Ismo Saarenpää

EXTRACAPSULAR HIP FRACTURES—ASPECTS OF INTRAMEDULLARY AND EXTRAMEDULLARY FIXATION
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Academic Dissertation to be presented, with the assent of the Faculty of Medicine of the University of Oulu, for public defence in Auditorium 1 of Oulu University Hospital, on November 7th, 2008, at 12 noon
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Abstract
The purposes of the present research were (1) to analyse and characterize the hip fractures treated at Oulu University Hospital during a one-year period using the special forms of the Standardized Audit of Hip Fractures in Europe (SAHFE) and to evaluate their value for quality control, (2) to compare gamma nail (GN) and dynamic hip screw (DHS) fixation for the treatment of trochanteric hip fractures, focusing especially on the functional aspects, (3) to compare the short-term outcome of gamma nail (GN) and dynamic hip screw (DHS) fixation for the treatment of subtrochanteric hip fractures, and (4) to examine the rate and reliability of the classification of basicervical hip fractures and the outcome of the operative methods used for their treatment.

Oulu University Hospital joined the Swedish Hip Fracture Project (Rikshöft), aimed at developing the quality control of hip fracture treatment, in 1989, and this later evolved into a project called the Standardized Audit of Hip Fractures in Europe (SAHFE), funded by the European Commission. Registration of hip fractures on the SAHFE forms was common practise in Oulu from 1st September 1997 until the end of December 2003. SAHFE data collection forms were used in all four studies belonging to this thesis.

There were 238 hip fracture patients during the one-year period of registration at Oulu University Hospital. The intracapsular / extracapsular fracture rate (60/40) and the female/male rate (80/20) seemed to be similar to those reported in the recent Finnish Health Care Register data. The most frequent method for treating cervical fractures was Austin-Moore hemiarthroplasty (68%) and that for trochanteric and subtrochanteric fractures GN fixation (86%). The SAHFE forms proved to be easy to use and practicable for evaluating the quality of hip fracture treatment.

In a matched-pair study the short-term outcomes of the treatment of trochanteric fractures (after 4 months) were slightly better in the DHS group than in the GN group with respect to walking ability and mortality. The difference in mortality was at least partly due to the higher number of complications requiring re-operations associated with GN fixation.

In the treatment of subtrochanteric hip fractures, there were four intraoperative complications (9.3%) in the GN group but none in the DHS group. On the other hand, postoperative complications were more common in the DHS group (20% vs. 2%). It is significant that all these complications in the DHS group occurred in Seinsheimer type IIIA fractures. It is concluded that, despite the perioperative problems associated with gamma nailing, this technique may be preferable to DHS fixation for specific fracture types with medial cortical comminution, such as Seinsheimer type IIIA.

Altogether 108 of the 1624 hip fractures were initially classified by the surgeons as basicervical fractures, but after a careful second look only 30 fulfilled all the criteria. The definitive rate of basicervical fractures was thus 1.8%. Treatment of basicervical fractures as trochanteric fractures proved superior to their treatment as cervical fractures, resulting in lower re-operation rates.

In conclusions; this thesis suggests that SAHFE forms are very useful for evaluating the quality of hip fracture treatment. Both GN fixation and DHS fixation are effective methods for the treatment of trochanteric hip fractures in elderly patients; in less comminuted fractures, the DHS method is the preferred method of treatment whereas GN fixation is alternative treatment for more comminuted fractures. GN fixation is preferable for the subtrochanteric fractures. Basicervical fractures should be regarded clinically as extracapsular fractures and managed in a similar manner to trochanteric fractures.

Keywords: dynamic hip screw, fracture classification, functional outcome, gamma nail, hip fracture, osteosynthesis, subtrochanteric hip fracture, trochanteric hip fracture
To my family
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Oulainen, September 2008              Ismo Saarenpää
# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ADL</td>
<td>Activities of daily living</td>
</tr>
<tr>
<td>AO/ASIF</td>
<td>Arbeitsgemeinschaft für Osteosynthesefragen/Association for the Study of Internal Fixation</td>
</tr>
<tr>
<td>DCS</td>
<td>Dynamic condylar screw</td>
</tr>
<tr>
<td>DHS</td>
<td>Dynamic hip screw</td>
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<tr>
<td>GN</td>
<td>Gamma nail</td>
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<tr>
<td>HA</td>
<td>Hemiarthroplasty</td>
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<tr>
<td>IMHS</td>
<td>Intramedullary hip screw</td>
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<tr>
<td>MIS</td>
<td>Minimal invasive surgery</td>
</tr>
<tr>
<td>MSP</td>
<td>Medoff sliding plate</td>
</tr>
<tr>
<td>OS</td>
<td>Osteosynthesis</td>
</tr>
<tr>
<td>PCCP</td>
<td>Percutaneous compression plate</td>
</tr>
<tr>
<td>SAHFE</td>
<td>Standardized Audit for Hip Fractures in Europe</td>
</tr>
<tr>
<td>SHS</td>
<td>Sliding hip screw</td>
</tr>
<tr>
<td>THA</td>
<td>Total hip arthroplasty</td>
</tr>
<tr>
<td>THR</td>
<td>Total hip replacement</td>
</tr>
<tr>
<td>T(F)N</td>
<td>Trochanteric (femoral) nail</td>
</tr>
<tr>
<td>TSP</td>
<td>Trochanteric stabilizing plate</td>
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List of original articles

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


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Original articles
1 Introduction

There were an estimated 1.33 million new hip fractures worldwide in 1990 (Johnell & Kanis 2006), and a half of these occurred in Europe and North America (Cooper et al. 1992). For the year 2000 Johnell & Kanis (2006) estimated approximately 1.6 million new hip fractures. The total number of hip fractures in Finland was 1857 in 1970 and 7122 in 1997, and it is expected to be almost three times this latter figure in 2030 (Kannus et al. 1999). The age-adjusted incidence of hip fracture also increased between 1970 and 1997, from 292 to 467 in women and from 112 to 233 in men (Kannus et al. 1999). The reliability of these figures has been questioned. First Huusko et al. (1999a) reported no change in the age and sex-adjusted incidence of hip fractures in Central Finland between 1982 and 1992, and Nymark et al. (2006) reported a decreasing incidence in Funen County in Denmark. Sund (2006) investigated the Finnish Health Care Register covering whole Finland and found that the number of hip fractures per year was stable, around 5500 patients per year, incidence being around 320 per 100,000, and age-adjusted incidence 415 in women and 200 in men during 1998–2002. He also found an unexpectedly large number of false or multiple data in the hospital discharge register (Sund 2006, Sund et al. 2007). Later, Kannus et al. (2006) reported that the number of hip fractures among elderly Finns rose very constantly between 1970 (1857 fractures) and 1997 (7122 fractures), but since then the rise has leveled off (7083 fractures in 2004). Concerning the age-adjusted fracture incidence, findings were similar (Kannus et al. 2006). However, the total number of hip fractures will continue to increase due to the ageing of the population (Huusko et al. 1999a, Kannus et al. 1999, Lönnroos et al. 2006).

Trochanteric fractures are commonly treated nowadays by either intramedullary or extramedullary fixation. The AO dynamic hip screw (DHS), which has become one of the standard treatment techniques for trochanteric fractures (Chapman et al. 1981, Esser et al. 1986, Davis et al. 1988, Bannister et al. 1990), has been thoroughly assessed in recent decades, and randomized comparisons have shown it to be superior to fixed nail plates (Esser et al. 1986, Bannister et al. 1990, Parker & Handoll 2006), Enders nails (Chapman et al. 1981) or Küntscher nails (Davis et al. 1988). The system is reported to involve high failure rates in unstable pertrochanteric and subtrochanteric fractures, however (Jensen et al. 1978, Kaufer 1980, Haynes et al. 1997, Madsen et al. 1998, Lundy 2007). Intramedullary fixation with a gamma nail (GN), introduced about 15 years ago for the treatment of trochanteric fractures (Lindsey et al. 1991), was designed
to overcome the problems implicit in sliding-screw fixations (Madsen et al. 1998),
but several later studies have focused on the relatively high complication rate
associated with its use with subtrochanteric and especially trochanteric fractures
(Bridle et al. 1991, Calvert 1992, Williams & Parker 1992, Radford et al. 1993,

Controversial results have been reported concerning the treatment of
trochanteric hip fractures by these two main methods, GN and DHS fixation.
Several studies have favoured DHS (Bridle et al. 1991, Sabharwal et al. 1992,
Radford et al. 1993, Parker & Pryor 1996), whereas some have failed to establish
any significant differences between the two methods (Leung et al. 1992,
al. 2006, Jiang et al. 2008). Most reports on the results of operative treatment of
trochanteric hip fractures deal with fracture healing, complications and mortality,
whereas functional outcome is more important in a socioeconomic respect
(Larsson et al. 1990, de Palma et al. 1992, Stavrou et al. 1997, Madsen et al.
1998). There is no consensus, however, as to which of these main treatment
modalities should be preferred.

Subtrochanteric fractures are relatively rare, accounting for 1% to 9% of all
hip fractures (Whitelaw et al. 1990, Lüthje et al. 1992b, Williams & Parker 1992,
predominantly in cortical bone and require a prolonged healing time compared
with other hip fractures (Zickel 1976). The problems encountered in the operative
treatment of subtrochanteric fractures have been failure of fixation and non-union
(Velasco 1978, Ruff et al. 1986, Parker et al. 1997) and high subtrochanteric
fractures with loss of the lesser trochanter and the medial buttresses are especially

Various intramedullary and extramedullary devices have been developed in an
attempt to address potential complications of device failure, mal-union, non-union
or deformities. Some decades ago, a sliding-screw plate system came into wider
use even for subtrochanteric fractures because of the successful treatment of stable
trochanteric fractures (Madsen et al. 1998). DHS has been reported to involve high
failure rates in cases of unstable pertrochanteric or subtrochanteric fractures,
however (Jensen et al. 1978, Kaufer 1980, Haynes et al. 1997, Madsen et al. 1998,
Lundy 2007, Cheng et al. 2005). It is recommended nowadays that subtrochanteric
fractures and hip fractures with associated femoral shaft fractures and pathological
extracapsular fractures should be treated by intramedullary fixation (van Doorn & Stapert 2000, Edwards et al. 2001, Borens et al. 2004, Moholkar et al. 2004). Because of the infrequency of subtrochanteric fractures, most reports on these are retrospective and include only a small number of patients (Lunsjö et al. 1999). This is why multicentre trials are recommended for hip fractures of this type (Whitelaw et al. 1990).


Surgical treatment of basicervical fractures is regarded as fundamentally non-problematic (De Palma 1970, Wilson 1982, Kuokkanen 1991, Russel 1992), but previous studies have demonstrated a high incidence of complications leading to re-operations (Indemini et al. 1982, Levy et al. 1983, Kuokkanen 1991). The treatment problems are related to the difficulties and errors in classification. There are only a few previous studies that have concentrated on basicervical fractures as a separate entity and most of them have not considered the problems of classification.

The aims of this thesis were to analyse and characterize the hip fractures treated at Oulu University Hospital during a one-year period using the special forms of the Standardized Audit of Hip Fractures in Europe (SAHFE) and to evaluate their value in quality control, to compare two widely used modalities of
treatment for extracapsular hip fractures, dynamic hip screw (DHS) and gamma nail (GN) fixation in cases of trochanteric and subtrochanteric fractures and to evaluate the rate and reliability of classification of basicervical fractures and the outcome of the operative methods used for their treatment.
2 Review of the literature

This thesis focuses on hip fractures, especially extracapsular hip fractures, in patients aged 50 years or over who have sustained the fracture through low-energy trauma associated with falling from standing height or lower. Such cases must be considered separately from traumas in younger patients, which are of the high energy type, caused by traffic accidents and falls from a height, etc. (Robinson et al. 1995, Hwang et al. 2001, Verettas et al. 2002).

2.1 Etiopathology of hip fractures

The elderly have a high tendency to fall, which may partly explain the dramatic age-related rise in the incidence of hip fractures (Hayes et al. 1993). Over 90% of hip fractures are due to falls (Grisso et al. 1991, Parkkari et al. 1999), but only about 1–1.5% of all falls suffered by the elderly result in a hip fracture (Tinetti et al. 1988, Nevitt et al. 1991, Nurmi 2000, Nurmi & Lüthje 2002). The incidence of hip fractures increases upon ageing, so that 90% occur after the age of 70 (Cummings et al. 1989, Melton, III 1996). According to Cooper (1998) the lifetime risk of hip fracture for a woman aged 50 years is 14–18%, compared with 3–6% for a man (Cooper 1998). However in the more current study, Kanis et al. (2000) suggested that lifetime risk of fracture of the hip in particular have been underestimated; they suggested that lifetime risk of hip fracture was 23.3 % for a woman and 11.2 % for a man respectively. The estimated rate for elderly people sustaining a hip fracture by the age 90 is 30% (Farmer et al. 1984).

The risk for falls is increased by advanced age, problems in motor control and various chronic and acute diseases (Tinetti et al. 1988, Grisso et al. 1991, Campbell et al. 1989, Luukinen et al. 1995, Nurmi 2000, Partanen 2003). Willig (2006) reported that low BMI, institutional residence and previous stroke with hemiparesis, Parkinson’s disease and use of neuroleptics were significantly more common among hip fracture patients than among fallers who did not sustain a hip fracture. There may also be some special risk factors for extracapsular and intracapsular fractures. It has been suggested, for example, that falling indoors is a risk factor for extracapsular fractures and an inability to walk alone out of doors for intracapsular fractures (Meriläinen et al. 2002).

