2008). There are no new publications involving Helix wire after 2010.

2.6.5 K-wires

K-wire systems are presently in use, and some new inventions have been introduced. Innocenti et al. published a consecutive series of 51 patients with severe co-morbidities treated with K-wiring (28 patients) or with a brace (23 patients, mean age 76 years). These patients were contraindicated for ORIF (Innocenti, Carulli et al. 2013). The operative group achieved a Constant score of 81 and VAS of 2.9, while the non-operative group achieved a Constant score of 76 and a VAS of 3.0.

Carbone et al. (2012) compared MIROS pinning (31 patients) with traditional pinning (27 patients) in 3- and 4-part proximal humerus fractures. After 2 years of follow-up the mean Constant score was 60 for MIROS pinning and 52 for traditional pinning. The MIROS was described as "a new percutaneous pinning device allowing correction of angular displacement and stable fixation of fracture fragments". The mean subjective shoulder evaluation value was 90 vs. 73. Although these results were statistically significant and favored MIROS pinning, they lacked clinical significance (Carbone, Tangari et al. 2012).

2.6.6 Humerus block

The humerus block is a relatively new concept for treating proximal humerus fractures. The ideology behind the humerus block is semi-rigidity and controlled impaction, which would be optimal for healing methaphyseal fractures (Fig. 5). The implant is simple: two pieces of 2-mm k-wire are introduced to the methaphyseal area from the direction of diaphysis and locked with a block to the shaft (Resch 2011). The theoretical advantage is the implant direction against load peak, which has been studied in vivo (Bergmann, Graichen et al. 2007). There are still only a few studies of the implant, and comparison with non-operative treatment is lacking.

Figure 5. Humerus block.
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2.6.7 Intramedullary nails

The advantage of intramedullary devices (nails) is thought to be minimal surgical trauma. After fracture reduction, only a small incision is needed for nail insertion and fixation of the fracture. The nail is inserted with a proximal approach through the rotator cuff and locked both proximally and distally with screws. With more advanced nails, locking screws might be inserted to obtain better rigidity between fracture fragments. Literature regarding outcomes is scarce, and comparative trials are lacking. Giannoudis et al. reported a small retrospective cohort study with 27 patients. The mean Constant score was 75 (range: 48–89), but the complication rate was high (28%) (Giannoudis, Xypnitos et al. 2012). Intramedullary nails have not gained wide popularity in Finland.

2.6.8 Non-locking plates

Before the locking plate era, a wide variety of non-locking plates were used, including T-plates, J-plates, and one-third tubular plates. The problems using this method include a great number of complications with infections, fixation loosening, avascular necrosis, and re-operations (Kristiansen and Christensen 1986, Wanner, Wanner-Schmid et al. 2003).

2.6.9 Locking plate systems

Locking plates were introduced in 2001 (Bell, Leung et al. 2011). In locking plates, the screw head has a thread that interlocks with the plate to form a stable-angle system. This construction is considered particularly beneficial in the context of osteoporotic, weakened bone matrix.

The majority of retrospective and case control studies focus on outcomes in different plates without uniform outcome measures. Results are mostly narrative and descriptive, showing good functional results with locking plates (Bjorkenheim, Pajarinen et al. 2004, Sudkamp, Bayer et al. 2009, Thanasas, Kontakis et al. 2009, Sproul, Iyengar et al. 2011, Brorson, Rasmussen et al. 2012).

There are only a few good RCTs on locking plates. The first RCT was published in 2011, 10 years after the introduction of the new method. Olerud et al. conducted an RCT on 3-part fractures, comparing non-operative treatment (n=30) with angle-stable plates (n=30) in elderly patients. The results indicated advantages in functional outcome and health-related quality of life favoring the locking plate, but clinical significance was lacking (Constant score: 61 plating group, 58 non-operative group) (Olerud, Ahrengart et al. 2011). Fjalestad et al. studied displaced 3- and 4-part fractures in patients older than 60 years of age. They found evidence that operative treatment (n=25) with an angle-stable device did not provide better results than non-operative treatment (n=25) (Fjalestad, Hole et al. 2012). Both reported high complication rates and re-operation rates reaching as high as 30%.

2.6.10 Hemiarthroplasty

Hemiarthroplasty (HA) is widely used in comminuted fractures when ORIF cannot be used (e.g., in cases of severe osteoporosis, head impression, or split fracture) (Maier, Jaeger et al. 2014). The treatment was proposed originally by Neer in 1970 (Neer 1970). In HA, the proximal humerus fracture fragments are removed and replaced with a metallic implant with a cemented stem, while the glenoideum is left untouched.

The main challenge in hemiarthroplasty is ensuring that the tuberculum heals in an anatomic position to enable normal rotator-cuff function. Up to 30% of tuberosities are resorbed, which has a negative effect on outcome measures (Sebastia-Forcada, Cebrian-Gomez et al. 2014). However, the median Constant score for hemiarthroplasty is reportedly similar to that of ORIF (70 and 77, respectively) (Bastian and Hertel 2009). In a consecutive series of 57 patients with a mean follow-up of 10 years, 47% gained satisfactory results measured with Neer score (Antuna, Sperling et al. 2008).

Olerud et al. published the first RCT on displaced 4-part fractures in elderly patients treated with hemiarthroplasty or non-operatively. When comparing treatments, they found that arthroplasty provided a clinically significant advantage with respect to quality of life. EQ-5D was used as the primary outcome measure; as noted in previous studies, it is known to have a ceiling effect, which diminishes the weight of the finding. The results of EQ-5D were 0.81 in the HA group and 0.65 in the non-operative group. The main advantage of HA was less pain, but there was no difference in functional outcomes (Olerud, Ahrengart et al. 2011). Another trial comparing HA with non-operative treatment in patients with 4-part fractures revealed no differences in functional outcomes (Boons, Goosen et al. 2012).

2.6.11 Reverse prosthesis

Reverse prosthesis (RSA) is a relatively new devise for proximal humerus fractures. As the name indicates, the idea of the prosthesis is to reverse the normal anatomy, in which the humerus has a spherical head and the scapula a glenoid cavity to articulate. After reverse prosthesis, the spherical articulation is attached to the scapula and the humerus has the concave counter-articulation (Fig. 6). The main idea is to lateralize the offset and the rotational center, leading to better momentum for deltoid muscle activation, and therefore better movement without the aid of the rotator cuff.

Figure 6. Reverse prosthesis in a patient with osteoarthrosis.

In a comparative retrospective series, a total of 21 patients were treated with ORIF, HA, or RSA (9 patients in each group had 3- or 4-part fractures). After 1 year of follow-up, there were no significant differences in the outcome measures used; however, significantly more patients gained over 90° of forward flexion (Chalmers, Slikker et al. 2014). Another comparative study included 53 consecutive patients (mean age 74 years) treated with HA or RSA. The RSA group gained better functional outcomes after 2 years of follow-up (minimum), according to both ASES (HA 62 vs. RSA 77) and SST (HA 5.8 vs. RSA 7.7) (Cuff and Pupello 2013). Both results are statistically significant, but because the SST MCID is 2, that result is not clinically significant. The MCID for ASES has not been assessed.

There is one recent RCT comparing HA to RSA. Thirty-one patients (with patients over 70 years old in both groups) were followed for a minimum of 2 years. Outcome measures in DASH were better in the RSA group than in the HA group (17 vs. 29, respectively), which is both statistically and clinically significant. The Constant score was reported as 56 vs. 40, which also exceeds the MCID. The end result was more reliable in the RSA group than in the HA group where, resorption of the major tuberculum was a severe problem (Sebastia-Forcada, Cebrian-Gomez et al. 2014). There is one ongoing RCT in which a locking plate is compared with RSA. Its results are far from complete (Fjalestad, Iversen et al. 2014).

2.7 Limitations of study design

Comparisons between retrospective studies are difficult or impossible to perform. The variations in inclusion criteria, different evaluation methods and outcome measures, and uncertain and varying fracture classifications lead to heterogeneous results. In addition, most of the previous studies reported only ROM without adjacent, validated outcome measures, resulting in unknown subjective patient satisfaction (Lanting, MacDermid et al. 2008, Thanasas, Kontakis et al. 2009). Retrospective studies offer lower level of evidence, at a time when modern evidence-based medicine requires multiple RCTs as high-quality evidence.

One limitation of published RCTs is that their study populations are too small, possibly because no previous information on the Standard Deviations (SD) or MCID have been available. Single-center trials are too small, as the patient input remains small or moderate (Olerud, Ahrengart et al. 2011, Fjalestad, Hole et al. 2012). Another problem in these studies is the selection of the primary outcome. All of the other RCTs have original or indexed Constant scores, and Olerud et al. had EQ-5D in the hemiarthroplasty trial (Olerud, Ahrengart et al. 2011). These are all so-called generic instruments that also lack validation for this specific fracture, leading to unnecessary risk of bias. Because there are only a few orthopaedic-specific outcome instruments, we must use the existing suboptimal ones (Sorensen, Howard et al. 2013, Franchignoni, Vercelli et al. 2014).

2.8 Introduction to evidence-based medicine

Evidence-based medicine was first applied to medical teaching in 1992, aiming to improve understanding and apply results from the medical literature in practice (Evidence-Based Medicine Working 1992). Earlier, expert opinion and masters of the field dictated current care and guidelines with lifelong experience. Conflicts with expert opinion and well-designed trial outcomes gave rise to a need to elucidate a hierarchy of evidence (Fig. 7) (Bhandari, Tornetta et al. 2004). According to evidence-based medicine, medical knowledge can be categorized in four levels: expert opinion, cohort studies, single RCTs, and meta-analyses. Meta-analyses consist of pooled and re-calculated data from several original trials. This process leads to stronger evidence than the original trial alone.

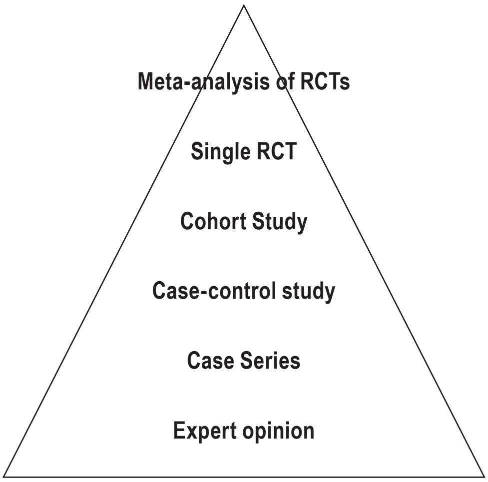

Figure 7. Hierarchy of evidence.
Adapted from Bhandari and Tornetta, 2004. With permission from Tuomas T Huttunen.

The current use of evidence-based medicine is well described by Sackett et al.: "Evidence-based medicine is the conscientious explicit and judicious use of current best evidence in making decisions about the care of individual patients" (Sackett, Rosenberg et al. 1996). With exponentially increased medical literature and easier access to databases, there was an increasing need to be able to extract relevant information. In helping to search for the relevant information, reviews and meta-analyses are increasingly published by different organizations, such as the Cochrane Collaboration. The practical implementation of knowledge from trials remains troublesome. Resistance to change is a known phenomenon in which adaptation to new information is rejected at individual and group levels (Coch 1948).

Evidence-based medicine has spread widely since its introduction. Although use of the term is heterogeneous, it has penetrated all levels of the healthcare system. Despite the availability of knowledge regarding the best possible care, patients still receive inappropriate or even harmful treatments. This institutional resistance to change is difficult to overcome. Although there are different methods to accomplish this goal, their shared characteristic is comprehensive intervention throughout all professional levels in hospitals and healthcare systems (Grol and Grimshaw 2003). Long-term work for evidence-based medicine has just begun, and it has changed how we think about medical knowledge.

3 AIMS OF THE STUDY

The aims of this thesis were to assess the epidemiology of proximal humerus fractures and their surgical treatment and to review the existing literature on the optimal treatment of proximal humerus fractures. This thesis also aimed to launch a high-quality RCT comparing non-operative and operative treatment of proximal humerus fractures.

The specific aims of each original publication are listed below:

I To assess the epidemiology of a well-defined population over a 5-year period

II To assess the nationwide incidence and trends of surgery in the treatment of proximal humerus fractures

III To assess high-quality evidence of proximal humerus fracture treatments by means of meta-analysis

IV To evaluate Nordic orthopeadic surgeons' decision making regarding proximal humerus fractures

V To develop a high-quality RCT that compares operative and non-operative treatment of proximal humerus fractures and addressed the weaknessess of previous literature

4 PATIENTS AND METHODS

4.1 Epidemiology, IV

In the area of this study, the city of Tampere, there are two hospitals that treat proximal humerus fractures: Hatanpää City Hospital (which includes a GP emergency clinic) and Tampere University Hospital. During the study period, both hospitals provided surgical treatment and they took care of all of the inhabitants of Tampere that acted as outpatient controls. We had no access to private clinic records but at the time of study period it was not common to treat fractures elsewhere than in municipal healthcare. The majority of the operations were performed at Tampere University Hospital.

During the study period, both hospitals had electronic patient records and radiographics archives. The patient sample consisted of individuals aged 18 years and older who had visited our study hospitals between 2006 and 2010 with the diagnosis of a proximal humerus fracture. Patients were selected by computer search from patient records using the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10) diagnostic code S42.2, (proximal humerus fracture). In addition, we conducted a keyword search with the following keywords (in Finnish): proximal humerus fracture, shoulder fracture, shoulder. The eligible patient records were read and analyzed by two researchers. Fractures of the proximal humerus that occurred during the study period were included. If the fracture originated before the study period (before 1 January 2006) or was other than a proximal humerus fracture, then the case was excluded. Duplicate records of the same patient were also excluded, after we confirmed that the patient did not have two separate fractures during the study period. Data was collected in a predefined data sheet.

The following data was collected from the included patients' medical records: age, sex, time of the fracture, laterality of the fracture, trauma mechanism, chosen treatment, degree of dislocation, and possible other fractures at the time of the original injury or later in the study period. Patients' radiographs were re-evaluated to confirm the fracture. Two independent researchers classified the fractures using the Neer classification system (Neer 1970). When there was a disagreement, a consensus was reached through negotiation.

To calculate age-specific incidences, the risk population was derived from Statistics Finland (www.tilastokeskus.fi), which updates the statistics of registered inhabitants in each city and specific areas of Finland annually. Thus, we gathered the exact number of inhabitants of the city of Tampere in different age groups each year and used this information to calculate fracture incidences.

Statistical analyses were calculated using the OpenEpi program, an open source epidemiological statistical program for public health (openepi.com). Fisher's exact (1-tail) test with 95% confidence intervals was used.

4.2 Trends in surgical treatment of proximal humerus fracture, II

All hospitalized and treated patients in Finland are mandatorily registered in the Finnish national hospital discharge register (NHDR). Subjects are each patient's age, sex, domicile, length of hospitalization, primary and secondary diagnoses, and operations performed. Patients older than 20 years of age who had proximal humerus fracture codes 81200 and 81210 from the 9th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-9) or code S42.2 from ICD-10 during years 1987 to 2009 were included in the study cohort. The main outcome was the surgical treatment of the fracture. ICD-9 codes 9126 (closed reduction and osteosynthesis), 9128 (open reduction and osteosynthesis), 9130 (external fixation), and 9132 (endoprosthesis) were used during 1987 to 1997. ICD-10 coding was introduced after 1998, and we included the following codes: NBJ60 (open reduction and osteosynthesis by nailing), NBJ62 (open reduction and plating), NBJ64 (fracture reduction and screw, percutaneous pinning, or absorbable screw fixation), NBJ70 (external fixation), NBB10 (hemiarthroplasty), or NBB20 (total prosthesis). In the study, all treatment codes were pooled regardless of the coding system (i.e., ICD-9 results were pooled with ICD-10 results). We categorized the pooled data to the following groups: closed fracture reduction and nailing (9126 and NBJ64), open reduction and osteosynthesis (9128, NBJ60, and NBJ62), reduction and external fixation (9130 and NBJ70), and arthroplasty (9132, NBB10, and NBB20).

Coding with ICD-10 enables us to obtain more specific analysis. The new coding covers the events between years 1998 and 2009. For specific analysis, the procedure codes NBJ60, NBJ62, NBJ64, NBJ70, NBB10, and NBB20 were analysed individually.

To complete the incidence information, the yearly mid-population was obtained from the electronic national population registry—Official Statistics Finland. The rates of surgically treated patients in our study were based on the entire population rather than a sample cohort estimation, and for that reason 95% confidence intervals were not calculated.

4.3 Systematic review, III

A systematic search of electronic databases was conducted in order to assess the literature on the treatment of proximal humerus fractures. The following databases, without language restrictions, were searched covering the years from 1946 to 2012: Ovid MEDLINE and Scopus database, which also includes Embase. The last search was carried out on 31 August 2013 to cover the most recent literature. The search terms used were "shoulder fractures", "proximal humeral fracture", "rehabilitation, surgery, therapy".

The abstracts of the retrieved publications were checked manually, and appropriate publications were selected for further analysis. Reviews, study protocols, and retrospective studies were excluded. In the next phase, full articles of all potentially relevant papers were obtained to determine whether they met the inclusion criteria. The PICO principle was used to determine the inclusion and exclusion criteria (Table 1). Three reviewers completed the preceding phases independently. Any discrepancies considering the inclusion criteria were settled by negotiations within the whole study group.

Table 1. PICOS criteria for included studies

Patients: Age 60 years or older with two, three, or four-part proximal humerus fracture due to recent trauma
Intervention: Any operative treatment (at least 20 patients in each treatment group)
Control: Any treatment (at least 20 patients in each treatment group)
Outcome: Any functional or disability score and/or any quality of life score after a minimum follow-up of one year
Study setting: Randomized, controlled trial or controlled clinical trial

One author used a predefined data sheet to conduct a data search of the studies. Two other authors independently controlled the data extraction. Data was collected for descriptive information (study design, fracture classification used, treatment types in intervention and control groups, group sizes, drop out rates, and patient demographics), effects of treatment (primary and secondary outcomes, complications as reported, re-operation rate, and range of motion), and study quality that included criteria for the risk of bias. The risk of bias was assessed as suggested by Furlan et al. (Furlan, Pennick et al. 2009). We assessed the risk of bias of a publication as low when ≥6 criteria of 12 were met. Accordingly, the risk of bias was rated high when <6 of 12 criteria were met. During the assessment of the risk of bias of the study, we contacted each principal author (all eight) in order to obtain additional information for clarification of bias in the event of poor reporting in the publication. Five of the authors replied to the query regarding randomization, allocation, and baseline group similarity. With the additional information from the authors, the risk assessment for bias was completed.

4.4 Survey, V

The study was conducted as a questionnaire-based, cross-sectional study. The internet-based program Webropol® (webropol.com) was used to query the current opinion regarding proximal humerus fracture treatments. The questionnaire link was sent to the surgeons responsible for treating proximal humerus fractures in major public hospitals in Estonia, Finland, Norway, and Sweden. If the orthopaedic surgeon did not respond, a reminder was sent by electronic mail. Data was collected between 15 November 2014 and 15 January 2015. In all, questionnaires were sent to 77 orthopaedic surgeons, and the percentage distribution among different countries was proportional to the number of inhabitants of each country. As the study covered four different languages, we used only English to avoid validity problems. Prior to sending the questionnaire, the questionnaire was piloted four times with 10 experienced shoulder surgeons to ensure the validity of each question.

