ETIOPATHOLOGY AND TREATMENT-RELATED ASPECTS OF HIP FRACTURE

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Abstract

Hip fracture is a trauma with serious consequences, especially in the elderly. Etiological factors should be known better than nowadays to recognize the individuals at high risk. Also, the treatment of displaced femoral neck fractures has been controversial, and the factors leading to a functional outcome are not known well. The true impact of deep infection on the outcome after hip fracture surgery has also been insufficiently examined.

The thesis is based on two etiological studies. In the first study, the geometrical parameters of the upper femur and pelvis in postmenopausal women with hip fracture were (n = 70) compared to age-adjusted controls (n = 40). Measurements were made from position-standardized and calibrated pelvic plain x-rays. The differences between the two different types of hip fracture, femoral neck fractures (n = 46) and trochanteric fractures (n = 24) were also defined. High femoral neck/shaft angle (NSA), thin femoral cortices, low femoral shaft diameter (FSD) and trochanter width and the pelvic dimensions associate strongly with the hip fracture risk in postmenopausal women. Greater NSA, smallest outer pelvic diameter and acetabular width, narrower FSD and smaller femoral neck/shaft cortex ratio were associated with femoral neck fracture rather than trochanteric fracture in postmenopausal women. In the second study, lifetime factors, some bone metabolism markers and bone mineral density were analyzed from postmenopausal women (n = 74; 49 with femoral neck fracture, 25 with trochanteric fracture) and age-adjusted controls (n = 40). Impaired functional ability, use of loop diuretics, antidiabetic, antidepressant and neuroleptic drugs, some concurrent diseases, such as stroke, diabetes, malignancy, cardiovascular diseases, low bone mineral density of the upper femur, low serum calcium, low serum 25-hydroxyvitamin D and high serum calcitonin, seem to be related to the risk of hip fracture, while low bone mineral density and low serum calcititin are related to the trochanteric type of fracture in postmenopausal women.

The treatment of displaced femoral fractures included two prospective case-control studies, and the first of these involved a comparison (357 matched pairs) of patients with osteosynthesis (OS) with two pins in Lund and patients with uncemented hemiarthroplasty (HA) in Oulu. The patients treated with OS had 4 months after fracture better ambulatory capacity, used walking aids less often and had less pain than the patients treated with HA. The other comparison (84 matched pairs) was made between OS with three screws and uncemented HA, and it revealed no significant differences between HA and OS in the short-term functional outcome. Both studies revealed a higher re-operation rate in OS patients than uncemented HA patients. The case-control study with 29 matched pairs showed that deep infection after a hip fracture operation impairs the short-term functional outcome and slightly increases mortality, with an attributable mortality rate of 10%. In conclusion, this thesis suggests that the geometry of the upper femur and pelvis, the aforesaid lifetime factors, the aforesaid metabolism markers and bone mineral density are associated with the etiopathology and type of hip fracture in postmenopausal women. The short-term functional outcome was better in OS patients treated with two pins compared to uncemented HA, but the higher re-operation rate should be considered among the OS patients. Deep infection is a serious complication of hip fracture surgery, which impairs function and increases mortality.

Keywords: bone geometry, functional outcome, hemiarthroplasty, hip fracture, osteosynthesis
To Mirja, Henrietta and Herkko
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Oulu August 2003  Juha Partanen
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADL</td>
<td>Active daily living</td>
</tr>
<tr>
<td>AP</td>
<td>Anteroposterior</td>
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<tr>
<td>AW</td>
<td>Acetabular width</td>
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<tr>
<td>BMC</td>
<td>Bone mineral content</td>
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<tr>
<td>BMD</td>
<td>Bone mineral density</td>
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<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>CFE</td>
<td>Calcar femorale</td>
</tr>
<tr>
<td>CV</td>
<td>Coefficient of variation</td>
</tr>
<tr>
<td>CVrms</td>
<td>Root mean square coefficient of variation</td>
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<tr>
<td>CRP</td>
<td>C-reactive protein</td>
</tr>
<tr>
<td>DXA</td>
<td>Dual X-ray absorptiometry</td>
</tr>
<tr>
<td>DHS</td>
<td>Dynamic hip screw</td>
</tr>
<tr>
<td>FEBMD</td>
<td>Femoral neck bone mineral density</td>
</tr>
<tr>
<td>FNALa</td>
<td>Femoral neck axis length a</td>
</tr>
<tr>
<td>FNALb</td>
<td>Femoral neck axis length b</td>
</tr>
<tr>
<td>FNC</td>
<td>Femoral neck cortex</td>
</tr>
<tr>
<td>FSC</td>
<td>Femoral shaft cortex</td>
</tr>
<tr>
<td>FSD</td>
<td>Femoral shaft diameter</td>
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<tr>
<td>FX (and fx)</td>
<td>Fracture</td>
</tr>
<tr>
<td>HA</td>
<td>Hemiarthroplasty</td>
</tr>
<tr>
<td>HAL</td>
<td>Hip axis length</td>
</tr>
<tr>
<td>HD</td>
<td>Head diameter</td>
</tr>
<tr>
<td>LIPD</td>
<td>Largest inner pelvic diameter</td>
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<tr>
<td>ND</td>
<td>Neck diameter</td>
</tr>
<tr>
<td>NSA</td>
<td>Neck-shaft angle</td>
</tr>
<tr>
<td>OR</td>
<td>Odd’s ratio</td>
</tr>
<tr>
<td>OS</td>
<td>Osteosynthesis</td>
</tr>
<tr>
<td>PICP</td>
<td>Intact C-terminal of procollagen type I</td>
</tr>
<tr>
<td>QCT</td>
<td>Quantitative computed tomography</td>
</tr>
<tr>
<td>RR</td>
<td>Relative risk</td>
</tr>
<tr>
<td>s-ALP</td>
<td>Serum alkaline phosphatase</td>
</tr>
<tr>
<td>s-BAP</td>
<td>Serum bone specific alkaline phosphatase</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Description</td>
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<tr>
<td>--------------</td>
<td>-----------------</td>
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<tr>
<td>s-Ca</td>
<td>Serum calcium</td>
</tr>
<tr>
<td>s-CT</td>
<td>Serum calcitonin</td>
</tr>
<tr>
<td>SD</td>
<td>Standard deviation</td>
</tr>
<tr>
<td>s-OC</td>
<td>Serum osteocalcin</td>
</tr>
<tr>
<td>s-25-(OH)-D</td>
<td>Serum 25-hydroxyvitamin D</td>
</tr>
<tr>
<td>SOPD</td>
<td>Smallest outer pelvic diameter</td>
</tr>
<tr>
<td>S-PINP</td>
<td>Serum intact N-terminal of procollagen type I</td>
</tr>
<tr>
<td>THA</td>
<td>Total hip arthroplasty</td>
</tr>
<tr>
<td>TRBMD</td>
<td>Trochanter bone mineral density</td>
</tr>
<tr>
<td>TW</td>
<td>Trochanter width</td>
</tr>
<tr>
<td>WABMD</td>
<td>Ward’s triangle femoral neck density</td>
</tr>
</tbody>
</table>
List of original articles

This thesis is based on the following articles and are referred to in the text by Roman numerals:


# Contents

Abstract  
Acknowledgements  
Abbreviations  
List of original articles  
1 Introduction .................................................. 15  
2 Review of the literature .................................. 17  
2.1 Anatomy of hip fracture ................................. 17  
2.2 Classification of the hip fractures ....................... 18  
2.3 Etiopathology of hip fractures ......................... 19  
2.3.1 Age ...................................................... 21  
2.3.2 Sex ...................................................... 21  
2.3.3 Race ...................................................... 21  
2.3.4 Anthropometric factors ............................. 22  
2.3.5 Bone mineral density ............................... 22  
2.3.6 Geometry .............................................. 23  
2.3.7 Fall ...................................................... 23  
2.3.8 Lifestyle factors ...................................... 24  
2.3.9 Medication and concurrent diseases ................ 25  
2.3.10 Gynaecological factors ............................ 27  
2.4 Differences in the etiopathology of femoral neck and trochanteric fractures .... 27  
2.5 Methods for identifying the risk of hip fracture .... 28  
2.6 Treatment of femoral neck fractures ................. 31  
2.6.1 Comparative studies .................................. 32  
2.6.2 Functional outcome after femoral neck fracture .. 34  
2.7 Deep infection after hip fracture surgery ............. 34  
2.7.1 Definition, risk factors and incidence .............. 34  
3 Aims ......................................................... 36  
4 Patients and methods ...................................... 37  
4.1 Upper femur and pelvic geometry and the risk of hip fracture and fracture type .... 37  
4.2 Lifetime factors, bone metabolism and bone mineral density in patients with hip fracture ............ 39  
4.3 Uncemented Austin-Moore hemiarthroplasty versus two hook pins .............. 41
1 Introduction

Hip fracture is a serious condition that has been found to increase morbidity and mortality in elderly men and women, especially community-dwelling ones (Baudoin et al. 1996). Hip fractures also cause incremental cost, especially during the first year (De Laet et al. 1999). The majority of fractures occur in women, at least one in four being postmenopausal white women (Melton, III 1993). Worldwide, the number of hip fractures has been estimated to rise from 1.7 million in 1990 to 6.26 million by the year 2050 and this is mostly due to the increasing life expectancy and increasing size of the population in nearly all countries (Cooper et al. 1992). In Finland, the age-specific incidence rose from 273/100,000 in 1970 to 412/100,000 in 1991 among women aged 50 or over and from 108/100,000 to 194/100,000 among Finnish men, respectively (Parkkari et al. 1994).

The etiology of hip fractures is multifactorial, and many of the risk factors have been identified (Ribot et al. 1993, Cummings et al. 1995). A combination of several of these independent risk factors may help to define the intervention thresholds for treatment and improve the design of population-level screening policies, particularly in elderly women, who have the greatest risk of hip fracture (Kanis & McCloskey 1996). It has also been postulated that the etiologies of the two main hip fracture types, femoral neck and trochanteric fractures, are different (Mautalen et al. 1996). Knowledge of these differences would also help us to improve the targeting of hip fracture prevention (Michäelsson et al. 1999).

Also, the treatment of hip fractures must be optimal to ensure recovery of the patients. Controversial results have been reported concerning the treatment of femoral neck fractures with the main treatment methods, hemiarthroplasty and osteosynthesis (Lu-Yao et al. 1994). Especially functional recovery has been largely ignored at the cost of the successful healing of the fracture, although it is very important to consider how well the patient is able to resume his/her pre-fracture level of functioning (Koval & Zuckerman 1994).

Deep infection after the treatment of hip fracture is a rare but severe complication (Pietschmann et al. 1988, Mackay et al. 2000), which is associated with high mortality (Eastwood 1993), a prolonged need for hospital stay, a marked decline in mobility, a great increase in social dependency and additional costs for the hospital and for society.
(Aagaard et al. 1994). However, the impact of deep infection on the true functional outcome and mortality of patients has been insufficiently examined.

This thesis focuses on hip fracture patients and the possible risk factors in Finnish postmenopausal women aged over 50 years, with special attention to the differences in the etiopathology of the two main hip fracture types, femoral neck and trochanteric fractures. The two main treatment modalities of femoral neck fracture, hemiarthroplasty and osteosynthesis, are also compared, with a special focus on short-term functional recovery. The determination of the true impact of deep infection after hip fracture surgery on function and mortality was the last topic of this work.
2 Review of the literature

This thesis focuses on hip fracture patients aged over 50 years who have sustained the fracture with “low-energy trauma”, which is a trauma associated falling on the standing height or less. This “low-energy trauma” must considered separately from the traumas of younger patients, who usually sustain hip fractures in traffic accidents and falls from height (Robinson et al. 1995, Hwang et al. 2001).

2.1 Anatomy of hip fracture

Hip fractures can be divided into four categories based on their anatomical location (Fig. 1): 1. femoral neck fracture. 2. basicervical fracture 3. trochanteric fracture and 4. subtrochanteric fracture.

Fig. 1. Anatomical location of hip fracture, modification from Sobotta, Atlas of Human Anatomy, printed with permission from Urban & Fischer Verlag, drawn by Tauno Partanen.

Femoral neck fractures (46 % to 54 % of all hip fractures) and trochanteric fractures (34-46 %) are the most common types of hip fracture. Basicervical fractures (2-8 %) and
2.2 Classification of the hip fractures

There are several classifications of femoral neck fractures, the Pauwels, AO and Garden classifications and the most widely used system is the Garden classification (Fig. 2) (Garden 1964, Müller et al. 1990, Bartonicek 2001).

Basicervical fractures are extracapsular two–part fractures, with the fracture plane running along the line of capsular insertion, just proximal to the lesser and greater trochanter (Parker et al. 1997). It is usually misdiagnosed as either a femoral neck fracture or a trochanteric fracture. It should be classified as a trochanteric fracture and treated as a trochanteric fracture (Saarenpää, I et al. 2002).

There are several classifications of trochanteric fractures. Evans started by classifying trochanteric fractures as stable and unstable fractures (Evans 1949). The most usable classification is the Jensen classification (Fig. 3), which is a modification of the Evans
classification, with the types I and II being regarded as stable fractures and the types 3-5 as comminuted or unstable fractures (Jensen & Michaelsen 1975).

Subtrochanteric fractures can be subdivided into undisplaced, two-part and comminuted fractures, and the Seinsheimer classification (Fig. 4) is mostly used (Seinsheimer 1978).