Cummings and Nevitt (1989) described how a hip fracture occurs upon falling in a cascade fashion, where upon four conditions need to be satisfied: the orientation of the fall must cause the person to fall straight on his/her hip, the
protective flexes fail, the local soft tissue absorbs less energy than would be necessary to prevent the fracture and bone strength is reduced. The writers also recognized the difference between simple falls suffered by elderly people and by younger persons: older people usually fall laterally on their hip, while younger people fall forward onto their hands (Fig.1). Parkkari et al (1999) reported similar findings in their later study; majority of the patients sustained a hip fracture (76%) reported that they had fallen directly to the side.

Fig. 1. Difference between a simple fall in an elderly person (above) and a younger person (below) (Cummings & Nevitt 1989).

2.2 Epidemiology of hip fractures

Hip fracture is a typical osteoporotic fracture in the elderly. In the year 2000 there were an estimated 9.0 million osteoporotic fractures of which 1.6 million were at the hip (Johnell & Kanis 2006). The annual number of hip fractures in the year 2000 compares with a previously published estimate for the year 1990 of 1.3 million hip fractures worldwide, representing an increase of approximately 25 % (Johnell & Kanis 2004, Johnell & Kanis 2006).

Earlier studies in Finland have also reported an increase in hip fracture incidence rates during the three last decades and predict a significant rise in the future (Kannus et al. 1999), but the reliability of these forecasts has been
questioned (Sund 2006, Sund et al. 2007). However, the total number of hip fractures will continue to increase due to the ageing of the population (Huusko et al. 1999a, Kannus et al. 1999, Lönnroos et al. 2006).

According to the data from the Finnish Health Care Register (Lüthje et al. 2001), the total number of hip fractures in Finland in 1998 was 7698, of which 5341 (73%) occurred in women and 1956 (27%) in men, 4488 (62%) being intracapsular and 2809 (38%) extracapsular. This is in line with the admissions reported at Peterborough District Hospital and Oulu University Hospital between 1989 and 1997 by Heikkinen et al. (2001), where the cervical / trochanter fracture ratio was 60/40 in Peterborough and 59/41 in Oulu. The intracapsular / extracapsular fracture ratio in Finland seems to be similar to that in the other Nordic countries (Hedlund et al. 1985, Jalovaara et al. 1992, Lüthje et al. 1992b, Berglund-Rödén et al. 1994, Heikkinen et al. 2001, Heikkinen et al. 2004, Lönnroos et al. 2006), but the ratio seems to be reversed in Central and Southern Europe, where extracapsular hip fractures are the main type (Dretakis et al. 1992, Scheerlinck et al. 2003). A recent study of 11,517 hip fractures in the county of Östergötland in Sweden between 1982 and 1996 has nevertheless reported that cervical/trochanteric fracture ratio has levelled off and the female/male ratio has declined (Löfman et al. 2002).

Löfman et al. (2002) from Sweden presented that the total age and sex-adjusted number of hip fractures will decrease by 11% up to 2010 as compared with 1996, although this will entail a decrease of 19% in women and an increase of 7% in men. If the incidence remains at the same level as at the end of this period, no significant change in the total numbers will occur. A break in the trend in the incidence of hip fractures was thus found for women but not for men. Whether this is due to therapeutic and/or preventive measures in women is unknown (Löfman et al. 2002). The age-adjusted incidence of hip fractures is lower in developing than in developed countries, lower in black people than in white (Cummings et al. 1989). A higher incidence of hip fractures has been reported among urban than among rural populations in Sweden in the 1980s (Sernbo et al. 1988), but no difference in the incidence of old people’s hip fractures have been found between urban and rural populations in Finland (Lüthje et al. 1995). Lüthje et al. (1992a) reported in their earlier study that hip fracture incidence in Finnish urban population was lower than what had been recorded in other Scandinavian countries.
2.3 Classification of extracapsular hip fractures

2.3.1 Anatomy of hip fractures

Hip fractures may be subdivided according to their anatomical location into intracapsular and extracapsular, depending on whether the fracture is inside or outside the capsule of the hip joint. Intracapsular fractures include subcapital and cervical fractures (Parker et al. 1997), while extracapsular fractures consist of basicervical, trochanteric and subtrochanteric fractures (Fig 2.). A number of terms have been used for trochanteric fractures. 'Pertrochanteric' (through) refers to a fracture running obliquely between the greater and lesser trochanter, while 'intertrochanteric' (between) traditionally refers to a more transverse fracture line running from below the greater trochanter to above the lesser trochanter and 'transtrochanteric' to a fracture line at the level of the lesser trochanter. Since these terms can cause confusion, it is recommended that only the term 'trochanteric' should be used (Parker et al. 1997).

Fractures at the level of the lesser trochanter or below are called subtrochanteric fractures. The actual dividing line between trochanteric and subtrochanteric fractures is debatable, as also is that between a subtrochanteric fracture and a femoral diaphyseal fracture (Parker et al. 1997). Most papers recommend a distance of 5 cm from the distal part of the lesser trochanter, although the AO classification suggests a distance of 3 cm (Müller et al. 1990, Parker et al. 1997).

Fig. 2. Anatomical locations of hip fractures, modified from Sobotta, Atlas of Human Anatomy, reproduced with permission from Urban & Fischer Verlag.
2.3.2 Basicervical hip fracture

The dividing line between basicervical and trochanteric fractures is debatable. Basicervical fractures constitute a controversial type and have been regarded by various authors as either extracapsular or intracapsular (Wilson 1982, De Lee 1991, Kuokkanen 1991, Russel 1992, Stambough 1992, Blair et al. 1994, Parker et al. 1997). Parker et al. (1997) defined them as fractures in which the fracture line runs along the line of the anterior attachment of the capsule, while Blair et al. (1994) specified them as proximal femoral fractures through the base of the femoral neck at its junction with the intertrochanteric region. Due to this anatomical location, basicervical fractures represent an intermediate form between femoral neck and intertrochanteric fractures (Blair et al. 1994). The authorized textbooks of orthopaedics and traumatology merely mention basicervical fractures as a category of extracapsular fractures, and the most frequently used classifications of hip fractures do not consider them as a separate entity (De Palma 1970, Wilson 1982, Müller et al. 1990, De Lee 1991, Russel 1992, Stambough 1992). The true quality of basicervical fractures may nevertheless be obscured by the fact that they are almost invariably included in the broader group of fractures of the trochanteric region (Indemini et al. 1982, Levy et al. 1983, Kuokkanen 1991).

2.3.3 Trochanteric hip fracture

There are several classifications of extracapsular fractures. As early as 1949, Evans described one of the first classification systems for trochanteric fractures, classifying them as either stable or unstable (Fig.3). This system had the twin merits of reproducibility and ease of use and it become widely used especially in the English-speaking countries. The modified grading proposed by Jensen and Michaelsen in 1975 was intended to improve the predictive value of the Evans classification system, to indicate which fractures could be reduced anatomically and which were entailed a risk of secondary displacement after fixation (Jensen & Michaelsen 1975). This modified classification divides trochanteric fractures into five groups. Types 1 and 2 are regarded as stable fractures and types 3, 4 and 5 as comminuted or unstable (Fig 3). This modified Jensen classification is highly practicable for clinical use (Jensen & Michaelsen 1975). The AO/ASIF classification proposed by Müller et al. (1990) attempts to be descriptive and to provide prognostic information. It divides trochanteric fractures into nine groups.
(Fig 4a) and subtrochanteric into nine groups (Fig. 4b) (Müller et al. 1990, Parker et al. 1997). There are also many other, not so well-known classification systems mentioned in the literature: that of Boyd and Griffin (1949), Ramadier et al. (1956), Ender (1970) and Tronzo (1974).

Evans’ classification of trochanteric fractures:

Stable:
   Type I: Undisplaced 2-fragment fracture
   Type II: Displaced 2-fragment fracture

Unstable:
   Type III: 3-fragment fracture without posterolateral support, owing to displacement of the greater trochanter fragment
   Type IV: 3-fragment fracture without medial support, owing to a displaced lesser trochanter or femoral arch fragment
   Type R: Reversed obliquity fracture

Fig. 3. Jensen & Michaelsen classification of trochanteric fractures.
Fig. 4a. AO classification of trochanteric fractures.
2.3.4 Subtrochanteric hip fracture

The classification of subtrochanteric fractures is very difficult, as the actual borderline between trochanteric and subtrochanteric fractures is controversial and the dividing line between subtrochanteric and femoral diaphyseal fractures is also open to debate (Parker et al. 1997). Traditional classifications such as those proposed by Fielding and Magliato (1966), Zickel (1976) and Seinsheimer (1978) include fractures at the level of the lesser trochanter with the subtrochanteric fractures, but the more recent AO classification includes only those distal to the lower part of the lesser trochanter (Müller et al. 1990). Fielding and Magliato
Fielding (1966) described a simple subdivision of subtrochanteric fractures in which the type chosen depended on the level at which the fracture line was predominantly located (Fig. 5), while later Zickel (1976) subdivided subtrochanteric fractures into six groups, which also included fractures within the proximal third of the femoral diaphysis. When Seinsheimer (1978) introduced his widely used classification of subtrochanteric fractures in 1978 (Fig. 6) this included any femur fracture in which any part of the fracture line was within the 5 cm of bone distal to the lesser trochanter (Parker et al. 1997). According to the AO classification (Fig. 4a, fig. 4b), subtrochanteric fractures are defined as those in which the fracture line transverses the femur in the 3 cm distal to the lesser trochanter, trochanteric fractures being divided into nine groups and subtrochanteric fractures into nine groups (Müller et al. 1990). The Boyd and Griffin classification (1949) is often mentioned, because their classification of trochanteric fractures also includes subtrochanteric elements in types 3 and 4. Although there are several classifications for subtrochanteric fractures, it is recommended nowadays that subtrochanteric fractures should simply be subdivided into undisplaced, two-part and comminuted fractures (Parker et al. 1997).

Fig. 5. Fielding classification of subtrochanteric fractures.
2.4 Operative treatment of extracapsular hip fractures

2.4.1 Historical view of trochanteric hip fracture treatment

Trochanteric fractures are nowadays treated by either intramedullary or extramedullary fixation. Internal fixation was a significant innovation popularized by Jewett and others in 1941 (Jewett 1956). Since fixation with the original single-piece implants often failed due to collapse at the fracture site and nail penetration of the head (Dimon 1973, Bannister & Gibson 1983), the sliding nail plate was introduced by Pugh in 1955 (Radford et al 1993) and also at this same time Treace in Richards Manufacturing Company promoted a sliding screw system (Tronzo 1974). Later, the AO dynamic hip screw (DHS) became one of the standard treatments for trochanteric fractures (Chapman et al. 1981, Esser et al. 1986, Davis et al. 1988, Bannister et al. 1990). This method has been thoroughly assessed in recent decades, and randomised comparisons have shown it to be superior to fixed nail plates (Esser et al. 1986, Bannister et al. 1990, Parker & Handoll 2006), Enders nails (Chapman et al. 1981) or Küntscher nails (Davis et al. 1988). The system was reported to involve high failure rates in cases of unstable pertrochanteric and subtrochanteric fractures, however (Jensen et al. 1978, Kaufer 1980, Haynes et al. 1997, Madsen et al. 1998, Lundy 2007).

About 15 years ago intramedullary fixation with a gamma nail (GN), which is based on the idea of the Y-nail proposed by Gerhard Küntscher, was introduced for

2.4.2 Gamma nail and DHS fixation of trochanteric fractures

Several studies comparing the gamma nail and DHS methods of fixation have shown DHS to be better for the treatment of trochanteric fractures (Bridle et al. 1991, Sabharwal et al. 1992, Radford et al. 1993, Parker & Pryor 1996), whereas some have failed to establish any significant differences between the two (Leung et al. 1992, Sabharwal et al. 1992, Goldhagen et al. 1994, O’Brien et al. 1995, Adams et al. 2001, Harrington et al. 2002, Jaworski et al. 2003, Giraud et al. 2005, Crawford et al. 2006, Jiang et al. 2008). On the other hand, Gill et al. (2007) compared trochanteric nail (TN), a redesigned short gamma nail to sliding hip screw (SHS) in intertrochanteric fractures, and found out that SHP group had a higher complication rate of 19.6% versus the TN group’s 11.4% rate (p=.13). The recent meta-analysis by Jiang et al. (2008) comparing GN fixation to sliding hip screw (SHS) fixation in trochanteric hip fractures, found no differences of mortality, cut-out, non-union, re-operation, wound infection, intra-operative fractures of femur, blood loss or surgical time. DHS fixation has been shown to require a slightly but not significantly longer hospital stay (Bridle et al. 1991,
Leung et al. 1992, Sabharwal et al. 1992). Most comparisons of GN and DHS fixation have focused on fracture healing, but the functional outcome has gained less attention (Parker & Pryor 1996). The facts that the gamma nail is said to be more rigid and to allow full weight bearing earlier than the DHS even in cases of very complex fractures (Utrilla et al. 2005) and that DHS fixation requires more extensive surgery than gamma nail fixation seem not to have any marked effects on the functional outcome (Sabharwal et al. 1992, Goldhagen et al. 1994, Ahrengart et al. 2002). On the contrary, walking ability compared with the preoperative situation was reported to be better in patients treated with DHS by Hoffman and Lynskey (1993), whereas Sabharwal et al. (1992), Goldhagen et al. (1994) and Ahrengart et al. (2002) observed no significant differences in these parameters.