The questionnaire consisted of four parts. The first part assessed the clinical experience of the participant and his/her area of work (8 questions). The second part included clinical patient cases with plain x-rays and different alternatives for treatment (9 questions). The third part concerned pre- and post-operative treatment, including post-operative physiotherapy protocols (9 questions). The fourth part inquired opinions between current treatment choices (5 questions). Parts 1, 2, and 4 were multiple-choice questions, and part 3 included open answers for the post-operative protocol.

4.5 RCT protocol, I

This study is a prospective, randomised, controlled, international multi-center trial. It aims to compare non-operative and operative treatment of proximal humerus fractures in patients aged 60 years and older. The trial includes two strata. Stratum I compares operative treatment with locking plates with non-perative treatment for 2-part fractures. Stratum II compares operative treatment with locking plates with hemiarthroplasty and with non-operative treatment for multi-fragmented fractures, including 3- and 4-part fractures. The criteria used in patient selection are listed in table 2:

Table 2. Inclusion and exclusion criteria of the trial

Inclusion criteria
Low energy proximal humeral displaced (more than 1 cm or 45 degrees) 2-part fracture where the fracture line emerges through the surgical (or anatomical) neck
Low energy proximal humeral displaced (more than 1 cm or 45 degrees) 3- or 4-part fracture

Exclusion criteria
Refusal to participate in the study
Younger than 60 years old
Non-independent
Has dementia and/or is institutionalized
Does not understand written and spoken guidance in either Finnish or Swedish
Pathological fracture or previous fracture in the same proximal humerus
Serious intoxicant dependency (e.g., during first aid, breathalyzer depicts more than 2%)
Other operational injury in the same upper limb
Major nerve injury (e,g., Complete radialis or delta palsy)
Rotator cuff tear arthropathy
Open fracture
Multi-trauma patient
Fracture dislocation or head-splitting fracture
Undisplaced fracture
Isolated tuberculum fracture
Fracture has no precondition to ossify through conservative treatment (no bony contact between fracture parts or the humeral shaft is in contact with the articular surface)
Treating surgeon considers patient unsuitable to attend the study on medical basis

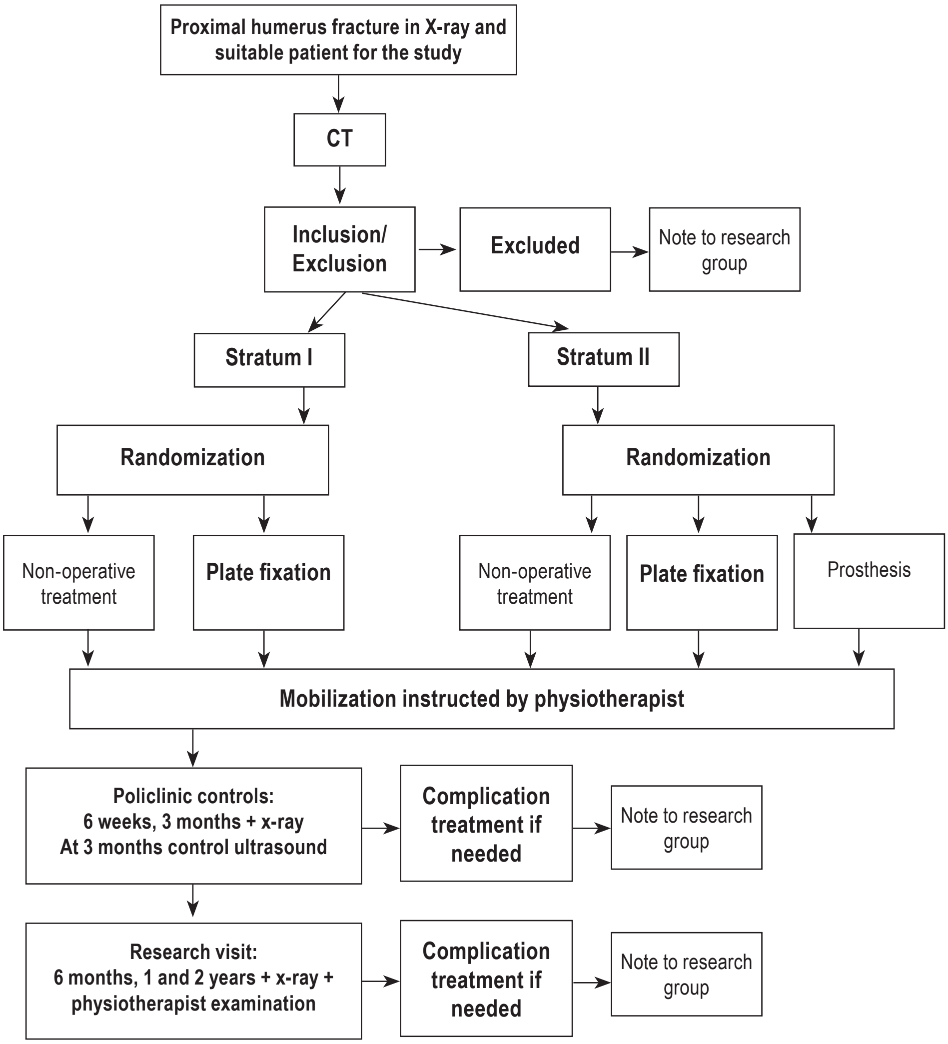

Figure 8. Study flow. Stratum I for 2 part fractures, Stratum II for 3 and 4 part fractures

A Tampere University Hospital research coordinator who will not attend the study will randomize all patients. Patients with a 2-part fracture (Stratum I) will be randomized to either non-operative or plate-fixation groups. Patients with multi-fragmented fractures (Stratum II) will be randomized to non-operative, plate fixation, or prosthesis groups (Fig. 8). Both fracture types will be randomized using a random number matrix in block allocation fashion. The blocks will be age-dependent because, data from the literature indicates that age and functional outcome are associated (Court-Brown and McQueen 2007). The treatment allocations from the matrix will be sealed in an envelope. After the patient's enrollment in the study has been confirmed, the research physician will contact the research coordinator, who will open the envelope and the randomized treatment will be carried out. The research coordinator will monitor the study flow. Although an independent monitoring committee has not been yet established, patients will be monitored.

During hospitalization, the patient will be asked to fill out (with help if necessary) the EQ-5D, 15D, DASH, and OSS, and basic patient questionnaires with a VAS to determine their baseline characteristics. A Case Report Form (CRF) will be completed for every patient.

5 RESULTS

5.1 Epidemiology, IV

The 5-year total incidence of proximal humerus fracture during this study period was 82 (SD 76–88) per 100,000 person-years. The total gross incidence was 114 (SD 104–124) in women and 47 (SD 41–54) in men per 100,000 person-years. In women, the incidence increased with age from 31 per 100,000 at 40 years of age to 379 per 100,000 person-years at 80 years of age (Fig. 9). In men, the corresponding increase was from 31 to 232 per 100,000 person-years (Fig. 10). The incidence remained at a low, steady level for all individuals younger than 40 years.

Between 2006 and 2010, a total of 678 patients experienced 692 proximal humerus fractures. One-half of the fractures (n=374, 54%) were in the left shoulder, and 318 fractures (46%) were in the right shoulder. The majority of patients were women (n=503, 73%). Fracture dislocations accounted for 11% of cases (n=75). The proportion of fracture dislocations was significantly higher in men vs. women (15% vs. 9%, respectively, p=0.03). Falling from standing height was the most common trauma mechanism (n=618, 89%), followed by traffic injuries (n=29, 4%), falling from ladders (n=15, 2%), and physical abuse (n=7, 1%). Alcoholic or epileptic seizures were also noted (n=9, 1.3%). Trauma mechanism was related to age: high-energy trauma predominated among younger patients (n=44; women 26 (59%), men 18 (41%)), and low-energy trauma predominated among elderly patients (n=619; women 469 (76%), men 150 (24%)).

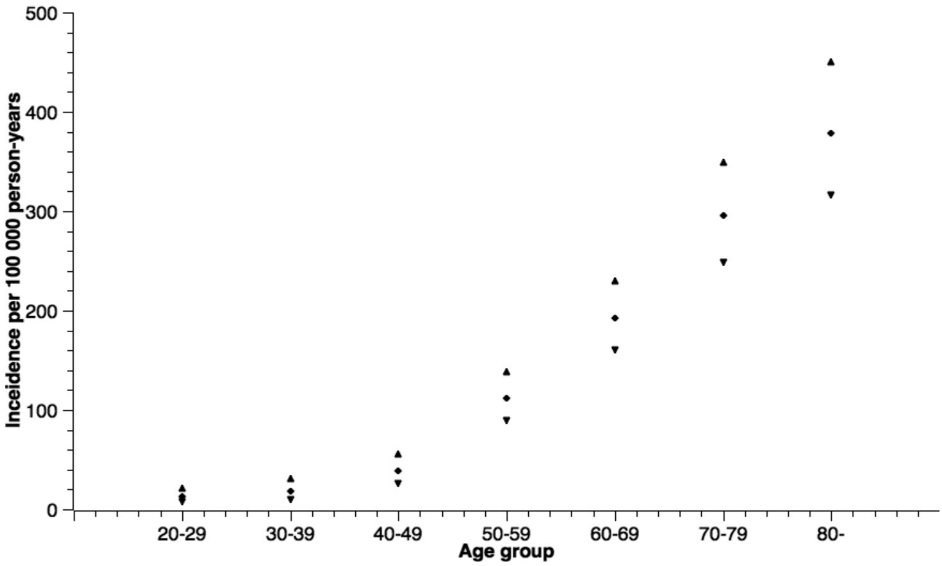

Figure 9. Five-year mean incidences, with 95% confidence intervals, among women by age group

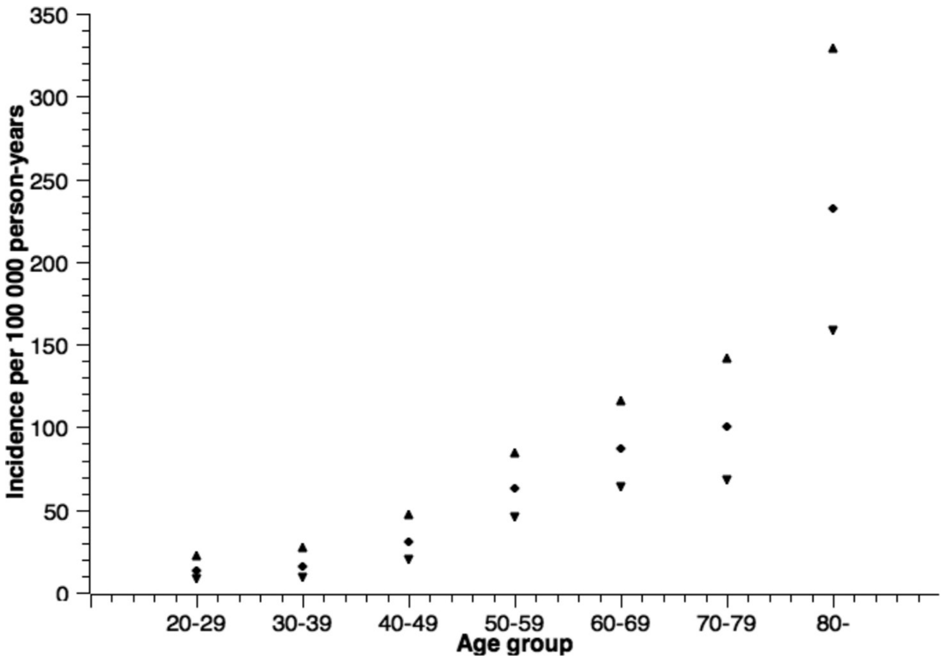

Figure 10. Five-year mean incidences, with 95% confidence intervals, among men by age group

When monthly incidence rates were calculated, it was observed that the highest incidence figures occurred during the late fall and winter (from November to March), while the incidence was the lowest in September (Fig. 11).

Based on medical records, 97 patients (14%) had another fracture or fractures of bones other than the proximal humerus during the 5-year follow-up. The most common concomitant fractures were of the distal radius, proximal femoris, and lateral malleolar fractures.

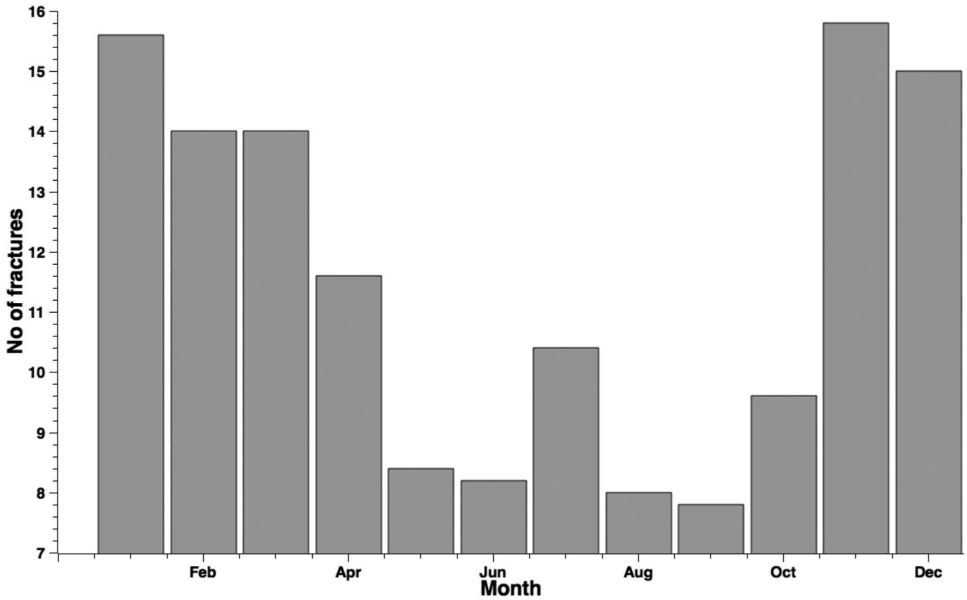

Figure 11. Number of fracture cases observed over a 5-year period, displayed by month

5.1.1 Classification

The most common fracture types were 2-part (428, 62%), 3-part (128, 19%), and isolated 1-part (90, 13%) fractures, while 4-part fractures accounted for only 7% of all fractures (n=46). Three-part and 4-part fractures significantly predominated in women compared with men (28% vs. 18%, p=0.05). Severity of the fracture increased with age: Mean ages distributed from 1- to 4-part fractures 59, 66, 67 and 71, respectively.

5.1.2 Treatment

The majority of fractures (n=539, 78%) were treated non-operatively. On operated fractures, the most common fixation method was the locking plate (n=115, 75%). The majority of locking plate operations were performed on women (n=75, 65%). Although the fractional plating rate was higher among men than women, the difference was not significant (21% vs. 15%, p=0.07) The most typical fracture classification among surgically treated fractures was 2-part (n=73, 64%), 3-part (n=43, 30%), and 4-part (n=7, 6%) fractures. Fracture prostheses were used in 25 cases (16% of operated fractures). Screws and tension wires were uncommon in our sample (n=13, 9%). The majority of prostheses were set for patients with 4-part fractures (n=16, 64%). During the 5-year period, the proportion of operative treatment varied non-significantly (p=0.43) between 21% and 27%.

5.2 Trends in surgical treatment of proximal humerus fracture, II

During the 23-year study period, 47,960 patients in Finland were hospitalized with proximal humerus fractures. The yearly number of hospitalized fractures increased from 1136 to 2944 between the years 1987 and 2009. The incidence of hospitalization during the period increased from 31 to 72 per 100,000 person-years. Surgical treatment was performed a total of 10,560 times. The incidence increased from 5 to 20 per 100,000 person-years during the study period. The mean ratio of women to men was 66:34, corresponding to 7008 operations in women and 3552 operations in men. In women, the incidence of surgical treatment increased from 6 to 26 per 100,000 person-years. Among men, a similar change was observed from 4 to 13 per 100,000 person-years during the study period.

During the 23-year period, ORIF was the most common surgical method (n=7774, 74%), followed by closed reduction and internal fixation (n=1515, 14%) and arthroplasty (n=1198, 11%). External fixation was used only 73 times (1%). The most prominent finding of the study was the proportional change of the procedures during the study period. Incidence of ORIF increased from 4 to 15 per 100,000 person-years between 1987 and 2009. The annual total increase was from 153 to 598. During the more specific ICD-10 period from 1998 to 2009, the proportion of plating more than doubled from 6 to 14 per 100,000 person-years, responding to an increase of total operations from 229 to 574. The incidence of plating in women increased from 8 to 18 per 100,000 person-years between 1998 and 2009 (Fig. 12). The incidence of plating almost doubled during the ICD-10 period in every age group in all surgical treatments except nailing, which decreased. Incidence and total number of nailing operations decreased between 1998 and 2009 from 1.2 to 0.6 per 100,000 person-years, from 48 to 24 procedures in all.

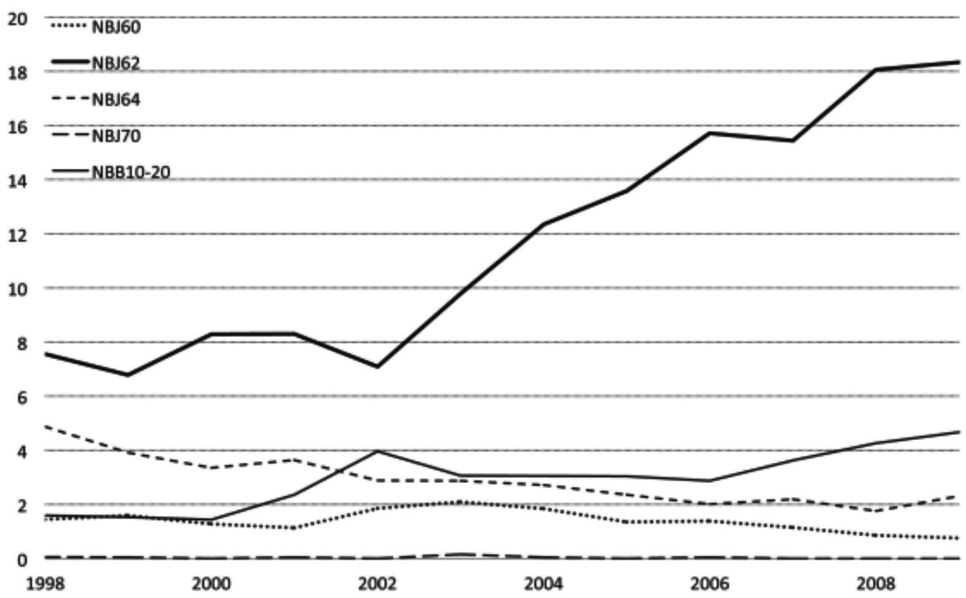

Figure 12. Rate of surgically treated proximal humeral fractures in adult Finnish women per 100,000 person-years between 1998 and 2009. NBJ60=nail, NBJ62=plate, NBJ64=screw, NBJ70=external fixation, NBB10-20=arthroplasty.