2.3 Etiopathology of hip fractures

The etiopathology of hip fracture is multifactorial (Fig. 5) but there are three main causes that play an important role in the etiopathology of hip fractures: age, diseases and trauma (Alffram 1964).
Cummings and Nevitt (1989) proposed that hip fracture occurs in a cascade fashion with four conditions that need to be satisfied: the orientation of the fall causes the person to fall straight on his/her hip, the protective flexes fail, the local soft tissues do not absorb the energy, and bone strength is reduced. They also recognized the difference between simple falls by elderly persons and younger persons: the former usually fall laterally on their hip, while the latter fall forward, usually on their hands (Fig. 6).
2.3.1 Age

The incidence of the hip fracture is closely related to age and increases almost exponentially, so that about 90% of hip fractures occur after age 70 (Cummings et al. 1989, Melton, III 1996). The lifetime risk for a woman aged 50 years is 14-18%, compared with 3-6% for a man (Cooper 1998). It is estimated that 30% of older adults will have a hip fracture by age 90. Normal postural stability deteriorates during aging because of changes in vision, vestibular function and the musculoskeletal system, and this contributes to the risk of falls as well as the types of falls (Birge et al. 1994). Bone loss affecting bone strength usually increases by aging (Cummings et al. 1990). Loss of weight during aging affects the local shock absorbers, reducing especially muscles and increasing the risk of fracture after the fall (Cummings & Nevitt 1989).

2.3.2 Sex

White women have a twofold risk compared to white men, while black women and men are at similar risk (Farmer et al. 1984). The cross-sectional geometry of the lower limb bones including the femur may play an important role in the differences of the hip fracture risk between women and men. Men undergo greater subperiosteal expansion upon aging than women and the cortical area remains almost constant in men, but decreases in women. Thus, age-related changes in bone cross-sectional geometry appear to compensate for age-related reductions in bone strength in men but not in women (Mow & Hayes 1991). The absence of a distinct equivalent of menopause with associated acceleration of bone loss in men, their shorter life expectancy, and their reduced propensity to fall, compared to elderly women, who fall two to four times more often than men, are other important factors explaining the difference in the risk of hip fracture between men and women. The risk factor patterns in osteoporosis are also partly different in men and women (Jackson J 1997).

2.3.3 Race

The risk of hip fracture in white Caucasian women is reported to be twofold compared to black women (Farmer et al. 1984). Cancellous bone density increases during a relatively short period in late puberty more in black women than in white women, and the authors conclude that metabolic and hormonal events related to the achievement of sexual maturity during adolescence may be important determinants of the racial differences in bone mass in women (Gilsanz et al. 1991). Body weight might also explain partly the lower incidence of hip fractures in black women than in white women, as the prevalence of obesity is higher in the older black female population (Pruzansky et al. 1989). Hip axis lengths vary between Caucasians, African-American and Asian women, with African and Asian women having significantly shorter hip axis lengths than their Caucasian counterparts, which may diminish the risk of hip fracture in African-American and Asian
women and the possible ethnic differences in geometry are postulated to be due to genetic and/or nutritional differences (Cummings et al. 1994, Theobald et al. 1998). However, there are also controversial findings concerning the hip geometry and the risk of hip fracture between the different ethnic groups (Chin et al. 1997).

### 2.3.4 Anthropometric factors

Anthropometric factors may have an influence on the occurrence of hip fractures (Farmer et al. 1989). Maternal height and a slow rate of childhood growth are major determinants of the subsequent hip fracture risk according to a longitudinal study. Whether a reduced growth rate is a consequence of childhood lifestyle, genetic background or intrauterine hormonal programming remains unknown (Cooper et al. 2001). Tall individuals have been observed to have a higher risk of hip fracture than short individuals in many studies (Hemenway et al. 1995, Lau et al. 2001), although opposite findings have been also reported (Huopio et al. 2000). Height may contribute to the risk of hip fracture by increasing the force associated with falling (Hayes et al. 1993) and height may also influence the geometrical proportions of the hip, such as the hip axis length (Faulkner et al. 1993) or the femoral neck length (Nakamura et al. 1994). Low weight has been reported to be an independent predictor of hip fracture (McGrother et al. 2002). Low weight is also a powerful predictor of very low BMD (T-score ≤ -3.5), which might explain the high risk of hip fracture and another possible explanation for the high risk of hip fracture in low-weight individuals is that a low body weight may be a general marker of poor health and frailty (Dargent-Molina et al. 2000). Low body mass index (BMI) has been established as a risk factor for hip fracture (Hemenway et al. 1988), because low BMI is related to low bone mass (Edelstein & Barrett-Connor 1993).

### 2.3.5 Bone mineral density

Many studies have shown that low bone mineral density (BMD) or low bone mass in the hip region is associated with hip fractures in women and may predict a future hip fracture risk (Libanati et al. 1992, Marshall et al. 1996). Each SD decrease in femoral neck bone density increased the age-adjusted risk of hip fracture 2.6-fold, and in the lowest quartile of BMD the risk of hip fracture was 8.5-fold in a cohort study (Cummings et al. 1993). There are fewer studies on men, but one study showed that men had OR 1.98 for a non-traumatic fracture risk, including hip fracture, compared to women with OR 2.39 based on the measurement of femoral neck bone mineral density (Nguyen et al. 1993). Peak adult bone mass is attained in early adulthood after the end of linear skeletal growth, and it is influenced by genetic factors, hormones, nutrition and physical activity (Stevenson et al. 1989, Tylavsky et al. 1989). Thereafter, there is a period of bone loss, which is associated with age, menopause and various risk factors, such as low body weight, alcohol use and smoking, nulliparity and lack of regular exercise (Stevenson et al. 1989).
2.3.6 Geometry

The geometry of the hip may be an important predictor of a future fracture, because the strength of an object is also a function of its geometry according to the basic engineering principles (Karlsson et al. 1996). Other important principles are the mechanical properties of the material from which the structure is made and the location and direction of the loads to which the structure is subjected in service (Mow & Hayes 1991). Torsional strain on a loaded femur will cause it to break at its weakest point, which is the more horizontal femoral neck. This was first pointed out in case histories by Sir Astley Cooper over 150 years ago (Parker et al. 1997). Since then, the upper femoral skeletal geometry has been presented to contribute to the hip fracture risk in dual-energy X-ray absorptiometry and conventional pelvic radiography studies but the results have been partly conflicting (Faulkner et al. 1993, Glüer et al. 1994, Karlsson et al. 1996, Dretakis et al. 1999, Michelotti & Clark 1999, Alonso et al. 2000).

2.3.7 Fall

Over 90 % of hip fractures are due to a fall (Grisso et al. 1991), but only about 1 % of all falls of the elderly results in a hip fracture (Tinetti et al. 1988, Nevitt et al. 1991). A comparison between the predictions of the impact force of falling and the in vitro measures of femoral fracture strength postulates that any fall from standing height producing a direct, lateral impact on the greater trochanter may break the elderly hip, (Robinovitch et al. 1991) and the influence of the direction of falling on the fracture risk has also been proven in a clinical series (Greenspan et al. 1998, Parkkari et al. 1999).

The tendency of the elderly to fall is high, which may partly explain the dramatic age-related rise in the incidence of hip fractures (Hayes et al. 1993). Established factors for an increased risk of falls are a slower hand reaction time, decreased grip strength, falls while using stairs and steps, turning around or reaching (Nevitt et al. 1991), cognitive impairment (at least five errors on the short portable mental status questionnaire), disability of the lower extremities (problems with strength, sensation or balance), use of sedatives (benzodiazepines, phenothiazines and antidepressants), foot problems (moderate or severe bunions, toe deformities, ulcers or deformed nails) (Tinetti et al. 1988), neuromuscular impairments (inability to walk in a line with feet in a tandem position and by a slower walking speed), visual acuity (Cummings et al. 1995, Dargent-Molina et al. 1996) and overall impaired mobility (Greenspan et al. 1998). For recurrent non-syncopal falls, increased risk ratios have reported for persons who have difficulty standing up from a chair, difficulty performing tandem walk (heel to toe), arthritis, Parkinson’s disease, three or more falls during the previous year and a fall with injury during the previous year and for whites (Nevitt et al. 1989). Alcohol intake and physical factors in the environment, such as stairs, lighting and streets and walkways, have also been cited as important factors (Gregg et al. 2000).
2.3.8 Lifestyle factors

The lifestyle factors having an influence on the occurrence of hip fracture are described in table 1.

Table 1. Lifestyle factors and the risk of hip fracture in recent studies.

<table>
<thead>
<tr>
<th>Study and year</th>
<th>Study design</th>
<th>Factor</th>
<th>Influence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gregg et al. 2000</td>
<td>Prospective randomized</td>
<td>Higher levels of leisure time physical activity</td>
<td>Reduces</td>
</tr>
<tr>
<td></td>
<td>study</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boonyaratavej et al. 201</td>
<td>Prospective case-control study</td>
<td>Recent physical activity</td>
<td>Reduces</td>
</tr>
<tr>
<td>Michäelsson et al. 1995</td>
<td>Prospective cohort study</td>
<td>High dietary iron, magnesium, vitamin C intake</td>
<td>Increases</td>
</tr>
<tr>
<td>Meyer et al. 1997</td>
<td>Prospective cohort study</td>
<td>High intake of protein in the presence of low calcium intake</td>
<td>Increases</td>
</tr>
<tr>
<td>Meyer et al. 1997</td>
<td>Prospective cohort study</td>
<td>Coffee intake 9 or more cups/day</td>
<td>Increases</td>
</tr>
<tr>
<td>Sowers et al. 1991</td>
<td>Prospective case-control study</td>
<td>High water fluoridation</td>
<td>Increases</td>
</tr>
<tr>
<td>Danielson et al. 1992</td>
<td>Prospective ecological cohort study</td>
<td>Low water fluoridation</td>
<td>Increases</td>
</tr>
<tr>
<td>Cauley et al. 1995</td>
<td>Prospective multicenter study</td>
<td>Exposition to water fluoridation 20 or more years in women</td>
<td>Decreases</td>
</tr>
<tr>
<td>Meyer et al. 1993</td>
<td>Prospective cohort study</td>
<td>Smoking 15 or more cigarettes/day</td>
<td>Increases</td>
</tr>
<tr>
<td>Law et al. 1997</td>
<td>Meta-analysis</td>
<td>Smoking</td>
<td>Increases</td>
</tr>
<tr>
<td>Baron et al. 2001</td>
<td>Prospective case-control study</td>
<td>Alcohol</td>
<td>Increases (weak inverse association with risk)</td>
</tr>
</tbody>
</table>

Physical activity in childhood and adolescence improves bone strength, while activity in adulthood seems merely to reduce bone loss (Frost 1999). Stair climbing and brisk walking are associated with increased bone mineral density at the hip and in the whole body in postmenopausal women (Coupland et al. 1999). One study indicated that women who could go out with walking did not have an increased risk of hip fracture and those who had to stay at home and use a gait aid had a 2-fold risk. The authors postulated that those who could go outside had greater muscle strength and better neuromuscular function, stability and visual acuity, which reduced their propensity to fall (Boonyaratavej et al. 2001). No load-bearing activity in the immediate past and no vigorous sport activities in early adulthood resulted in RRs for hip fracture 2.0 and 7.2, respectively, for women in the Asian Osteoporosis Study (Lau et al. 2001). A lack of physical activity has also been found to associate with the risk of hip fracture in European women (Johnell et al. 1995).

A high-magnesium diet in postmenopausal women has been found to increase urinary calcium excretion, and this may explain the increased risk of hip fracture (Nielsen 1990). High intake of iron was also related to an increased risk of hip fracture according to one study, but the mechanism was uncertain (Michäelsson et al. 1995). High intake of vitamin C might cause negative calcium balance (Allen 1982) and may reduce cancellous and
cortical bone (Thornton 1970). Nondairy animal foods (meat, fish, and eggs) are low in calcium and high protein/low calcium may be harmful to skeletal health and may increase hip fracture risk (Meyer et al. 1997). An inverse relation between coffee intake and bone mass has been observed, which is due to the calciuric effect of caffeine, which may thus increase the hip fracture risk (Hasling et al. 1992). An increase in bone mass caused by fluoride may be associated with an increase in bone fragility (Lindsay 1990). The reported influence of the fluoridation of drinking water on the hip fracture risk is controversial, and the differences between these studies might be due to different study designs (Sowers et al. 1991, Danielson et al. 1992, Cauley et al. 1995). Calcium intake declines with age, because of a decrease in the consumption of dairy products. The intestinal absorption of calcium also decreases with age because of the reduced ability of the intestine to adapt to a low calcium intake (Meunier 1996). The poor vitamin D status is mainly due to low exposure to sunshine not compensated for by vitamin D supplementation (Lips et al. 1987). Aging also decreases the capacity of human skin to produce previtamin D3 (MacLaughlin & Holick 1985). The cumulative response to a deficit in calcium intake and a low vitamin D status is a negative calcium balance, which induces secondary hyperparathyroidism and increases the risk of hip fractures (Parfitt et al. 1982, Meunier 1996).