Cutting-out of the sliding screw is regarded as a typical complication of DHS fixation (Bridle et al. 1991, Guyer et al. 1992, Leung et al. 1992, Pervez et al. 2004, Jewell et al. 2008). Fornander et al. (1992), Hoffman & Lynskey (1993) and Park et al. (1998) reported roughly similar cutting-out rates for both methods, but some authors have observed more cutting-out of the sliding screw in GN fixation (Benum et al. 1992, Høgh et al. 1992, Sabharwal et al. 1992, Goldhagen et al. 1994, Baumgaertner & Gibson 1995, Adams et al. 2001). Fracture of the femoral shaft at the end of the intramedullary part of the implant is considered the most serious complication of GN fixation (Bridle et al. 1991, Leung et al. 1992, Radford et al. 1993, Parker & Pryor 1996), with an incidence rate of between 1.6% to 7.1% in earlier reports (Boriani et al. 1991, Lindsey et al. 1991, Halder 1992, Williams & Parker 1992, Forthomme et al. 1993, Osnes et al. 2001). Robinson et al. (2002) reported an incidence of 18.75 periprosthetic fractures/1,000 patients treated with gamma nail compared to 4,46/1,000 patients treated with dynamic hip screw fixation. On the other hand, Abhay et al. (2007) reported no intra-operative or post-operative femoral shaft fractures either in gamma nail or DHS treated patients. Also Leung et al. (1992) reported no cases of femoral shaft fracture with a modified gamma nail, and some other studies suggest that this complication can be reduced by developing the gamma nail design (Parker & Pryor 1996, Rantanen & Aro 1998). Comparing different types of design modifications of intramedullary nails used in the fixation of extracapsular hip fractures, no significant differences were seen between implants for fracture healing complications, re-operations and other post-operative complications (Parker & Handoll 2008c).

**2.4.3 A historical view of subtrochanteric hip fracture treatment**

Although subtrochanteric fractures occur less than 10% of all hip fractures (Whitelaw et al. 1990, Lüthje et al. 1992b, Williams & Parker 1992, Lunsjö et al. 1999, Heikkinen et al. 2004, Cheng et al. 2005), their treatment is problematic partly due to a prolonged healing time compared with other hip fractures (Zickel 1976). Historically the problems encountered in the operative treatment of subtrochanteric fractures have been failure of fixation and non-union (Velasco 1978, Ruff et al. 1986, Parker et al. 1997). Various intramedullary and extramedullary devices have been developed in an attempt to address potential complications of device failure, mal-union, non-union or deformities, but the risk of failure has been high regardless of the fixation method (Ruff & Lubbers 1986, Rantanen & Aro 1998, Cheng et al. 2005), especially in high subtrochanteric fractures with loss of the lesser trochanter and the medial buttresses (Whitelaw et al. 1990, Guyton 1998, Cheng et al. 2005).

Some decades ago a sliding-screw plate system came into wider use even for subtrochanteric fractures (Madsen et al. 1998), but DHS has been reported to involve high failure rates in cases of unstable pertrochanteric and subtrochanteric fractures, however (Jensen et al. 1978, Kaufer 1980, Haynes et al. 1997, Madsen et al. 1998, Lundy 2007).

Bergman et al. (1988), in a study of 38 fractures fixed with compression screws and side plates, found high union rates in stable configurations, but recommended intramedullary nailing techniques if the medial cortical buttress could not be restored. Earlier studies of trochanteric and subtrochanteric fractures have also reported that the compression screw and side plate cannot be recommended for fractures in which reconstruction of the medial cortical buttress is not achieved (Enders 1970, Enders & Simon-Weidner 1970, Zickel 1976, Müller et al. 1979, Waddell 1980). The Zickel nail was introduced in the late 1960’s for the fixation of unstable pertrochanteric and subtrochanteric fractures of the femur (Zickel 1967), but it was subsequently criticized for its lack of rotational and axial
stability (Reynders et al. 1993). Condylocephalic (Enders) nails were adopted 10 years after the Zickel nail but were criticized for their lack of stability in the treatment of subtrochanteric fractures (Pankovich & Tarabishy 1980, Levy et al. 1983). Pankovich and Tarabishy (1980) noted a 30% re-operation rate and Levy et al. (1983) reported migration of the Enders pins in 66% of subtrochanteric fractures. The use of Enders nails as a treatment for subtrochanteric fractures is no longer regarded as appropriate nowadays (Parker & Handoll 2008a), and intramedullary fixation is recommended for treating subtrochanteric fractures and hip fractures with associated femoral shaft fractures and pathological extracapsular fractures (van Doorn & Stapert 2000, Edwards et al. 2001, Borens et al. 2004, Moholkar et al. 2004).

The gamma nail (GN) was designed in the late 1980s in order to overcome the problems implicit in sliding-screw fixations (Madsen et al. 1998) and in the use of the Zickel nail (Halder 1992), but several later studies have focused on the relatively high complication rate associated with its use for subtrochanteric and especially trochanteric fractures (Bridle et al. 1991, Calvert 1992, Williams & Parker 1992, Radford et al. 1993, Madsen et al. 1998, Rantanen & Aro 1998). The primary enthusiasm for the gamma nail may therefore be said to have subsided, and the wide range of indications has been narrowed down to fractures of the subtrochanteric region (Rantanen & Aro 1998). The Russell-Taylor reconstruction nail has become the most commonly used nail worldwide and has given excellent results with acute and pathological subtrochanteric fractures and ipsilateral femoral neck and shaft fractures (Coleman et al. 1991, Smith et al. 1991, Weikert & Schwartz 1991, Bose et al. 1992, Karachalios et al. 1993, Barlow & Thomas 1994).

Because of the infrequency of subtrochanteric fractures, most reports on these are retrospective and include a small number of patients (Lunsjö et al. 1999). Consequently, multicentre trials are recommended for hip fractures of this type (Whitelaw et al. 1990).

2.4.4 Gamma nail and DHS fixation of subtrochanteric fractures

It has been claimed earlier that the compression screw and side plate techniques are not recommended for fractures in which reconstruction of the medial cortical buttress is not achieved (Enders 1970, Enders & Simon-Weidner 1970, Müller et al. 1979, Waddell 1980, Zickel 1976). Accordingly, Ruff & Lubbers (1986), describing the outcomes of 45 subtrochanteric fractures treated with a sliding
screw-plate device, concluded that subtrochanteric fractures with medial cortical comminution, such as Seinsheimer type IIIA and type V fractures, were the most unstable and entailed the greatest risk of complication. On the other hand, Kyle (1994) found comminution of the trochanter region to be incompatible with the use of intramedullary devices and recommended an extramedullary device for fractures of this type. For stable subtrochanteric femur fractures with preservation of the lesser trochanter and medial column the standard first-generation femoral nail with transverse or antegrade cross-locking has proved to be a useful alternative to plate fixation (Kempf et al. 1985, Thoresen et al. 1985, Klemm & Borner 1986, Wiss et al. 1986, Brumback et al. 1988, Hanks et al. 1988, Blumberg et al. 1990, Wiss et al. 1990, Alho et al. 1991, Seiler & Swiontkowski 1991, Wiss et al. 1991, Wu et al. 1991, Wiss et al. 1994). The fixation of high subtrochanteric fractures with loss of the lesser trochanter and medial buttress is more challenging, however (Wheeler et al. 1997, Cheng et al. 2005). Several intramedullary constructs, including second-generation reconstruction nails with retrograde interlocking devices, have been considered as alternatives to screw and plate fixation (Kyle & Chadwick 1991, Parker & Handoll 2008c). Modern reconstruction nails have greatly improved the outcome and ease of treatment of subtrochanteric fractures (Guyton 1998). The classic mechanical study of Cochran et al. (1980) comparing several first-generation intramedullary devices concluded that intramedullary (Zickel nail) fixation was superior to extramedullary fixation, while a later biomechanical study by Mahommed et al. (1994) comparing a locked gamma nail to a standard sliding hip screw (SHS) for the fixation of stable and unstable subtrochanteric fractures showed that the intramedullary nail was more rigid and permitted less fracture displacement. Haynes et al. (1997) also reported biomechanical results indicating that the intramedullary gamma locking nail is preferable to a standard dynamic hip screw (DHS) in cases of subtrochanteric fracture or under conditions of very poor bone quality. Also in more recent study by Cheng et al. (2005) suggested that closed reduction and fixation with long gamma nail were proven to be safe and effective in the treatment of complex traumatic subtrochanteric fractures. Lundy (2007) concluded in his paper that DHS is not suitable in the treatment of subtrochanteric fractures, because of increased risk of loss of fixation and fracture displacement.

Rantanen and Aro (1998), comparing the outcomes of subtrochanteric femoral fractures treated with the original gamma nail with those achieved with the newly designed intramedullary hip screw, the IMHS, reported that intramedullary gamma nail-type fixation of subtrochanteric femoral fractures is biomechanically and
biologically feasible, and that the new implant design features found in the IMHS may reduce the rate of inherent implant-related complications. On the other hand, Kummer et al. (1998) found in their biomechanical study that an intramedullary hip screw (IMHS) and Medoff sliding plate (MSP) provided similar stability. Lunsjö et al. (1999) compared the efficacy of a load-sharing device, the Medoff sliding plate (MSP), with that of three other load-bearing screw-plate devices, the dynamic hip screw (DHS), with or without a trochanteric stabilizing plate (TSP) or with a dynamic condylar screw (DCS), for the fixation of subtrochanteric fractures in a randomized multicentre trial involving 107 elderly patients, and concluded that the sliding capacity along the femoral shaft achieved with the MSP, which provides for load-sharing and fracture impaction, is favourable for the treatment of high subtrochanteric fractures in the elderly. They also recognized a correlation between a certain type of subtrochanteric fracture and the likelihood of postoperative complication. All the fixation failures occurred in patients with a Seinsheimer type V fracture, and a higher failure rate was found with the other three screw-plate systems than with the MSP (Lunsjö et al. 1999). The greater load-sharing capacity of the MSP than of the DHS has been also shown in biomechanical tests involving subtrochanteric fractures (Medoff & Maes 1990) and unstable intertrochanteric fractures (Olsson et al. 1998). On the other hand, Miedel et al. (2005) compared GN fixation to MSP fixation in unstable trochanteric or subtrochanteric fractures and found out that GN showed good results in both trochanteric and subtrochanteric fractures, while MSP had a low rate of failure in trochanteric fractures but an unacceptably high rate when used in subtrochanteric fractures.

Krause et al. (1996) observed that use of the new operative techniques (DHS and gamma nail) for the treatment of subtrochanteric fractures in the elderly was followed by a shortened hospital stay, a reduced complication rate and an increased rate of discharge home. Likewise, Pakuts (2004) reported that early recovery is faster after GN fixation than after DHS fixation. On the other hand, Madsen et al. (1998) found that 69% of their GN-treated patients, 73% of those receiving a cephalic hip screw and 91% of the DHS/TSP patients had regained their pre-fracture walking ability by 6 months after the operation.

2.4.5 Treatment of basicervical hip fracture

Su et al. (2006) reported in their study that basicervical fractures collapsed more than stable intertrochanteric fractures, suggesting that they may have greater biomechanical instability. This agrees with the previous studies reporting a high incidence of complications in the treatment of basicervical fractures leading to re-operations (Indemini et al. 1982, Levy et al. 1983, Kuokkanen 1991). Partly due to previous, a variety of operative techniques have been used for basicervical fractures: fixation with a sliding hip screw or rigid nail plate, fixation with multiple pins or cancellous screws, fixation with condylocephalic nails (Enders nails) and hemiarthroplasty (Seinsheimer 1978, Jensen 1980, Jensen et al. 1980a, Jensen et al. 1980b, Olerud et al. 1980, Pankovich & Tarabishy 1980, Chen et al. 2008).

In a biomechanical cadaver study comparing the stability of multiple cancellous screws and the sliding hip screw with or without an additional antirotation cancellous screw placed proximal to the sliding hip screw/plate device, Blair et al. (1994) found the sliding hip screw (SHS) to be biomechanically superior for the treatment of basicervical femoral neck fractures. Deneka et al. (1997) also reported in their biomechanical comparison of internal fixation techniques for the treatment of unstable basicervical femoral neck fractures that sliding screw plate fixation was superior to fixation with multiple cancellous screws. In other comparative studies, sliding screw plate fixation was found to be superior to both Mc Laughlin nail-plate fixation (Svenningsen et al. 1984) and to sliding nail plate fixation (Nordkild et al. 1985) and the sliding hip screw to be superior to other methods of treatment, resulting in the lowest re-operation rate (Grenis & Uhl 1989, Madsen et al. 1987). The recent study by Chen et al. (2008) showed out that surgical treatment of basicervical fractures of femur by closed reduction and internal fixation with DHS was very effective. On the other hand, Broos et al. (1998) were convinced that blade plate fixation with an antirotation screw was the best way of providing stable fixation with rotational stability for unstable femoral neck fractures. Some earlier large series also showed a nail plate device to compare favourably with a dynamic compression screw (Kuokkanen 1991, Quint & Wahl 1991). Kuokkanen (1991) reported that conventional rigid nail plates (ASIF, Jewet) gave superior results to the dynamic hip screw for the treatment of basicervical femoral neck fractures and that Enders nails and hemiarthroplasty may not be appropriate for basicervical fractures, which is in line with earlier conclusions (Cobelli & Sadler 1985, Kuokkanen et al. 1986, Russel 1992). Levy et al. (1983) published a study of the use of Enders nails in which they concluded that these are contraindicated for the treatment of basicervical fractures,

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which is in accordance with the recommendation by Parker & Handoll (2008a). Although basicervical fractures are not considered in the classification of trochanteric fractures, they should be regarded clinically as extracapsular fractures and managed in a similar manner to trochanteric fractures (Parker et al. 1997).
3 Aims

1. To analyse and characterize the hip fractures treated at Oulu University Hospital over a one-year period using the special forms of the Standardized Audit of Hip Fractures in Europe (SAHFE) and to evaluate their value for quality control.