5.3 Systematic review, III

The database search was completed with 777 abstracts, after the elimination of duplicates. We excluded 692 abstracts because they did not meet the inclusion criteria, as they were retrospective or lacked a control group. Four potential papers were excluded because they were in languages that our study group did not master (Czech, Chinese) (Krivohlavek, Lukas et al. 2008, Wu, Cha et al. 2010, Edelmann, Obruba et al. 2011, Smejkal, Lochman et al. 2011). According to the English-language abstracts, all four of these papers would have been excluded for other reasons. Eighty-one papers met the inclusion criteria based on the abstracts and were subjected to further analysis. After examining the full texts of these papers, 72 of these studies did not meet the inclusion criteria. Finally, nine papers met our inclusion criteria and were accepted for the review (Fig. 13). Two papers (Fjalestad, Hole et al. 2010, Fjalestad, Hole et al. 2012) were from the same study population, but one of these discusses clinical results and the other is focused on HRQoL. Because of these different endpoints, both of these papers were accepted and their results were merged. Accepted papers are as follows: Zyto et al. (Zyto, Ahrengart et al. 1997) and Olerud et al. (Olerud, Ahrengart et al. 2011, Olerud, Ahrengart et al. 2011) from Sweden; Fjalestad T et al. (Fjalestad, Hole et al. 2012) from Norway; Boons H et al. (Boons, Goosen et al. 2012) from the Netherlands; Voigt C et al. (2011) (Voigt, Geisler et al. 2011) from Germany; Fialka C et al. (Fialka, Stampfl et al. 2008) from Austria; and Carbone S et al. (Carbone, Tangari et al. 2012) from Italy.

The eight study populations in our review included 409 patients. Eight studies were RCTs and one was a controlled clinical trial (Carbone et al. 2012). In all trials, patients each had a 3- or 4-part fracture based on Neer's classification (Neer 1970).

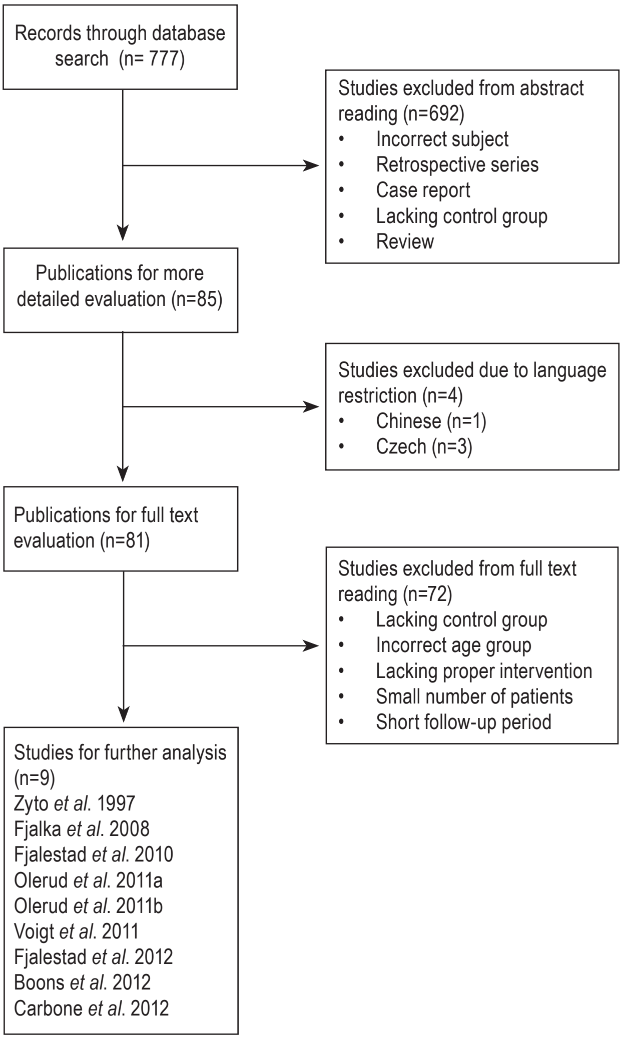

Figure 13. Flowchart: disposition of publications, from initial database search through final analysis

Six trials compared operative treatment with non-operative treatment. Voigt C et al. (2011) compared monoaxial with polyaxial constructions in locking plates; Fialka C et al. (2008) compared two different prostheses; and Carbone et al. (2012) compared two different pinning operations. One trial (Zyto K et al. 1997) compared employment of the tension band with non- operative treatment. In two trials (Olerud P et al. 2011b, Fjalestad T et al. 2010 and 2012) the locking plate was compared with non-operative treatment in 3- and 4-part fractures. Two trials (Olerud P et al. 2011a, Boons H et al. 2012) compared prosthesis use with non-operative treatment in 4-part fractures. Table 3 presents study designs and included patients, and Table 4 summarizes the results.

5.3.1 Results

5.3.1.1 Tension band

Zyto K et al. (1997) reported the results of tension band vs. non-surgical treatment after 1 year of follow-up. The Constant score was 60 (tension band) vs. 65 (non-surgical) at 1 year; this difference was neither statistically nor clinically significant, as the minimum difference considered clinically significant is 10.4 points (Kukkonen, Kauko et al. 2013).

5.3.1.2 Pinning

Carbone et al. (2012) reported the results of MIROS pinning over traditional pinning after 2 years of follow-up. The MIROS was described as “a new percutaneous pinning device allowing correction of angular displacement and stable fixation of fracture fragments”. The Constant score was 60 (MIROS) vs. 52 (traditional pinning), and the subjective shoulder value was 90 vs. 73 (p=0.02 for both). Although both values were statistically significant and favored MIROS pinning, both differences lacked clinical significance (Kukkonen, Kauko et al. 2013).

5.3.1.3 Locking plate

Fjalestad T et al. (2012) compared the locking plate to non-surgical treatment in 3- and 4-part fractures. The primary outcome was the Constant score difference at 12 months (CSD12), where “to reduce the influence of age, the difference between the scores of the injured and uninjured shoulder was used”. CSD12 was 35.2 vs. 32.8 (p=0.62) and ASES was 14.8 vs. 15.5 in operative and non-operative treatment groups, respectively

Table 3. Study designs of included trials

Author	Design	Classification after Neer	Intervention (N at baseline)	Control (N at baseline)	Follow-up, months	Number of patients at baseline/ follow-up	Drop out rate, N/%	Comparison
Zyto 1997 Sweden	RCT	3(-4)	Tension band (20)	Non-operative (20)	12	40/38	2/5%	Tension band vs. non-op
Fialka 2008 Austria	RCT	4	Hemiarthroplasty (Epoca (20))	Hemiarthroplasty (HAS (20))	12	40/35	5/12.5%	Prosthesis vs. prost-hesis
Fjalestad 2010 Norway ++	RCT	3-4	Plating (Non-specific LCT* (25))	Non-operative (25)	12	50/48	2/4%	Locking plate vs. non-op
Olerud 2011[a] Sweden	RCT	3	Plating (Philos (30))	Non-operative (30)	24	60/53	7/11.6%	Locking plate vs. non-op
Olerud 2011[b] Sweden	RCT	4	Hemiarthroplasty (Global FX (27))	Non-operative (28)	24	55/49	6/11%	Prosthesis vs. non-op
Voigt 2011 Germany	RCT	3-4	Plating (Humeral sutu-re plate (25))	Plating (Philos (31))	12	56/48	8/14%	Polyaxial plate vs. locking plate
Fjalestad 2012 Norway ++	RCT	3-4	Plating (Non-specific LCT* (25))	Non-operative (25)	12	50/48	2/4%	Locking plate vs. non-op
Boons 2012 the Netherlands	RCT	4	Hemiarthroplasty (Global FX (25))	Non-operative (25)	12	50/47	3/6%	Prosthesis vs. non-op
Carbone 2012 Italy	CCT	3-4	MIROS pinning (31)	Traditional pinning (27)	24	58/52	6/10%	Pinning vs. pinning

*AO-type locking plate
++Both publications are from the same population

(p=0.71). In the other publication by Fjalestad T et al. (2010) with the same study population, HRQoL was assessed with 15D (surgical group 0.84 vs. non-surgical group 0.82, p=0.42).

The study by Olerud et al. (2011a) revealed no significant difference in Constant scores between the operative and non-operative groups with 3-part fractures (61.0 vs. 58.4, respectively; p=0.64). The DASH score (operative 26.4 vs. non-operative 35.9, p=0.19) or HRQoL, Euroqol-5D (EQ-5D) (operative 0.70 vs. non-operative 0.59, p=0.26) also exhibited no between-group differences at 2 years.

Voigt C et al. (2011) observed no differences between polyaxial and monoaxial constructions in locking plates in the SST (8.6 vs. 9.7, p=0.27), DASH (17.8 vs. 15.7, p=0.95) or Constant score (73 vs. 81, p=ns).

5.3.1.4 Hemiarthroplasty

In the studies that compared hemiarthroplasty with non-operative treatment, all patients had 4-part fractures. Olerud P et al. (2011b) learned that EQ-5D is significantly better in the operative group than the non-operative group (0.81 vs. 0.62, respectively; p=0.02). However, DASH (30.2 vs. 36.9, p=0.25) and the Constant score (48.3 vs. 49.6, p=0.81) did not differ significantly between the two groups at 2 years.

Boons H et al. (2012) observed no significant differences with regard to the Constant score (operative 64 vs. non-operative 60, p=0.41), SST (25 vs. 23, p=0.59), or VAS (Yavasoglu, Tombuloglu et al.) (23 vs. 25, p=0.73) at 12 months. However, the difference in VAS at 3 months significantly favored operative treatment (19 vs. 37, p=0.002).

Table 4. Functional results of the trial

Author	Primary outcome measure: Intervention; mean±SD	Primary outcome measure: Control; mean±SD	p-value	Secondary Outcome measure: Intervention; mean±SD	Secondary Outcome measure: Control; mean±SD	p-value	Adjacent Outcome measure: Intervention; mean±SD	Adjacent Outcome measure: Control; mean±SD	p-value
Zyto 1997 Sweden	CS: 60±19	CS: 65±15	>0.05						
Fialka 2008 Austria	CS_{indiv}: 70% (38-102)*	CS_{indiv}: 46% (15-80)*	0.001	CS: 52±20-80	33±8-68	na			
Fjalestad 2010 Norway ++	CSD12: 35 (28-43)*	CSD12: 33 (26–40)*	0.62	ASES: 15±12-18	ASES: 16±13-18	0.71			
Olerud 2011[a] Sweden	CS: 61±19	CS: 58±23	0.64	DASH: 26±25	36±27	0.19	EQ: 0.70±0.34	0.59±0.35	0.26
Olerud 2011[b] Sweden	EQ index: 0.81±0.12	EQ index: 0.65±0.27	0.02	CS: 48±16	50±21	0.81	DASH: 30±18	DASH 37±21	0.25
Voigt 2011 Germany	SST: 8±3	SST: 10±2	0.27	DASH: 18±16	DASH: 16±12	0.95	CS: 73	CS: 81	>0.05
Fjalestad 2012 Norway ++	15D: 0.84±0.11	15D: 0.82±0.08	0.42						
Boons 2012 the Netherlands	CS: 64±16	CS: 60±18	0.41	SST: 25±8-100	SST: 23±0-92	0.59	VAS 12mo: 23 (range 1–65)	VAS 12mo: 25 (range 1–93)	0.73
Carbone 2012 Italy	CS: 60	CS: 52	0.02	SSV: 90	SSV 73	0.015			

CS = Constant Score; CSindiv = Individual Constant Score determined by comparing the operated shoulder to the patient's unaffected shoulder; CSD12 = Constant Score difference at 12 months, and to reduce the influence of age, the difference between the scores for the injured and uninjured shoulders was used; ASES = American Shoulder and Elbow Surgeons Shoulder Score; EQ: Euroqol-5D = EQ-5D; DASH = disabilities of the arm, shoulder, and hand; SST = Simple Shoulder Test; SSV = Subjective Shoulder Value

++Both publications are from the same population

*Threshold values

Fialka C et al. (2008) compared two different prostheses: Epoca (Depuy Synthes) vs. HAS (Stryker). The individual Constant score (CSindiv) was "determined by comparing the operated shoulder with the individual patient's unaffected shoulder" CSindiv results were 70.4% vs. 46.2% (p=0.001) and absolute Constant scores were 52 vs. 33 (p not presented) at 1 year follow-up; both results favored use of the Epoca prosthesis.

5.3.2 Complications and re-operations

5.3.2.1 Tension band

Altogether, Zyto K et al. (1997) reported eight complications. The surgical site infection rate was 2/19 (11%) in the intervention group; and K-wire penetrated into the glenohumeral joint in one case, and one patient experienced a pulmonary embolism. In the later phase, two patients in the intervention group developed osteoarthritis, one patient after non-union, and two patients in the control group developed osteoarthritis.

5.3.2.2 Pinning

In total, Carbone et al. (2012) reported 3/28 (11%) complications in the MIROS group and 7/26 (27%) in the traditional pinning group, including 4/26 (15%) pin track infections. They reported no re-operations.

5.3.2.3 Locking plate

Fjalestad T et al. (2012) reported one hardware failure, seven screw cut-outs, and two deaths in 3 months in the operative group. Four of 25 patients (16%) required re-operation. One patient among the non- operatively treated patients was operated later. Olerud et al. (2011a) reported screw penetrations in 5/30 (17%) cases in the primary post-operative period, and 3/26 (12%) additional screw penetrations were noted at 4 months. There was one case of primary post-operative infection, and one patient in the non-operative group experienced non-union. Altogether, four patients died (two from each group) because of non-surgical reasons. Re-operations were required for 9/30 patients (30%) in the locking plate group during the 2-year follow-up period. Voigt C et al. (2011) reported 6/20 (30%) complications in the intervention (polyaxial) group and 8/28 (29%) in the control (monoaxial) group. Re-operations were done in 6/20 (30%) cases (intervention polyaxial group) vs. 4/28 (14%) cases (control monoaxial group).

5.3.2.4 Hemiarthroplasty

Olerud et al. (2011b) reported one non-union in the non-surgical group. Of all patients, five died (5/55, 9%): three in the operative group and two in the non-operative group, all because of reasons unrelated to their humeral fracture. Three patients of the intervention group (3/27, 11%) required re-operation and one patient with non-union from the non-surgical group was operated. Boons H et al. (2012) reported four tuberculum malpositions (16%), and two tuberculum majus non-unions (8%) in the operative group. Five cases of non-union (20%) were reported in the non-operative group. One patient in the non-operative group required re-operation, and the other patient was operated at 13 months. Fialka C et al. (2008) reported 2/18 (11%) infections in the operative group; they were treated non-operatively with antibiotics.

5.4 Survey, V

There were 59/77 responses to the questionnaire, leading to a response rate of 77%. Table 4 shows the proportion of respondents in each country. All but one of the responders was either a trauma or a shoulder surgeon, and 80% had been working in the field for more than 5 years. Seventy-nine percent of recipients stated that a special shoulder surgeon team exists in their hospital. Forty-three percent of respondents were working in a university hospital. The most common catchment area of the responder's hospital was between 100,000 and 500,000 inhabitants (72% of responders).

Ninety-one percent of the respondents treated more than 50 proximal humerus fractures each year, and 25% reported more than 200 each year. Fifty-nine percent of respondents operated on more than 25 proximal humerus fracture patients per year.

Table 5. Number of sent questionnaires, answers, and inhabitants per country. Percentages of the total are presented in parentheses

	Estonia	Finland	Norway	Sweden	Total
Number of sent questionnaires	8 (10%)	22 (29%)	14 (18%)	33 (43%)	77 (100%)
Number of responders	7 (9%)	19 (25%)	11 (14%)	23 (38%)	59 (77%)
Number of inhabitants in millions	1.3 (6%)	5.5 (26%)	5.1 (24%)	9.6 (45%)	21.5 (100%)

The second part of the survey, which concerned treatment alternatives, included 2- to 4-part fractures as classified by Neer (Neer 1970). Of the 8 patient cases presented in Annex (Figures 15–22), three were 2-part fractures, three were 3-part fractures, and two were 4-part fractures. Each patient case was shown with two different x-ray projections of the shoulder, and the following options were given: non-operative treatment, operative treatment with K-wire or tension band, locking plate, hemiarthroplasty, or reverse prosthesis. Each responder was able to choose the one or two most preferred options, and the provided answers were regarded as votes for each case. The total number of votes was 547.

In the 8 patient cases presented, the locking plate was preferred in 35% of cases, followed by hemiarthroplasty (27%). Non-operative treatment was preferred in 19% of the cases. The proportion of willingness for non-operative treatment did not differ among countries (p=0.110). Surgery with K-wire and tension band was preferred only in 1% of cases. In Estonia, 14% of surgeons preferred nailing as a operative method; this was significantly higher than the remaining countries, where only 0% to 7% preferred nailing (p=0.036). Forty-one percent in Estonia and Norway and 38% in Finland preferred operative treatment with the locking plate; in Sweden, the percentage was 28% (p=0.003). The preference of prosthesis option was different in Norway, as the use of hemiarthroplasty was significantly lower (12%, p=0.002), while the use of reverse prosthesis was significantly higher (31%, p=0.000) compared with all of the other countries. The preferred percentages were 23%, 32%, and 34% regarding hemiarthroplasty and 4%, 5%, and 11% regarding reverse prosthesis in Estonia, Finland, and Sweden, respectively. The results are summarized in Table 6.

Table 6. Treatment methods stratified by country. Data is presented as percentages, with number of votes in parentheses

	Estonia	Finland	Norway	Sweden	Total	p
Non-surgical treatment	15% (11/71)	25% (41/167)	15% (18/120)	18% (34/189)	19% (104/547)	0.111
K-wire	3% (2/71)	1% (1/167)	0% (0/120)	2% (4/189)	1% (7/547)	0.152
Nailing	14% (10/71)	0 (0/167)	2% (2/120)	7% (14/189)	5% (26/547)	0.036
Locking plate	41% (29/71)	38% (63/167)	41% (49/120)	28% (53/189)	35% (194/547)	0.003
Hemiprosthesis	23% (16/71)	32% (54/167)	12% (14/120)	34% (64/189)	27% (148/547)	0.002
Reverse prosthesis	4% (3/71)	5% (8/32)	31% (37/120)	11% (20/189)	12% (68/547)	0.000

Before decision-making, 40/58 (69%) respondents preferred CT imaging of the shoulder, and 50/58 (86%) used CT in pre-operative planning. The majority of respondents (n=46, 79%) had a post-operative care protocol in their clinic. All 58 respondents had an in-ward physiotherapist to guide post-operative care. Almost all respondents (n=56, 97%) referred patients to outpatient post-operative physiotherapists. One-half (n=27, 47%) of respondents preferred to schedule two post-operative outpatient visits, while six respondents (10%) scheduled more than three. There were no differences among countries.

Post-operative protocols for non-operatively treated patients and cases operated with a locking plate were quite similar among the respondents. Most frequently, a sling was used for 2 to 3 weeks, and pendulum movements were started immediately after the operation. Passive movements were allowed from 2 weeks to 4–6 weeks, and free active mobilization was encouraged thereafter. Post-operative treatment varied broadly after operation with prostheses. In general, after an anatomic prosthesis, a sling and pendulum movements were recommended for 4 to 6 weeks after the operation. With reverse prosthesis, after-care was started (e.g., with passive mobilization) as early as 1 week after the operation, continuing with active flexion exercises from 4 weeks on.

Finally, we gave respondents two different methods to choose between in an imaginary patient case. The differences in recommended treatments were minor and statistically non-significant among the four countries. The results are summarized in figure 14.