Smoking has been reported as a risk factor for hip fracture among postmenopausal women (Meyer et al. 1993, Law & Hackshaw 1997) and the risk was decreased after cessation (Baron et al. 2001). There is also a report showing no association between cigarette smoking and the hip fracture risk (Johnell et al. 1995). The possible mechanisms through which cigarette smoking could affect the fracture risk are the lower body weight of smokers and lower levels of parathyroid hormone and 25-hydroxyvitamin and lower BMD and BMI (Mellström et al. 1993).

Excessive alcohol use may play an important role in the pathogenesis of osteoporosis and increase the risk of hip fracture (Moniz 1994). On the other hand, social drinking is associated with higher bone mineral density in men and postmenopausal women. The beneficial effect on bone might be due to elevated serum estradiol levels (Holbrook & Barrett-Connor 1993). Any use of alcohol, however, seems to suppress the function of osteoblasts, as evidenced by the low serum levels of osteocalcin, and prolonged moderate drinking elevates the serum levels of vitamin D metabolites with consequent malabsorption of calcium, hypocalemia and hypocaliuria (Laitinen & Valimäki 1991).

### 2.3.9 Medication and concurrent diseases

Several medications and concurrent diseases are associated with the risk of hip fracture and the previous literature is described in Table 2.
Sedative and autonomic effects of psychotropic drugs increase the risk of falling in the elderly (Ray et al. 1987) and may increase the risk of hip fracture (Cummings et al. 1995).

Thiazides may increase the bone mineral content in postmenopausal women (Wasnich et al. 1986), but the use of thiazides seemed not to decrease the risk of hip fracture or osteoporosis (Adland-Davenport et al. 1985). Furosemide is a diuretic agent that promotes calcium excretion by the kidney (Suki et al. 1970). It may expose users to an increased risk for osteoporosis and osteoporotic fractures (Tromp et al. 2000) by reducing BMD (Ooms et al. 1993). On the other hand, thiazides and furosemide may increase the risk for syncope, producing a possible mechanism of action for the noted association between the use of diuretics and hip fracture (Heidrich et al. 1991).

The use of oral corticosteroids has been established as an independent risk factor for hip fracture (RR=2.1) (Baltzan et al. 1999) and for both nonvertebral fracture (RR=1.44) and vertebral fracture (RR=2.83) (van Staa et al. 2000). In the study by van Staa et al. (2000), a strong correlation was observed between the daily corticosteroid dose, rather than the cumulative dose, and the risk of fracture, with a higher risk in people using higher doses.

A weak relationship between the risk of hip fracture and cardiovascular diseases been reported earlier. The relationship was more prominent in women than in men (Lau et al. 2001).

Some new prospective studies have reported an increased risk of hip fracture in patients with diabetes. According to these studies, the relative risk of hip fracture was 6.9 in Type I (insulin dependent) diabetes (Forsén et al. 1999) and 1.8 in Type II (non-insulin-dependent) diabetes (Schwartz et al. 2001). The increased fracture risk could be due to altered bone status or complications of diabetes predisposing to trauma (e.g. retinopathy, peripheral neuropathy) (Meyer et al. 1993).

A history of stroke has been found as a risk factor for hip fracture (Ramnemark et al. 1998, Lau et al. 2001). The risk of hip fracture increases over 7-fold after hospitalization for stroke (Kanis et al. 2001). Hip fractures might be caused by the high incidence of

<table>
<thead>
<tr>
<th>Study and year</th>
<th>Study design</th>
<th>Medication/concurrent disease</th>
<th>Influence on the risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ray et al. 1987</td>
<td>Prospective case-control study</td>
<td>Use of psychotropic drugs</td>
<td>Increases</td>
</tr>
<tr>
<td>Heidrich et al. 1991</td>
<td>Prospective case-control study</td>
<td>Use of thiazide diuretics</td>
<td>+/−</td>
</tr>
<tr>
<td>Heidrich et al. 1991</td>
<td>Prospective case-control study</td>
<td>Use of loop diuretics</td>
<td>Increases</td>
</tr>
<tr>
<td>Solomon et al. 1993</td>
<td>Prospective case-control study</td>
<td>Use of thyroid hormone</td>
<td>+/−</td>
</tr>
<tr>
<td>Baltzan et al. 1999</td>
<td>Prospective cohort study</td>
<td>Use of oral corticosteroid</td>
<td>Increases</td>
</tr>
<tr>
<td>Solomon et al. 1993</td>
<td>Prospective study</td>
<td>Hyperthyroidism</td>
<td>+/−</td>
</tr>
<tr>
<td>Wjeda et al. 1995</td>
<td>Prospective case-control study</td>
<td>Hyperthyroidism</td>
<td>Increases</td>
</tr>
<tr>
<td>Forsén et al. 1999</td>
<td>Prospective cohort study</td>
<td>Diabetes (Type 1)</td>
<td>Increases</td>
</tr>
<tr>
<td>Schwartz et al. 2001</td>
<td>Prospective multicenter study</td>
<td>Diabetes (Type II)</td>
<td>Increases</td>
</tr>
<tr>
<td>Kanis et al. 2001</td>
<td>Prospective study</td>
<td>Stroke</td>
<td>Increases</td>
</tr>
<tr>
<td>Lau et al. 2001</td>
<td>Prospective multicenter study</td>
<td>Cardiovascular disease</td>
<td></td>
</tr>
<tr>
<td>Sato et al. 2001</td>
<td>Prospective study</td>
<td>Parkinson’s disease</td>
<td>Increases</td>
</tr>
</tbody>
</table>
accidental falls in stroke patients (Forster & Young 1995). Muscle weakness and an increased risk of developing osteoporosis on the paralyzed side might be other important factor predisposing to fractures in stroke patients (Hamdy et al. 1993).

The risk of hip fracture among patients with Parkinson’s disease was observed to be high in elderly women, and they had decreased BMI, lower BMD, and lower concentrations of serum ionized calcium and 25(OH)D with compensatory hyperparathyroidism (Sato et al. 2001). The increased risk of hip fracture in patients with Parkinson’s disease is probably due to their tendency to fall in specific ways (Johnell et al. 1992).

The frequency of hyperthyroidism has been suggested to be 2.5-fold in hip fracture patients compared to controls (Wejda et al. 1995). The increased risk of hip fracture associated with hyperthyroidism was not found in another study, and women with a history of hyperthyroidism and the use of thyroid hormone for a variety of thyroid disorders did not appear to have an enhanced prevalence of hip fracture (Solomon et al. 1993).

**2.3.10 Gynaecological factors**

Postmenopausal women with undetectable serum estradiol concentrations and high serum concentrations of sex hormone-binding globulin appear to have an increased risk of hip and vertebral fracture (Cummings et al. 1998). Estrogen deficiency results from declining ovarian function (Thomsen et al. 1986). The estrogen deficiency and bone loss might be caused by the higher prevalence of dead osteocytes (Tomkinson et al. 1997).

Bone turnover is altered during pregnancy and lactation, as demonstrated by a change in the markers of bone formation and resorption (Sowers 1996) and, in the case of lactation, even with measurement of bone mineral density (Holmberg-Marttila & Sievänen 1999). Despite this turnover activity, there appears to be little ultimate loss of mineral from the maternal skeleton during the pregnancy or lactation of well-nourished women if, during or after lactation, consistent menstrual cycling is re-established within a reasonable length of time (Sowers 1996). The actual net long-term effect of parity and lactation on the osteoporotic fracture risk is uncertain. Higher parity might be modestly associated with a reduced hip fracture risk, and this risk reduction seems partially attributable to weight gain with parity. According to the same authors, lactation is not associated with the hip fracture risk (Michaëllson et al. 2001).

**2.4 Differences in the etiopathology of femoral neck and trochanteric fractures**

It has been postulated that the etiologies are different in femoral neck and trochanteric hip fracture patients (Backman 1957, Mautalen et al. 1996, Michaëllson et al. 1999).
Women with trochanteric fractures are, on an average, 5 years older, have lower body weight about 6 kg, are about 3 cm shorter and have lower bone mineral density than women with femoral neck fracture (Bohr & Schaadt 1983, Eriksson & Widhe 1988, Vega et al. 1991b).

The size and architecture of the upper femur and pelvis are important in the pathogenesis of these two main hip fracture types. Decreased femoral shaft cortical thickness has been reported to predict trochanteric fractures and acetabular width and decreased femoral neck cortical thickness femoral neck fractures, which is compatible with the different mechanisms of these fracture types (Glüer et al. 1994). Hip axis length has also been found to be a predictor of femoral neck fracture. Differences in the compressive and tensile stress on the hip, which are related to differences in femoral neck length and shape, may partly explain these differences (Duboeuf et al. 1997).

No significant differences were found in the energy or characteristics of falls between femoral neck and trochanteric fracture patients (Greenspan et al. 1994).

Major differences in several lifetime factors between femoral neck and trochanteric fractures have been found, but these differences were age-dependent and not real risk factors after age adjustment (Sernbo & Johnell 1987). In another study, it was concluded that femoral neck fractures compared to trochanteric fractures are more strongly influenced by hormonal and environmental factors, such as smoking, the duration of menstrual cycling and exogenous estrogens (Michaelsson et al. 1999).

### 2.5 Methods for identifying the risk of hip fracture

The most commonly used method for the measurement of BMD or bone mineral content (BMC) is dual X-ray absorptiometry (DXA) or quantitative computed tomography (QCT). QCT in clinical practice is too costly for screening large populations (Krischak et al. 1999). With the newest DXA machines, both the spine and the hip can be scanned in a few minutes, which reduces the cost. For screening purposes, however, DXA machines are too expensive and not portable (Raisz 1999). Careful repositioning of the foot and leg is essential, to reduce the effect of anteversion when measuring BMD by DXA (Cheng et al. 1997).

Ultrasonographic heel measurements have been found to predict the risk of hip fracture in elderly women living at home equally well as DXA of the hip (Hans et al. 1996). It has been suggested that ultrasound correlates better with the type of hip fracture than DXA, patients with trochanteric fractures having significantly lower ultrasound parameters than those with femoral neck fractures (Schott et al. 1995).

Assessment of the Sing Index on ordinary X-rays of the hip is an inexpensive and simple method and allows a rough estimation of the mechanical quality of the femur (Singh et al. 1970). However, due to its subjective character, its predictive value for the mechanical quality of bone in individual patients remains uncertain (Krischak et al. 1999).

Conventional pelvic radiography is widely available at low cost, and it offers sufficient spatial resolution and contrast to assess the macroscopic structure of the proximal femur (Glüer et al. 1994). Several studies using conventional pelvic radiography
measurements have revealed an association between the pelvic and upper femur geometry and the risk of hip fracture in postmenopausal women (Glüer et al. 1994, Peacock et al. 1995, Karlsson et al. 1996, Michelotti & Clark 1999). On the other hand, linear and angular measurement parameters from pelvic radiography have been mutually conflicting in these studies (Table 3).

Table 3. Review on radiographic studies on pelvic and upper femur geometry in hip fracture patients.

<table>
<thead>
<tr>
<th>Study and year</th>
<th>No. of patients</th>
<th>Assessment of magnification</th>
<th>Positioning</th>
<th>Digital image</th>
<th>Evaluation of reproducibility and accuracy</th>
<th>The risk is increased by</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glaër et al. 1994</td>
<td>162</td>
<td>No</td>
<td>Supine, feet taped at a 15–30° internal rotation</td>
<td>Yes</td>
<td>No</td>
<td>Reduced thickness of the femoral cortex</td>
</tr>
<tr>
<td>Peacock et al. 1995</td>
<td>22</td>
<td>No</td>
<td>Supine, feet at a 15° internal rotation</td>
<td>No</td>
<td>No</td>
<td>Long hip axis length, reduced lateral cortical thickness</td>
</tr>
<tr>
<td>Karlsson et al. 1996</td>
<td>92</td>
<td>No</td>
<td>Supine, feet in a resting position</td>
<td>No</td>
<td>No</td>
<td>Reduced thickness of the calcar femorale, increased NSA</td>
</tr>
<tr>
<td>Michelotti &amp; Clark 1999</td>
<td>43</td>
<td>Yes</td>
<td>Supine, the toes touching</td>
<td>No</td>
<td>No</td>
<td>Reduced thickness of the femoral cortex, larger femoral head and neck diameter</td>
</tr>
</tbody>
</table>

Body habitus affects magnification in radiographic images (Clarke et al. 1976). It has been estimated that the average difference in buttock soft tissue thickness is 8.7 cm. All but one of the previous studies involved direct measurements from pelvic radiography without any calibration at the bone level to exclude the magnification error implicit in linear measurements (Pocock et al. 1997). On the other hand, the angular parameter called neck-shaft angle (NSA), defined as the angle between the femoral shaft and the femoral neck, is comparable between different measurement setups if the patient’s position is similar. The subject’s positioning also reflects the linear parameters, while abduction shortens the apparent hip axis length and external rotation shortens the apparent femoral neck length. Data concerning the error value for linear and angular measurements have generally been lacking in these previous studies (Michelotti & Clark 1999). A digital image analysis system has been found more accurate than the human eye but the measurements were made by digital imaging in only one study (Bould et al. 1999).

Linear and angular geometric parameters of the pelvis and upper femur and their relation to the hip fracture risk in postmenopausal women have been also measured from DXA scans in many previous works, and controversial results, especially as regards the predictive value of hip axis length and the risk of hip fracture, have been reported. Some studies have found increased hip axis length to be an independent risk factor for hip fracture in postmenopausal women (Faulkner et al. 1993, Boonen et al. 1995) while some
others have not found any differences in hip axis length between the hip fracture patients and controls (Center et al. 1998, Dretakis et al. 1999, Alonso et al. 2000). Differences in the measurement setup might also explain partly the conflicting findings (Michelotti & Clark 1999).