2. To compare gamma nail (GN) and dynamic hip screw (DHS) fixation for the treatment of trochanteric hip fractures, focusing especially on short-term functional aspects.

3. To compare gamma nail (GN) and dynamic hip screw (DHS) fixation for the treatment of subtrochanteric hip fractures in the elderly caused by low-energy trauma.

4. To evaluate the rate and reliability of classification of basicervical fractures and the outcome of the operative methods used for their treatment.
4 Patients and methods

Oulu University Hospital joined the Swedish Hip Fracture Project (Rikshöft), aimed at developing quality control methods for hip fracture treatment, in 1989 (Jalovaara et al. 1992, Berglund-Rödén et al. 1994), (appendix I), and this later evolved into the project called Standardized Audit of Hip Fractures in Europe (SAHFE) funded by the European Commission. Hip fractures were recorded on SAHFE forms in Oulu from 1st September 1997 until the end of December 2003. The basic SAHFE data collection set consisted of three forms. Form 1 contained baseline information on the patient, fracture and treatment. Form 2 was for the four-month assessment and enabled the treatment to be evaluated in terms of functional outcome. All the patient’s places of residence and re-admissions during the four postoperative months were to be recorded on this form. Form 3 was for the recording of re-operation and briefly specified any reason for re-operation and the method adopted (appendix II) (Parker et al. 1998, Heikkinen 2005).

Forms 1 and 3 were filled in by a nurse assisted by a surgeon on the items concerning the type of fracture and treatment. Form 2 was given to the patient at discharge to be completed and returned 120 days after the primary admission. The completeness and validity of the information recorded on form 2 was checked by a nurse from the patient files, operation records and the patients themselves, family members, the staff of the patients’ service blocks or the institutions where the patients were living.

4.1 Hip fracture treatment in Oulu – one-year survey with a four-month follow-up

The population-based series of 242 consecutive hip fracture patients over 49 years of age was collected during a one-year period between 1st September 1997 and 31st August 1998, from which four patients with pathological fractures were subsequently excluded. Thus the final series consisted of 238 patients. The data were computerized and analysed using the special SAHFE software.

4.2 Gamma nail and dynamic hip screw fixation for the treatment of trochanteric hip fractures

A total of 575 trochanteric femoral fractures in 563 patients aged over 49 years were treated at Oulu University Hospital in the years 1991–1999, 372 were treated
with gamma nail (GN) fixation (mean age 78.6 years, range 51–96, 100 males/272 females) and 203 with dynamic hip screw (DHS) fixation (mean age 79.9 years, range 51–101, 50 males/153 females). The patients in the two groups were cross-matched by a statistician for age, sex, place of residence at the time of the fracture, walking ability at the time and fracture type, and 134 pairs were found. The cross-matching data are presented in Table 1. 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, the need for institutional care, preoperative and postoperative ADL functions and locomotor ability. Follow-up was continued for four months by recording the same functional parameters as on admission. The changes in residential status and walking ability with respect to the situation at the time of the fracture were also evaluated, on a scale of worse, same, better. Mortality and re-operation rates were recorded for up to one year after the fracture.

Table 1. Demographic data.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gamma nail group</th>
<th>DHS group</th>
<th>p-value for difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Sex</td>
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<td></td>
</tr>
<tr>
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</tr>
<tr>
<td>Female</td>
<td>111</td>
<td>83</td>
<td>111</td>
</tr>
<tr>
<td>Age on operation day</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (range)</td>
<td>80 (52–93)</td>
<td>80 (51–94)</td>
<td></td>
</tr>
<tr>
<td>Marital status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unmarried</td>
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<td>11.9</td>
<td>20</td>
</tr>
<tr>
<td>Married</td>
<td>28</td>
<td>20.9</td>
<td>32</td>
</tr>
<tr>
<td>Divorced</td>
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<td>3.0</td>
<td>7</td>
</tr>
<tr>
<td>Widowed</td>
<td>86</td>
<td>64.2</td>
<td>75</td>
</tr>
<tr>
<td>Lived alone at the time of fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>80</td>
<td>59.7</td>
<td>89</td>
</tr>
<tr>
<td>No</td>
<td>54</td>
<td>40.3</td>
<td>45</td>
</tr>
<tr>
<td>Need for home help at the time of fracture</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean h/week</td>
<td>1.5</td>
<td></td>
<td>1.8</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.0</td>
<td></td>
<td>0.0</td>
</tr>
<tr>
<td>Maximum</td>
<td>21.0</td>
<td></td>
<td>30.0</td>
</tr>
<tr>
<td>Side of fracture</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>66</td>
<td>49.3</td>
<td>70</td>
</tr>
<tr>
<td>Left</td>
<td>68</td>
<td>50.7</td>
<td>64</td>
</tr>
<tr>
<td>Type of fracture</td>
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<td></td>
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</tr>
<tr>
<td>Trochanteric two-fragment fracture</td>
<td>54</td>
<td>40.3</td>
<td>40.3</td>
</tr>
<tr>
<td>Trochanteric multifragment fracture</td>
<td>80</td>
<td>59.7</td>
<td>59.7</td>
</tr>
</tbody>
</table>
4.3 Gamma nail and dynamic hip screw fixation for the treatment of subtrochanteric hip fractures

Out of the 1624 femoral hip fractures in 1511 patients aged over 49 years treated at Oulu University Hospital from January 1989 until December 1996 and prospectively recorded on special forms, 73 (4.5%) were subtrochanteric. After the exclusion of 13 patients with pathological fractures and two with multiple high-energy traumas, the final series consisted of 58 patients, of whom 43 were treated with a gamma nail (GN) and 15 with a dynamic hip screw (DHS).

The subtrochanteric fracture patterns were classified using three systems: Müller’s (AO) classification (Müller et al. 1990), Seinsheimer’s classification (Seinsheimer 1978) and Fielding’s classification (Fielding & Mangliato 1966). The patient’s functional status was recorded at the time of the fracture and four months after surgery using standardized forms with data concerning the place of residence, walking ability and use of walking aids (Parker et al. 1998, Partanen & Jalovaara 2004, Heikkinen et al. 2005). Function was expressed in terms of the change relative to the situation at the time of fracture (better, same, worse). Re-operations and the reasons for these, and also mortality, were recorded on a separate form up to one year. Intraoperative and hospital data were collected from the patient records.

4.4 Basicervical fractures

The 1624 hip fractures treated at Oulu University Hospital during the eight-year period from January 1989 until the end of December 1996, with a mean follow-up time of 5.0 years, (range 2–10 years), were classified by the surgeons into six types, as described earlier by Jalovaara et al. (1992): 1) undisplaced cervical fractures (Garden I&II), 2) displaced cervical fractures (Garden III&IV) (Garden 1964), 3) basicervical fractures, 4) trochanteric, two-fragment fractures, 5) trochanteric multi-fragment fractures, and 6) subtrochanteric fractures. The classification was performed with the help of routine radiographs. All the fractures initially classified as basicervical were re-evaluated independently by the authors of the paper, cases of disagreement being re-evaluated jointly. The fractures initially classified as cervical and trochanteric were also re-evaluated, but no cases that could be regarded as basicervical fractures were found. Both antero-posterior and lateral x-ray projections were analysed, and special attention was paid to the possibility of an extension of the fracture line into the cervical or trochanteric
region. If any extension was found, the case was excluded from the category of bascervical fractures. Altogether 108 of the 1624 fractures had initially been classified by the surgeons as bascervical. In a careful second-look check 51 of these were re-classified as transcervical fractures with a small piece of lateral collum left, while 27 were excluded because of a trochanteric extension (the two examiners agreed on the classification in all but 5 cases, which were all excluded after a joint re-evaluation). Thus, thirty cases fulfilled all the criteria for a bascervical fracture (11 males, mean age 75 years /19 females, mean age 78 years).

4.5 Statistical analysis

The data organization and statistical analyses were performed by a statistician using the SPSS statistical software: version 8.0.1, version 9.0.1 and version 12.0.1; SPSS, Inc., Chicago, IL, USA. The data for Paper I was computerized and analysed using the special SAHFE software. The Chi-square test with Yates correction, Fischer´s exact test, and the non-parametric Mann-Whitney U test were used to evaluate the significance of differences. The Mann-Whitney U-test was used whenever the material was not normally distributed. The Chi-square test and Fishers exact test (2 x 2 table) were used to compare the dichotomous variables and the Chi-square and exact tests for the analysis of multiple categorial variables. Kaplan-Meier survival analysis was used in Papers II, III and IV.

A difference was considered to be statistically significant when \( p < 0.05 \).
5 Results

5.1 Hip fracture treatment in Oulu – one-year survey with a four-month follow-up (paper I)

There were 238 hip fracture patients treated at Oulu University Hospital during the one-year period, with a mean age of 78.4 (50–102) years and comprising 52 males (mean age 74, range 50–91) and 186 females (mean age 80, range 50–102). There were slightly more left-side than right-side fractures (55% vs. 45%). The majority of the patients were admitted from their own homes (59%) or from nursing homes (18%). Thirty-two per cent lived alone, 30% in institutional care of some kind and 38% together with a spouse or a relative. The majority (57%) were able to walk alone out of doors. About half of the patients could walk without any walking aids, but the use of a walking frame was quite common among the others.

There were markedly more intracapsular (n=145) than extracapsular (n=93) fractures. The most frequent treatment for cervical fractures was Austin-Moore hemiarthroplasty (68%) and that for trochanteric and subtrochanteric fractures gamma nail fixation (86%).

The mean hospitalization time in the orthopaedic department was 7.8 days (median 6 days). Upon discharge, 45% of the patients went to acute hospitals (health centre hospitals), 44% to rehabilitation units, and only 3% were able to return to their own homes from the primary hospital. At four months, 74% of the patients admitted from home had managed to return to their own homes, while 6% of the survivors were still in acute hospitals and 2% in rehabilitation units (Table 2). Thirty-three per cent were able to walk alone out of doors and 13% could walk without any aids (Table 2). A walking frame was the most frequently used walking aid (56%), as also before the fracture (Table 2).
Table 2. Data at four months of follow-up (Paper I)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assessment done by</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Face to face interviews with patient</td>
<td>30</td>
<td>15.5</td>
</tr>
<tr>
<td>Face to face interviews with carer/relative/friend</td>
<td>2</td>
<td>1.0</td>
</tr>
<tr>
<td>Phone to patient</td>
<td>47</td>
<td>19.1</td>
</tr>
<tr>
<td>Phone to carer/relative/friend</td>
<td>49</td>
<td>20.1</td>
</tr>
<tr>
<td>Postal questionnaire completed by patient</td>
<td>20</td>
<td>10.3</td>
</tr>
<tr>
<td>Postal questionnaire completed by carer/relative/friend</td>
<td>60</td>
<td>30.9</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
<td>3.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>194</td>
<td>100</td>
</tr>
<tr>
<td><strong>Died</strong></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>191</td>
<td>100</td>
</tr>
</tbody>
</table>

**Residential status of survivors**

<table>
<thead>
<tr>
<th>Residential status of survivors</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Own home</td>
<td>98</td>
<td>50.0</td>
</tr>
<tr>
<td>Sheltered housing</td>
<td>13</td>
<td>6.6</td>
</tr>
<tr>
<td>Institutional care</td>
<td>7</td>
<td>3.6</td>
</tr>
<tr>
<td>Nursing home</td>
<td>34</td>
<td>17.4</td>
</tr>
<tr>
<td>Permanent hospital inpatient</td>
<td>26</td>
<td>13.3</td>
</tr>
<tr>
<td>Rehabilitation unit</td>
<td>4</td>
<td>2.0</td>
</tr>
<tr>
<td>Acute hospital</td>
<td>11</td>
<td>5.6</td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>196</td>
<td>100</td>
</tr>
</tbody>
</table>

**Walking ability**

<table>
<thead>
<tr>
<th>Walking ability</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walked alone out of doors</td>
<td>64</td>
<td>33.0</td>
</tr>
<tr>
<td>Walked out of doors only if accompanied</td>
<td>16</td>
<td>8.2</td>
</tr>
<tr>
<td>Walked alone indoors but not out of doors</td>
<td>44</td>
<td>22.7</td>
</tr>
<tr>
<td>Walked indoors only if accompanied</td>
<td>46</td>
<td>23.7</td>
</tr>
<tr>
<td>Unable to walk</td>
<td>24</td>
<td>12.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>194</td>
<td>100</td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>196</td>
<td>100</td>
</tr>
</tbody>
</table>

**Walking aids**

<table>
<thead>
<tr>
<th>Walking aids</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can walk without aids</td>
<td>25</td>
<td>13.0</td>
</tr>
<tr>
<td>One aid</td>
<td>27</td>
<td>14.1</td>
</tr>
<tr>
<td>Two aids</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Frame</td>
<td>108</td>
<td>56.2</td>
</tr>
<tr>
<td>Wheelchair/bedbound</td>
<td>27</td>
<td>14.1</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>192</td>
<td>100</td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>196</td>
<td></td>
</tr>
</tbody>
</table>

**Pain at the hip**

<table>
<thead>
<tr>
<th>Pain at the hip</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe and spontaneous, even with rest</td>
<td>5</td>
<td>2.6</td>
</tr>
<tr>
<td>Severe when walking and prevents all activity</td>
<td>12</td>
<td>6.3</td>
</tr>
<tr>
<td>Tolerable, permitting limited activity</td>
<td>30</td>
<td>15.7</td>
</tr>
<tr>
<td>Occurs only after some activity, disappears quickly with rest</td>
<td>26</td>
<td>13.6</td>
</tr>
<tr>
<td>Slight or intermittent, gets less with normal activity</td>
<td>37</td>
<td>19.4</td>
</tr>
<tr>
<td>No pain in hip</td>
<td>61</td>
<td>31.9</td>
</tr>
<tr>
<td>Unable to answer</td>
<td>20</td>
<td>10.5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>191</td>
<td>100</td>
</tr>
<tr>
<td><strong>Missing</strong></td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
The re-operation rate was 9%, the most frequent type of re-operation being re-osteosynthesis and the most common reason an additional fracture around the implant (Table 3).