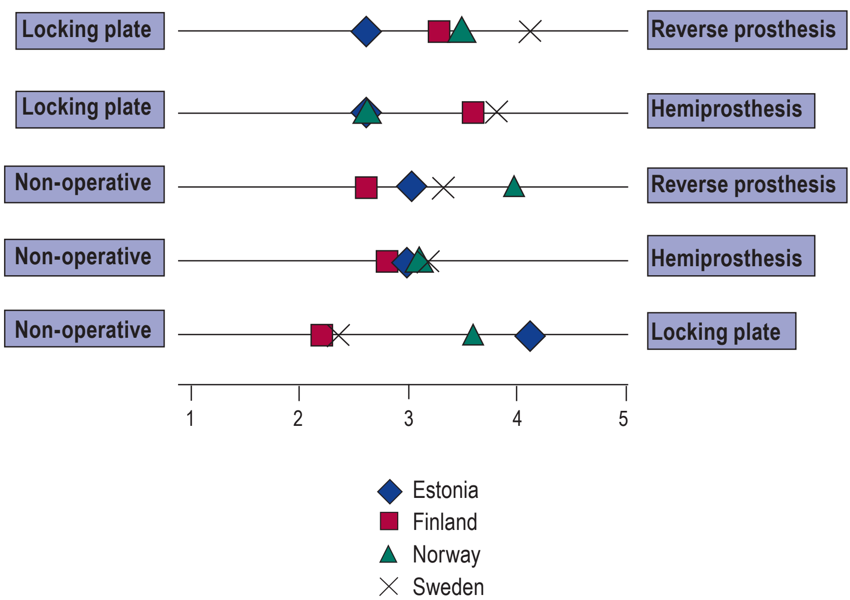

Figure 14. Respondents' answers plotted on a continuum between imaginary claims

6 DISCUSSION

6.1 Statement of primary findings

The most important finding in our nationwide hospital discharge registry-based study was that during the 23-year study period surgical treatment increased almost four-fold from 5 to 20 per 100,000 person-years. During the same period, we also observed a two-fold increase in the incidence of hospitalization owing to fractures. After the introduction of locking plates in Finland in 2002, the incidence of plate fixation more than doubled between 2002 and 2009 (from 6 to 14 per 100,000 person-years). The same increasing trend in operative treatment has also been observed in North America (Bell, Leung et al. 2011). This is interesting, as RCT studies comparing operative versus non-operative treatment were published first in 2011, and provided no evidence that operative treatments were superior (Olerud, Ahrengart et al. 2011, Olerud, Ahrengart et al. 2011).

In total, the 5-year unadjusted incidence of proximal humerus fracture in the Tampere region was 82 (95% CI: 76 to 88) per 100,000 person-years. The incidence was 114 (95% CI: 104 to 124) per 100,000 person-years in women and 47 (95% CI: 41 to 54) per 100,000 person-years in men, and it increased with age. It must be taken into account that our study also included fractures that were treated on an outpatient basis. Previously, in Finland, the age-adjusted incidence of proximal humerus fractures leading to hospitalization in elderly patients was 105 to 298 per 100,000 person-years (Palvanen, Kannus et al. 2006, Kannus, Palvanen et al. 2009). When comparing our figures with those reported by previous studies, we noticed that the incidence of proximal humerus fractures is influenced by geographic area, as well as by activity, health, and level of care provided to the elderly; however, the data from these studies cannot rigorously be compared with each other (Rose, Melton et al. 1982, Kristiansen, Barfod et al. 1987, Hagino, Yamamoto et al. 1999, Court-Brown and Caesar 2006).

During the 5-year study period, the surgical rate in the Tampere region increased from 21% to 27%. Our percentages are almost twice as high as reported previously by Bell (Bell, Leung et al. 2011), who reported the overall rate of operative treatment among proximal humerus fractures in adults to be 13% to 16%. In our study, 22% of fractures were treated operatively, and the most commonly used method was locking plate fixation.

One important finding in our study was the high incidence of proximal humerus fractures during the winter months. Previously, Flinkkilä et al. revealed a similar monthly occurrence trend regarding distal radius fractures in Northern Finland (Flinkkila, Sirnio et al. 2011). They also demonstrated a correlation between slippery days and fracture occurrence. Determining whether this is true for proximal humerus fractures will require additional studies.

When we compared the clinical decision making after proximal humerus fracture in Nordic countries and Estonia, we found the prevailing trends quite similar. Uniform insecurity about the best treatment was notable, and the need for more non- operative treatments over operative ones seemed important among all responders. This finding corresponds with the latest Cochrane review, which emphasized the need for additional high-quality studies (Handoll, Ollivere et al. 2012). However, when comparing non-operative treatment with locking plate fixation, Finland and Sweden appeared to be more conservative than Norway and Estonia. The difference in treatment (using a locking plate vs. a reverse prosthesis) tended towards the use of a reverse prosthesis in all countries except Estonia. Case-by-case x-ray comparison among physicians was surprising similar, and only minor differences were noted. This is interesting because inter-observer agreement was previously noted to be low; however, the decision-making in our study was quite similar (Brorson, Bagger et al. 2009).

Based on our systematic review, we observed no differences in functional outcomes between operative treatment with the tension band and non-operative treatment. Notably, the complication rate was greater with surgical treatment. Operative treatment with locking plate fixation did not significantly improve function or HRQoL scores compared with non-operative treatment. Furthermore, operatively treated patients experienced high rates of complication (10% to 29%) and re-operation (16% to 30%). This finding is consistent with the latest RCT comparing non-operative with a variety of surgical treatments in the United Kingdom (Rangan, Handoll et al. 2015).

Based on our review, fracture prosthesis treatment of 4-part fractures provided better short-term pain relief at 3 months than non-operative treatment; however, the difference was no longer notable at 12 months. Although operative treatment with hemiarthroplasty resulted in significantly better HQRoL than non-operative treatment, functional scores did not differ between the two groups. Up to 20% of patients in the non-operative treatment group experienced non-union, while tuberculum malposition was detected in 16% of patients in the operatively treated group. Non-union and tuberculum malposition compromise clinical results and lead to poor ROM. The recent publication from Sebastian-Forcada et al. reported 30% tuberbulum majus resorption among patients treated with hemiarthroplasty. This leads to poor functional outcome for the shoulder (Sebastia-Forcada, Cebrian-Gomez et al. 2014).

6.2 Added value of the study

There are few epidemiological studies available that include both outpatient and inpatient clinical information, as most studies are discharge registry studies and include only hospitalized patients. This study adds valuable information on the epidemiology of proximal humerus fractures, as well as changes in treatment policies through past decades. In addition, although Cochrane Review has been regularly updated, there has not been any systematic review concentrating on troublesome fragility fractures. The treatment survey yields valuable information about the decision-making of orthopaedic surgeons as they treat proximal humerus fracture patients in Nordic countries and in Estonia. This study is the first to assess such decision-making extensively. One important mid-term result of our on-going RCT is network of researchers achieved. We have been able to create a working Nordic and Estonian team of similar minded clinical researchers collaborating in the large consortium. The effort towards the result has been broad up to date and the effort will continue. All participating clinics are practicing hands-on co-operation as the historic way of executing trials have been within the own hospitals and larger collaborations have been a rare approach. (Launonen, Lepola et al. 2012.)

6.3 Criticism

This study shows that the treatment of proximal humerus fractures has changed during the past decade, and now favors locking plate fixation. Based on our survey, treatment opinions are surprisingly similar throughout the Nordic countries and Estonia. Interestingly, although the incidence of plate fixation has increased markedly, there is no high-quality evidence to support this change (Launonen, Lepola et al. 2015, Rangan, Handoll et al. 2015). On the contrary, our review showed that there might be some short-term benefit regarding pain at 3 months for elderly patients with 4-part fractures treated with hemiarthroplasty. This finding was observed in only one trial, and it does not judge or explain the increased trend in surgical incidence (Launonen, Lepola et al. 2015).

The reasons for this increase in operative treatment with locking plates can only be hypothesized. It seems interesting and humane to be excited about new implants and modern treatment methods. However, one point worth noting is that we have examples in orthopaedics and general medicine in which adverse events render a treatment unusable. For example, in the cases of thalidomide treatment and metal-on-metal resurfacing hip prostheses, good intentions ended in tragedy (Sipek, Sipek et al. 2012, Mokka, Makela et al. 2013). One reason for the increasing number of plate fixations might be preliminary reports that contain promising positive results (Lungershausen, Bach et al. 2003, Fankhauser, Boldin et al. 2005). The positive results, combined with high expectations and the beliefs of the surgeon and patient, bend the chosen option towards operative treatment. It is noteworthy that these studies were not RCTs and included relatively small numbers of patients. Interestingly, the first RCT comparing operative treatment to non-operative treatment was published 10 years after the release of the implant (Olerud, Ahrengart et al. 2011).

In EBM, the hierarchy of decision should originate from meta-analyses or systematic reviews rather than case series and uncontrolled cohort studies. However, in the case of new treatment methods, the publication of meta-analyses that include several RCTs would take too much time. Yet, it is essential that some minimum criteria be generated before the wider release of orthopaedic implants takes place. Based on the recent literature, it seems that researchers have not been able to concentrate on the correct questions (whether or not to operate). Instead, they have been focusing on surgical techniques and surrogate variables. Previously, quite common questions included whether there was difference between one intervention and another, while the most important question—do we *need* to operate—has remained unanswered (Voigt, Geisler et al. 2011, Carbone, Tangari et al. 2012). The explanation for this is unknown.

Orthopaedic implants are not assessed as thoroughly as medicines prior to launching. Every new drug must be inspected and studied with approved double-blind trials, while the use of orthopaedic implants can be started much more quickly and with much less documentation. The medical device industry appears to play a great role in our decision-making. Aggressive marketing and excessive hype around new methods certainly affect our decisions. However, in the end, we as orthopaedic surgeons are the ones to make the final decision regarding whether to use the devices. Thus, it is essential that our treatment policies be transparent and evidence-based. High-quality research comparing operative and non-operative treatment should always be the gold standard in orthopaedics.

At the moment, there is much debate regarding fracture reverse prosthesis (Cuff and Pupello 2013, Chalmers, Slikker et al. 2014). The controversy can be compared to the questions surrounding locking plates a decade ago. There are no high-quality studies regarding long-term results, nor have locking plates been adequately compared with non-surgical treatment. However, reverse prosthesis is eagerly used to treat fracture patients. In addition, primary reports indicate a long learning curve and rather high rate of complications. Fortunately Fjalestad et al. are overseeing an ongoing multicenter RCT on the subject (Fjalestad, Iversen et al. 2014).

Our own multicenter RCT (Launonen, Lepola et al. 2012) overcomes previously emphasized problematic classifications of proximal humerus fractures, as well as the inadequate measures of outcome used in former trials. The use of CT before treatment decisions is essential. In operative cases, CT is of greater help to the pre-operative planning than fracture classification could be. As shown previously, fracture classification is demanding. We only aim to recognize 2-part fractures separately from multi-fragmented fractures, with or without true head-splits. Because fracture classifications and clinical outcome are only poorly associated (if at all), in the future it might be more useful to distinguish only between osteoporotic and non-osteoporotic fractures. The patient's activity level and other patient characteristics might also guide our treatment. Poor outcome measures are another important limitation of previous studies, and as a result our RCT uses only validated patient-related outcome measures (PROMs), such as the Constant and DASH scores. Therefore, it is possible to combine our results with the findings of others by means of meta-analysis. The third significant problem noted by previous literature is the time-consuming nature of recruiting patients to trials. The multi-center, multinational design of our study ensures a plausible timetable and adequate flow of patients.

In the future, it is essential to evaluate new implants more thoroughly and to compare their results with non-surgical treatment in the RCT setting before taking these devices into wider use. Because this process requires significant resources and knowledge, national orthopaedic societies and the Nordic Orthopaedic Federation could take a more active role to create international collaborations, which in turn would be able to assess these important questions. Such a process could contribute to the implementation of study findings.

7 SUMMARY AND CONCLUSION

The 5-year unadjusted incidence in Tampere was 82 (95% CI: 76 to 88) per 100,000 person-years overall, 114 (95% CI: 104 to 124) per 100,000 person-years in women, and 47 (95% CI: 41 to 54) per 100,000 person-years in men. There was high incidence of proximal humerus fractures during the winter months.

After the introduction of locking plates in Finland in 2002, the incidence of plate fixation doubled between 2002 and 2009 (from 6 to 14 per 100,000 person-years). Twenty-two percent of fractures in Tampere were treated with surgery during the years 2006–2010, and the most common fixation method used was the locking plate system. Based on our survey, uniform lack of confidence regarding the best treatment was notable, and the need for more non-operative treatments over operative ones seemed important among trauma surgeons in Nordic countries and Estonia. Comparison of the locking plate with reverse prosthesis tended to favor reverse prosthesis in all countries except Estonia.

We reviewed the currently available EBM literature and found no differences in functional outcomes between operative treatment with the tension band or locking plate and non-operative treatment. Measured with HRQoL, surgical treatment with prosthesis was significantly better than non-surgical treatment. However, surgically treated patients exhibited high rates of complication (10% to 29%) and re-operation (16% to 30%).

Based on the current evidence based medicine literature, surgery should not be considered the gold standard when treating proximal humerus fractures. Nevertheless, because the superiority of single treatment has not been confirmed, the final decision should be made with the patient. Patients should be advised of the high rate of complications that is associated with choosing surgical treatment. It will be interesting to see whether future ongoing randomized controlled studies comparing surgical and non-surgical treatment will shed light on this issue (Brorson, Olsen et al. 2009, Launonen, Lepola et al. 2012, Verbeek, van den Akker-Scheek et al. 2012, Fjalestad, Iversen et al. 2014).

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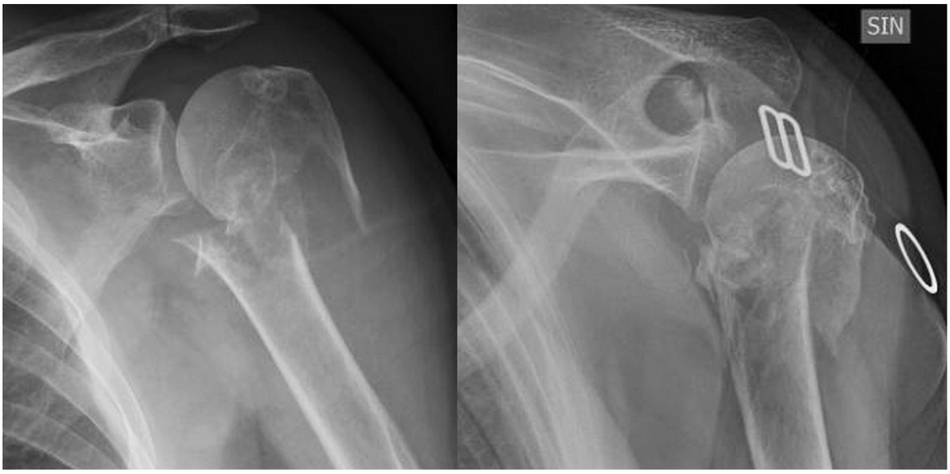
10 ANNEX

Case 1 of the survey

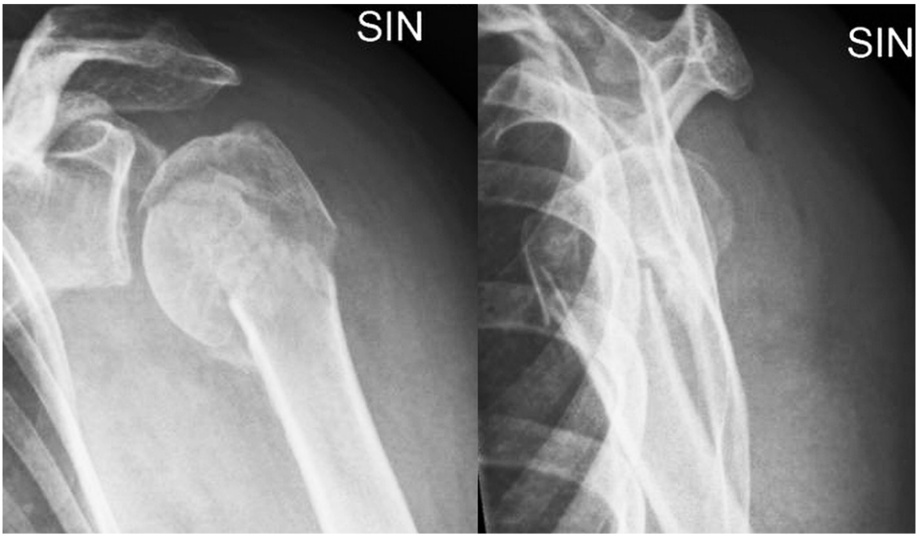
Case 2 of the survey

Case 3 of the survey

Case 4 of the survey



Case 5 of the survey



Case 6 of the survey

Case 7 of the survey

Case 8 of the survey

11 ORIGINAL COMMUNICATIONS

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BMC Musculoskeletal Disorders

STUDY PROTOCOL Open Access

Conservative treatment, plate fixation, or prosthesis for proximal humeral fracture. A prospective randomized study

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Abstract

Background: Proximal humerus fracture is the third most common fracture type after hip and distal radius fracture in elderly patients. A comprehensive study by Palvanen *et al*. demonstrated an increase in the annual fracture rate of 13.7% per year over the past 33 years. Should this trend continue, the fracture rate would triple over the next three decades. The increasing incidence of low-energy fractures raises questions about the optimal treatment in terms of functional outcome, pain, and rehabilitation time, as well as the economical impact. Despite the high incidence and costs of proximal humerus fractures, there is currently no valid scientific evidence for the best treatment method. Several publications, including a Cochrane review outline the need for high-quality, well-designed randomized controlled trials.

Methods/Design: The study is a prospective, randomized, national multi-center trial. The hypothesis of the trial is that surgical treatment of displaced proximal humerus fractures achieves better functional outcome, pain relief, and patient satisfaction compared to conservative treatment. The trial is designed to compare conservative and surgical treatment of proximal humerus fractures in patients 60 years and older. The trial includes two strata. Stratum I compares surgical treatment with locking plates to conservative treatment for two-part fractures. Stratum II compares multi-fragmented fractures, including three- and four-part fractures. The aim of Stratum II is to compare conservative treatment, surgical treatment with the Philos locking plate, and hemiarthroplasty with an Epoca prosthesis. The primary outcome measure will be the Disabilities of the Arm, Shoulder and Hand (DASH) score and the secondary outcome measures will be the EuroQol-5D (EQ-5D) value, OSS, Constant-Murley Score, VAS, and 15D. Recruiting time will be 3 years. The results will be analyzed after the 2-year follow-up period.

Discussion: This publication presents a prospective, randomized, national multi-center trial. It gives details of patient flow, randomization, aftercare and also ways of analysis of the material and ways to present and publish the results.

Trial registration: ClinicalTrials.gov identifier: NCT01246167

Keywords: Proximal, Humerus, Fracture, Conservative, Operative, Locking plate, Prosthesis, Philos, Epoca, RCT

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Background

Proximal humerus fracture is the third most common fracture type after hip and distal radius fracture in elderly patients [1-3]. Proximal humerus fracture accounts for approximately 4% of all fractures [1-3]. Approximately 85% of the patients are treated conservatively and will regain shoulder function without surgery [4]. Most of these fractures are stable and minimally or non-displaced osteoporotic fractures and they commonly occur in women [4]. The mechanism of low-energy injury in elderly patients is usually falling from standing height. In Finland in 2002, the age-adjusted fracture incidence in persons 60 years and older was 105 per 100,000 person-years [5]. A comprehensive study by Palvanen *et al.* demonstrated an increase in the annual fracture rate of 13.7% per year over the past 33 years [5]. Should this trend continue, the fracture rate would triple over the next three decades.