The dramatic increase in the bone turnover rate, which results in an imbalance between bone formation and bone resorption, in the first years after the cessation of ovarian function is responsible for the accelerated rate of postmenopausal bone loss (Garnero et al. 1996).

Direct, region-specific measurements of bone formation and resorption in the femoral neck are hard to perform and have seldom been attempted (Eastell et al. 2001). Bone metabolism markers can be also measured indirectly by determining the markers for bone formation and bone resorption. It is postulated that a combination of baseline perimenopausal bone density and an assessment of biochemical markers may better predict the future hip fracture risk (Tromp et al. 2000), but they lack sufficient sensitivity and specificity to be very helpful in the day-to-day management of patients with osteoporosis (Adachi 1996).

Bone-specific alkaline phosphatase appears to be more sensitive than total alkaline phosphatase for clinical purposes. Osteocalcin is a vitamin D-dependent protein that has been estimated to represent up to 20 % of all noncollagenous protein in bone. It is only found in bone tissue and dentin. A proportion of newly synthesized osteocalcin is released into the circulation, where it can be measured by immunoassay. Thus, the serum level of osteocalcin is a very specific marker of the rate of bone formation. Procollagen type I extension peptides, PICP and PINP assays are measures of bone formation. Type I collagen is synthesized as procollagen precursor molecules. Before insertion into the existing extracellular matrix, the terminal propeptide extensions are proteolytically removed, and both PICP and PINP are released into the circulation (Adachi 1996). The immunoassays of osteocalcin and bone alkaline phosphatase have been established as the most effective markers of bone formation in osteoporosis (Garnero & Delmas 1996).

The measurement of pyridinium cross-links (urinary free pyridinoline, pyridinoline-containing type I collagen cross-linking peptides) and some of the related peptides is the most sensitive marker of bone resorption, and immunoassays are recommended valid techniques for their evaluation (Garnero & Delmas 1996).

On the other hand, metabolic changes in bone, other than osteoporosis, have been reported to be possible additional risk factors for hip fractures, while osteomalacia was present in 24 % and hyperparathyroid histological changes in 3 % of the hip fracture patients (Arnala et al. 1997). Histological osteomalacia was also diagnosed in 24 % of the patients with hip fracture in another report (Hoikka et al. 1982). Vitamin D metabolite, 25(OH)D, is important in Europe at the end of the winter, due to a lack of sun exposure (Baker et al. 1979, Benhamou et al. 1995). 25(OH)D deficiency has been found in elderly people with hip fracture (Harju et al. 1985, Benhamou et al. 1995). Parathyroid hormone is associated with increased bone turnover resulting in net resorption, and the PTH effect is more marked on cortical than trabecular bone (Gupta & Rolla 1995, Lips 2001). Concerning the levels of PTH in hip fracture patients, controversial results have been found in the literature. Some studies have reported higher levels in hip fracture patients than non-hip fracture controls (Benhamou et al. 1995, Dubin et al. 1999) and one found no increase in PTH levels after hip fracture (Johansen et al. 1997).
Low serum calcium concentrations in hip fracture patients have been reported, although no changes in total calcium levels were found in one study (Benhamou et al. 1995, Boonen et al. 1997). The normal serum calcium concentration can be maintained by mobilization of calcium from bone in the case of osteoporosis (Harju et al. 1985). Calcitonin is a peptide from the parafollicular cells of the thyroid regulated by serum calcium levels (Dubin et al. 1999). It inhibits bone resorption (Benhamou et al. 1995). Higher levels of serum calcitonin have been observed in hip fracture patients (Prince et al. 1989) but contrary to this, no increase in serum calcitonin levels was found in some other reports (Reginster et al. 1992, Boonen et al. 1997).

2.6 Treatment of femoral neck fractures

Speed introduced intra-capsular femoral neck fracture as the “unsolved fracture” about 70 years ago (Speed 1935). Even today, there are a number of controversies concerning the methods of treating displaced fractures of the femoral neck and the main problem is whether to reduce the fracture and to use internal fixation or to perform total or partial hip replacement arthroplasty (Lu-Yao et al. 1994).

The surgeon Nicholas Senn first reported the importance of reduction and nailing of hip fracture on the basis of animal experiments. He also reported that femoral neck fractures involve two main indications: (1) immediate reduction and (2) permanent fixation. He used immediate reduction, a specific external compression screw and a plaster-of-Paris dressing in the treatment of femoral neck fractures (Senn 1889).

In the early 20th century, Murphy began to nail femoral heads (Speed 1935). Since then, more than a hundred devices have been used in the treatment of femoral neck fractures (Swiontkowski 1994). Nowadays, the osteosynthesis (OS) modality to treat femoral neck fractures consists of either reduction and fixation with one or more hook pins, nails (Strömqvist et al. 1987), or screws (Kuokkanen et al. 1991), or reduction and fixation with a sliding screw and plate (Elmerson et al. 1995).

The prospective comparisons between different types or numbers of pins, screws, or nails have not reported any significant differences in the main results (Sernbo et al. 1990, Herngren et al. 1992, Lagerby et al. 1998).

Osteosynthesis with one or more hook pins, screws or nails did not basically differ from the use of a sliding screw and plate in one of the prospective studies (Elmerson et al. 1995), while another study was in favour of a sliding screw and plate due to the lower failure rate (Sorensen et al. 1992) and two were in favour of screws due to the better union of the fracture (Madsen et al. 1987) and the lower infection rate (Christie et al. 1988).

In 1940, the self-locking metal hip prosthesis, called Austin-Moore prosthesis, was introduced as the first vitallium prosthesis to replace the upper portion of the femur (Moore 1957). Since then, the Austin-Moore prosthesis has undergone much development and has been the most commonly utilized mode of uncemented hemiarthroplasty (HA) along with the cemented Thompson hemiarthroplasty in the treatment of displaced femoral neck fractures (Thompson 1954, Lindholm et al. 1976, Kwock & Cruess 1982, Jalovaara & Virkkunen 1991). Many designs of hemiarthroplasty have been used in the
treatment of femoral neck fractures (Lausten & Vedel 1982, Lo et al. 1994). The main difference between the different hemiarthroplasties is the design of the stem, the use of cement, and whether a second articulating joint is included within the prosthesis (Parker & Rajan 2001).

Concerns about the possible lower effects on the cardiopulmonary system and technically easier revision are the main factors in favour of an uncemented implant. Early loosening with associated pain and poor function with an uncemented implant may motivate the surgeon to choose a cemented implant (Khan et al. 2002). According to the previous prospective studies, fixation of the prosthesis with cement might improve the outcome, resulting in better pain relief and better gait than fixation of the prosthesis without cement (Emery et al. 1991, Godsiff et al. 1992, Khan et al. 2002). Consequently, cemented prostheses may give a better outcome, but because of the under-reporting of outcomes and the small number of patients involved, no definitive conclusions can be made based on a Cochrane Database of systematic Reviews (Parker & Rajan 2001).

The results of prospective randomized trials comparing the use of unipolar and bipolar prosthesis suggest that the less expensive unipolar prosthesis for hemiarthroplasty may be justified in the elderly. These previous studies demonstrated a greater range of hip motion in rotation and abduction and faster walking speed when the bipolar prosthesis was used (Cornell et al. 1998), while the degree of return to the pre-injury state was better when the unipolar prosthesis was used (Calder et al. 1996). On the other hand, one study found no significant differences between the use of unipolar and bipolar prostheses (Wathne et al. 1995).

Total hip arthroplasty (THA) in selective cases of acute femoral neck fracture may provide consistent pain relief and a good functional outcome without any increase in complications (Coates & Armour 1979, Taine & Armour 1985). THA should be considered in the case of acute displaced femoral neck fractures in previously active elderly individuals with acetabular articular cartilage changes. Other indications may include rheumatoid arthritis, Paget’s disease, mentally deficient patients and short life expectancy in otherwise active individuals (Delamarter & Moreland 1987).

For centuries, femoral neck fractures have been treated conservatively by some kind of extension and imperfect immobilization (Senn 1889). Non-operative management still remains a feasible option for truly non-ambulatory, demented, aged patients with proximal femoral fracture. It has been suggested that the decision concerning treatment should be made in the chronic care institution by professionals who know the individual (Winter 1987).

### 2.6.1 Comparative studies

The treatment of femoral neck fractures, especially displaced femoral neck fractures, is controversial, and the results of the previous prospective studies concerning the treatment with osteosynthesis or hemiarthroplasty (Table 4) have been inconsistent (Søreide et al. 1979, Søreide et al. 1980, Sikorski & Barrington 1981, Parker 1992, van Vugt et al. 1993, Lu-Yao et al. 1994, Parker & Pryor 2000, Puolakka et al. 2001).
Table 4. Prospective comparative studies on HA and OS in the treatment of displaced femoral neck fractures.

<table>
<thead>
<tr>
<th>Study and year</th>
<th>Study design and number of patients</th>
<th>Follow-up</th>
<th>Main results</th>
<th>Re-operation rate</th>
<th>Mortality at one year</th>
</tr>
</thead>
</table>
| Søreide et al.
1979          | Prospective randomised (104)        | 1-year    | Mobilization better in HA patients | HA 5.7 %            | HA 21 %              |
|                 |                                     |           |              | OS 17.6 %         | OS 18 %              |
| Søreide et al.
1980          | Prospective randomised (104)        | 1-year    | Cost of the treatment lower in OS patients | HA 5.7 %            | HA 21 %              |
|                 |                                     |           |              | OS 17.6 %         | OS 18 %              |
| Sikorski & Barrington
1981      | Prospective randomised (218)        | 2-year    | Mobilisation better in HA patients | HA (posterior approach) 6% | HA (posterior approach) 41 % |
|                 |                                     |           |              | HA (anterior approach) 13 % | HA (anterior approach) 23 % |
|                 |                                     |           |              | OS 38 %           | OS 35 %              |
| Parker et al.
1992          | Prospective (200)                   | 1-year    | Less wound infections in OS patients | HA 7 %              | HA 33 %              |
|                 |                                     |           |              | OS 22 %           | OS 36 %              |
| Van Vugt et.
al. 1993 | Prospective randomised (43)         | 2-year    | Better clinical results in OS patients | HA 27.1 %           | HA 31.3 %             |
|                 |                                     |           |              | OS 22.7 %         | OS 11.1 %            |
| Parker et al.
2000          | Prospective randomised (208)        | 3-year    | Less wound infections in OS patients | HA 3.8 %            | HA 29.4 %             |
|                 |                                     |           |              | OS 35 %           | OS 26.8 %            |
| Puolakka et
al. 2001    | Prospective randomised (32)         | 2-year    | Lower re-operation rate in HA patients | HA 0 %              | HA 46.7 %             |
|                 |                                     |           |              | OS 44 %           | (2-year mortality)    |

Many studies favour OS and report fewer postoperative infections (Parker 1992, Parker & Pryor 2000), lower costs (Parker 1992), lower morbidity and mortality (Raine 1973, Bracey 1977, Rodriguez et al. 1987) and better long-term outcome (van Vugt et al. 1993). Some studies have failed to indicate any differences between HA and OS (Stewart 1984). The remaining studies recommend HA as more suitable for the treatment of femoral neck fracture because of less pain (Broos et al. 1987), more satisfactory results (Johnson & Crothers 1975), lower re-intervention rates (Parker et al. 2000, Puolakka et al. 2001), better walking ability and functional condition (Bray et al. 1988, Rogmark et al. 2002) and better postoperative mobilization (Søreide et al. 1979, Sikorski & Barrington 1981).

There are few studies comparing OS and THA. One study reported that patients, which were treated with THA, used less outdoor walking aids, and were more likely to do their own shopping than patients treated with OS (Jónsson et al. 1996). In another prospective, randomized study, the THA group performed better than the OS group concerning weight change over time, locomotion and pain, and the authors concluded that THA could be safely performed on the elderly without increased postoperative mortality (Bachrach-Lindström et al. 2000). THA has been also recommended to patients with normal functional capacity and high functional demands after a comparison between OS and THA (Johansson et al. 2000).
According to Smrke et al. (2000) HA gives a better range of motion compared to THA patients (Smrke et al. 2000). On the other hand, younger patients treated with THA was found to have a better outcome than patients treated with HA (Gebhard et al. 1992).

The patients treated with THA had the least pain and the best mobility in both short- and long-term outcome assessment and also had a lower revision rate compared to OS and HA. Skinner et al. (1989) found that HA had the worst outcome, and both OS and HA resulted in the poorest outcome in the study by Ravikumar et al. (2000). The high dislocation rate following THA, 12.5-20 %, should be noted (Skinner et al. 1989, Ravikumar & Marsh 2000).

### 2.6.2 Functional outcome after femoral neck fracture

Functional outcome has received less attention than more frequently reviewed aspects, such as mortality, re-operation rate, bone healing, complications, and cost. It is also very important to know how well patients are able to regain their pre-injury level of function and independence, because this is a good indicator of the efficacy of the treatment with regard to the socioeconomic aspects (Koval & Zuckerman 1994, Young et al. 1996). Functional status on admission predicts the occurrence of a hospital-acquired complication, (Becker et al. 1987) and functional recovery has also been used to determine the effect of geriatric rehabilitation of hip fracture patients (Huusko et al. 2002). Most previous studies concerning the functional outcome of OS and HA have revealed no significant differences (Söreide et al. 1979, Young et al. 1996, Parker & Pryor 2000).