**Table 3. Re-operations in 234 patients.**

<table>
<thead>
<tr>
<th>Reason for re-operation</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture displacement</td>
<td>2</td>
<td>10,0</td>
</tr>
<tr>
<td>Additional fracture around the implant</td>
<td>7</td>
<td>35,0</td>
</tr>
<tr>
<td>Non-union (pseudarthrosis)</td>
<td>2</td>
<td>10,0</td>
</tr>
<tr>
<td>Femoral head necrosis</td>
<td>1</td>
<td>5,0</td>
</tr>
<tr>
<td>Wound haematoma</td>
<td>1</td>
<td>5,0</td>
</tr>
<tr>
<td>Dislocation of arthroplasty</td>
<td>6</td>
<td>30,0</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>5,0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of re-operation</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removal of implant</td>
<td>1</td>
<td>5,0</td>
</tr>
<tr>
<td>Total hip arthroplasty</td>
<td>5</td>
<td>25,0</td>
</tr>
<tr>
<td>Re-osteosynthesis</td>
<td>6</td>
<td>30,0</td>
</tr>
<tr>
<td>Girdlestone</td>
<td>1</td>
<td>5,0</td>
</tr>
<tr>
<td>Reduction of dislocation</td>
<td>5</td>
<td>25,0</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>10,0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>20</td>
<td>100</td>
</tr>
</tbody>
</table>

Forty-two patients had died (overall mortality 18%) at four months, and the general condition of four patients was so poor that they could not be operated on (died a mean of four days after admission). Mortality among the patients operated on was thus 16.2% (Table 4).
Table 4. Mortality at 4 months.

<table>
<thead>
<tr>
<th>Hip fracture patients</th>
<th>Mortality</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Patients</td>
</tr>
<tr>
<td>Overall</td>
<td>238</td>
</tr>
<tr>
<td>Operated patients</td>
<td>234</td>
</tr>
<tr>
<td>Males</td>
<td>51</td>
</tr>
<tr>
<td>Females</td>
<td>183</td>
</tr>
<tr>
<td>Cervical fractures</td>
<td>146</td>
</tr>
<tr>
<td>Osteosynthesis</td>
<td>35</td>
</tr>
<tr>
<td>Hemiarthroplasty</td>
<td>102</td>
</tr>
<tr>
<td>Trochanteric fractures</td>
<td>88</td>
</tr>
<tr>
<td>Gamma nail</td>
<td>78</td>
</tr>
<tr>
<td>DHS</td>
<td>8</td>
</tr>
</tbody>
</table>

5.2 Gamma nail and dynamic hip screw fixation for the treatment of trochanteric hip fractures (paper II)

The DHS and GN groups did not differ significantly with respect to delay from admission to operation (1.2 days vs. 1.3 days, $p=0.64$) and length of hospital stay (8.8 days vs. 7.1 days, $p=0.28$), nor with respect to living in their own homes at 4 months (56% vs. 50%, $p=0.35$, Table 5), or returning to their pre-fracture dwelling (78% vs. 73 %, $p=0.224$). The change in walking ability at 4 months relative to the pre-fracture situation was nevertheless significantly better in the DHS group ($p=0.042$), although there was no significant difference in the change in the use of walking aids ($p=0.09$) or in walking ability at 4 months ($p=0.18$) or ADL activities at 4 months ($p=0.40$) (Table 6). Pain upon weight-bearing at 4 months was somewhat more common in the GN group ($p=0.108$), as was the medication with analgesics ($p=0.111$).
Table 5. Functional parameters before the fracture and at 4 months after the fracture.

| Functional parameters | Gamma nail group | | | DHS group | | |
|-----------------------|------------------|--------------------|-----------------|------------------|-----------------|
|                       | Before fracture  | At 4 months | p-value (preoper.) | Before fracture | At 4 months | p-value (4 months) |
|                       | n  | %  | n  | %  | n  | %  | n  | %  | n  | %  | n  | %  | n  | %  |
| Residential status    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Own home              | 97 | 72.4 | 67 | 50.0 | 97 | 72.4 | 75 | 56.0 | 0.349 |
| Sheltered housing     | 1  | 0.7 | 1  | 0.7 | 1  | 0.7 | 0  | 0.0 |    |    |    |    |    |    |
| Home for the aged     | 28 | 21.6 | 16 | 12.0 | 29 | 21.6 | 19 | 14.2 |    |    |    |    |    |    |
| Permanent hospital inpatient | 7 | 5.2 | 32 | 23.9 | 7 | 5.2 | 29 | 21.6 |    |    |    |    |    |    |
| Nursing home          | 0  | 0.0 | 0  | 0.0 | 0  | 0.0 | 0  | 0.0 |    |    |    |    |    |    |
| Acute hospital        | 0  | 0.0 | 0  | 0.0 | 0  | 0.0 | 3  | 2.2 |    |    |    |    |    |    |
| Death                 | 0  | 0.0 | 18 | 13.4 | 0  | 0.0 | 8  | 6.0 |    |    |    |    |    |    |
| ADL (dressing)        |    |    |    |    | 100 | 74.6 | 60 | 52.6 | 0.151 |
| Yes                   | 100 | 74.6 | 60 | 52.6 | 101 | 75.4 | 77 | 62.1 |    |    |    |    |    |    |
| No                    | 34  | 25.4 | 54 | 47.4 | 33  | 24.6 | 47 | 37.9 |    |    |    |    |    |    |
| Walking               |    |    |    |    |    |    |    |    | 0.175 |
| Walked alone outdoors | 80 | 59.7 | 24 | 21.1 | 80 | 59.7 | 29 | 23.0 |    |    |    |    |    |    |
| Walked outdoors only accompanied | 15 | 11.2 | 12 | 10.5 | 15 | 11.2 | 8 | 6.9 |    |    |    |    |    |    |
| Walked alone indoors  | 34 | 25.4 | 34 | 29.8 | 34 | 25.4 | 35.5 |    |    |    |    |    |    |
| Walked indoors only accompanied | 5 | 3.7 | 34 | 29.8 | 5 | 3.7 | 16.1 |    |    |    |    |    |    |
| Unable to walk, able to sit | 0 | 0.0 | 8 | 7.0 | 0 | 0.0 | 7 | 3.2 |    |    |    |    |    |    |
| Bedbound              | 0  | 0.0 | 2  | 1.8 | 0  | 0.0 | 3 | 2.2 |    |    |    |    |    |    |
| Walking aids          |    |    |    |    | 0.572 |    |    |    | 0.113 |
| Able to walk without aids | 72 | 54.1 | 8 | 7.0 | 71 | 53.0 | 13 | 10.5 |    |    |    |    |    |    |
| One stick             | 25 | 18.8 | 19 | 16.7 | 33 | 24.6 | 26 | 21.0 |    |    |    |    |    |    |
| Two sticks            | 5  | 3.8 | 6  | 5.3 | 6  | 4.5 | 12 | 9.7 |    |    |    |    |    |    |
| One stick and tripod  | 0  | 0.0 | 1  | 0.9 | 1  | 0.7 | 4  | 3.2 |    |    |    |    |    |    |
| Two tripods           | 0  | 0.0 | 0  | 0.0 | 1  | 0.7 | 0  | 0.0 |    |    |    |    |    |    |
| Rollator/walking frame | 31 | 23.4 | 66 | 57.9 | 21 | 15.7 | 52 | 41.9 |    |    |    |    |    |    |
| Wheelchair            | 1  | 0.8 | 12 | 10.5 | 1  | 0.7 | 10 | 8.1 |    |    |    |    |    |    |
| Does not walk         | 0  | 0.0 | 2  | 1.8 | 0  | 0.0 | 7  | 5.6 |    |    |    |    |    |    |
| Living alone          |    |    |    |    | 0.311 |    |    |    | 0.381 |
| Yes                   | 54 | 40.3 | 34 | 29.8 | 45 | 33.6 | 30 | 24.2 |    |    |    |    |    |    |
| No                    | 80 | 59.7 | 80 | 70.2 | 89 | 66.4 | 94 | 75.8 |    |    |    |    |    |    |
Table 6. Residential status, dressing and undressing, walking ability, use of walking aids and mortality at 4 months, evaluated in terms of the change relative to the situation before the fracture.

<table>
<thead>
<tr>
<th>Functional parameters</th>
<th>Gamma nail group</th>
<th>DHS group</th>
<th>p-value for difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>%</td>
<td>n</td>
</tr>
<tr>
<td>Residential status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worse</td>
<td>29</td>
<td>25.0</td>
<td>28</td>
</tr>
<tr>
<td>Same</td>
<td>85</td>
<td>73.3</td>
<td>98</td>
</tr>
<tr>
<td>Better</td>
<td>2</td>
<td>1.7</td>
<td>0</td>
</tr>
<tr>
<td>ADL (dressing)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worse</td>
<td>29</td>
<td>25.7</td>
<td>24</td>
</tr>
<tr>
<td>Same</td>
<td>81</td>
<td>71.7</td>
<td>92</td>
</tr>
<tr>
<td>Better</td>
<td>3</td>
<td>2.7</td>
<td>6</td>
</tr>
<tr>
<td>Walking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worse</td>
<td>78</td>
<td>69.0</td>
<td>70</td>
</tr>
<tr>
<td>Same</td>
<td>34</td>
<td>30.1</td>
<td>46</td>
</tr>
<tr>
<td>Better</td>
<td>1</td>
<td>0.9</td>
<td>7</td>
</tr>
<tr>
<td>Walking aids</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worse</td>
<td>79</td>
<td>69.9</td>
<td>90</td>
</tr>
<tr>
<td>Same</td>
<td>32</td>
<td>28.3</td>
<td>25</td>
</tr>
<tr>
<td>Better</td>
<td>2</td>
<td>1.8</td>
<td>8</td>
</tr>
<tr>
<td>Mortality 4 months</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alive</td>
<td>116</td>
<td>86.6</td>
<td>126</td>
</tr>
<tr>
<td>Died</td>
<td>18</td>
<td>13.4</td>
<td>8</td>
</tr>
<tr>
<td>Mortality 1 year</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alive</td>
<td>102</td>
<td>76</td>
<td>114</td>
</tr>
<tr>
<td>Died</td>
<td>32</td>
<td>24</td>
<td>20</td>
</tr>
</tbody>
</table>

The frequency of re-operations within one year was somewhat lower in DHS group (11 vs. 17, p= 0.318). Twenty five out of the 28 re-operations occurred within the first 4 months, and the reasons (DHS group / GN group) were 11 fracture displacements (4/7), 6 losses of position of the nail (2/4), 3 infections (2/1), 3 femoral head collapses (1/2) and 2 re-fractures (0/2). The re-operation types were re-osteosynthesis in 14 of cases, arthroplasty in 5, Girdlestone in 1 and other procedures in 4. Three re-operations were performed after the first 4 months, 1 extraction of osteosynthesis in the GN group and 1 arthroplasty and 1 re-osteosynthesis in the DHS group. Non-union was the reason for two of these re-operations.

Mortality was lower in the DHS group both at 4 months (6.0 % vs. 13.4%, p= 0.061) and at 12 months (14.9% vs. 23.9%, p= 0.044) (Table 6).
5.3 Gamma nail and dynamic hip screw fixation for the treatment of subtrochanteric hip fractures (paper III)

Eight patients were lost during the follow-up in the GN group (all deaths) and three in the DHS group (2 deaths, one lost). There were no statistically significant differences in fracture patterns between the groups in any of the classifications (Table 7). Seinsheimer fracture type IIIA was the most common fracture pattern in both treatment groups when the Seinsheimer classification system was used, and Fielding II and AO 31A3.3 respectively (Table 7).

<table>
<thead>
<tr>
<th>Fracture classifications</th>
<th>Gamma (n=43)</th>
<th>DHS (n=15)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seinsheimer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I Non-displacement</td>
<td>0</td>
<td>0</td>
<td>0.220</td>
</tr>
<tr>
<td>II Two-part fracture</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>A Transverse</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B Spiral fracture, lesser trochanter part of the proximal fragment</td>
<td>9</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>III Three-part fracture</td>
<td>14</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>A Spiral fracture, lesser trochanter part of the third fragment</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>B Spiral fracture, lesser trochanter not part of the third fragment</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>IV Four or more fragments, Greater trochanter not involved</td>
<td>8</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>V Four or more fragments, Greater trochanter involved</td>
<td>12</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Fielding</td>
<td></td>
<td></td>
<td>0.367</td>
</tr>
<tr>
<td>I At the level of lesser trochanter</td>
<td>24</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>II 2.5–5 cm below lesser trochanter</td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>III 5 to 7 cm below lesser trochanter</td>
<td>1</td>
<td>1</td>
<td>0.500</td>
</tr>
<tr>
<td>AO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31–A1.3</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>31–A2.2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>31–A3.3</td>
<td>18</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>32–A1</td>
<td>3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>32–A2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>32–A3</td>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>32–C3</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The mean delay, operating time and hospital stay were 1.1 (range 1–3 days), 93.2 (range 15–260 minutes) and 6.1 (range 1–24 days) in the GN group and 1.3 (range 0–4 days), 136.3 (range 80–220 minutes) and 7.4 (range 2–17 days) in the DHS group. The differences were not significant.