The increasing incidence of low-energy fractures raises questions about the optimal treatment in terms of functional outcome, pain, and rehabilitation time, as well as the economical impact. Despite the high incidence and costs of proximal humerus fractures, there is currently no valid scientific evidence for the best treatment method. Several publications, including a Cochrane review outline the need for high-quality, well-designed randomized controlled trials. The challenge for the future is to determine which patients will benefit from surgery and to establish surgical techniques that produce optimal results for each fracture type. The aim of this randomized controlled trial is to evaluate whether the outcome in patients over 60-years of age with displaced two-, three-, and four-part fractures of the proximal humerus is improved by surgical intervention.

Diagnosis and treatment

Diagnosis of proximal humerus fracture is based on clinical and radiologic findings and the mechanism of injury. A standard set of three radiographs from different views is generally obtained. The Neers's or AO (Arbeitsgemeinschaft für Osteosynthesefragen) classification systems are widely used to define these complex fractures [6]. Although these systems have been used extensively for many decades, their reliability has been challenged. The AO system categorizes the fracture types into 27 fracture patterns, making its use labor- and time-intensive and complicated (Müller 1990). The Codman-Hertel binary fracture description system does not address the fracture pathomechanism (Hertel 2004). The Codman-Hertel system was improved by Resch by adding the pathomechanism of the fracture to the classification [7]. In all classification systems, however, the intra- and inter-observer agreement are graded as poor or, at best, moderate [8]. Due to poor intra- and inter-observer agreement of the Neer's or AO classification systems, various radiographic protocols have been introduced to improve the diagnostic reliability of the classification. CT is often performed to facilitate treatment decisions.

Approximately 15% of patients with proximal humerus fracture are treated surgically [9]. Several fixation methods have been introduced, including Kirschner-wire fixation, screw fixation, plate fixation, intramedullary fixation, and prosthesis [10]. Currently, the locking plate system is the most frequently used method for fixation in two- and three-part fractures and a locking plate or prostheses is often used in displaced three- and four-part fractures in elderly patients [11]. With locking plates, the normal anatomy may be restored and the range of motion (ROM) is reported to recover up to 80% to 85% that of the healthy side [10,12]. The disadvantage of the locking plates includes a rather high complication rate of up to 49% [13]. A stable and usually pain-free shoulder is achieved with a prosthesis, but recovery of ROM is poor [10,12,14-17].

Evaluation of treatment

Tools that are widely used for measuring the mobility and usability of the shoulder include the Constant-Murley score; Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire; Oxford Shoulder Score (OSS); and Visual Analog Scale (VAS). In addition, the EuroQol-5D (EQ-5D) and 15D questionnaires survey the patient's general quality of life through different questions pertaining to various areas of life and are widely used in medical trials [18]. The outcomes are indexed and are comparable with reference populations as well as with the patient's own results in other stages of the treatment. Finnish versions of the EQ-5D and 15D have been validated [19,20].

Previous studies

Although the literature on proximal humerus fractures is extensive, the majority of studies lack randomization, comparators, and independent evaluation, which makes it impossible to draw clinically meaningful conclusions [21]. Recent publications include three well done randomized, controlled trials. Olerud *et al.* carried out randomized controlled trials on three-part fractures, comparing nonsurgical treatment with angle-stable plates in elderly patients. The results indicated advantages in functional outcome and health-related quality of life favoring the locking plate, but the clinical significance remains unclear [22]. Fjalestad *et al.* studied displaced three and four-part fractures in patients over 60 years of age. They found no evidence that surgical treatment with an angle-stable device provided better results than conservative treatment [23]. Others have reported conflicting results. Olerud *et al.* studied displaced four-part fractures in elderly patients. They compared hemiarthroplasty and conservative treatment and found that arthroplasty provided a significant advantage in terms of quality of life. The main advantage was less pain although there was no difference in ROM [24].

In 2009, Hanson *et al.* published functional results of 160 patients treated conservatively. After a 12-month follow-up, the difference compared to the healthy side was 8.2 points measured with the Constant-Murley score. The difference in the DASH score was 10.2 points, which is below the minimal detectable change. Non-union risk was 7.0%, with smokers having a 5.5 times greater risk than nonsmokers [25].

The updated Cochrane meta-analysis published in 2010 was unable to provide guidelines for treating proximal humerus fractures due to a lack of solid evidence. Three- and four-part fractures in patients over 60 years of age are especially challenging as scientific consensus on their treatment has yet to be established [21].

Methods/Design

The present randomized controlled trial is designed to compare conservative and surgical treatment of proximal humerus fractures. The trial includes two strata. Stratum I compares surgical treatment with locking plates to conservative treatment for two-part fractures. Stratum II compares multi-fragmented fractures, including three- and four-part fractures. The aim of Stratum II is to compare conservative treatment, surgical treatment with the Philos locking plate (Synthes®), and hemiarthroplasty with an Epoca prosthesis (Synthes®).

Hypothesis

The study is a prospective, randomized, national multicenter trial. The hypothesis of the trial is that surgical treatment of displaced proximal humerus fractures achieves better functional outcome, pain relief, and patient satisfaction compared to conservative treatment in terms of ROM, and Constant-Murley, DASH, OSS, EQ-5D, 15D, and VAS scores. Subgroup analysis will be performed in an effort to obtain limit values for specific treatments of different age and fracture groups. In addition, we hypothesize that shoulder function will improve for up to 1 year from the time of fracture, and after 1 year significant improvement will be arrested [26]. The primary outcome measure will be the Disabilities of the Arm, Shoulder and Hand (DASH) score and the secondary outcome measures will be the EuroQol-5D (EQ-5D) value, OSS, Constant-Murley Score, VAS, and 15D.

Objectives

The results of both strata will be analyzed and the results will be reported separately, as recommended by the CONSORT statement.

Patients and methods

Inclusion criteria

- Low energy proximal humerus displaced (displacement more than 1 cm or 45 degrees) two-part fracture in which the fracture line emerges through the surgical (or anatomic) neck
- Low energy proximal humerus displaced (displacement more than 1 cm or 45 degrees) three- or four-part fracture

Exclusion criteria

- Refusal to participate in the study
- Under 60 years of age
- Not independent
- Dementia and/or institutionalized
- Does not understand written and spoken guidance in either Finnish or Swedish
- Pathologic fracture or a previous fracture of the same proximal humerus
- Alcoholism or drug addiction, e.g., in the emergency department, breathalyzer indicates blood alcohol concentration of more than 2‰
- Other injury to the same upper limb requiring surgery
- Major nerve injury (e.g., complete radial- or axillary nerve palsy)
- Rotator cuff tear arthropathy
- Open fracture
- Multi-trauma or -fractured patient
- Fracture dislocation or head-splitting fracture
- Non-displaced fracture
- Isolated fracture of the major or minor tubercle
- Gross displacement of the fracture fragments (no bony contact between fracture parts or the humerus shaft is in contact with the articular surface)
- Any medical condition that excludes surgical treatment

Patients with an x-ray verified proximal humerus fracture meeting the inclusion criteria will undergo a CT scan to assess the fracture classification. The scan area will include the entire scapula with the upper third of the humerus. Coronal, sagittal, and 3-dimensional volume reformats will be reconstructed. If the fracture meets the radiologic inclusion criteria, the patient will be invited to participate in the study. The patient will be informed of the study and will receive a written information sheet. When patients decide to participate in the study, they will be asked to fill-out a written informed consent form. The patients can withdraw from the study at any stage, on any grounds, and this will have no influence on the medical care given to the patients. If the patient is excluded from the study, information about age, sex, fracture type, reason for exclusion, medical condition, basic medication, and chosen treatment will be communicated to the research group using a case report form.

During hospitalization, the patient will be asked to fill out, with help if necessary, the EQ-5D, 15D, DASH, and OSS, and basic patient questionnaires with a VAS to determine their baseline characteristics. The patient's medical history, medication, and surgery will be recorded by a research nurse or researcher on a medical case report form. Potential primary complications will be recorded (e.g., nerve injury).

Randomization

All patients will be randomized by a Tampere University Hospital research coordinator who will not attend the study. Patients with a two-part fracture will be randomized to either conservative or plate-fixation groups. Patients with multi-fragmented fractures will be randomized to conservative, plate fixation, or prosthesis groups. Both fracture types will be randomized using a random number matrix in block allocation fashion. The blocks will be age-dependent because, based on the literature, age and functional outcome are associated [27]. The treatment allocations from the matrix will be sealed in an envelope. After the patient's enrollment in the study has been confirmed, the research physician will contact the research coordinator, who will open the envelope and the randomized treatment will be carried out. The research coordinator will monitor the study flow. An independent monitoring committee has not been established.

Surgical technique

The surgical procedures (plate fixation or hemiarthroplasty) are performed by shoulder-oriented orthopedic surgeons of the Tampere, Kuopio, Turku, and Oulu University hospitals. In this trial, we will use the Philos locking plate system (Synthes®, Solothurn, Switzerland) and an uncemented Epoca fracture prosthesis (Synthes®, Solothurn, Switzerland) with a hydroxyapatite coating. Additional cement fixation will be used if necessary. All patients randomized to surgical treatment will undergo the surgery within 2 weeks after the fracture. During the operation, the Neer's classification and evidence of potential rotator cuff rupture will be recorded.

Patients will be placed in the beach-chair position. Plexus anesthesia will be used when possible. The deltopectoral, deltoid-split, or minimally invasive plate osteosynthesis approach will be used. Cuff tendons will be routinely inspected and sutures passed through each tendon to ease the handling of the fragments. For plating, the fragments will be preliminarily reduced with sutures and k-wires. The plate will be placed lateral from the biceps groove and 5 mm distal from the tip of the tuberculum majus. Six to eight locking screws will be placed in the head and three conventional or locking screws will be placed in the shaft.

The prosthesis height will be determined from the medial rim of the articular fragment. Anatomic retroversion will be determined from the shaft configuration. Reaming will be performed until the trial stem is stable. If needed, a minimal amount of cement will be used to stabilize the stem. Head size is determined from the articular fragment. The offset will be left to neutral. Before tightening the cables underneath the tuberculi, bone grafts from the head fragment will be placed against the stem. Sutures will be knotted to secure the cuff.

Drainage will be left in if necessary and the wound closed in layers. The shoulder will be immobilized with a collar-cuff in the operating theater.

Conservative treatment

Patients randomized to non-operative treatment will be instructed with regard to joint mobilization by a physiotherapist during hospitalization. Patients will receive a written aftercare protocol with detailed pictures. A collar-cuff or a sling will be used for 3 weeks to relieve pain. During the first 3 weeks, pendulum exercises are allowed, and free joint mobilization and normal limb activation throughout treatment will be strongly supported. Active ROM exercises, as allowed by pain, will begin at 3 weeks. Physiotherapist contacts will be arranged to begin 3 and 6 weeks after surgery and all patients will have 5 physiotherapist contacts within the 3 first months.

Postoperative aftercare

Patients operated with a plate will follow the same protocol as in conservative treatment. Patients treated with a prosthesis will wear a sling for 6 weeks. Two weeks postoperatively, they will begin pendulum movements. Free, active mobilization will be allowed at 6 weeks. Patients will be advised to mobilize their free joints from the beginning of the treatment and normal limb activation during aftercare will be supported. Contact with a hospital physiotherapist will begin after 3 and 6 weeks postoperatively and all patients will have 5 physiotherapist contacts within 3 months from the beginning of treatment. Patients will receive a detailed written aftercare protocol with instructional pictures and formal physiotherapy will be instructed before leaving the hospital.

Follow-up

Follow-up will be carried out at the orthopedic outpatient clinic of the hospital where the patient was primarily treated. The patients will visit the outpatient clinic at 6 weeks and 3 months. Ultrasound examination of the fractured shoulder to assess possible rotator cuff injury will be performed at the 3-month visit by an experienced musculoskeletal radiologist.

Orthopedic outpatient clinic visits will be continued if necessary. In addition to these visits, in each center a blinded physiotherapist or sports physiologist will perform a research examination at 6 months, and 1, 2, 5, and 10 years from the beginning of the treatment. Patients are supposed to wear a shirt to blind the examiner. During these visits, radiographs will be taken of the treated shoulder, ROM and Constant-Murley scores of both shoulders will be obtained, and the patient will complete the EQ-5D, 15D, DASH, and OSS questionnaires.

Should any adverse event demanding separate outpatient or inpatient care or surgery occur during the follow-up, an adverse event form will be completed within 24 hours of the execution of treatment. The information will be sent to the research coordinator. If the patient is not willing to continue in the study, or does not appear at appointments, or dies, a research discontinuation form will be completed. The study flow is outlined in Figure 1 and assessments and procedures are outlined in Table 1.

Power analysis

In Stratum I, when assuming an effect size of a 10-point difference in the DASH score and a standard deviation of 15 points, the estimated sample size is 37 patients (delta = 10, sd = 15, alpha = 0.05, power = 0.8). Thus Stratum I requires 74 patients (2 comparison groups). In Stratum II, when assuming an effect size of a 10-point difference in the DASH score and a standard deviation of 15 points, the estimated sample size is 66 patients (ANOVA, alpha = 0.05, power = 0.8). The number of comparison groups is three. The total number of patients in Stratum II is 198. Thus, the total number of patients in the study will be 272. We will assume a 10% drop-out rate in both groups; therefore, the total patient number required will be 299 (81 + 218). In cases in which the patient changes to a different treatment group, they will be analyzed according to the intention-to-treat principle. SD value has been estimated after Gummerson *et al.* (2003). The article describes the minimal detectable change in

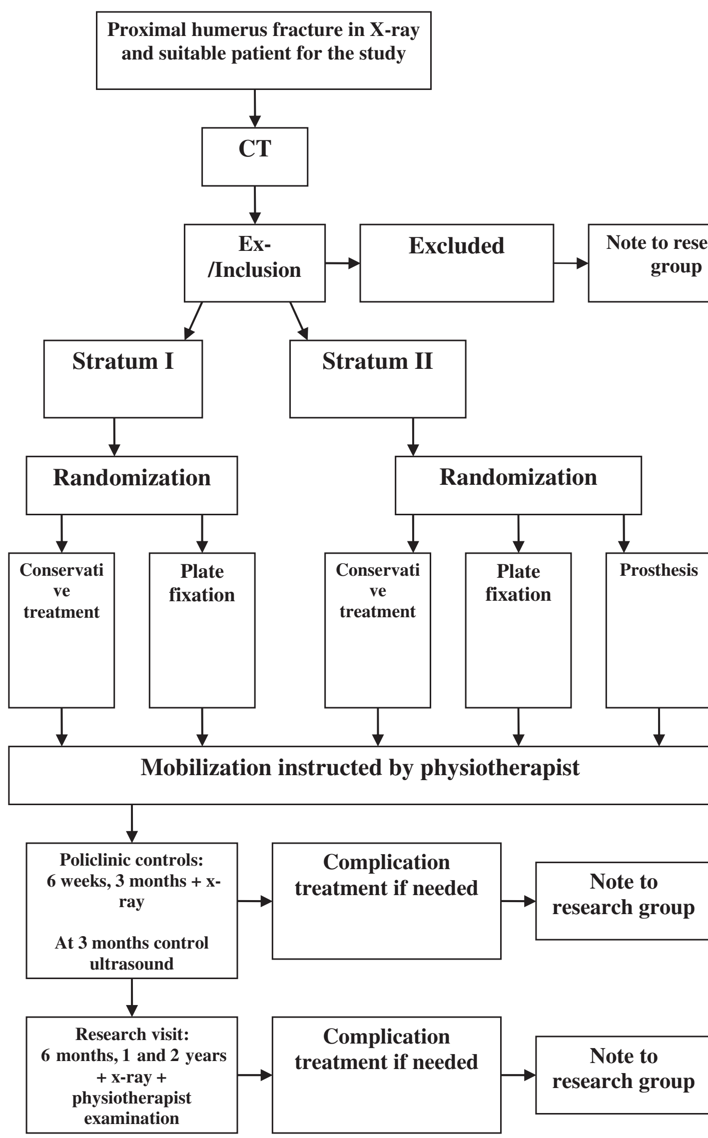

Figure 1 Study flow. Stratum I for 2 part fractures, Stratum II for 3 and 4 part fractures.

Table 1 Assessments and procedures of the trial

Assessment	Preoperative	1. visit 6 weeks	2. visit 3 months	3. visit 6 months	4. visit 1 year	5.visit 2 years
x-ray	X	X	X	X	X	X
CT	X					
Ultrasound			X			
Ex-/inclusion	X					
Medical history	X					
Consent	X					
Questionnaire	X		X	X	X	X
VAS-pain	X			X	X	X
EQ-5D	X			X	X	X
15D	X			X	X	X
OSS	X			X	X	X
DASH	X			X	X	X
Constant-Murley Score				X	X	X
Doctors visit		X	X			
Research visit				X	X	X

DASH as 10 points with an SD of 13 with a mean score of 15 points [28].

Statistical analysis
Differences between groups in continuous skewed main outcome variables will be analyzed by the Mann–Whitney U-test and t-test when variables are unskewed. Results are presented with 95% confidence intervals. Two-way-tables with the chi-square test will be used for dichotomous variables. Multivariate analysis will be conducted with regression analysis. In subgroup analysis the effect of age, sex, fracture group, smoking, and other diseases will be evaluated against the ROM, OSS, Constant-Murley, and overall quality of life after fracture.

Analysis of the material
All radiographs and CT scans will be sent to the research center at Tampere University Hospital.

All information gathered will be stored in a study registry at Tampere University Hospital. The registry is protected with passwords, and will be deleted 2 years after the end of the study.

Ethics
The trial protocol has been approved by the Ethics Committee of Pirkanmaa District Hospital. The study protocol and additional papers, including the consent form, patient information sheet, questionnaires, and case report form, have also been approved by the Ethics Committee (Approval number R10127). Permission to collect registry data and to combine it with the hospitalization data maintained by the NIHW will be requested from the NIHW and Social Insurance Institution.

Time schedule
Recruiting time will be 3 years. The results will be analyzed after the 2-year follow-up period. The final report will be published by the end of the year 2017.

Discussion
This publication presents a prospctive, randomized, national multi-center trial. It gives details of patient flow, randomization, aftercare and also ways of analysis of the material and ways to present and publish the results.

Competing interests
The authors declare that they have no competing interests.

Authors' contributions
AL, ML, TF, JO, NS and TV are responsible for developing the trial. AL, VM, TF, PE, PR, AM, NS, TV, VL and ML drafted the protocol. AM will monitor and advise the methodologic aspects of the trial. PE is responsible for the radiologic aspects and PR is responsible for the economical aspect of the trial. VM performed the power calculations and determination of sufficient study group size and will perform the statistical analyses. All authors read and approved the final manuscript.

Authors' information
ML is the Principal Investigator of the study and she, as well as the Co-Principal Investigators in Oulu and Turku – TF and NS, are experienced in carrying out randomized controlled trials. TF, VL and NS are also nationally respected shoulder surgeons. JO is Co-Principal Investigator at Kuopio University Hospital. AL is the main researcher and is responsible for coordinating the medical aspects and the practical side of the study. TV is a nationally respected senior shoulder surgeon and will aid in planning the study and instructing junior colleagues. PE is an experienced musculoskeletal radiologist and will provide advice on radiologic issues and is the head of the radiologic board of the trial. PR is Professor of Public Health of University of Tampere and is responsible for the economical aspects of the study. VM is Associate Professor in the Department of Traumatology. AM is a researcher at the National Institute for Health and Welfare.