### 2.7 Deep infection after hip fracture surgery

Deep infection is a rare, but serious complication after hip fracture surgery (Pietschmann et al. 1988, Dávid et al. 1995) often leading to prolonged hospitalization, reduced activity level, poor quality of life, and additional costs for the hospital and for society (Aagaard et al. 1994). It also increases morbidity, mortality and social dependency (Eastwood 1993).

Only one study was found in the literature comparing hip fracture patients with deep infection to patients without deep infection (Eastwood 1993). However, some studies have given special attention to deep infection by focusing on the monitoring of infective complications and undertaking prophylactic measures to lower infection rates (Enstone & Humphreys 1998, Mackay et al. 2000).

### 2.7.1 Definition, risk factors and incidence

The criteria for deep infection have been defined as follows: A major infection extending through the deep fascia (Hedström et al. 1998) with purulent discharge complicated by
spreading cellulites, systemic upset (Mackay et al. 2000), positive or negative cultures from the deep tissues (McQueen et al. 1990), pockets of pus or wound breakdown (Eastwood 1993).

Patient-related risk factors for deep postoperative infection include previous surgery of the joint, rheumatoid arthritis, corticosteroid therapy, diabetes mellitus, poor nutritional state, obesity and advanced age (Brause 1986, Enstone & Humphreys 1998). Perioperative risk factors include a break in sterility during the operation, postoperative wound infection, postoperative urinary tract infection and an unhealed wound at discharge (Enstone & Humphreys 1998).

The deep infection rate after hip fracture surgery is varies from 0.8 to 2.8 % (Chiu et al. 1993, Lu-Yao et al. 1994, Meissner 1994, Mackay et al. 2000). Older studies generally have higher infection rates ranging within 2.2-16.9 % (Boyd et al. 1973, Tengve & Kjellander 1978, McQueen et al. 1990). The decreased incidence is mostly due to advances in theatre design, surgical techniques, antibiotic prophylaxis, wound care, and special attention to detail and good practice (Mackay et al. 2000).
3 Aims

1. To clarify if the simple radiographical geometry of the upper femur and pelvis is related to the hip fracture risk and fracture type.
2. To find out the relation of lifetime factors, parameters of bone metabolism and bone mineral density with the hip fracture risk and fracture type.
3. To investigate which one, osteosynthesis or uncemented hemiarthroplasty is better in the treatment of femoral neck fractures in terms of functional outcome.
4. To determine the impact of deep infection after hip fracture surgery on functional outcome and mortality.
4 Patients and methods

4.1 Upper femur and pelvic geometry and the risk of hip fracture and fracture type

The basic study series consisted of 93 consecutive postmenopausal women with non-pathological femoral neck fractures or trochanteric fractures without previous hip fractures or hip surgery. They were admitted to Oulu University Hospital between January 1998 and October 1998. Inclusion criteria and the ambulation were assessed by a trained nurse at admission. The radiographs were inadequate in 9 cases (missing calibration scale or inability to maintain the required position on the x-ray table), and they were excluded from the study. Further 14 patients were excluded because of a failure to find suitable controls with regard to age (patients aged over 85 years were excluded). Thus, 70 patients (fracture group, mean age 74.9 years, range 53–85 years) constituted the final study group. Forty-six of them had a femoral neck fracture (femoral neck group, mean age 73.7 range 53–85) and 24 a trochanteric fracture (trochanteric group, mean age 77.3, range 60–85). 67 % of the patients were fully ambulatory (able to walk outdoors without help) and all were ambulatory indoors with or without support. 55 % of the patients did not use any walking aids.

The control subjects (40 women, mean age 73.7 years, range 63–84 years) were recruited in 1998–1999 from a private clinic’s densitometry series, excluding women with previous hip fracture, metabolic bone disease, or treatment with sex hormones, calcitonin, or bisphosphonates. All but one was fully ambulatory and 90 % did not use any walking aids.

Anteroposterior pelvic radiographs of the fracture patients were taken within a few days postoperatively, and those of the controls were taken using the same x-ray equipment. A standard position was used in all cases: supine with the pelvis and both legs straight forward and the big toes touching each other, resulting slight internal rotation of the femur. The beam was centered on symphysis pubis in the midline, and the focus-to-film distance was always 1 meter. The 43 cm x 38 cm cassette was placed under the patient. A calibration scale was fixed at the level of the greater trochanter of the noninvolved hip for calibrating the dimension measurements (Fig. 7).
Fig. 7. Calibration scale fixed at the trochanteric level.

The X-rays were digitized with a ccd camera (Dage MTI 72E, Dage, USA) on a light table (Northern Light Desktop Illuminator, Imaging Research Inc., Canada), using an objective Canon CI-TV 16 mm lens, and digitally stored in a PC computer. The images were calibrated using the calibration scale, and the dimensions were measured by a digital image analysis system MCID M4 with software version 3.0, rev. 1.1 (Imaging Research Inc., Canada). Several dimensions of the uninjured hip and pelvis were measured (Fig. 8). All the measurements were made by a single observer.
Fig. 8. Definition of the parameters measured from the ap roentgenograms of the pelvis and the upper femur. L-LL= largest inner pelvic diameter (LIPD), M-MM=smallest outer pelvic diameter (SOPD), A-H= hip axis length (HAL), A-B and A-C= femoral neck axis length (FNALa and FNALb, respectively, measured in two ways), B-H= acetabular width (AW), D-DD= femoral head diameter (HD), E-EE= femoral neck diameter (ND), F-FF= trochanteric width (TW), G-GG= femoral shaft diameter (FSD), I= femoral neck cortex width (FNC), J= medial calcar femoral width (CFE), K= femoral shaft cortex width (FSC) and P= neck/shaft angle (NSA). O shows the calibration scale and N is a 3 cm bar generated with the software.

The reproducibility of the measurements was evaluated by three blind repeat measurements of the geometrical parameters from 10 radiographs. The root mean square coefficient of variation (CV_{rms}) was used as a measure of reproducibility, being 0.9 %, 1.5 %, 2.5 %, 2.5 %, 3.3 %, 1.5 %, 0.7 %, 1.2 %, 1.1 %, 1.2 %, 1.5 %, 5.2 % and 9.9 % for FNALa, FNALb, FSD, TW, AW, ND, HD, HAL, NSA, SOPD, LIPD, FSC and FNC. These values indicate that the method was highly reproducible for all the other parameters except cortical thickness.

The accuracy of dimension measurements was evaluated from the radiographs of 18 patients with a hip prosthesis (Austin Moore). The diameter of the spherical head of the prosthesis was measured from the radiographs with image analysis and compared with the known head size of the prosthesis. The root mean square accuracy error was 2.3 %.

4.2 Lifetime factors, bone metabolism and bone mineral density in patients with hip fracture

The study subjects consisted of 102 consecutive postmenopausal women with nonpathological femoral neck fractures or trochanteric hip fractures in 1998 without previous hip fracture or surgery. 28 patients aged over 84 years were excluded because of a failure to find suitable controls with regard to age. Thus, 74 patients (fracture group,
mean age 74.2 years, range 53–84 years) constituted the study group. 49 had a femoral neck fracture [cervical group, mean age 73.1 (53–84) years] and 25 a trochanteric fracture [trochanteric group, mean age 76.3 (61–84) years]. There was no significant difference in age between the femoral neck and trochanteric fracture patients.

The control group [40 women, mean age 73.7 (63–84) years] was the same control group as described in the chapter 4.3.1.

Thirty-seven patients and 19 controls were excluded from the statistical comparison of BMD and the biochemical measurements of bone metabolism because they had had treatments with calcium, D-vitamin, biphosphonates, estrogens, calcitonin or corticosteroids, and one fracture patient was excluded for primary hyperparathyroidism.

BMD of the upper femur was measured by two different equally tested and calibrated scanners (Lunar DPX, Lunar Radiation Corporation, Madison, WI, USA) using equal measurement routines. Before the measurements, a control phantom was scanned daily, and the same measurement program was used in both similar Lunar DPX densitometries. The coefficient variation of the femoral neck in vivo reported by the manufacturer was 0.6–1.7 %. The measurement of the patients was performed 2–4 days after the fracture. Three parts of the hip (nonfracture side of the fracture patients and left side of the controls) were measured at sites of femoral neck (FEBMD), Ward’s triangle (WABMD) and trochanter (TRBMD).

Blood samples for measurements of bone metabolism markers from the patients (on the first or second postoperative day) and controls were obtained in the morning after an overnight fast. Serum was separated and the samples were analyzed immediately, with the exception of the samples for s-CT and serum osteocalcin (s-OC), which were stored at –20°C for 1–2 months until assayed. All assays were performed in clinical laboratory according to good clinical practise.

Serum (s)-Intact N-terminal of procollagen type 1 (s-PINP) was measured using a radioimmunoassay test kit (Orion Diagnostica, ISO9001, Orion Corporation, Orion Diagnostica, Espoo, Finland, sensitivity 3.0 µg/l, intra-assay CV 5.5%, interassay CV 5.6 %) (Tähtelä et al. 1997). S-25-hydroxyvitamin D (s-25-(OH)-D) was measured using a commercial radioimmunoassay test kit (25-hydroxyvitamin D H3 RIA, DiaSorin, Catalog No./REF./KAT.-NR.: 68100E, Stillwater, Minnesota, sensitivity 4.0 nmol/l, intra-assay CV 8.8 %) (Hollis et al. 1993). S-Parathyroid hormone (s-PTH) was assayed using a commercial radioimmunoassay (Intact PTH Parathyroid Hormone 100T Kit-Catalog no: 40–2170, Nichols Institute Diagnostics, San Juan Capistrano, California, USA, sensitivity 7.5 ng/l, intra-assay CV 2.6 %, interassay CV 5.9 %) according to the manufacturer’s instruction. S-Alkaline phosphatase (s-ALP) was analyzed by the method recommended by the Committee on Enzymes of Scandinavian Society for Clinical Chemistry and Clinical Physiology (Reagents: Oy Reagenla Ltd, Finland, Analyzer: BM/Hitachi 911 Automatic Analyzer, sensitivity 3.7.10⁻⁹ΔA/min per U/l, intra-assay CV 0.8%, interassay CV 2.9%). S-Bone specific alkaline phosphatase isoenzyme (s-BAP) was measured by the REP Electrophoresis kit (Helena Bio-Sciences, Cat No. 3200, Sunderland, Tyne & Wear, SR5 3XB, U.K.). Total s-calcium (s-Ca) was analysed by flamephotometry (Eppendorf A/FIX 5055, Eppendorf-Netheler-Hinz GmbH, Hamburg, sensitivity 2.4.10⁻³ΔA per mmol/l, intra-assay CV 0.7%, interassay CV 3.3%) (Robertson & Marshall 1979). S-Calcitonin (s-CT) was assayed by a radioimmunoassay test kit (Calcitonin, Diagnostic system laboratories, INC catalog. No: DSL-1200, Webster, Texas,
S-Osteocalcin (s-OC) was measured by an immunoradiometric assay test kit (Human Osteocalcin Kit, immunoradiometric assay (IRMA), 40–2248, Nichols Institute Diagnostics, San Juan Capistrano, CA, 92679 USA, sensitivity 4.0 µg/l, intra-assay CV 5.2 %, interassay CV 8.3 %).

The data were recorded on a special form by the same interviewer, a trained nurse, who interviewed both the fracture patients at admission and the controls. The following lifetime data were collected: body weight, height, body mass index (BMI), menarcheal age, age at menopause, parity, ovarian surgery, independence, walking ability, femoral muscle strength, vision, current medication, and concurrent diseases. “The lifestyle factors”, including diet, use of alcohol and coffee, smoking and physical activity, were also recorded.

4.3 Uncemented Austin-Moore hemiarthroplasty versus two hook pins

In 1989–1996, all femoral neck fractures were prospectively registered at the University Hospitals of Oulu, Finland and Lund, Sweden (Jalovaara et al. 1992, Berglund-Röden et al. 1994, Parker et al. 1998). In Lund, the main treatment method was OS with two hook pins (n=1277). In Oulu, the commonest treatment method was uncemented Austin-Moore HA (n=546).

Cross-matching of these patients was performed by a statistician for age (± 2 years), sex, preoperative residence, walking capacity and displacement of the fracture. 357 pairs of displaced femoral neck fractures were found (Table 5).

Standardized forms were prospectively filled in with data concerning the patients’ background, hospital stay, resource demands and quality of life, i.e. information concerning their place of residence, need for institutional care as well as pre- and postoperative ADL functions (the patients were asked if they were able to dress and undress themselves without any help) and locomotor ability. Follow-up was continued for four months by recording the re-operation rate, mortality and the same functional parameters that were recorded preoperatively. Mortality and re-operation rate were also recorded at one year after the fracture.

OS with two hook pins in Lund was performed using atraumatic insertion and firm intracapital fixation (Strömqvist et al. 1992) (Fig. 9).
Table 5. Cross-matched data of patients with femoral neck fracture treated with hemiarthroplasty (HA) in Oulu and osteosynthesis with two hook pins (OS) in Lund.