Difficulties in reduction, as recorded by the operating surgeon, were slightly less common with the DHS than with the GN technique, requiring open reduction in two cases. Supplementary fixation had to be performed in five cases (11.6%) in
the GN group and in four cases (26.7%) in the DHS group (Table 8). There were four intraoperative complications (9.3%) in the GN group but none in the DHS group (Table 9). Insertion of the distal locking screws was the most hazardous step in gamma nailing, resulting in four intraoperative femoral shaft fractures. Two of these were treated with a longer gamma nail and one with Dall-Miles cable fixation, while one required no treatment.

### Table 8. Intraoperative data.

<table>
<thead>
<tr>
<th></th>
<th>Gamma nail (n=43)</th>
<th>DHS (n=15)</th>
<th>Fracture type (Seinsheimer)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating time (min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>93.2</td>
<td>136.3</td>
<td></td>
<td>0.160</td>
</tr>
<tr>
<td>Range</td>
<td>15–260</td>
<td>80–220</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulties in closed reduction</td>
<td>9</td>
<td>2</td>
<td>IIC, IIC</td>
<td>0.154</td>
</tr>
<tr>
<td>Of which open reduction</td>
<td>2</td>
<td>0</td>
<td>IIC, IIC</td>
<td></td>
</tr>
<tr>
<td>Deviation from routine operation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerglage wire</td>
<td>3</td>
<td>0</td>
<td>IIC, IIC, IIIA</td>
<td></td>
</tr>
<tr>
<td>Dall-Miles cable</td>
<td>2</td>
<td>0</td>
<td>IIC, V</td>
<td></td>
</tr>
<tr>
<td>Interfragmentary screw</td>
<td>0</td>
<td>4</td>
<td>V, IIIA, IIIA, V</td>
<td></td>
</tr>
</tbody>
</table>

On the other hand, postoperative complications were more common in the DHS group (Table 9). One postoperative fracture re-displacement (femoral medialization) was treated with DCS fixation, one breakage of the lateral plate with intramedullary Grosse-Kempf fixation and another with a longer plate. It is significant that all these complications occurred in Seinsheimer type IIIA fractures. One femoral shaft fracture appeared four months postoperatively in the GN group, following a new trauma, and this was treated with a longer gamma nail. Bone union was achieved despite complications in all cases in both groups. Of the two wound infections in the GN group, one was successfully treated by revision and the other by extraction of the nail three months after the primary operation, by which time the fracture had healed. No infections were observed in the DHS group.
Table 9. Summary of major intraoperative and postoperative complications.

<table>
<thead>
<tr>
<th>Complications</th>
<th>Gamma nail (n=43)</th>
<th>DHS (n=15)</th>
<th>Fracture type (Seinsheimer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fracture of the femoral shaft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intraoperative</td>
<td>4</td>
<td>–</td>
<td>IIIA, IIIA, IIIA, V</td>
</tr>
<tr>
<td>Postoperative</td>
<td>1</td>
<td>–</td>
<td>IIC</td>
</tr>
<tr>
<td>Fixation failure</td>
<td>–</td>
<td>2</td>
<td>IIIA, IIIA</td>
</tr>
<tr>
<td>Fracture displacement</td>
<td>–</td>
<td>1</td>
<td>IIIA</td>
</tr>
<tr>
<td>Other complication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep wound infection</td>
<td>1</td>
<td>–</td>
<td>IIB</td>
</tr>
<tr>
<td>Superficial wound infection</td>
<td>1</td>
<td>–</td>
<td>IIC</td>
</tr>
<tr>
<td>Haematoma</td>
<td>–</td>
<td>1</td>
<td>IIIA</td>
</tr>
<tr>
<td>Reoperation due to complication</td>
<td>4</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Four months after the fracture 29% (10/43) of the patients in the GN group were able to walk alone out of doors and 20% (7/43) could walk without any aids, the corresponding proportions in the DHS group being 33% (4/15) and 8% (1/15) (Table 10). There were no statistically significant differences in place of residence, walking ability or the use of walking aids between the groups, however, at the time of fracture, at four months or at the evaluated change in locomotor ability (Table 10).

Four-month mortality was 18.6% (8/43) in the GN group and 13.3% (2/15) in the DHS group, and mortality at one year was 32.6% (14/43) and 20.0% (3/15), respectively, showing no significant differences.
Table 10. Functional parameters before the fracture and 4 months after the fracture.

<table>
<thead>
<tr>
<th>Functional parameters</th>
<th>Gamma nail (n=43)</th>
<th>DHS (n=15)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before the fracture</td>
<td>At 4 months</td>
<td>Before the fracture</td>
<td>At 4 months</td>
</tr>
<tr>
<td>Residential status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own home</td>
<td>28</td>
<td>16</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>Sheltered housing</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Home for the aged</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Permanent hospital inpatient</td>
<td>6</td>
<td>16</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Nursing home</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Acute care hospital</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Died</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Missing</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Walking</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alone out of doors</td>
<td>25</td>
<td>10</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Out of doors only when accompanied</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Alone indoor</td>
<td>11</td>
<td>11</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Indoors only when accompanied</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Unable to walk, able to sit</td>
<td>3</td>
<td>6</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Bedbound</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walking aids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Able to walk without aids</td>
<td>27</td>
<td>7</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>One stick</td>
<td>3</td>
<td>5</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Two sticks</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>One stick and tripod</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Two tripods</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rollator/walking frame</td>
<td>8</td>
<td>11</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Does not walk</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Walking ability subjectively compared to prefracture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same</td>
<td>6</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worse, because of the fracture</td>
<td>11</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worse, because of some other reason</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.4 Basicervical fractures (paper IV)

The study material included 30 patients, which fulfilled all the criteria for a basicervical fracture (11 males, mean age 75 years /19 females, mean age 78 years). The definitive rate of basicervical fractures was thus 1.8%.

Sixteen of these cases were treated as intracapsular fractures, seven with fixation using three cancellous screws (mean age 71 years, range 53 to 84, 6 males/1 female), and 9 with cementless Austin-Moore hemiarthroplasty (mean age 80 years, range 63 to 90, 3 males/6 females). Fourteen were treated as extracapsular fractures, 10 with a DHS, (mean age 77 years, range 51 to 89, 1 male/9 females), and 4 with a GN (mean age 78 years, range 66 to 87, 1 male/3 females).

In three of the cases treated with cancellous screw osteosynthesis the screw penetrated through the femoral head. One of these was managed with total hip replacement (THR) and two with removal of the screws, leading to
pseudoarthrosis in one case and to a Girdlestone hip in the other. One of the patients treated with Austin-Moore hemiarthroplasty underwent a total hip replacement seven months after the primary operation because of continuous hip pain. There was only one re-operation in the DHS group: on a patient who sustained a re-fracture due to a fall and was treated with THR four months after the primary operation. The GN group included two late nail removals after healing of the fracture, which was not regarded as complications.
6 Discussion

6.1 Hip fracture treatment in Oulu – one-year survey with a four-month follow-up

The majority of our hip fractures were cervical, with an intracapsular / extracapsular ratio of 60/40, similar to that reported in the data from the Finnish Health Care Register (Lüthje et al. 2001), where the ratio was 62/38, and to ratios observed in the other hospitals in Finland and in the other Nordic countries (Hedlund et al. 1985, Jalovaara et al. 1992, Lüthje et al. 1992b, Berglund-Rödén et al. 1994, Heikkinen et al. 2001, Heikkinen et al. 2004, Lönnroos et al. 2006), but different from that prevailing in Crete, representing the Mediterranean area (Dretakis 1992). In Central and Southern Europe the ratio seems to be the reverse, extracapsular hip fractures being the main type (Dretakis 1992, Scheerlinck et al. 2003), although recent reports suggest that the cervical/trochanteric fracture ratio has levelled off and the female/male fracture ratio has declined (Löfman et al. 2002).

The proportion of osteosynthesis in relation to hemiarthroplasty in the treatment of cervical hip fractures is the reverse in Finland from that in the other Nordic countries, as hemiarthroplasty has been the primary mode of treatment for cervical fractures in almost every northern hospital in Finland, where both cementless (Austin Moore) and cemented (Thompson) hemiarthroplasties have been used (Jalovaara & Virkkunen 1991, Heikkinen et al. 2004), whereas in Lund, Sweden, almost all cervical fractures have been treated with osteosynthesis (Thorngren 1991, Berglund-Rödén et al. 1994), although the use of different arthroplasties seems to be increasing in Sweden as well (Tidermark 2003). The use of a “fracture-prothesis” (sement or sementless hemiarthroplasty) as the primary treatment for a displaced cervical fracture has increased in our hospital in recent years, in accordance with national recommendations.

The majority of our trochanteric fractures were treated with a gamma nail during the year examined here, although this has been suggested to be entailing more complications and higher mortality than dynamic hip screw fixation (Bridle et al. 1991, Calvert 1992, Williams & Parker 1992, Radford et al. 1993, Aune et al. 1994, Albareda et al. 1996, Madsen et al. 1998, Rantanen & Aro 1998, Valverde et al. 1998, Ahrengart et al. 2002, Parker & Handoll 2008b). We therefore set out to minimize the use of gamma nail fixation and promote dynamic hip screw fixation as a primary treatment for stable trochanteric fractures. Since our policy has been to discharge the hip fracture patients from the orthopaedic
department to health centre hospitals or rehabilitation units as soon as possible, i.e. when the patient’s general medical condition allows, the stay in the primary hospital is very short (median 6 days). We didn’t know exactly the impact of this rehabilitation system on functional recovery, and thus we had another trial by Willig (2006) running at the same time to evaluate the impact of effective centralized rehabilitation. This is the reason why about fifty per cent of the patients not discharged to their original place of residence were discharged to health centre hospitals and the other fifty per cent to rehabilitation units. Living at home is inexpensive, and therefore the goal of treatment for elderly people with hip fracture should be to enable them to return home. In the present series 29% of the patients coming from their own homes were institutionalized after four months of follow-up. This figure should be reduced as far as possible.

There are only a few studies reporting outcome and mortality at four months after a hip fracture. Jalovaara et al. (1992) reported that mortality was 14% in Sundsvall and Oulu and 10% in Lund, while Berglund-Rödén et al. (1994) quoted figures of 15% in Rotterdam, 16% in Sundsvall and 12% in Lund, Kitamura et al. (1998) 6% in Nagoya and Scheerlinck et al. (2003) 16% in Brussels. Our mortality rate of 17.6% is slightly higher than the figures reported earlier, including the earlier report from Oulu (Jalovaara et al. 1992). This minor difference may attribute to temporal variation and not to any change in the quality of treatment. It is also noteworthy that according a study by Huusko et al. (1999b), altought there had been a dramatic change in surgical methods, in the length of hospital stay, and in discharge patterns, the first-year mortality had remained almost unchanged between the study intervals 1982–1983 and 1992–1993 in Central Finland.

The re-operation rate depends on the type of fracture and the method of treatment. Comparison of re-operation rates is difficult because four-month rates have not been given in previous studies, and four months is too short period to show all the re-operations associated with osteosynthesis. On the other hand, the aim of this study was not to compare treatment methods but to make a survey of hip fractures treated at Oulu University Hospital over a one-year period.

It has been claimed that SAHFE is too blunt instrument to allow any more fine-tuned evaluation of the different aspects of treatment. In our opinion, however, SAHFE is simple and handy and can be used in everyday clinical practice for quality control in the context of hip fracture treatment. More extensive queries are not suitable for this purpose because they require more staff resources. Anyhow, the use of some standardized system in the hip fracture surveys that allows adequate comparison with other assessments is recommendable.
6.2 Gamma nail and dynamic hip screw fixation for the treatment of trochanteric hip fractures

The incidence of hip fractures has been predicted to increase because of ageing of the population (Leung et al. 1992, Huusko et al. 1999a, Kannus et al. 1999, Johnell & Kanis 2006, Lönnroos et al. 2006). It is thus important to strive to improve treatment and to develop better surgical devices, of which the gamma nail is one example. The new treatment modalities must prove their usefulness and superiority over the old methods even in terms of functional outcome, an aspect which is lacking from most of the earlier comparisons between gamma nailing and other fixation methods.

Our investigation was a prospective matched-pair comparison of gamma nail fixation and DHS fixation for trochanteric fractures, focusing on functional recovery, re-operation rate and mortality. The functional outcome was assessed at 4 months, by which time ADL, walking ability and household activities have been shown to reach a constant level (Borgquist et al. 1990, Heikkinen & Jalovaara 2005).

DHS fixation required a slightly but not significantly longer hospital stay than GN fixation, as noted in many earlier reports (Bridle et al. 1991, Leung et al. 1992, Sabharwal et al. 1992). The average lengths of hospital stay here were definitely shorter in both groups than those reported in the meta-analysis of 10 trials of GN versus DHS fixation by Parker and Pryor (1996), where the means ranged from 12 to 39 days for DHS and from 12 to 37 days for GN. The explanation for this difference lies in the Finnish system of care for the elderly, as the catchment area for our hospital has an extensive network of health centre hospitals capable of providing rehabilitation at a very early postoperative stage. On the other hand, Willig (2006) reported that intensive postoperative rehabilitation did not seem to improve significantly the functional capacity of hip fracture patients at 6 and 12 months postoperatively. The total length of postoperative treatment after primary care did not differ significantly between the intensive rehabilitation group and health centre hospital group either (Willig 2006).