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RESEARCH ARTICLE Open Access

Trends in the surgical treatment of proximal humeral fractures – a nationwide 23-year study in Finland

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Abstract

Background: Proximal humeral fractures are common osteoporotic fractures. Most proximal humeral fractures are treated non-surgically, although surgical treatment has gained popularity. The purpose of this study was to determine changes in the surgical treatment of proximal humeral fractures in Finland between 1987 and 2009.

Methods: The study covered the entire adult (>19 y) population in Finland over the 23-year period from 1st of January 1987 to 31st of December 2009. We assessed the number and incidence of surgically treated proximal humeral fractures in each year of observation and recorded the type of surgery used. The cohort study was based on data from Finnish National Hospital Discharge Register.

Results: During the 23-year study period, a total of 10,560 surgical operations for proximal humeral fractures were performed in Finland. The overall incidence of these operations nearly quadrupled between 1987 and 2009. After the year 2002, the number of patients treated with plating increased.

Conclusion: An increase in the incidence of the surgical treatment of proximal humeral fractures was seen in Finland in 1987–2009. Fracture plating became increasingly popular since 2002. As optimal indications for each surgical treatment modality in the treatment of proximal humeral fractures are not known, critical evaluation of each individual treatment method is needed.

Background

Proximal humeral fractures are common and they are the third most common osteoporotic fracture after hip and distal radius fractures [1-3]. The rate of proximal humeral fractures typically increases in women after age 50 and in men after age 70 [4]. Based on recent literature, the age- and sex-specific incidence rate of proximal humeral fractures varies from 10 to 300 per 100,000 person-years in different populations [1,2,4,5].

Proximal humeral fractures typically occur due to a low-energy trauma, most commonly by falling from standing height [6]. The incidence of proximal humeral fractures has clearly increased over the past few decades [5,7]. Despite the high prevalence of these injuries, surprisingly little is known which proximal humeral fractures should be treated surgically [8].

Most proximal humeral fractures are treated nonsurgically [1,9,10]. A variety of different methods can be used for surgical treatment of proximal humeral fractures, including percutaneous fixation, open reduction and internal fixation (ORIF), and arthroplasty. While there are a few clinical case series of surgical treatment few high-quality randomized controlled trials have been performed [11].

Fjalestad and coworkers found no evidence of a difference between surgical and conservative treatment, whereas Olerud and coworkers reported that arthroplasty is associated with a better quality of life. In another study Olerud et al. compared plating to conservative treatment but found no statistical difference for quality of life in elderly patients [11-14].

New treatment options, such as locking plates, were introduced to clinical practice during the recent decade,

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but their superiority over other treatment options has not yet been demonstrated [8,11].

The aim of the current study was to assess the incidence and trends in the surgical treatment of fractures of the proximal humerus. We were especially interested to see how the number and incidence of different surgical treatment methods have evolved at this site.

Methods

The Institutional Review Board approved the study.

Patient data were obtained from the Finnish National Hospital Discharge Register (NHDR) between 1987 and 2009. All patients 20 years of age or older admitted to hospitals alive were included. The Finnish NHDR, founded in 1967, provides data on age, sex, domicile of the subject, hospital stay duration, primary and secondary diagnosis, and operations performed during the hospital stay. The data collected by the NHDR is mandatory for all hospitals, including private, public, and other institutions. The validity of the NHDR is excellent regarding both coverage and accuracy of the database [15-17]. On the other hand, the NHDR is a *hospital discharge register* and it does not provide conclusive data on co-morbities and other risk factors for fractures.

Patients were selected in the study if they had either primary or secondary diagnosis of a proximal humeral fracture. As the ICD-coding changed during the study period, ICD-9 codes 81200 and 81210 were used to select patients in the study between 1987 and 1995. ICD-10 code S42.2 was used to select patients in the study between 1996 and 2009. The main outcome variable for the study was the number of patients undergoing surgical treatment of a proximal humeral fracture. The procedural codes also changed during the study period. The ICD-9 was used in Finland from 1987 to 1997. During this period, we included ICD-9 surgical treatment codes 9126 (closed reduction and osteosynthesis), 9128 (open reduction and osteosynthesis), 9130 (external fixation), and 9132 (endoprosthesis). In 1998, the more specific ICD-10 procedural coding system was introduced. The ICD-10 surgical treatment codes for the proximal humeral fractures included NBJ60 (open reduction and osteosynthesis by nailing), NBJ62 (open reduction and plating), NBJ64 (fracture reduction and screw, percutaneous pinning or absorbable screw fixation), NBJ70 (external fixation), and NBB10-20 (arthroplasty). For analysis of the data for the whole study period from 1987 to 2009, the codes of the ICD-9 system were pooled with those of the ICD-10 system, and surgical treatment was categorized into four groups; closed reduction and osteosynthesis (codes 9126 and NBJ64), open reduction and osteosynthesis (codes 9128, NBJ60, and NBJ62), fracture reduction and external fixation (codes 9130 and NBJ70), and arthroplasty (codes 9132 and NBB10-20).

Implementation of the ICD-10 in 1998 allowed us to further dissect the proximal humeral procedures, and therefore a more specific analysis was performed for the years 1998 to 2009 to specify the proportions of individual surgical procedures. For this period, from 1998 to 2009, the numbers and incidences of procedures NBJ60, NBJ62, NBJ64, NBJ70, and NBB10-20 were analysed individually.

Statistical analysis

To compute the incidence ratios of proximal humerus fractures requiring surgical intervention and thus leading to hospitalization, the annual mid-population was obtained from the Official Statistics of Finland, an electronic national population register [18]. The rates of surgically treated proximal humerus fractures (per 100,000 persons) were based on the entire adult population of Finland rather than cohort-based estimates and thus 95% confidence intervals were not calculated. Statistical analysis was performed using PASW19.0®.

Results

A total of 47,960 hospitalizations with a diagnosis of proximal humeral fracture were registered in the NHDR during the 23-year study period. The number of patients was 1136 in 1987 and 2944 in 2009. The incidence of hospitalization following proximal humeral fracture increased from 31.1 per 100,000 person years in 1987 to 71.5 per 100,000 person years in 2009.

During the 23-year period, 10,560 surgical operations of these fractures were registered in the NHDR. The number of surgically treated proximal humerus fractures increased from 1987 to 2009. The number of surgical procedures in women was roughly twice that in men (n = 7008; 66% in women and n = 3552; 34% in men). The total incidence of surgical procedures was 5.1 per 100,000 person years (n = 185) in 1987 and 19.6 per 100,000 person years (n = 808) in 2009. In women, the incidence increased from 5.7 per 100,000 person years (n = 110) in 1987 to 26.1 per 100,000 person years (n = 553) in 2009. In men, the incidence increased from 4.3 per 100,000 person years (n = 75) in 1987 to 12.8 per 100,000 person years (n = 255) in 2009 (Figure 1).

During the entire 23-year study period, ORIF was the most common surgical procedure performed (n = 7774, 73.6%), followed by closed reduction and osteosynthesis (n = 1515, 14.3%), arthroplasty (n = 1198, 11.3%), and external fixation (n = 73, 0.7%). As the number and incidence of external fixations were so low during the entire study period, they were excluded from further analysis.

The number and incidence of different surgical procedures changed markedly (Figure 2). The incidence for ORIF was 4.2 per 100,000 person years (n = 153) in 1987 and 14.5 per 100,000 person years (n = 598) in 2009. The steepest rise in the number and incidence of the ORIF was observed

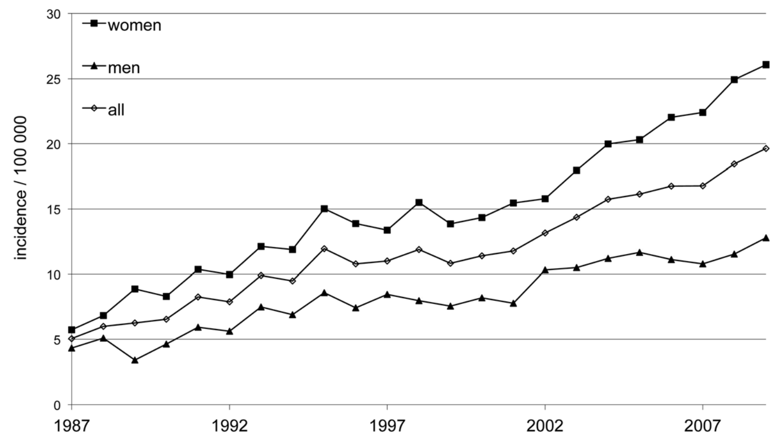

Figure 1 Incidence of surgically treated proximal humeral fractures in Finnish men and women per 100,000 person-years between 1987 and 2009.

among women: from 4.4 per 100,000 person years (n = 84) in 1987 to 19.1 per 100,000 person years (n = 405) in 2009. The incidence of closed reduction and osteosynthesis was 0.25 per 100,000 person years (n = 9) in 1987 and 2.0 per 100,000 person years (n = 81) in 2009. The corresponding values for arthroplasty were 0.5 (n = 17) and 3.1 (n = 129).

Between 1998 and 2009, when the more specific ICD-10 codes were available, the incidence in plating (NBJ62) increased from 5.9 per 100,000 person years (n = 229) in 1998 to 13.9 per 100,000 person years (n = 574) in 2009 (Figure 3). The increase in plating was greater in women as the incidence rose from 7.6 per 100,000 person years (n = 152) in 1998 to 18.3 per 100,000 person years (n = 389) in 2009 (Figure 4). The plating incidence nearly doubled in every age group between 1998 and 2009 (Figure 5).

The incidence of nailing (NBJ60) decreased over time, from 1.2 per 100,000 person years (n = 48) in 1998 to 0.6 per 100,000 person years (n = 24) in 2009 (Figure 3). The corresponding values for fracture reduction with screw, and percutaneous pinning or absorbable screw fixation (NBJ64) were 3.6 (n = 139) and 2.0 (n = 81). The incidence of arthroplasty (NBB10-20) increased from 1.0 (n = 40) in 1998 to 3.1 per 100,000 person-years (n = 129) in 2009 (Figure 3). The mean age by surgery type varied: 65.0 yrs. (SD 15) for nailing, 61.7 yrs. (SD 15) for plating, 59.3 yrs. (SD 16) for screw, pin or absorbable screw, 68.1 (SD 12) for external fixation and 69.5 (SD 11) for arthroplasty.

Discussion

In this cohort study based on a nationwide register, we analysed the trends for surgical treatment of proximal humeral fractures in the entire adult Finnish population. The main finding was that the incidence of surgical treatment of proximal humeral fractures nearly quadrupled between

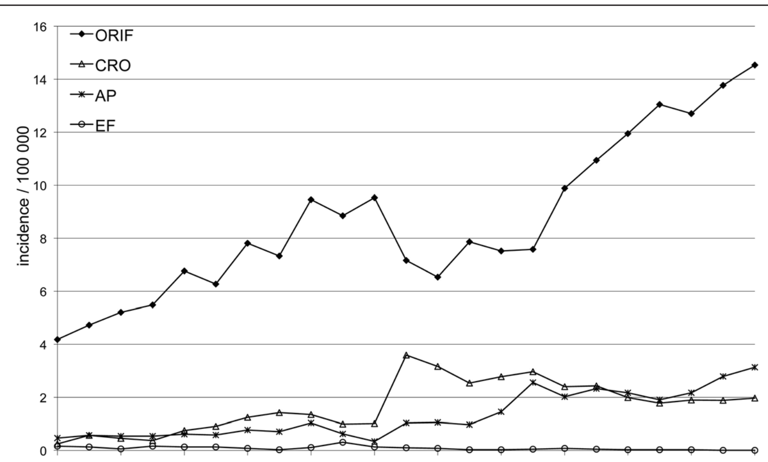

Figure 2 Changes in the incidence of surgically treated proximal humeral fractures in Finnish adults per 100,000 person-years from 1987 to 2009. ORIF = open reduction and internal fixation, CRO = closed reduction and osteosynthesis, AP = arthroplasty, EF = external fixation.

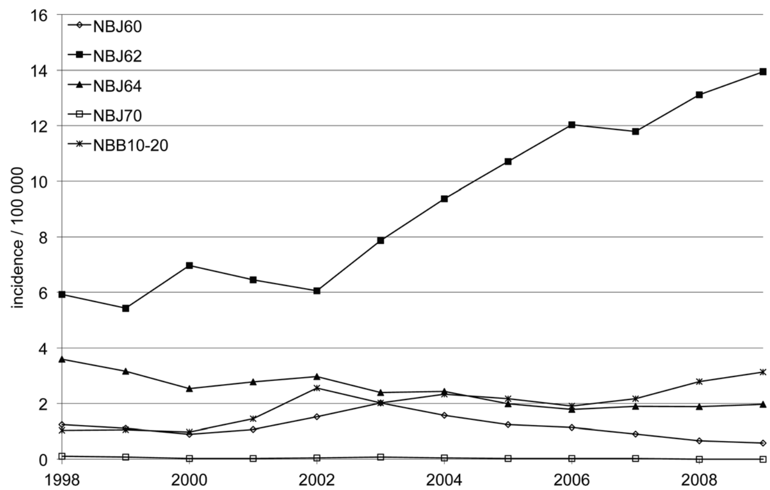

Figure 3 Incidence of plating for proximal humeral fractures in Finnish adults per 100,000 person-years between 1998 and 2009. NBJ60 = nail, NBJ62 = plate, NBJ64 = screw, NBJ70 = external fixation, NBB10-20 = arthroplasty.

1987 and 2009. This is of interest as proximal humeral fracture is the third most common osteoporotic fracture type and as such poses considerable strain on our healthcare system. At the same time the incidence of hospitalization due to proximal humeral fractures only doubled, and more specifically, in the oldest age groups the age-adjusted incidence of these fractures has stayed quite constant since the late 1990s [5].

A majority of proximal humeral fractures occur in women with incidence increasing almost exponentially with aging [19,20]. According to our study the incidence for surgical treatment rose for both men and women but it is unclear why the rise in incidence is steeper with women. Aging women have shown to have a greater risk than men for an osteoporotic fracture such as proximal humeral fractures [21,22].

Surprisingly little is known regarding whether two, three, or four part humeral fractures in elderly patients should be treated operatively or conservatively [8,11]. There are few randomized controlled trials comparing nonsurgical versus surgical treatment with adequate scoring in follow-up reports [12-14]. In light of the scarce evidence, the significant increase in plating that occurred after the introduction of locking plates in Finland in 2002 is noteworthy. The number and incidences of ORIF with plating more than doubled between 1998 and 2009. These findings may imply that orthopaedic surgeons adopt new fixation systems without conclusive evidence or knowledge whether these fractures should be treated surgically at all. In a previous independent study we observed a significant increase in the surgical treatment of humeral shaft fractures [23]. The change in the rate of surgical treatment was

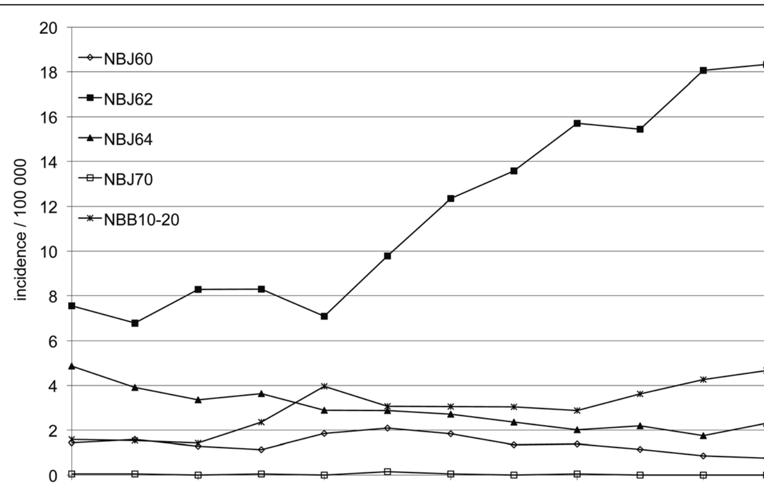

Figure 4 Incidence of surgically treated proximal humerus fractures in Finnish female adults per 100,000 person-years between 1998 and 2009. NBJ60 = nail, NBJ62 = plate, NBJ64 = screw, NBJ70 = external fixation, NBB10-20 = arthroplasty.

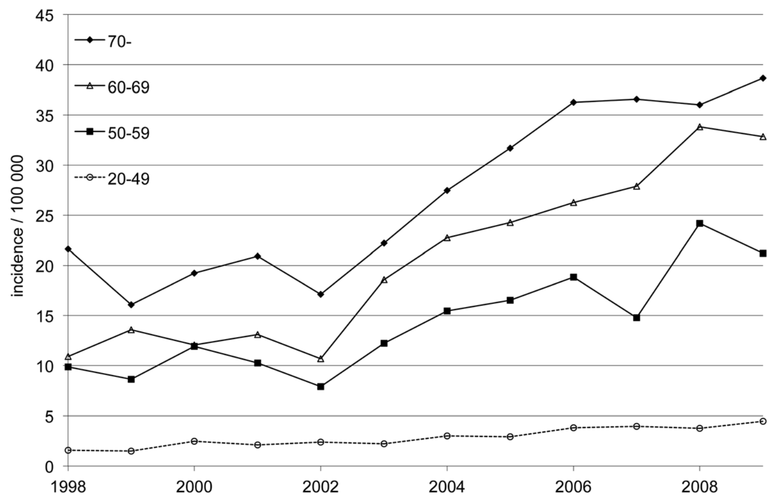

Figure 5 Age-specific incidence of platings for proximal humeral fractures in Finnish female adults per 100,000 person-years between 1998 and 2009.

not as drastic as in the current study on proximal humeral fractures.

The small number of arthroplasty in the surgical treatment of proximal humeral fractures was surprising as based on the literature, joint replacement is usually suggested especially in age groups of 70 years and older [24]. The incidence of arthroplasty was quite steady from the late 80's until the late 90's. The incidence has since risen (Figure 4) but not as sharply as plating. At the same time fracture plating in women over 70 has gained popularity (Figure 5).

In Finland, medical treatment is equally available to everyone and the study population comprised the entire Finnish adult population; therefore, we consider our study reliable. In addition, previous studies reported the coverage and accuracy of the NHDR injury codes to be over 90% [17]. A strength of our study is the excellent national coverage of surgically treated proximal humeral fractures; all surgically treated proximal humeral fractures between 1987 and 2009 are included in this study, whether treated as outpatients or inpatients.

A weakness of this study is that the precise incidence of all proximal humeral fractures cannot be assessed using the NHDR data alone because an unknown number of the fractures were treated conservatively on an outpatient basis. Thus we are not able to deduct whether a part of the increase in the incidence of operative treatment of proximal humeral fractures is due to growing numbers of proximal humeral fractures or a growing tendency towards surgical treatment. The available scientific literature suggests that the majority of proximal humeral fractures are still treated nonsurgically [10,25]. Another limitation of our 23-year study is the change in the ICD procedure-coding system in 1998. Due to the less specific procedural codes in the ICD-9 system, specific data about the implants (i.e., pinning, plates) used could not be evaluated during 1987–1997. Because of this, the main finding of this study between 1987 and 1997 is the increase in the incidence of surgical treatment of proximal humeral fractures. The implementation of locking plates in Finland occurred at the beginning of the 2000s when the more specific ICD-10 coding system was already in use.

In Finland the use of procedural coding of humeral fracture surgery is exercised as explained in Methods but the practical use of procedural coding between different countries may vary. For instance plating of humeral fracture in Finland is NBJ62 but NBJ61 in Norway. The possible differences in procedural coding have to therefore be taken into account when comparing results between different countries.