<table>
<thead>
<tr>
<th>Operation type</th>
<th>HA (%)</th>
<th>OS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Female</td>
<td>287</td>
<td>287</td>
</tr>
<tr>
<td>All</td>
<td>357</td>
<td>357</td>
</tr>
<tr>
<td>Mean age (years) and range</td>
<td>82 (63–98)</td>
<td>82 (63–98)</td>
</tr>
<tr>
<td>Female mean age and range</td>
<td>82 (63–98)</td>
<td>82 (63–98)</td>
</tr>
<tr>
<td>Male mean age and range</td>
<td>81 (64–97)</td>
<td>81 (64–97)</td>
</tr>
<tr>
<td>Admitted from</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own home</td>
<td>232 (65)</td>
<td>232 (65)</td>
</tr>
<tr>
<td>Convalescent home</td>
<td>7 (2)</td>
<td>0</td>
</tr>
<tr>
<td>Fullservice unit</td>
<td>92 (26)</td>
<td>99 (28)</td>
</tr>
<tr>
<td>Geriatric department, nursing home</td>
<td>24 (6)</td>
<td>24 (6)</td>
</tr>
<tr>
<td>Other</td>
<td>2 (1)</td>
<td>2 (1)</td>
</tr>
<tr>
<td>Acute hospital</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walking capacity before the fracture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>could walk alone outdoors</td>
<td>192 (54)</td>
<td>192 (54)</td>
</tr>
<tr>
<td>could walk outdoors only supported by another person</td>
<td>48 (13)</td>
<td>48 (13)</td>
</tr>
<tr>
<td>could walk alone indoors but not outdoors</td>
<td>92 (26)</td>
<td>92 (26)</td>
</tr>
<tr>
<td>could walk indoors only supported by another person</td>
<td>23 (6)</td>
<td>23 (6)</td>
</tr>
<tr>
<td>could sit on a chair but not walk</td>
<td>2 (1)</td>
<td>2 (1)</td>
</tr>
<tr>
<td>bedridden</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 9. Osteosynthesis with two hook pins in Lund.
HA in Oulu was always performed through a posterior approach using an uncemented Austin-Moore prosthesis (Fig. 10).

![Fig. 10. Austin Moore hemiarthroplasty in Oulu.](image)

Full weight bearing was allowed on the first postoperative day for both OS and HA patients. The patients were encouraged to walk as soon as possible.

The after-care policies were different in Lund and Oulu. In Lund, the policy was to treat the patients in the primary hospital until they were able to return to their original residence, but in Oulu, nearly all patients including the OS and HA patients, were discharged into health care centre hospitals or rehabilitation units as soon as possible.

4.4 Uncemented Austin-Moore hemiarthroplasty versus osteosynthesis with three screws

During 1989–1999, all hip fractures treated in Oulu University Hospital were prospectively registered (Jalovaara et al. 1992, Berglund-Rödén et al. 1994, Parker et al. 1998). There were 1055 femoral neck fractures. 161 patients with displaced femoral neck fractures (Garden III–IV) underwent OS with three hip screws and 711 uncemented Austin-Moore HA.

These patients were also cross-matched for age (±2 years), sex, preoperative residence, walking capacity and displacement of the fracture, and 84 pairs with displaced femoral neck fractures were found (Table 6).
Table 6. Cross-matched data of patients with femoral neck fracture treated with hemiarthroplasty (HA) and osteosynthesis with three screws (OS).

<table>
<thead>
<tr>
<th>Operation type</th>
<th>HA (%)</th>
<th>OS (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N:o of patients</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td>Mean age (years) and range</td>
<td>75 (63–92)</td>
<td>75 (62–92)</td>
</tr>
<tr>
<td>Male</td>
<td>29</td>
<td>29</td>
</tr>
<tr>
<td>mean age (range)</td>
<td>75 (63–87)</td>
<td>74 (62–86)</td>
</tr>
<tr>
<td>Female</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>mean age (range)</td>
<td>75 (62–86)</td>
<td>75 (63–92)</td>
</tr>
<tr>
<td>Residential status at fracture</td>
<td></td>
<td></td>
</tr>
<tr>
<td>own home</td>
<td>70 (83)</td>
<td>70 (83)</td>
</tr>
<tr>
<td>convalescent home or fullservice unit with meals</td>
<td>12 (14)</td>
<td>12 (14)</td>
</tr>
<tr>
<td>geriatric department, rehabilitation or long term care</td>
<td>2 (3)</td>
<td>2 (3)</td>
</tr>
<tr>
<td>Walking capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>walked alone or accompanied out of doors</td>
<td>64 (76)</td>
<td>64 (76)</td>
</tr>
<tr>
<td>walked alone indoors but not out of doors</td>
<td>17 (20)</td>
<td>17 (20)</td>
</tr>
<tr>
<td>walked indoors only accompanied</td>
<td>3 (4)</td>
<td>3 (4)</td>
</tr>
<tr>
<td>unable to walk, able to sit</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Use of walking aids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>can walk without aids</td>
<td>49 (59)</td>
<td>59 (70)</td>
</tr>
<tr>
<td>one stick</td>
<td>17 (20)</td>
<td>13 (16)</td>
</tr>
<tr>
<td>two sticks</td>
<td>2 (2)</td>
<td>1 (1)</td>
</tr>
<tr>
<td>rollator/walking frame</td>
<td>16 (19)</td>
<td>11 (13)</td>
</tr>
<tr>
<td>wheelchair</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>ADL-functions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>yes</td>
<td>65 (77)</td>
<td>68 (81)</td>
</tr>
<tr>
<td>no</td>
<td>19 (23)</td>
<td>16 (19)</td>
</tr>
</tbody>
</table>

The same standardized forms were prospectively filled in with data as in the study III and follow-up was continued for four months by recording the re-operation rate, mortality and the same functional parameters that were recorded preoperatively. Mortality and re-operation rate were also recorded at one year after the fracture.

OS with three screws in Oulu was performed through a lateral incision after closed reduction and fixation (Fig. 11). HA in Oulu was always performed through a posterior approach using an uncemented Austin-Moore prosthesis (Fig. 10).

Fig. 11. Osteosynthesis with three screws in Oulu.
Full weight bearing was allowed on the first postoperative day for both OS and HA patients. The patients were encouraged to walk as soon as possible.

### 4.5 Deep infection after hip fracture surgery

2299 patients with non-pathological hip fractures aged over 50 years (mean age 78.2 years, 1718 female, and 583 male) were admitted into the Oulu University Hospital during 1989–1999. 287 had undisplaced femoral neck fractures (13 %), 1027 displaced femoral neck fractures (45 %), 55 bascervical fractures (2 %), 371 trochanteric two-fragment fractures (16 %), 460 trochanteric multi-fragment fractures (20 %) and 99 subtrochanteric fractures (4 %).

437 patients were treated with two or three screws (19 %), 814 patients with HA (Austin-Moore, 35 %), 70 patients with THA (3 %), 291 patients with dynamic hip screw (DHS, 13 %), two patients with AO plate (0.1 %), 657 patients with Gamma nail (29 %), 5 patients with girdlestone (0.2 %) and 23 patients conservatively (1 %).

A control group was formed by a statistician. Matching was performed for age, sex, fracture type, operative method, place of residence and walking ability (Table 7).

<table>
<thead>
<tr>
<th>N:o of patients</th>
<th>Patients with deep infection (%)</th>
<th>Patients without deep infection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential status</td>
<td></td>
<td></td>
</tr>
<tr>
<td>own home</td>
<td>14 (48)</td>
<td>14 (48)</td>
</tr>
<tr>
<td>convalescent home or fullservice with meals</td>
<td>14 (48)</td>
<td>14 (48)</td>
</tr>
<tr>
<td>geriatric department, rehabilitation or long term care</td>
<td>1 (2)</td>
<td>1 (2)</td>
</tr>
<tr>
<td>Walking Ability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>walked alone out of doors</td>
<td>12 (42)</td>
<td>12 (42)</td>
</tr>
<tr>
<td>walked out of doors only accompanied</td>
<td>5 (17)</td>
<td>5 (17)</td>
</tr>
<tr>
<td>walked alone indoors but not out of doors</td>
<td>10 (35)</td>
<td>10 (35)</td>
</tr>
<tr>
<td>walked indoors only accompanied</td>
<td>1 (3)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>unable to walk</td>
<td>1 (3)</td>
<td>1 (3)</td>
</tr>
<tr>
<td>Use of walking aids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>can walk without aids</td>
<td>13 (45)</td>
<td>14 (48)</td>
</tr>
<tr>
<td>one stick</td>
<td>10 (34)</td>
<td>4 (14)</td>
</tr>
<tr>
<td>two sticks</td>
<td>1 (3)</td>
<td></td>
</tr>
<tr>
<td>rollator/walking frame</td>
<td>4 (14)</td>
<td>9 (31)</td>
</tr>
<tr>
<td>wheelchair</td>
<td>2 (7)</td>
<td>1 (4)</td>
</tr>
</tbody>
</table>

Standardized forms were prospectively filled in with data concerning the same data as in the studies III and IV and follow-up was also continued for four months by recording the same functional parameters that were recorded preoperatively. Mortality and re-operation rate were recorded up till December 2000.
4.6 Ethical considerations

Written informed consent was obtained from all the patients and controls, and the study protocols were approved by the institutional ethical committee.

4.7 Classification of fractures

The femoral neck fractures were classified according to Garden, the trochanteric fractures according to Jensen and the subtrochanteric fractures according to Seinsheimer (Garden 1964, Jensen & Michaelsen 1975, Seinsheimer 1978). Basicervical fractures were classified here as a two-fragment undisplaced trochanteric fractures (Jensen & Michaelsen 1975).

4.8 Statistical analyses

The data organization and statistical analyses were performed by a statistician using the SPSS statistical software: version 8.0, version 9.0, and version 10.0; SPSS, Inc., Chicago, IL, USA. Pearson’s linear correlation coefficients were calculated in the study I and II. Student's t-test and the Mann-Whitney U-test were used to compare the differences for significance. The Mann-Whitney U-test was used whenever the material was not normally distributed. The Chi-square test and Fisher's exact test (2 x 2 table) were used to compare the dichotomous variables and the Chi-square and exact tests in the analysis of multiple categorical variables. P<0.05 was considered significant.

Statistical analyses in the studies with cross-matched data were performed as described by Breslow and Day (1980) for matched-pair studies III, IV and V, comparing the pair members to each other with McNemar's test for dichotomous variables and with marginal homogeneity for multiple categorical variables. Only the pairs with complete data were considered in the statistical analyses (Breslow & Day 1980). This explains the great variation in the numbers of observations. P< 0.05 was considered significant.

The sample power test (power=0.80, alpha=0.05) was used to find the number of pairs reaching the level of significant difference in the analysed parameters in the study IV and Kaplan-Meier analysis was used for survival analysis in the study V.
5 Results

5.1 Geometrical measures

The fracture group had a higher NSA than the controls (Fig. 12). The cortical thickness values were significantly lower in the fracture group (Fig. 13). FSD ($p<0.001$) and TW ($p<0.01$) were also significantly lower in the fracture group than in the control group. The pelvic dimensions SOPD and LIPD were smaller in the fracture group than in the control group ($p<0.01$ and $p<0.05$, respectively).

Fig. 12. NSA in fracture patients and controls.
The ratio FNC/FSC was significantly lower in the femoral neck fracture patients (p<0.05). NSA was significantly greater in the femoral neck fracture patients (Fig. 14). SOPD and AW were significantly wider in the femoral neck fracture patients (p<0.01 and p<0.05, respectively). FSD was significantly narrower in the femoral neck fracture group than in the trochanteric group (p<0.05).

Fig. 13. Femoral cortices in fracture patients and controls.

Fig. 14. NSA between femoral neck fracture patients and trochanteric fracture patients.
5.2 Bone mineral density, parameters of bone metabolism, and lifetime factors

Body weight and BMI (p=0.004) were significantly lower in the fracture group compared to the control group. The BMD in the upper femur differed significantly between the fracture and the control group (Table 8).

Body weight, BMD of the upper femur and BMI (p=0.021) were higher in the femoral neck fracture patients compared to the trochanteric fracture patients (Table 8).

Table 8. Weight, height and bone mineral density (BMD) measured at femoral neck (FEBMD), Ward’s triangle (WABMD) and trochanter region (TRBMD) in postmenopausal hip fracture patients and controls.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Weight kg</th>
<th>Height cm</th>
<th>FEBMD g/cm²</th>
<th>WABMD g/cm²</th>
<th>TRBMD g/cm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture (mean and SD)</td>
<td>74</td>
<td>61 (13)</td>
<td>159 (6)</td>
<td>0.68 (0.13)</td>
<td>0.57 (0.16)</td>
<td>0.62 (0.15)</td>
</tr>
<tr>
<td>Control</td>
<td>40</td>
<td>68 (9)</td>
<td>160 (4)</td>
<td>0.84 (0.09)</td>
<td>0.68 (0.1)</td>
<td>0.78 (0.09)</td>
</tr>
<tr>
<td>Femoral neck fx</td>
<td>49</td>
<td>63 (13)</td>
<td>160 (5)</td>
<td>0.73 (0.12)</td>
<td>0.62 (0.15)</td>
<td>0.67 (0.14)</td>
</tr>
<tr>
<td>Trochanteric fx</td>
<td>25</td>
<td>55 (11)</td>
<td>158 (6)</td>
<td>0.61 (0.12)</td>
<td>0.46 (0.12)</td>
<td>0.55 (0.13)</td>
</tr>
</tbody>
</table>

p=0.022, *p=0.011, **p=0.005, ***p=0.003, ****p=0.002, *****p=0.001, ******p<0.001

The s-Ca and s-25-(OH)-D levels were significantly lower in the fracture group than in the control group. The level of s-CT was significantly higher in the fracture group than in the control group.