The facts that GN is said to be more rigid and to allow full weight-bearing earlier than DHS even in cases of very complex fractures (Utrilla et al. 2005) and that DHS fixation requires more extensive surgery than GN fixation did not have any marked effects on the functional outcome (Sabharwal et al. 1992, Goldhagen et al. 1994, Ahrengart et al. 2002). On the contrary, walking ability evaluated as the change relative to the preoperative situation was better in the DHS group.
Similar results have also been reported by Hoffman and Lynskey (1993), whereas Sabharwal et al. (1992), Goldhagen et al. (1994), Park et al. (1998) and Ahrengart et al. (2002) observed no significant differences. The greater impairment of walking ability observed here after GN fixation than after DHS fixation may be at least partly due to the higher rate of complications in the GN group.

Cutting-out from the femoral head is regarded as a typical complication of DHS fixation (Bridle et al. 1991, Guyer et al. 1992, Leung et al. 1992, Pervez et al. 2004, Jewell et al. 2008), but such cutting-out occurred more often with gamma nails in our series. These findings are in agreement with some earlier reports (Benum et al. 1992, Høgh et al. 1992, Sabharwal et al. 1992, Goldhagen et al. 1994, Baumgaertner & Gibson 1995, Adams et al. 2001), whereas Fornander et al. (1992), Hoffman and Lynskey (1993), and Park et al. (1998) reported roughly similar cutting-out rates for both methods. We agree with the conclusion reached by Bridle et al. (1991), that cutting-out from the femoral head is usually due to a technical error rather than implant dysfunction.

Complications specific to GN are fractures around the greater trochanter, fracture displacement upon nail insertion and fractures of the shaft of the femur (Park et al. 1998). Fracture of the femoral shaft at the distal end of the intramedullary part of the implant is considered the most serious complication (Bridle et al. 1991, Leung et al. 1992, Radford et al. 1993, Butt et al. 1995, Parker & Pryor 1996, Parker & Handoll 2008b). Both fractures of the femoral shaft that occurred in our GN group were associated with a new fall. The rate of fracture of the femoral shaft in our series, 1.5%, was similar to those published in earlier reports (Boriani et al. 1991, Lindsey et al. 1991, Halder 1992, Williams & Parker 1992, Forthomme et al. 1993, Osnes et al. 2001). Robinson et al. (2002) reported an incidence of 18.75 periprosthetic fractures/1,000 patients treated with gamma nail compared to 4.46/1,000 patients treated with dynamic hip screw fixation. On the other hand, Abhay et al. (2007) reported no intra-operative or post-operative femoral shaft fractures either in gamma nail or DHS treated patients. Also Leung et al. (1992) reported no cases of femoral shaft fracture with a modified gamma nail. We agree with some earlier studies suggesting that this complication can be reduced by developing the gamma nail design (Parker & Pryor 1996, Rantanen & Aro 1998).

Most studies have failed to reveal any difference in postoperative mortality between GN and DHS fixation (Guyer et al. 1992, Høgh et al. 1992, Leung et al. 1992, Radford et al. 1993, O’Brien et al. 1995, Jiang et al. 2008), although some have reported higher mortality after GN fixation (Sabharwal et al. 1992, Hoffman
& Lynskey 1993) and some after DHS fixation (Bridle et al. 1991, Fornander et al. 1992). Our findings of higher mortality after GN fixation are in line with some earlier results, and we think that the difference was at least partly due to the higher number of complications requiring re-operations.

The percutaneous compression plate (PCCP) is a recently developed, alternative device that involves minimal invasive surgery (MIS). According to a recent study by Ho et al. (2008) MIS technique produces better outcome in the operating time, length of hospital stay, and blood loss compared to the conventional DHS technique as a treatment for trochanteric hip fractures. The studies by Laufer et al. (2005), Giancola et al. (2008) and the meta-analysis of all head to head trials (1995–2006) by Panesar et al. (2008) reported similar results; the PCCP showed lower blood loss and consequently lower transfusion need, fewer implant-related complications and comparable surgery times, and enhanced short- and long-term recovery of functional abilities in comparison to DHS. However, these new treatment modalities need further trials to prove their usefulness and superiority over the old methods even in terms of functional outcome.

6.3 Gamma nail and dynamic hip screw fixation for the treatment of subtrochanteric hip fractures

It is very difficult to classify subtrochanteric fractures, as the actual borderline with trochanteric fractures is controversial and the dividing line with femoral diaphyseal fractures is also open to debate (Parker et al. 1997). The poor reliability and reproducibility of all classification systems for hip fractures has been reported earlier (Andersen et al. 1990, Gehrchen et al. 1997, Jin et al. 2005). We classified the fracture patterns according to three systems and concluded that they are not comparable, as has been pointed out earlier (van Doorn & Stapert 2000). We used Seinheimer's classification in the evaluation of the results, as this has been employed in the majority of studies on subtrochanteric fractures and also proved the most practicable system in our opinion.

The average lengths of hospital stay, which were about one week in both groups, were definitely shorter than those reported earlier, ranging from 10 to 29 days for DHS and from 13 to 23 days for GN (Ruff & Lubbers 1986, Whitelaw et al. 1990, Madsen et al. 1998, Hotz et al. 1999, van Doorn & Stapert 2000). This is due to an extensive network of health centre hospitals capable of providing rehabilitation at a very early postoperative stage.
Where 43% of the patients in the GN group and 33% in the DHS group regained their pre-trauma walking ability, previous studies have reported better functional results in both groups. Madsen et al. (1998) reported that 69% of the gamma nail patients, 73% of the cephalic hip screw patients & 91% of those treated with DHS & TSP had regained their pre-fracture walking ability by 6 months after the operation. Our shorter follow-up time (4 months) than in earlier reports (6 months – 1 year) naturally prevents proper comparison, but it is clear that the clinical results are not so satisfactory. On the other hand, it has been shown that the main recovery of functions in the activities of daily living has normally been achieved by four months after the fracture (Ceder et al. 1980, Borgquist et al. 1990, Heikkinen & Jalovaara 2005). Pakuts (2004) reported that early recovery is faster after GN than DHS fixation, but we did not record the early stage of recovery.

Overall, complications occurred in 16% of the GN group and 26% of the DHS group, which is in accordance with previously reported complication rates, ranging from 8% to 30% in patients treated with GN fixation (Bridle et al. 1991, Rantanen & Aro 1998, Hotz et al. 1999, Hesse & Gachter 2004, Cheng et al. 2005) and from 5% to 17% in those treated with DHS fixation (Whitelaw et al. 1990, Haynes et al. 1997, Madsen et al. 1998, Lundy 2007). The major complication associated with GN fixation, fracture of the femoral shaft, occurred in 12% of the patients, which is in line with earlier reports showing rates ranging from 2 to 11% (Madsen et al. 1998, Rantanen & Aro 1998, van Doorn & Stapert 2000, Parker & Handoll 2008b). The majority of the complications of GN fixation occurred during the operation, whereas those of DHS fixation occurred later, during the follow-up, as has been observed elsewhere (van Doorn & Stapert 2000).

It seems that most intraoperative complications and difficulties occurred in certain types of fractures in both groups, being most common in Seinsheimer type IIc fractures in the GN group and in Sensheimer type IIIa fractures in the DHS group. These findings are in line with earlier studies (Ruff & Lubbers 1986, Whitelaw et al. 1990, Parker 1996, Haynes et al. 1997, Madsen et al. 1998, van Doorn & Stapert 2000, Lunsjö et al. 1999, Ahrengart et al. 2002) and should be considered when choosing between these two fixation methods.

### 6.4 Basicervical fractures

The definition of basicervical fracture is inaccurate, and misdiagnosis is hence possible. Classification on the basis of radiographs may often be difficult due to
poor quality and possible inadequate projections. A basicervical fracture can be obscured by the trochanteric area in anterior-posterior radiographs, which makes the fracture line poorly visible or invisible. Two thirds of the incorrectly classified cases in the present series belonged to this category.

A proper lateral projection shows the level of the fracture line and the possible remnant of the collum at the cervico-trochanteric junction, and is thus essential for reliable classification. Extensions of fractures into the trochanteric area are easier to observe in both anterior-posterior and lateral projections, and the main reason for an inadequate classification thus seemed to be the surgeon’s ignorance of the exact definition of a basicervical fracture. Sometimes adequate classification of a basicervical hip fracture is not possible until reposition on the traction table, and thus the surgeon’s knowledge of fracture classification is always crucial.

Surgical treatment of basicervical fractures is regarded as fundamentally non-problematic (De Palma 1970, Wilson 1982, Kuokkanen 1991, Russel 1992), but previous studies have demonstrated a high incidence of complications leading to re-operations (Indemini et al. 1982, Levy et al. 1983, Kuokkanen 1991), as was the case here. Hence this special hip fracture entity is worth considering in the present context.

Treatment of basicervical fractures as trochanteric fractures proved superior to their treatment as cervical fractures, resulting in lower re-operation rates, which is in accordance with previous reports (Grenis & Uhl 1989, Madsen et al. 1987, Blair et al. 1994). Similar findings were also reported by Kuokkanen (1991), who demonstrated that the use of multiple pins or screws may be hazardous in the treatment of basicervical fractures. Our result is also in agreement with the biomechanical study of Blair et al. (1994), who found the sliding hip screw to be biomechanically superior to the multiple cancellous screws used for the treatment of basicervical femoral neck fractures. We also agree with the current opinion that hemiarthroplasty is not indicated as the primary treatment for basicervical fractures (Kuokkanen 1991, Russel 1992) and with the current opinion by Chen et al. (2008) that surgical treatment of basicervical fractures of femur by closed reduction and internal fixation with DHS is recommendable.

6.5 General discussion

Our study showed that SAHFE is simple and handy and can be used in everyday clinical practice for quality control in the context of hip fracture treatment and in our opinion it should be recommended for use in other hospitals. The use of some
standardized system in the hip fracture surveys that allows adequate comparison of
the quality of treatment between hospitals is desirable.

Earlier studies in Finland have reported an increase in hip fracture incidence
rates during the three last decades and predict a significant rise in the future
(Kannus et al. 1999), but the reliability of these forecasts has been questioned
(Sund 2006, Sund et al. 2007). Also our data collected during SAHFE project in
1989–2003 disagree with these predictions; the yearly amount of hip fractures has
been almost constant during the study-time (unpublished data). Furthermore recent
reports suggest that the cervical/trochanteric fracture ratio has levelled off and the
female/male fracture ratio has declined (Löfman et al. 2002). However, in our data
both the female/male fracture ratio and intracapsular / extracapsular ratio have
been stable; the female/male ratio being 3:1 and the ratio of trochanteric to cervical
fractures 2:3 (unpublished data).

According to the national guidance for the diagnosis and management of hip
fracture (Finnish Medical Association Duodecim & Finnish Orthopaedic
Association 2006), the sliding hip screw method is recommended for less
comminuted, stable trochanteric fractures while the gamma nail fixation is
recommended for more comminuted and instable fractures and the intramedullary
device or dynamic condylar screw (DCS) for subtrochanteric fractures but no
advice is mentioned for the treatment of basicervical fractures. The practices of
our hospital have adapted to the National Guidelines. During the SAHFE project
1989–2003 the use of sliding hip screw (SHS) as a standard implant for stable
trochanteric fractures has increased, and currently the use of GN or another
intramedullary device is a preferred method of treatment for unstable trochanteric
fractures or subtrochanteric fractures. Our policy for the treatment of bascervical
fractures has changed. Currently these fractures are treated by closed reduction
and internal fixation with DHS with or without an antirotational screw as recently
suggested also by the study of Chen et al. (2008).
7 Conclusions

1. The intracapsular / extracapsular fracture ratio (60/40) and female/male ratio (80/20) of the hip fractures treated at Oulu University Hospital over a one-year period seemed to be similar to those reported in the data from the Finnish Health Care Register. The most frequently used method for treating cervical fractures was Austin-Moore hemiarthroplasty (68%) and that for trochanteric and subtrochanteric fractures was GN fixation (86%). The SAHFE forms were very useful for evaluating the quality of hip fracture treatment.

2. Both methods, GN and DHS fixation, are useful for treating trochanteric fractures, although the results four months postoperatively with respect to walking ability and mortality were slightly in favour of DHS fixation.

3. Overall, complications occurred in 16 % of the GN group and 26 % of the DHS group. Majority of the complications of GN fixation occurred during the operation, whereas those of DHS fixation occurred later, during the follow-up. It is significant that all these complications in the DHS group occurred in Seinsheimer type IIIa fractures. However, there were no statistically significant differences in short-term outcomes between the GN and DHS groups.

4. Altogether 108 (6.7 %) of the 1624 hip fractures were initially classified as basicervical fractures, but after a careful second look only 30 fulfilled all the criteria. The definitive rate of basicervical fractures was thus 1.8%. Treatment of basicervical fractures as trochanteric fractures proved superior to their treatment as cervical fractures, resulting in lower re-operation rates.
References


Appendices
Appendix I Following are the patient registration forms (Rikshöft) used in studies III and IV.
The hospital is identified by the code number designated by the State Medical Board.