According to Bell and co-workers, the incidence of surgical treatment for proximal humeral fractures has increased in North America [10]. With the lack of consensus on the treatment of choice for proximal humeral fractures, this increased incidence of surgical treatment seems controversial, especially for the older age groups. The lack of evidence makes it difficult to determine whether ORIF with plating is the best surgical treatment option. According to our data, with the exception of plating and arthroplasty, the incidence of all other surgical treatment options has decreased with time, consistent with the findings of Bell et al. [10].

Conclusions

Given the scarce amount of evidence concerning surgical versus nonsurgical treatment of proximal humeral fractures, the marked increase in plating procedures performed after the introduction of locking plates in 2002 is noteworthy. In clinical practice good functional outcome and patient satisfaction in shoulder-specific questionnaires, and minimal rate of complications and reoperations should be characteristic for surgical treatment of the proximal humeral fractures. To assess whether (or which) surgical treatment provides this we need more high-quality prospective randomised clinical studies with adequate follow-up.

Competing interests
The authors declare no competing interests.

Authors' contributions
TH and VM were in charge and contributed in all stages of the study. AL contributed in data interpretation and writing the final manuscript. PK and HP contributed in study design, data collection, data interpretation and writing the final manuscript. All authors read and approved the final manuscript.

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Treatment of proximal humerus fractures in the elderly

A systematic review of 409 patients

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Background and purpose — There is no consensus on the treatment of proximal humerus fractures in the elderly.

Patients and methods — We conducted a systematic search of the medical literature for randomized controlled trials and controlled clinical trials from 1946 to Apr 30, 2014. Predefined PICOS criteria were used to search relevant publications. We included randomized controlled trials involving 2- to 4-part proximal humerus fractures in patients over 60 years of age that compared operative treatment to any operative or nonoperative treatment, with a minimum of 20 patients in each group and a minimum follow-up of 1 year. Outcomes had to be assessed with functional or disability measures, or a quality-of-life score.

Results — After 2 independent researchers had read 777 abstracts, 9 publications with 409 patients were accepted for the final analysis. No statistically significant differences were found between nonoperative treatment and operative treatment with a locking plate for any disability, for quality-of-life score, or for pain, in patients with 3- or 4-part fractures. In 4-part fractures, 2 trials found similar shoulder function between hemiarthroplasty and nonoperative treatment. 1 trial found slightly better health-related quality of life (higher EQ-5D scores) at 2-year follow-up after hemiarthroplasty. Complications were common in the operative treatment groups (10–29%).

Interpretation — Nonoperative treatment over locking plate systems and tension banding is weakly supported. 2 trials provided weak to moderate evidence that for 4-part fractures, shoulder function is not better with hemiarthroplasty than with nonoperative treatment. 1 of the trials provided limited evidence that health-related quality of life may be better at 2-year follow-up after hemiarthroplasty. There is a high risk of complications after operative treatment.

Proximal humerus fractures are common, and most of them occur in elderly patients. The incidence in Finland was reported to be 105 per 10^5 person-years in 2002 (Palvanen et al. 2006), but this varies depending on the geographic area (Hagino et al. 1999, Court-Brown and Caesar 2006). The number of proximal humerus fractures has increased during the last few decades. As the population ages, the number of proximal humerus fractures would be expected to increase further (Palvanen et al. 2006).

Proximal humerus fractures are often displaced and comminuted in the elderly. The treatment method varies between countries, hospitals, and different surgeons. The popularity of plate fixation has increased in Finland with no real evidence to support it (Huttunen et al. 2012).

The literature on proximal humerus fractures is vast, but there has been little high-quality research comparing different treatments. There have been a few randomized controlled trials (RCTs), but rather than giving exact answers, these studies appear to have raised even more questions. Because previous systematic reviews (Lanting et al. 2008, Sproulet al. 2011, Brorson et al. 2012) and the latest Cochrane review (Handoll et al. 2012) have not included the RCTs published in recent years, we wanted to evaluate all of the relevant literature and to summarize the current evidence-based knowledge on the treatment of proximal humeral fractures in the elderly. Moreover, the above reviews did not concentrate on the troublesome osteoporotic fractures. We assessed the effect of operative treatment on function and/or disability and complications of different treatments in elderly patients with proximal humeral fractures.

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Table 1. PICOS criteria for the trials included

Patients:	Age 60 years or older with a 2-, 3-, or 4-part proximal humerus fracture due to recent trauma
Intervention:	Any operative treatment (at least 20 patients in each treatment group)
Control:	Any treatment (at least 20 patients in each treatment group)
Outcome:	Any functional or disability score and/or any quality-of-life score after a minimum follow-up of 1 year
Study setting:	Randomized, controlled trial or controlled clinical trial

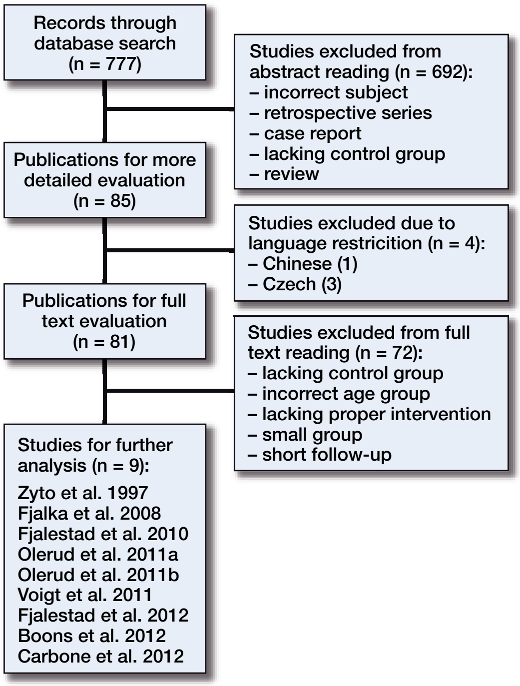

Figure 1. Flow chart of publications investigated, from search for abstracts to final analysis.

Materials and methods

We conducted a systematic search of the following electronic databases, without language restrictions, covering the years 1946 to 2012: Ovid MEDLINE and the Scopus database, which includes Embase. The last search was carried out on April 30, 2014. The search terms were: “shoulder fractures”, “proximal humeral fracture”, and “rehabilitation, surgery, therapy”. The detailed MESH terms are given in the appendix (see Supplementary data).

The abstracts of the publications retrieved were manually checked and relevant publications were selected for further analysis. Reviews, trial protocols, and retrospective studies were excluded. In the next phase, full articles were obtained for all potentially relevant papers, to determine whether they fulfilled the inclusion criteria. The PICOS principle was used to determine the inclusion and exclusion criteria (Table 1). These phases were performed independently by 3 authors. Any discrepancies regarding the inclusion criteria were settled by negotiation between the authors.

Data extraction and quality assessment

The data in the studies were evaluated by 1 author using a predefined data sheet. The extraction was checked independently by 2 other authors; thus, each citation was checked at least twice. We collected information on study design and descriptive data, such as the fracture classification used, types of treatment in the intervention and control groups, group sizes, drop-out rates, and patient demographics; the effects of treatment, including primary and secondary outcomes, reported complications, and reoperation rate; and study quality, including the criteria for the risk of bias. The risk of bias was assessed as suggested by Furlan et al. (2009). The risk of bias was considered to be low when 6 or more criteria out of 12 were met, and the risk was rated as high when less than 6 out of 12 criteria were met. During this assessment, we contacted each main author (n = 8) in order to obtain additional information and clarification if there was inadequate reporting in the publication. 5 of the authors replied to queries regarding missing information on randomization, allocation, and baseline group similarities. With the additional information from the authors, the analysis of bias risk was complete. In addition, the potential conflicts of interests reported by the authors were documented.

Results

After eliminating duplicates, the database search resulted in 777 abstracts. 9 papers met the inclusion criteria and were accepted for review (Figure 1 and Table 2). 692 abstracts did not meet the inclusion criteria and were excluded, due to being retrospective in design or to lacking a control group.

The study populations involved 409 patients. 8 studies were randomized controlled trials (RCTs) and 1 was a controlled clinical trial (Carbone et al. 2012). In all trials, the patients had a recent 3- or 4-part fracture based on Neer’s classification (Neer 1970). 6 trials compared operative treatment and nonoperative treatment. Voigt et al. (2011) compared monoaxial and polyaxial constructions in locking plates, Fialka et al. (2008) compared 2 different prostheses, and Carbone et al. (2012) compared 2 different pinning operations. Zyto et al. (1997) compared use of a tension band and conservative treatment. In 3 studies (Fjalestad et al. 2010, Olerud et al. 2011b, Fjalestad et al. 2012), locking plates were compared to nonoperative treatment for 3- and 4-part fractures. 2 trials (Olerud et al. 2011a, Boons et al. 2012) compared prosthesis and nonoperative treatment for 4-part fractures. The study designs and patient populations are given in Table 2. Table 3 summarizes the primary and secondary outcomes.

Table 2. Study designs

A	B	C	D	E	F	G	H	I	J	K	L
Zyto 1997	Sweden	RCT	3(-4)		Tension band (20)	Nonoperative (20)	12	40/38	73	75	2
Fialka 2008	Austria	RCT	4	11-C	Hemiarthroplasty (Epoca (20))	Hemiarthroplasty (HAS (20))	12	40/35	74	73	5
Fjalestad 2010	Norway[b]	RCT	3-4	11-B2, 11-C2	Plating [a] (25)	Nonoperative (25)	12	50/48	72	73	2
Olerud 2011a	Sweden	RCT	4		Hemiarthroplasty (Global FX (27))	Nonoperative (28)	24	55/49	76	78	6
Olerud 2011b	Sweden	RCT	3		Plating (Philos (30))	Nonoperative (30)	24	60/53	73	75	7
Voigt 2011	Germany	RCT	3-4		Plating (humeral suture plate (25))	Plating (Philos (31))	12	56/48	76	72	8
Fjalestad 2012	Norway[b]	RCT	3-4	11-B2, 11-C2	Plating [a] (25)	Nonoperative (25)	12	50/48	72	73	2
Boons 2012	Netherlands	RCT	4		Hemiarthroplasty (Global FX (25))	Nonoperative (25)	12	50/47	76	80	3
Carbone 2012	Italy	CCT	3-4		MIROS pinning (31)	Traditional pinning (27)	24	58/52	78	81	6

A Author
B Country
C Design
D Neer
E AO-OTA
F Intervention (n at baseline)
G Control (n at baseline)
H Follow-up, months
I No. of patients at baseline/follow-up
J Mean age (intervention group)
K Mean age (control group)
L Drop-out, n
[a] Nonspecific LCT AO-type locking plate.
[b] Both publications are from the same population.

Table 3. Functional results of the trial. Values are mean (SD) unless otherwise stated

	Primary outcome measure			Secondary outcome measure			Adjacent outcome measure		
Author	Intervention	Control	p-value	Intervention	Control	p-value	Intervention	Control	p-value
Zyto 1997	CS: 60 (19)	65 (15)	> 0.05						
Fialka 2008	ICS: 70 (38–102)[b]	46 (15–80)[b]	0.001	CS: 52 (20–80)[b]	33 (8–68)[b]	na			
Fjalestad 2010 [a]	CD: 35 (28–43)[b]	33 (26–40)[b]	0.6	ASES: 15 (12–18)[b]	16 (13–18)[b]	0.7			
Olerud 2011a	EQ: 0.81 (0.12)	0.65 (0.27)	0.02	CS: 48 (16)	50 (21)	0.8	DASH: 30 (18)	37 (21)	0.3
Olerud 2011b	CS: 61 (19)	58 (23)	0.6	DASH: 26 (25)	36 (27)	0.2	EQ: 0.70 (0.34)	0.59 (0.35)	0.3
Voigt 2011	SST: 8 (3)	10 (2)	0.3	DASH: 18 (16)	16 (12)	1.0	CS: 73	81	> 0.05
Fjalestad 2012 [a]	15D: 0.84 (0.11)	0.82 (0.08)	0.4						
Boons 2012	CS: 64 (16)	60 (18)	0.4	SST: 25 (8–100)	23 (0–92)	0.6	VAS12: 23 (1–65)[c]	25 (1–93) [c]	0.7
Carbone 2012	CS: 60	CS: 52	0.02	SSV: 90	73	0.02			

CS = Constant Score;
ICS = Individual Constant Score determined by comparing the operated shoulder to the patient's unaffected shoulder in percent;
CD = Constant Score difference at 12 months, and to reduce the influence of age, the difference between the scores for the injured and uninjured shoulders was used;
ASES = American Shoulder and Elbow Surgeons Shoulder Score
EQ = Euroqol-5D
DASH = Disabilities of the Arm, Shoulder, and Hand
SST = Simple Shoulder Test
SSV = Subjective Shoulder Value
VAS12 = Visual Analogue Scale at 12 months, mean (range)
[a] Both publications are from the same population.
[b] Threshold values
[c] Range

3 of the 9 studies had a high risk of bias. They lacked appropriate randomization (e.g. sealed envelopes, random number generation, and/or concealment of allocation) or did not report baseline characteristics in an appropriate way. The remaining 6 studies had a low risk of bias (Table 4, see Supplementary data).

Outcomes and complications

Tension band

Zyto et al. (1997) reported the results of a comparison of tension band and nonoperative treatment after 1-year follow-up. The Constant score (CS) was 60 and 65, respectively, at 1 year, but the difference was reported as not being significant. A 10-point difference in CS has been considered to be clinically significant in rotator-cuff tears (Kukkonen et al. 2013).

Zyto et al. (1997) reported a total of 8 complications among patients. In the intervention group, the surgical site infection rate was 2 out of 19. In 1 case, the K-wire penetrated the glenohumeral joint and another patient experienced a pulmonary embolus. In the later phase, 2 patients in the intervention group developed osteoarthritis (1 patient after non-union) and 2 patients in the control group developed osteoarthritis.

Pinning

Carbone et al. (2012) reported the results of a comparison of MIROS pinning and traditional pinning after 2 years of follow-up. The MIROS was described as "a new percutaneous pinning device allowing correction of angular displacement and stable fixation of fracture fragments". The mean CS was 60 for MIROS pinning and 52 for traditional pinning, and the mean subjective shoulder evaluation value was 90 vs. 73. Both results were statistically significant in favor of MIROS pinning, but they lacked clinical significance.

Carbone et al. (2012) also reported 3 complications in 28 patients in the MIROS group and 7 complications in 26 patients in the traditional pinning group, including 4 pin-track infections. They did not report any reoperations.

Locking plate

Fjalestad et al. (2010, 2012) compared locking plate and nonoperative treatment in 3- and 4-part fractures. The primary outcome was a difference in CS (CSD 12) at 12 months; in order to reduce the influence of age, the difference between the scores of the injured and uninjured shoulder was used. No statistically significant or clinically significant differences were found in any of the following outcomes. The mean CSD12 was 35 and 33 in the surgical and nonoperative treatment groups, respectively, and the mean American Shoulder and Elbow Surgeons shoulder score (ASES) was 15 and 16. In assessing health-related quality of life (HRQoL), mean 15D in the surgery group was 0.84 and it was 0.82 in the nonoperative group.

Olerud et al. (2011b) found similar CS in operative and nonoperative groups for 3-part fractures (61 vs. 58). Disabilities of the arm, shoulder, and hand (DASH) (operative 26 vs. nonoperative 36; $p = 0.2$) and Euroqol-5D (EQ-5D; operative 0.70 vs. nonoperative 0.59; $p = 0.3$) were similar between groups at 2 years.

Voigt et al. (2011) found no significant differences between polyaxial and monoaxial constructions in locking plates in the simple shoulder test (8.6 vs. 9.7; $p = 0.3$), DASH (18 vs. 16; $p = 1.0$), and CS (73 vs. 81; $p > 0.05$)

Fjalestad et al. (2010, 2012) reported 1 hardware failure, 7 screw cut-outs, and 2 deaths in 3 months in the surgery group. 4 of the 25 patients needed a reoperation. 1 of the nonoperatively treated patients was operated on later. Olerud et al. (2011b) reported screw penetrations in 5 of 30 cases in the primary postoperative period, and 3 additional screw penetrations at 4 months. 1 case of primary postoperative infection was reported, and 1 patient in the nonoperative group had non-union. Altogether, 4 patients died (2 from each group), for reasons not related to surgery. Reoperations were required for 9 of 30 patients in the locking plate group during the 2-year follow-up period. Voigt et al. (2011) reported 6 complications in the intervention (polyaxial) group ($n = 20$) and 8 in the control (monoaxial) group ($n = 28$). Reoperations were performed in 6 and 4 cases.

Hemiarthroplasty

In the studies comparing hemiarthroplasty with nonoperative treatment, all the patients had 4-part fractures. Olerud et al. (2011a) found that the operative group had better mean EQ-5D (0.81) than the nonoperative group (0.62), which was clinically and statistically significant ($p = 0.02$). However, mean DASH (30 vs. 37; $p = 0.3$) and CS (48 vs. 50; $p = 0.8$) were not significant at the 2-year follow-up. Boons et al. (2012) found no statistically significant differences in mean values for CS (operative treatment 64 vs. nonoperative treatment 60), the simple shoulder test (25 vs. 23), or the visual analog scale (VAS) at 12 months (23 vs. 25).

Fialka et al. (2008) compared 2 prostheses: Epoca (Depuy Synthes) and HAS (Stryker). The individual Constant score (CSindiv) was determined by comparing the operative shoulder to the patient's unaffected shoulder. The CSindiv was 70% and 46% for the Epoca and HAS ($p = 0.001$), and absolute CS was 52 vs. 33 (p-value not reported) at the 1-year follow-up, with both results favoring the Epoca prosthesis.

Olerud et al. (2011a) reported 1 non-union in their nonoperative group ($n = 28$). Of all 55 patients, 5 died—3 in the operative group ($n = 27$) and 2 in the nonoperative group ($n = 28$), and none fracture-related. 3 patients in the operative group required reoperation, and 1 patient in the nonoperative group with non-union received operative treatment. Boons et al. (2012) reported 4 tuberculum malpositions and 2 greater tubercle non-unions in the operative group. 5 cases of non-union were reported in the nonoperative group ($n = 25$). 1 patient required reoperation, and the other patient in the nonoperative group was operated on at 13 months. Fialka et al. (2008) reported 2 infections in the operative group ($n = 18$); these were treated nonoperatively with antibiotics.

Discussion

8 RCTs from 7 study populations and 1 controlled clinical trial—all published between 1946 and April 30, 2014—ful-

filled our inclusion criteria. In these trials, there were no significant differences in functional outcomes between surgical treatment with a tension band and nonoperative treatment. Moreover, the complication rate was greater with operative treatment. With locking plate systems, operations did not result in substantial improvement in function or HRQoL scores compared to nonoperative treatment. Furthermore, patients treated operatively had high complication rates (10–29%) and high reoperation rates (16–30%).

In 4-part fractures, HRQoL measured with the EQ-5D was better, both clinically and statistically, with fracture prosthesis than with nonoperative treatment. However, the reliability of EQ-5D in the assessment of HRQoL in patients with a proximal humeral fracture is controversial. Olerud et al. (2011c) reported good internal and external responsiveness of EQ-5D in patients with a proximal humeral fracture. In contrast, Slobogean et al. (2010) and Skare et al. (2013) found a substantial ceiling effect, which limits the reliability of this instrument. Thus, the results of Olerud et al. (2011a) must be interpreted with caution. In addition, they did not find any significant differences in mean functional shoulder scores between the 2 groups. Up to 20% of patients in the nonoperative group had non-union, whereas tuberculum malposition was detected in 16% of the patients in the operative group. Non-union and tuberculum malposition compromise clinical results and lead to poor range of movement (ROM).