There were no significant differences between the trochanteric and femoral neck fracture groups in any other biochemical measurements except s-CT, which was higher in the femoral neck fracture group than in the trochanteric fracture group (Table 9).

Table 9. Biochemical measurements associated with bone and calcium metabolism in postmenopausal hip fracture patients and controls.

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>S-ALP U/L</th>
<th>S-Ca mmol/L</th>
<th>S-CT pmol/L</th>
<th>S-25-(OH)-D nmol/L</th>
<th>Fs-PTH ng/L</th>
<th>S-PINP µg/L</th>
<th>S-BAP µg/L</th>
<th>S-OC µg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture (mean and SD)</td>
<td>36</td>
<td>160.6 (60.8)</td>
<td>**2.1 (0.2)</td>
<td>**7.4 (5.2)</td>
<td>**24.7 (12.9)</td>
<td>54.7 (33)</td>
<td>49.1 (39)</td>
<td>61.4 (27.7)</td>
<td>27 (26)</td>
</tr>
<tr>
<td>Controls</td>
<td>21</td>
<td>148.5 (50.1)</td>
<td>2.3 (0.2)</td>
<td>4.9 (2.3)</td>
<td>6.9 (27.1)</td>
<td>41.4 (14.3)</td>
<td>38.9 (20)</td>
<td>64.6 (37)</td>
<td>24.2 (8.6)</td>
</tr>
<tr>
<td>Femoral neck fx</td>
<td>24</td>
<td>162.4 (61.6)</td>
<td>2.1 (0.1)</td>
<td>**8.3 (5.9)</td>
<td>26 (13.9)</td>
<td>57 (36.5)</td>
<td>48.6 (39.3)</td>
<td>58.1 (25.8)</td>
<td>28 (30.4)</td>
</tr>
<tr>
<td>Trochanteric fx</td>
<td>12</td>
<td>156.7 (61.9)</td>
<td>2.2 (0.2)</td>
<td>5.4 (2.5)</td>
<td>22 (10.5)</td>
<td>50 (25.1)</td>
<td>50.2 (40.1)</td>
<td>68.3 (31.4)</td>
<td>25 (12.7)</td>
</tr>
</tbody>
</table>

* p=0.044, **p=0.022, ***p<0.001

The fracture group included more users of loop diuretics, i.e. furosemid, insulin, oral antidiabetics, neuroleptics and antidepressants, than the control group. Asthma drugs (inhaled cortison, inhaled decongestants) and thyroid hormone were more often used in the control group (Table 10).
Table 10. Main differences between postmenopausal women with hip fracture compared to controls regarding to medication, concurrent diseases and gynaecological and lifestyle factors.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loop diuretics</td>
<td>More used in fracture patients</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>Insulin and antiabiotics</td>
<td>More used in fracture patients</td>
<td>p=0.029</td>
</tr>
<tr>
<td>Neuroleptics</td>
<td>More used in fracture patients</td>
<td>p=0.049</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>More used in fracture patients</td>
<td>p=0.005</td>
</tr>
<tr>
<td>Astma drugs</td>
<td>More used in controls</td>
<td>p=0.032</td>
</tr>
<tr>
<td>Thyroid drugs</td>
<td>More used in controls</td>
<td>p=0.021</td>
</tr>
<tr>
<td>Cardiovascular diseases</td>
<td>More in fracture patients</td>
<td>p=0.011</td>
</tr>
<tr>
<td>Stroke</td>
<td>More in fracture patients</td>
<td>p=0.002</td>
</tr>
<tr>
<td>Diabetes</td>
<td>More in fracture patients</td>
<td>p=0.002</td>
</tr>
<tr>
<td>Malignancies</td>
<td>More in fracture patients</td>
<td>p=0.031</td>
</tr>
<tr>
<td>Physical activity</td>
<td>Fracture patients less active</td>
<td>p&lt;0.001</td>
</tr>
<tr>
<td>The use of alcohol</td>
<td>More used in controls</td>
<td>p=0.006</td>
</tr>
<tr>
<td>Deliveries</td>
<td>More in fracture patients</td>
<td>p=0.036</td>
</tr>
</tbody>
</table>

Cardiovascular diseases (coronary disease, hypertension, heart failure, valvular diseases) and stroke (ischemic brain disorders) were significantly more frequent in the fracture group compared to the control group. Type I and type II diabetes mellitus and malignancies were also significantly more common in the fracture group than in the control group (Table 10).

Use of alcohol was more frequent in the control group than in the fracture group. The fracture group was less active physically compared to the controls (Table 10).

The fracture group included more women who had had one or more deliveries (Table 10).

More of the controls lived independently (p<0.001), their walking ability was better (p<0.001), and they used walking aids less often (p=0.002) than the fracture patients. Femoral muscle strength and vision were also better in the control group than in the fracture group (p<0.001).

No significant differences were seen in any medication, concurrent diseases, gynaecological and lifestyle factors, femoral muscular strength, independency, walking ability or use of walking aids between the femoral neck and trochanteric fracture groups.

5.3 Functional outcome after uncemented Austin-Moore hemiarthroplasty and osteosynthesis with two hook pins

The median duration of hospitalization after the first admission into a primary hospital was significantly longer for OS patients in Lund than for HA patients in Oulu (p=0.001). On the other hand, more of OS patients were discharged directly into their own home from the primary hospital (p=0.001).
Table 11. Outcome after comparison between uncemented HA in Oulu and OS with two hook pins in Lund.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Results</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking capacity</td>
<td>OS patients better ambulatory capacity</td>
<td>0.001</td>
</tr>
<tr>
<td>Use of walking aids</td>
<td>OS patients less use of walking aids</td>
<td>0.001</td>
</tr>
<tr>
<td>Pain</td>
<td>OS patients less pain</td>
<td>0.007</td>
</tr>
<tr>
<td>Re-operation rate</td>
<td>OS patients higher re-operation rate at one year</td>
<td>0.005</td>
</tr>
</tbody>
</table>

More OS patients than HA patients were able to manage in their own home or lived semi-independently in a convalescent home or full-service unit at four months (p=0.025).

71% of the HA patients and 87% of the OS patients who had been living in their own homes at the time of the fracture had returned to their own home at four months.

OS patients had better ambulatory capacity. OS patients also used less walking aids than HA patients (Table 11). When asked if they could walk equally well at four months as before the fracture, OS patients reported better walking capacity (p=0.002).

OS patients were able to manage better in ADL skills, but this was the case also at fracture. OS patients also had less pain in the involved hip than HA patients (Table 11).

Mortality was 4% higher at four months and 5% higher at one year among HA patients than among OS patients.

The re-operation rates were of the same magnitude in both HA and OS patients at 4 months, while at one year, OS patients had a higher re-operation rate (17%) than HA patients (10%) (Table 11).

5.4 Functional outcome after uncemented Austin Moore hemiarthroplasty and osteosynthesis with three screws

There were no significant differences between the study groups in Oulu concerning functional outcome.

Significantly more of the OS patients than the HA patients had been re-operated by four months and one year (re-operation rates at 4 months 19% and 4% and those at one year 20% and 6%, p=0.004 and p=0.012, respectively). Mortality was of the same magnitude among both HA and OS patients (at four months 7% and 10%, at one year 17% and 14%, respectively).

5.5 Deep infection after hip fracture surgery

Twenty-nine patients (mean age 80, range 56-92 years) out of the 2276 treated surgically developed deep infection (rate 1.3%), and all of them had revision surgery in accordance with our treatment policy. Eight patients were men (mean age 74 range 56-89 years) and 21 were women (mean age 82, range 60-92 years). The infection appeared after the primary operation in 25 cases and after a re-operation in 4 cases. The mean delay of the
revision for infection was 84 (range 5-300) days. Bacteriological culture was positive in 27 of the patients and negative in two cases. One or more concurrent diseases were present in 93 % of the patients and in 92 % of the controls. The cases had more often diabetes than the controls (41 % vs. 14 %, p=0.038). The corresponding figures for cardiovascular diseases (coronary heart disease, chronic heart failure, valvular heart disease, hypertension) were 76 % and 59 %, respectively (p=0.213).

Infection impaired the functioning of the patients as evaluated at 4 months after primary surgery. Their walking ability was poorer and they used more walking aids, but the place of residence was not affected (Table 12).

Table 12. Outcome data after comparison between patients with and without deep infection after hip fracture surgery.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Patients with deep infection (%)</th>
<th>Patients without deep infection (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential status</td>
<td></td>
<td></td>
<td>0.785</td>
</tr>
<tr>
<td>own home</td>
<td>6 (21)</td>
<td>10 (34)</td>
<td></td>
</tr>
<tr>
<td>convalescent home or full service with meals</td>
<td>5 (17)</td>
<td>8 (28)</td>
<td></td>
</tr>
<tr>
<td>geriatric department, rehabilitation or long term care, acute hospital</td>
<td>14 (48)</td>
<td>6 (21)</td>
<td></td>
</tr>
<tr>
<td>unknown or dead</td>
<td>4 (14)</td>
<td>5 (17)</td>
<td></td>
</tr>
<tr>
<td>Walking Ability</td>
<td></td>
<td></td>
<td>0.039</td>
</tr>
<tr>
<td>walked alone out of doors</td>
<td>4 (16)</td>
<td>7 (29)</td>
<td></td>
</tr>
<tr>
<td>walked out of doors only accompanied</td>
<td></td>
<td>2 (8)</td>
<td></td>
</tr>
<tr>
<td>walked alone indoors but not out of doors</td>
<td>5 (20)</td>
<td>7 (29)</td>
<td></td>
</tr>
<tr>
<td>walked indoors only accompanied</td>
<td>5 (20)</td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>unable to walk</td>
<td>11 (44)</td>
<td>5 (21)</td>
<td></td>
</tr>
<tr>
<td>Use of walking aids</td>
<td></td>
<td></td>
<td>0.022</td>
</tr>
<tr>
<td>can walk without aids</td>
<td></td>
<td>1 (4)</td>
<td></td>
</tr>
<tr>
<td>one stick</td>
<td>3 (12)</td>
<td>2 (8)</td>
<td></td>
</tr>
<tr>
<td>two sticks</td>
<td></td>
<td>3 (13)</td>
<td></td>
</tr>
<tr>
<td>rollator/walking frame</td>
<td>10 (40)</td>
<td>13 (54)</td>
<td></td>
</tr>
<tr>
<td>wheelchair</td>
<td>12 (48)</td>
<td>5 (21)</td>
<td></td>
</tr>
<tr>
<td>Mortality</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>at four months</td>
<td>4 (14)</td>
<td>4 (14)</td>
<td>1.000</td>
</tr>
<tr>
<td>at one year</td>
<td>10 (35)</td>
<td>7 (24)</td>
<td>0.508</td>
</tr>
</tbody>
</table>

In the infection group, one-year mortality was 34 %, while the corresponding figure for the control group was 24 %, giving attributable mortality of 10 % for deep infection. The highest mortality at one year was seen in the patients who had undergone removal of an Austin-Moore prosthesis (67 %). Infection seemed to increase mortality over the first three postoperative years, but the difference in comparison with the patients without infection was not significant (p=0.1594, Fig. 15).
The operations for infection could be divided into two categories: Removal of the whole osteosynthesis or prosthesis and salvaging of the implant or prosthesis. One-year mortality tended to be higher after the removal procedures (8 patients at one year, 44 %) than after the salvage procedures (2 patients at one year, 18 %, \( p=0.234 \)). When the revision surgery for infection was done more than 1.5 months after the primary operation, significantly more patients needed removal of the osteosynthesis or prosthesis compared to those with less than 1.5 months’ delay (\( p=0.0078 \)). However, the delay had no significant effect on mortality (\(< 1.5 \) months vs. \( >1.5 \) months, \( p=0.449 \)).

*Staphylococcus aureus* was the most common causative micro-organism either alone, in 14 cases (48 %), or as a mixed infection, in 3 cases (10 %), and it was recovered from blood in four cases, giving a bacteremia rate of 24 %. *Staphylococcus aureus* infection seemed to be associated with higher mortality at one year (\( p=0.014 \)) than the other bacteria. The course of *Staphylococcus epidermidis* infection seemed to be milder and did not increase mortality.
6 Discussion

6.1 Upper femur and pelvic geometry and hip fracture risk

The geometrical parameters of the pelvis and the proximal femur were measured from plain pelvic radiographs. To reduce the variability of the data, the patients’ position was standardized and the dimension measurements calibrated. The method appeared to be highly reproducible for all the other parameters except cortical thickness. The root mean square accuracy error was also quite low, 2.3%. No relevant comparison could be made, because of no error values have been reported by any other authors. Accuracy and reproducibility were also improved by using digital image analysis, which has been shown to be more accurate than the human eye (Bould et al. 1999). Digital analysis was seldom used in other conventional pelvic x-ray studies (Glüer et al. 1994).

We found that women with thin cortices have an increased risk to sustain a hip fracture, which is in good accordance with the other studies (Glüer et al. 1994, Peacock et al. 1995). The neck-shaft angle was larger in the fracture group compared to the control group in our study. This finding has been inconsistent in previous studies: some studies have found NSA to be larger in the fracture group (Glüer et al. 1994, Karlsson et al. 1996), while others have failed to reveal any differences (Peacock et al. 1995, Michelotti & Clark 1999). It has been reported that the medial cortex becomes thinner when the NSA increases (Putz 1993). We found a correlation in hip fracture patients between thin cortices in the upper femur and NSA, which is in agreement with this previous finding of individual cases. A high neck/shaft angle seems to increase more the risk of femoral neck fracture (Fig. 16).
The risk of hip fracture might be lower if the NSA value is low (Fig. 17). In patients with severe osteoporosis, the trochanteric area might be exposed to the highest risk of fracture, whenever the person sustains a typical fall on the lateral aspect of the hip (Parkkari et al. 1999).

The lower TW and FSD in our hip fracture patients compared to the controls may indicate that the bone breaks more easily because of the smaller cross-sectional area due to the basic biomechanical properties of cortical and trabecular bone (Mow & Hayes 1991). Contrary to our findings, smaller pelvic diameters in hip fracture patients compared to controls were not found by Karlsson et al. (Karlsson et al. 1996). The significance of this controversy is uncertain.
6.2 Lifetime factors, markers of bone metabolism and a risk of hip fracture

The fact that our control group was obtained from a private outpatient clinic with strict exclusion criteria may cause some bias: the controls were probably more health-oriented and vital. However, we do not consider this crucial because public health care centers also refer patients for DEXA measurements in this private clinic. We therefore believe that the control group, by and large, represents an average and comparable population in our area. There were some limitations in our study: the study was cross-sectional, the group sizes, especially the size of the trochanteric fracture group, were relatively small, and we did not measure bone resorption markers.

The body weight and BMI of the controls turned out to be higher than those of the fracture patients, which difference is in line with earlier reports (Eriksson & Widhe 1988, Karlsson et al. 1993). We did not see any differences in body height, as previously reported (Hemenway et al. 1995, Farahmand et al. 2000, Lau et al. 2001).

It is generally known that hip fracture patients have lower BMD than non-fracture controls or the average population (Nakamura et al. 1992, Sugimoto et al. 1994, Tromp et al. 2000), which was also shown in our study. But one third of our fracture patients did not fully meet the criteria of osteoporosis as defined by WHO (≤-2.5 SD) (WHO Study Group 1994), and a minor part of them even had almost normal bone density. The important roles of the falling mechanism and bone geometry in the pathogenesis of hip fractures might explain the occurrence of hip fractures among these patients (Hayes et al. 1993, Glüer et al. 1994, Duboeuf et al. 1997). The geometry was also shown to be important by our findings.

Hip fracture patients had lower levels of total calcium and lower levels of 25(OH)D in serum than the controls in line with the findings reported earlier (Arnala et al. 1997), (Hoikka et al. 1982, Harju et al. 1985, Punnonen et al. 1986) and there was a significant inverse correlation between s-25-(OH)-D and s-PTH. This might imply subsequent secondary hyperparathyreoidism, which is postulated to be largely responsible for the excessive bone loss (Parfitt et al. 1982).

Our fracture patients were less healthy than the controls, as a greater proportion of them had had heart diseases, strokes, diabetes and malignant diseases. Diabetes has been reported to be associated with hip fractures (Forsén et al. 1999), and heart diseases also appear to associate with the occurrence of hip fractures (Lau et al. 2001). Whether the increased risk should be attributed to a reduced bone mass or to factors associated with the falling has not yet been determined (Forsén et al. 1999). A history of stroke is a major risk factor for hip fracture (Rammemark et al. 1998, Lau et al. 2001), and this was also true in our study.

The use of loop diuretics was markedly higher in fracture patients than in controls. The lower BMD in the fracture patients might be partly explained by their more abundant use of loop diuretics. It must be emphasized that loop diuretics are in common use worldwide, and this might explain partly the increased incidence of hip fractures in many countries.

The functional ability of the fracture patients was poor when evaluated in terms of independence, walking ability, physical activity, use of walking aids, vision and femoral muscle strength. Similar findings have been reported by other authors (Tromp et al. 2000,
The lesser mobility of the elderly enhances bone resorption (Lips et al. 1990) and might also partly explain the lower BMD values in the fracture group.

6.3 Etiopathology of femoral neck and trochanteric fracture

The main geometrical differences between the features of femoral neck and trochanteric fractures were the greater NSA, SOPD and AW, the narrower FSD and the smaller FNC/FSC in femoral neck fracture patients. Similar findings have been reported by Glüer et al. for FNC/FSC and AW, but they did not measure the pelvic diameters or FSD. However, we did not find any significant difference in HD or cortical thickness, as Glüer et al. did (Glüer et al. 1994). Ferris et al. reported a shorter femoral neck length in patients with trochanteric fractures, but no differences in HD, FSD or NSA. However, they did not differentiate between women and men, their cervical fracture patients were significantly younger than those with a trochanteric fracture, and the group size (n=10) was relatively small (Ferris et al. 1989). Our findings support the postulation that differences in geometry play a role in the etiopathology of these two common hip fracture types.

Other important difference between patients with trochanteric hip fracture and femoral neck fracture is the fact that trochanteric fracture patients are more osteoporotic than femoral neck fracture patients (Eriksson & Widhe 1988, Vega et al. 1991a). This was also observed here.

We also found the body weight of the women with femoral neck fractures to be higher than those with trochanteric fractures, which is also in line with the previous reports (Eriksson & Widhe 1988, Karlsson et al. 1993). This difference may be related to the lower BMD observed in patients with trochanteric hip fractures compared with patients with the femoral neck fractures.

The increased calcitonin level seen in fracture patients, especially ones with femoral neck fractures, might be the result of a feedback mechanism in osteoporotics with increased bone resorption tending to increase the calcium level. Calcitonin antagonizes this mechanism. The mechanism might be more closely related to patients with femoral neck fractures than patients with trochanteric fractures.

We found no significant differences in the lifetime factors between the femoral neck and trochanteric fracture groups, although the groups were quite small in size. This is in agreement with the study of Sernbo et al. (1987), who found differences in several lifetime factors, but these were age-dependent and not real risk factors after age adjustment (Sernbo & Johnell 1987).
6.4 Osteosynthesis or hemiarthroplasty in the treatment of displaced femoral neck fractures?

The groups were drawn from an extensive prospective series, which made it possible to match them for several parameters. This makes the comparison fairly reliable, and we believe that our method is nearly as adequate as randomization. We were also able to perform cross-matching for walking ability, which reflects the patient’s general condition and concurrent diseases. In view of the fact that there were no significant differences in any other background factors, the pairs should be reliably matched and comparable. We did not find any controlled comparison between OS and HA at this level of matching in the literature, which made adequate comparison with other published results difficult. However, the results previously reported on functional outcome have been very inconsistent.

In the study comparing osteosynthesis with two pins and uncemented hemiarthroplasty, the patients were drawn from two hospitals in different countries. Both hospitals were university hospitals in Scandinavia, where the climate, housing conditions, social welfare system and care facilities are fairly similar. Thus, the quality and results of treatment should be similar. It should also be emphasized that both hospitals were very familiar with their respective methods of treating femoral neck fractures. There were some missing data at the 4-month follow-up, more so in Lund. This may be due to the fact that Lund used mainly mailed forms filled in by the patients, while in Oulu the patients who did not return the follow-up forms were contacted for a telephone interview. This should not significantly influence the results, since only the complete pairs of patients were considered in the statistical tests.

The patients of the study comparing osteosynthesis with three screws and uncemented hemiarthroplasty were drawn from another participating hospital, Oulu University Hospital, and the same parameters as in the above-mentioned study were comparatively assessed.

The duration of treatment after the primary admission was longer for OS patients in Lund, but this reflects the different after-care policies in Lund and Oulu. Oulu has numerous local hospitals in the vicinity, that can admit the patients almost immediately after surgery, but in Lund, rehabilitation begins in the primary hospital.

Ambulatory capacity was better among our OS patients than among our HA patients, although the differences were not significant between the study groups, OS and HA, in Oulu. The better functioning of OS patients may be partially explained by the less pain associated with OS, as reported earlier (Skinner et al. 1989, Ravikumar & Marsh 2000). One prospective and randomized study (Dorr et al. 1986) reported that the patients with uncemented HA had increased pain and decreased ambulation compared to the patients with THA and cemented HA, which might partly explain the better functional outcome and residential status in our study because OS patients had less pain compared to uncemented HA patients. However, we did not compare cemented HA to osteosynthesis, and it remains unclear if the patients with cemented HA would have had an equal or better functional outcome compared to OS. In their prospective and randomized study, (Bray et al. 1988) concluded that the two-year functional results were better in the cemented HA group than in the OS group, but the number of patients was small, and the
differences were not statistically significant. On the other hand, many authors have reported similar functional outcomes in HA and OS patients (Söreide et al. 1979, Berglund-Rödén et al. 1994, Young et al. 1996, Parker & Pryor 2000b). The discrepancy between our paper and the previous studies may be explained by the facts that no randomization or matching was used in some of them, and that the number of patients in all these studies was markedly smaller than in our study groups in Lund and Oulu. The difference in functional capacity seems to be small and does not reach the level of significance in small series, as it was also seen in the comparison between the study groups in Oulu.

Mortality has mostly been reported to be lower in OS patients than in HA patients (Bracey 1977, Raine 1973, Rodriguez et al. 1987). On the other hand, some prospective trials (Söreide et al. 1979, Parker & Pryor 2000) have not revealed any difference in mortality following OS or HA. We found no significant differences in mortality between the study groups.

At four months, there were no differences in the re-operation rates between Oulu and Lund, but the OS group in Oulu had a higher re-operation rate than the HA group in Oulu. At one year, the re-operation rate was significantly higher in the OS groups in Lund and Oulu compared to the HA group in Oulu. The re-operation rate has been found to be higher in OS than HA patients in most earlier studies (Lu-Yao et al. 1994).

6.5 Deep infection

Our results showed that deep infection after hip fracture surgery impaired the patients’ functional ability in the assessment of short-term outcome and also tended to increase mortality. This is partly in harmony with an earlier case-control study, where deep infection after hip fracture impaired mobility, increased social dependency and prolonged the inpatient period. In that study (Eastwood 1993), however, mortality was much higher (62% at 6 months) than in our study (35% at one year). This difference might be partly due to the higher mean age of the patients (86 years) in that study than in ours (80 years).

Underlying diseases, especially diabetes, have been shown to be risk factors for deep infection after hip fracture surgery (Enstone & Humphreys 1998). This was also seen in our study, where 41% of the cases but only 14% of the controls had diabetes. The most frequent bacterial specimen isolated from the wound area or from blood was *Staphylococcus aureus*, which is in agreement with previous studies (McQueen et al. 1990, Aagaard et al. 1994). *Staphylococcus aureus* infections also involved higher mortality than other micro-organisms, which can be explained by the generally known severity of *Staphylococcus aureus* infections and especially septicemia (Lowy 1998, Jensen et al. 2002). Actually, one fourth of our patients with *Staphylococcus aureus* infection had bacteremia.
6.6 Future

Falling mechanics, low hip bone mineral density (BMD) and impaired mobility have all been identified as independent risk factors for hip fracture (Robinovitch et al. 1991, Hayes et al. 1993, Greenspan et al. 1998). In the future, it would be useful to combine geometric measurements with an analysis of falling mechanics, BMD and mobility.

The effectiveness of bone geometry as measured from plain pelvic x-ray images, BMD, markers of bone metabolism and lifetime factors in the risk of hip fracture and type could be tested in a longitudinal study.
7 Conclusions

1. The radiographical geometry of the upper femur, especially high neck/shaft angle, thin cortices and low femoral shaft diameter and trochanter width, and the pelvic dimensions associated strongly with the hip fracture risk in postmenopausal women. Greater neck/shaft angle, smaller outer pelvic diameter and acetabular width, narrower femoral shaft diameter and smaller femoral neck/shaft cortex ratio were associated with femoral neck fractures rather than trochanteric fractures in postmenopausal women.

2. Impaired functional ability, use of loop diuretics, antidiabetic, antidepressant and neuroleptic drugs, some concurrent diseases, such as strokes, diabetes, malignant diseases and cardiovascular diseases, low bone mineral density of the upper femur, low serum calcium, low serum 25-hydroxyvitamin D and high serum calcitonin, seemed to be related to the risk of hip fracture, while low bone mineral density and low serum calcitonin were related to the trochanteric fracture type in postmenopausal women.

3. Short-term functional outcome was better after osteosynthesis with two pins compared to uncemented Austin-Moore hemiarthroplasty with regard to more frequent return to the previous place of residence, better ambulatory capacity, less use of walking aids and less pain. Osteosynthesis with three screws was equally good as Austin Moore hemiarthroplasty with regard to short-term functional outcome. On the other hand, Osteosynthesis was associated with a higher re-operation rate than uncemented Austin-Moore hemiarthroplasty.

4. Deep infection after hip fracture surgery impaired the short-term functional outcome and slightly increased mortality, with an attributable mortality rate of 10 %.
References