Comparison of surgical alternatives

The functional outcomes favored the Epoca prosthesis over the HAS prosthesis. Both groups had very few complications. However, 1-year follow-up is too short for detection of loosening, detection of wear, and determination of prosthesis survival. Some studies have addressed the treatment of complicated proximal humerus fractures with reverse prostheses (Cuff and Pupello 2013, Cazeneuve and Cristofari 2014), but there have been no high-quality trials to match the inclusion criteria of our review. No differences were found in function or complication rate between patient groups in whom monoaxial or polyaxial screws were used with the locking plate. Comparing MIROS pinning and traditional pinning, MIROS gave better functional results and a lower complication rate. All of the results comparing 2 surgical alternatives are from publications with a high risk of bias.

We realize that the criteria used in our review are tight, excluding trials that may have potential clinical significance, but our primary aim was to collect evidence for treatment of elderly patients with proximal humerus fracture. Although we initially limited inclusion to patients aged 60 years or more, we decided to include 3 papers with some younger patients (Fialka et al. 2008, Olerud et al. 2011a, b). However, the mean age of the patients in these studies was 74–77 years. Leaving these 3 rather good-quality trials out of the analysis would have left us with too few trials to draw any conclusions from, so they were included according to the PRISMA recommendations acknowledging the need for an iterative process in some systematic reviews (Moher et al. 2009). Another limitation may be related to uncertain classifications systems, and therefore unknown patient recovery for distinct fracture types (Majed et al. 2011). 3 publications had a high risk of bias. As the publications in this review were heterogeneous regarding patient groups, interventions, and outcome measures, a meta-analysis was not justified.

The Cochrane library published the latest systematic review on this subject in December 2012 (Handoll et al. 2012). They concluded that, "There is insufficient evidence to inform the management of these fractures". The difference with our analysis is that we set the age limit at 60 years and older, and we had criteria for the appropriate group sizes. Furthermore, our analysis includes papers by Fjalestad et al. (2012), Boons et al. (2012), and Carbone et al. (2012), which were published after the Cochrane review. According to the trial registries (clinicaltrials.com, controlled-trials.com), there are currently 5 trials enrolling patients to compare operative and nonoperative treatment.

In summary, there are too few trials for a solid evidence base. Furthermore, 3 of the publications had a high risk of bias, but these papers assessed differences between 2 operative treatments and did not provide evidence for the main question: whether to use operative or nonoperative treatment. However, there is some weak evidence in favor of nonoperative treatment over surgery with locking plate systems and tension banding. 2 trials have provided weak to moderate evidence that for 4-part fractures, shoulder function is not better with hemiarthroplasty than with nonoperative treatment. One of the trials has provided limited evidence that health-related quality of life may be better at 2-year follow-up after hemiarthroplasty. With high complication rates for all operative treatments, these should not be considered to be the gold standard in the treatment of proximal humerus fractures.

Supplementary data

Table 4 and Appendix are available at Acta's website (www.actaorthop.org), identification number 7918.

AL, VL, and TF performed the data extraction. All the authors took part in data analysis and in drafting of the manuscript.

No competing interests declared.

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ORIGINAL ARTICLE

Epidemiology of proximal humerus fractures

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Abstract

Summary There are only a few previous population-based studies that include both inpatient and outpatient treatment data. The aim of this study was to investigate the epidemiology of proximal humerus fractures. The incidence of proximal humerus fractures increases with age, and we observe a seasonal variation strongly favoring winter months.

Purpose Proximal humerus fractures are the third most common osteoporotic fracture type observed in elderly patients, after wrist and hip fractures. However, few previous population-based studies include both inpatient and outpatient treatment data. The aim of this study was to investigate the incidence, fracture morphology, and treatment method provided in cases of proximal humerus fractures.

Methods We retrospectively studied patient records from a mid-sized town in Finland between the years 2006 and 2010. The following data were collected from the medical records: age, sex, date of the fracture, laterality of the fracture, mechanism of injury, treatment method, and other associated fractures at the time of the original injury. Sex and age distributions of the patient population at risk (>18 years old) were calculated for the study period.

Results A total of 678 patients (females n=503, 73 %) with 692 proximal humerus fractures were identified. The unadjusted incidence was 82 (95 % CI 76 to 88) per 100,000 person-years, 114 (95 % CI 104 to 124), and 47 (95 % CI 41 to 54) per 100,000 person-years in females and males, respectively. Incidence increased toward the older age groups. Clear seasonal variation was observed, two-part fractures were most common (428, 62 %), the majority of the fractures (n=539, 78 %) were treated nonoperatively with a sling.

Conclusion The incidence of proximal humerus fractures increases with age, and we observe a seasonal variation strongly favoring winter months. It is evident that proximal humerus fractures cause considerable morbidity among elderly people and consume health care resources.

Keywords Epidemiology · Proximal · Humerus · Fracture

Introduction

Proximal humerus fractures are the third most commonly observed osteoporotic fracture type in elderly patients, after wrist and hip fractures [1, 2]. The crude incidence rate displays great variance, depending on geographic area and year in which the study was conducted [3, 4]. It has been suggested that the overall fracture rate is increasing along with the increase in the elderly, post-war population [5, 3]. This trend in overall fractures in elderly patients is also seen in the incidence of proximal humerus fractures [6, 7]. However, little data exist about changes in the age-specific incidence rates over the past decades.

When interpreting incidence figures taken from different studies, one must consider the methodology of the data collection. When the data are derived from a hospital discharge register, such as in the study of Palvanen et al. [8, 7], the total incidence rate is underestimated, as discharge registers include only hospitalized patients and thus exclude patients treated on

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an outpatient basis in emergency departments. In addition, a great number of proximal humerus fractures in Nordic countries are treated on an outpatient basis at local health care centers, and these patients are also not included in the hospital discharge registers. To our knowledge, only a few population-based studies exist that include both inpatient and outpatient treatment [9–11]. In Rochester, Minnesota, USA, unadjusted incidences were observed to be 30 per 100,000 person-years for males and 71 per 100,000 person-years for females, as measured from 1965 to 1974. In Copenhagen, Denmark, the incidences were observed to be 48 per 100,000 person-years for males and 142 per 100,000 person-years for females, as measured in 1983. In Edinburgh, Scotland, a study conducted from 1992 to 1996 did not determine the total incidences, but observed peak incidence rates among 80- to 89-year-old females of 260 per 100,000 person-years and 109 per 100,000 person-years among males.

The aim of this study was to investigate the incidence, fracture morphology, and treatment methods provided to patients with proximal humerus fractures over a 5-year period in a mid-sized city in Finland, using both inpatient and outpatient data.

Materials and methods

Tampere is a mid-sized town in southern Finland with a population of approximately 220,000. Within the catchment area included in this study, Tampere City, two hospitals treat patients with proximal humerus fractures: Hatanpää City Hospital and Tampere University Hospital. During the study period, both hospitals provided inpatient operative treatment and outpatient treatment for the Tampere inhabitants included in the study.

The criteria for inclusion in this study were as follows: patients over 18 years of age; had visited our study hospitals between January 1, 2006 and December 31, 2010, with a diagnosis of proximal humerus fracture; and were registered in Tampere. Patients who were temporarily living in Tampere, but registered elsewhere, were not included into the study. Eligible patients were identified by a computer-based search of electronic patient records and files using ICD-10 diagnostic code S42.2 (proximal humerus fracture) and a keyword search (for "proximal humerus fracture," "shoulder fracture," or "shoulder"). All patient records were reviewed and analyzed by two researchers (AL, AS). Duplicates were checked and excluded after confirming that the patient in question was truly a duplicate rather than an individual who had two separate fractures during the study period. The data were gathered in predefined data sheets.

The following data were collected from the medical records: age, sex, date of the fracture, laterality of the fracture, mechanism of injury, treatment method, and whether there were associated fractures at the time of the original injury or later in the study period. Two independent researchers (AL, VL) evaluated the patients' radiographs to confirm the diagnosis and classified the fractures according to Neer classification [12]. In cases where there was disagreement, a consensus was reached by negotiation.

The total number, sex distribution, and age distribution of the population at risk (>18 years old) for each year of the study period was derived using the Statistics Finland website (www.tilastokeskus.fi). The Statistics Finland holds information of each registered inhabitant of Finland and extraction of risk population in any given region is easy by computer. The crude incidence rate and the sex- and age-specific incidence rates were calculated using 10-year age intervals per 100,000 person-years.

Categorical data were analyzed using Fisher exact tests using OpenEpi software (openepi.com). A P value of <0.05 was considered statistically significant. Confidence intervals (CI) of 95 % were calculated with respect to incidence rates.

Results

A total of 678 patients (females n=503, 73 %) with 692 proximal humerus fractures were identified during the study period between 2006 and 2010. The overall unadjusted incidence of proximal humerus fractures was 82 per 100,000 person-years (95 % CI 76 to 88). The unadjusted incidence in females was 114 (95 % CI 104 to 124) per 100,000 person-years; in males, it was 47 (95 % CI 41 to 54) per 100,000 person-years. The incidence rate ratio (male to female) was 0.42 (95 % Cl 0.41 to 0.42). Age- and sex-specific incidences in females are shown in Table 1, and males are shown in Table 2. In females, the incidence increased with age from 39 per 100,000 person-years at the age of 40–49 to 379 per 100,000 person-years over the age of 80 (Table 1, Fig. 1). The corresponding increase in males was from an incidence of 31 to 232 per 100,

Table 1 Five-year mean incidences, number of fractures, and number of at-risk members of the female population, displayed by age group with 95 % confidence intervals

Age group	Person-years	Fractures (n)	Incidence (95 % CISD)
20–29	100,966	13	13 (7–22)
30–39	65,806	12	18 (10–31)
40–49	66,743	26	39 (26–56)
50–59	70,418	79	112 (89–139)
60–69	61,740	119	193 (160–230)
70–79	44,300	131	296 (248–350)
80–	32,169	122	379 (316–451)

Incidences are per 100,000 person-years

Table 2 Five-year mean incidences, number of fractures, and number of at-risk members of the male population, displayed by age group with 95 % confidence intervals

Age group	Person-years	fractures (*n*)	Incidence (95 % CISD)
20–29	104,468	14	13 (8–22)
30–39	74,828	12	16 (9–27)
40–49	66,846	21	31 (20–47)
50–59	63,430	40	63 (46–85)
60–69	51,684	45	87 (64–116)
70–79	28,960	29	100 (68–142)
80–	12,514	29	232 (158–329)

Incidences are per 100,000 person-years

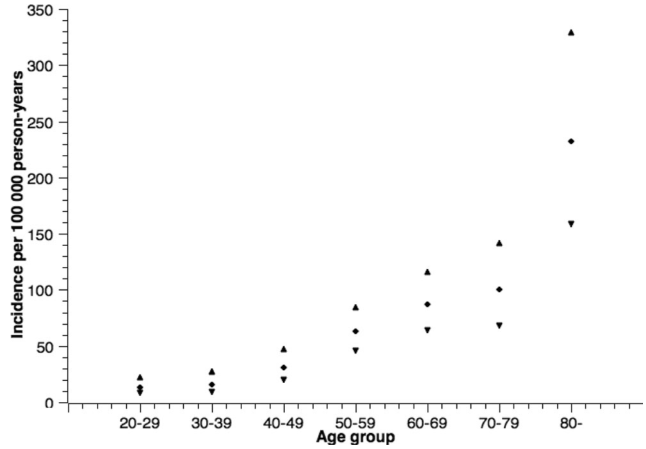

Fig. 2 Five-year mean incidences with 95 % confidence intervals in male population by age group

000 person-years (Table 2, Fig. 2). In persons under 40 years of age, the incidence was low.

A fall from standing height was the most common trauma mechanism that recorded (*n*=618, 89 %), followed by traffic injuries (*n*=29, 4 %), a fall from a ladder (*n*=15, 2 %), and physical abuse (*n*=7, 1 %). Alcoholic or epileptic seizures were also noted as a causal trauma (*n*=9, 1 %). The type of trauma mechanism was related to age: high-energy trauma (*n*=44) in younger patients and low-energy trauma (*n*=619) predominated in elderly patients. A total of 97 patients (14 %) had another fracture or fractures in addition to the proximal humerus fracture during the 5-year follow-up period. Those most commonly observed were distal radius, proximal femoris, and lateral malleolar fractures.

The monthly distribution of the fractures showed a clear seasonal variation. The highest number of fractures occurred during the late fall and winter, from November to March (Fig. 3), while the lowest number occurred in September.

Classification

More than half of the fractures (*n*=374, 54 %) were seen in the left shoulder and 318 fractures (46 %) were in the right shoulder. The most common classification, using the system established by Neer, was two-part (428, 62 %), followed by three-part (128, 19 %), and one-part (90, 13 %) fractures, while four-part fractures accounted for only 7 % of the total (*n*=46). Three- and four-part fractures were more common in females compared to males (28 % vs. 18 %, *p*=0.05).

Treatment

The majority of the fractures (*n*=539, 78 %) were treated nonsurgically with a sling. Within the surgically treated fractures, the most common fixation method used was locking plate (*n*=115, 75 %). The most typical fracture classification among patients receiving surgery was two-part (*n*=73, 64 %), followed by three-part (*n*=43, 30 %), and four-part (*n*=7, 6 %) fractures. In 25 cases (16 % of surgically treated fractures), fracture prostheses were used. The use of screws and tension wires was uncommon in our sample (*n*=13, 9 %). The majority of prostheses were used for patients with four-part fractures (*n*=16, 64 %). During the 5-year period studied, the yearly

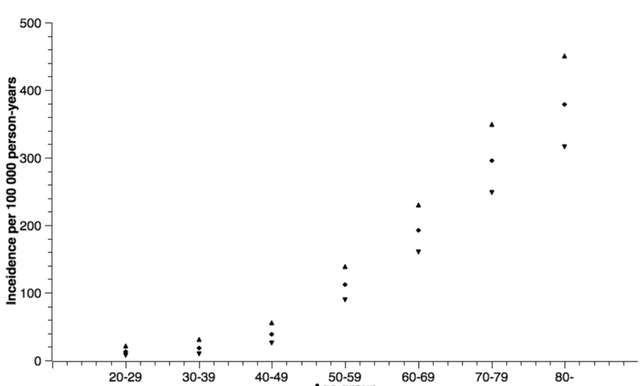

Fig. 1 Five-year mean incidences with 95 % confidence intervals in female population by age group

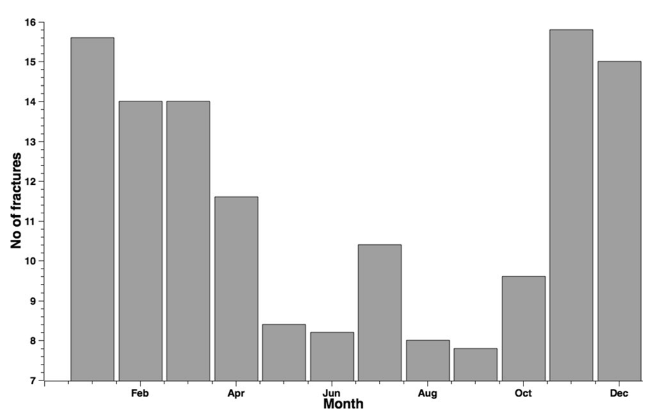

Fig. 3 Number of fracture cases observed over a 5-year period, displayed by month

proportion of patients subject to surgical treatment did not vary significantly (p=0.43), between 21 and 27 %.

Discussion

Proximal humerus fractures predominantly affect older patients, and as the elderly population continues to rise, the number of these fractures seen in the clinical setting is substantially increasing. The incidence of proximal humerus fractures has been growing steadily, and it has been suggested that the rate might triple over the next 30 years [8]. In this study, we found the total incidence of proximal humerus fractures to be 82 per 100,000 person-years, which is in accordance with the previous results. The total unadjusted incidence in females was 114 per 100,000 person-years and 47 per 100,000 person-years in males. The incidence of proximal humerus fractures in our study is slightly greater than the results from Edinburgh, where it was measured in inpatients over 16 years of age and found to be 63 per 100,000 person-years in 2000 when including both surgically and nonsurgically treated patients with or without hospitalization [4]. Another study from Edinburgh showed that the incidence within female patients 80–90 years old was 260 per 100,000 person-years, which is also less than we observe [9].

We note that differences in the reported incidence of proximal humerus fractures are reported in the literature with respect to elderly female groups in particular; for example, an incidence in females 80 years old and older of 502 per 100,000 person-years in Denmark and an incidence of 439 per 100,000 person-years in Rochester, Minnesota, USA [11, 10]. These figures may lead us to conclude that the incidence of proximal humerus fractures varies by geographical area and by activity, health, and level of care provided to the elderly; however, the data from these studies cannot rigorously be compared with each other [13, 14]. We note that the seasonal variation that we find in proximal humerus fracture incidence is important. Higher incidence of fractures was seen in winter months when roads are icy and slippery. Not all osteoporotic fractures show this strong seasonal variation; for example, lower extremity fractures within the same age groups [15, 16]. Previously, it has been reported that elderly women who sustain proximal humerus fractures tend to live independently in their own houses. Together with the seasonal variation that is observed, this may suggest that proximal humerus fracture patients tend to be more active and ambulatory than hip fracture patients [17].

During the 5-year study period, the annual proportion of surgical treatment varied between 21 and 27 %. This is almost double the rate previously reported by Bell [18]. We found that the most common fixation method used was the locking plate system followed by prosthesis. As shown previously, the use of the locking plate method has increased rapidly compared to other methods, without clear evidence of its superiority [19, 20, 18, 21]. In our sample, the most frequent fracture was two-part (62 %), which is more than twice the number in Edinburg where the one-part was leading with 49 % [9]. The difference may be explained by poor intra- and interobserver sensitivity of all proximal humerus classifications [22, 23].

The retrospective nature and relatively small catchment population of the study is a limitation. We may have missed some fractures, because we did not include private clinics in our study. However, the number of missed fractures is probably very small, because the vast majority of all fractures are treated by the municipal health care in Finland. It is unlikely that the missing fractures affect the results substantially. It would have been interesting to assess the use of anti-osteoporotic drugs, but we were unable to get reliable information from the patient records. The strength of the present work is that we could reliably include both surgically and conservatively treated patients in a single, well-defined population. We were able to gather data for the majority of humerus fracture patients within this entire typical mid-sized western European city. As our health care system is equally available to everyone, and the coverage of the injured patients within these data is excellent, the incidence rates we calculate for both surgically and conservatively treated patients are reliable, in contrast to the majority of previous studies, in which only hospitalized patients were included [6].

In summary, the incidence of proximal humerus fractures during this 5-year study period was 114 per 100,000 person-years in females and 47 per 100,000 person-years in males. The present study assessed the total population-based incidence of proximal humerus fractures, as it included not only surgically treated patients upon hospital discharge, but also those treated nonsurgically in hospitals and health care centers. The incidence of proximal humerus fractures increases with age, and we observe a strong seasonal variation favoring the winter months. The incidence may also vary by geographical area, presumably reflecting activity, health, and level of care provided to the elderly; however, it is not possible to rigorously compare the data from these geographically distinct studies. Proximal humerus fractures cause substantial morbidity among elderly people as well as substantial cost in the use of health care resources. In our sample, one-fifth of the patients were treated surgically, despite a lack of evidence to support surgical treatment, and further research comparing approaches and outcomes is warranted.

Conflicts of interest None.

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