**Operation-methods:**

1. von Bahr
2. Two screws, type .................................................................
3. Three or more screws, type ..................................................
4. LIH-Lars Ingvar Hansson pins ..............................................
5. Rydell three flanged nail ....................................................
6. Other flanged nail, type .......................................................  
7. Multiple pins, type ...............................................................
8. Telescoping screw + plate, type ...........................................
9. Telescoping nail + plate, type ............................................... 
10. Fixed nail-plate, type ...........................................................
11. Endernail ...........................................................................
12. AO-plate ...........................................................................
13. Other osteosynthesis, type ................................................. 
14. Hemiarthroplasty, type .......................................................  
15. Total hip arthroplasty, type ................................................ 
16. Not operated .......................................................................
17. Other type ........................................................................

Note that appliance of traction is not coded!

This multicenter study has been initiated by the Swedish Orthopedic Society and is supported by the Swedish Medical Research Council.
TO THE PATIENT

(Or to the district nurse, physiotherapist, physician or similar personnel at servicehome, convalescent home, nursing home etc).

You have been operated for a hip fracture on ______________ side. Four months after the operation (date: ______________) we wish you to complete this form and return it to the following address: ________________________________

____________________________ (name of the hospital where operated).

When you complete the form encircle the digit or letter for the alternative which makes up your answer.

Do not forget to give all the dates and locations you have been at since discharge from the department where you were operated (question 9).

This form will be the basis for further treatment of your hip fracture if necessary. The forms will also be used for statistical analysis without identification of individual patients.

This survey has been initiated by the Swedish Orthopedic Society and is supported by the Swedish Medical Research Council.

TO THE WARD

Complete questions 1–6 before the form is given to the patient. Instruct the patient before discharge how he/she should complete the form and return it to your department.
HIP FRACTURE

1. FORM
2. HOSPITAL CODE
3. PATIENT IDENTIFICATION (DATE OF BIRTH) (year, month, day)
4. NAME
5. SIDE OF FRACTURE 1 = left, 2 = right.
6. FRACTURE TYPE Use the code noted in question 16 in the yellow form

7. WHERE DO YOU LIVE NOW, 4 months after your hip fracture? (encircle one of the following alternatives)
   1. own home
   2. convalescent home
   3. full-service unit with meals, home for the elderly
   4. geriatric department, rehabilitation clinic
   5. long-term care institution,
   6. acute hospital
   7. other
   8. unknown

8. WHERE DID YOU LIVE AT THE TIME OF YOUR HIP FRACTURE? (Alternatives as above – write digit in this square)

9. We are interested to know where you have stayed after you were discharged from the hospital where you were operated. Please describe below where you have been (even new hospital admissions), including the dates and number of days for these periods. Describe all the places you have moved to (if there are not enough space below, use the back of this form).

   TYPE OF STAY
   DATES
   NUMBER OF DAYS
   (alternatives as for question 7).

9.  
10.  
11.  
12.  
13.  
14.  
15.  
16.  
17.  
18.  

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HIP FRACTURE

CONTINUOUS OF FORM 2

19. □ DO YOU LIVE ALONE NOW?  1 = yes,  2 = no

20. □ Which WALKING AIDS do you use indoors now?
   1. can walk without aids   5. two tripods
   2. one stick (crutch or tripod, hemiwalker)
   3. two sticks
   4. one stick + one tripod
   6. rollator/walking-frame
   7. wheelchair
   8. does not walk

21. □ DO YOU HAVE PAIN WHEN YOU PUT WEIGHT ON THE OPERATED EXTREMITY?
   1. Yes, quite a lot
   2. Yes, a little
   3. No, not at all

22. □ HAVE YOU TAKEN ANALGESICS SEVERAL DAYS DURING THE LAST WEEK BECAUSE OF PAIN FROM YOUR HIP?  1 = yes,  2 = no

23. □ HOW GOOD IS YOUR WALKING ABILITY? (choose what best applies to you)
   1. can walk alone out of doors
   2. can walk out of doors only accompanied
   3. can walk alone indoors but not out of doors
   4. can walk indoors only accompanied
   5. can not walk but is sitting in a chair
   6. always bedridden
   7. unknown

24. □ DO YOU WALK EQUALLY WELL NOW AS BEFORE THE FRACTURE?
   1. yes
   2. no, the fractured hip gives me problems
   3. no, for other reasons

25. □ CAN YOU DRESS — UNDRESS YOURSELF?  1 = yes,  2 = no

26. □ HOW MANY HOURS PER WEEK DO YOU HAVE HOMEEHELP

   __________________________ hours per week (No homehelp = 0).

27. □ A (Do not fill in this)

28. □ B (Do not fill in this)

The form completed by _____________________________________________

______________________________________________________________

Telephone: ______________________________________________________

Thank you for your help!
Appendix II Following are the SAHFE hip fracture patient registration forms used in studies I–II.

<table>
<thead>
<tr>
<th>Standardised Audit of Hip Fractures in Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary questions—form 1</td>
</tr>
</tbody>
</table>

1. Country and hospital code
   * First 3 numbers are the countries international visiting code, then 6 numbers for the hospital code.

2. Patient ID number
   * Each hospital may choose their own ID number, e.g., social security number, hospital record number.
   * Even if the patient is admitted later for a second fracture, the same number is used.

3. SAHFE number (Computer generated when form 1 is registered).

4. Side of fracture
   - Left
   - Right
   (If simultaneous bilateral fracture, use 2 forms.)

5. Date of fracture
   (If not known, use "Date of admission", form 1.)

6. Date of birth (e.g., 25/06/1916)

7. Sex
   - Male
   - Female

8. Date of admission

9. Admitted from
   - Own home
   - Skilled nursing home
   - Institutional care
   - Nursing home
   - Rehabilitation unit
   - Acute hospital
   - Other

10. Living alone
    - Yes
    - No

11. Walking
    - Walked alone out of doors
    - Walked out of doors only if accompanied
    - Walked alone indoors but not out of doors
    - Walked indoors only if accompanied
    - Unable to walk

12. Walking aids
    - Can walk without aid
    - One aid (stick, crutch, tripod or hemiwalker)
    - Two aids (stick, crutch, tripod or hemiwalker)
    - Frame (walking frame orcollator)
    - Wheelchair/bound

13. ASA grade
    - 1: Completely fit and healthy
    - 2: Some illness but has no effect on normal daily activity, that is, asymptomatic condition such as hypertension, Symptomatic illness present, but minimal restriction on life, e.g., mild diabetes mellitus.
    - 3: Symptomatic illness causing severe restriction, e.g., severe chronic bronchitis, unstable diabetes, 3–Moribund

14. Type of fracture
    (see figure on the back of this form)
    - Choose the area of bone in which the main fracture line crossing femur is predominantly found.
    - Femoral neck
    - Intra-capsular intertrochanter
    - Extra-capsular intertrochanter
    - Other

15. Pathological fracture
    - No
    - Malignant secondary bone tumour
    - Malignant primary bone tumour
    - Paget's disease
    - Other

16. Date of operation
    Leave blank if not operated on.

17. Primary operation
    - Single screw, pin or nail
    - Two screws, pin or nail
    - Three or more screws, pin or nail
    - Single screw, pin or nail with side plate
    - Intramedullary nail
    - Hemiarthroplasty
    - Total hip arthroplasty
    - Other

18. Date of discharge from primary admission ward
    Has any re-operation been performed? If yes, complete form 3 (questions 28–34) for each re-operation.

19. Discharged to
   (code as question 9)
Codes for "Admitted from"
1 = Own home. Independent living accommodation although the person may receive assistance from relatives and outside agencies at home. Own, rented house, family member's home.
2 = Sheltered housing, warden controlled accommodation, special flat. Partly independent living accommodation where major assistance is given.
3 = Institutional care. Long term/permanent placement in a full service residential home, home for the elderly or infirm where meals are provided but the patient is mobile and generally able to carry out basic activities of daily living (dressing, washing, feeding to toileting). A social provision with minimum nursing input.
4 = Nursing home. Long term/permanent placement in an institutional home which has provision of nursing facilities to provide assistance in the basic activities of daily living of dressing, washing and toileting.
5 = Permanent hospital inpatient. Long term/permanent placement of a patient in hospital which has nursing and medical support and for which there are no plans for discharge.
6 = Rehabilitation unit. Short term/temporary placement in either a community rehabilitation unit, temporary nursing care, geriatric assessment unit, respite care, convalescent home.
7 = Acute hospital. Short term/temporary placement.
8 = Other (specify)
9 = Died (only applies when answering question 19, 34)

Codes for "Type of fracture"
1 = Undisplaced intracapsular (subcapital or cervical). Garden grade 1 or 2
2 = Displaced intracapsular (subcapital or cervical). Garden grade 3 or 4
3 = Base-cervical (baseal)
4 = Trochanteric two fragments (a two part fracture, unstable fracture) Trochanteric fractures are also termed intertrochanteric or pertrochanteric fractures.
5 = Trochanteric multi-fragments (the extra fragments are generally the greater or lesser trochanter or both)
6 = Subtrochanteric (any number of fragments)
1. Country and hospital code
   First 3 numbers are the country international dialing code, then 6 numbers for the hospital code.

2. Patient ID number
   Each hospital may choose their own ID number, e.g. social security number, hospital record number.
   Even if the patient is admitted later for a second fracture the same number is used.

3. SAIHE number (Computer generated when form 1 is registered).

4. Side of fracture
   1=Left 2=Right
   (If simultaneous bilateral fracture, use 2 forms.)

5. Date of fracture
   (If not known, use "Date of admission", form 1.)

6. Date of birth
   (e.g. 25/06/1945)

7. Sex
   1=Male 2=Female

20. Assessment done by
   1=Face to face interview with patient
   2=Face to face interview with care/relative/friend
   3=Phone to patient
   4=Phone to care/relative/friend
   5=Postal questionnaire completed by patient
   6=Postal questionnaire completed by care/relative/friend
   7=Other (specify)

21. Residential status
   Choose the one option that best applies. For full explanation see on the back of this form.
   1=Owning house
   2=Sheltered housing
   3=Institutional care
   4=Nursing home
   5=Permanent hospital inpatient
   6=Rehabilitation unit
   7=Acute hospital
   8=Other
   9=Died

22. Locomotor ability
   Refers to the patient's normal walking ability at 4 months after the fracture occurred.
   1=Walks alone out of doors
   2=Walks alone indoors but not out of doors
   3=Walks alone indoors only if accompanied
   4=Walks indoors only if accompanied
   5=Unable to walk

23. Walking aids
   Refers to the walking aids normally used at 4 months after the fracture occurred.
   1=Walks without aids
   2=One aid (stick, crutch, tripod or hemiwalker)
   3=Two aids (stick, crutch, tripod or hemiwalker)
   4=Frame (walking frame or rollator)
   5=WheeledChair/wheelchair

24. Pain at the hip
   (choose the one most relevant option)
   1=The pain in my hip is severe and spontaneous. I experience it even when I am not moving.
   2=The pain in my hip is severe when I attempt to walk and prevents all activity.
   3=The pain in my hip is tolerable, permitting limited activity.
   4=The pain in my hip occurs only after some activity and disappears quickly with rest.
   5=The pain in my hip is slight or intermittent. I experience pain when starting to walk but the pain goes less with normal activity.
   6=I experience no pain in my hip.
   7=Unable to answer.

25. Type of stay/re-admissions
   For type of stay, use options in question 9 (see the back of this form). For days, give number of days stay at each residential category from the time of discharge from primary admission up to 120 from fracture. For reasons, use the following codes.
   1=Surgical complications requiring re-operation (ensure questions 29-34 have been completed for each re-operation).
   2=Surgical complications not requiring re-operation
   3=Medical complications related to hip fracture
   4=Failure to manage at place of origin due to hip fracture
   5=Admitted for reasons not related to hip fracture
   6=Return to place of origin

26. Date of death
   (If death within 4 month of fracture give date of death.)
Codes for "Residential status"

1—Own house. Independent living accommodation although the person may receive assistance from relatives and outside agencies at home. Own, rented house, family member’s home.

2—Sheltered housing, warden controlled accommodation, special flat. Partly independent living accommodation where major assistance is given.

3—Institutional care. Long term/permanent placement in a full service residential home, home for the elderly or infirm where meals are provided but the patient is mobile and generally able to carry out basic activities of daily living (dressing, washing, feeding, toileting). A social provision with minimum nursing input.

4—Nursing home. Long term/permanent placement in an institutional home which has provision of nursing facilities to provide assistance in the basic activities of daily living (dressing, washing, feeding, toileting).

5—Permanent hospital inpatient. Long term/permanent placement of a patient in hospital which has nursing and medical support and for which there are no plans for discharge.

6—Rehabilitation unit. Short term/temporary placement in either a community rehabilitation unit, temporary nursing care, geriatric assessment unit, respite care, convalescent home.

7—Acute hospital. Short term/temporary placement.

8—Other (specify)

9—Dead (only applies when answering question 19, 34)
### Standardised Audit of Hip Fractures in Europe

<table>
<thead>
<tr>
<th>1.</th>
<th>Country and hospital code</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.</td>
<td>Patient ID number</td>
</tr>
<tr>
<td>3.</td>
<td>SAHFE number (Computer generated when form 1 is registered)</td>
</tr>
<tr>
<td>4.</td>
<td>Side of fracture 1—Left 2—Right (If simultaneous bilateral fracture, use 2 forms)</td>
</tr>
<tr>
<td>5.</td>
<td>Date of fracture (If not known, use &quot;Date of admission&quot;, form 1)</td>
</tr>
<tr>
<td>6.</td>
<td>Date of birth (e.g. 25/06/1945)</td>
</tr>
<tr>
<td>7.</td>
<td>Sex 1—Male 2—Female</td>
</tr>
</tbody>
</table>

| 28. | Date of admission |

If already in hospital and not discharged since primary admission use same date as question 8

| 29. | Admitted from |

Choose the one option that best applies. For full explanation see the back of this form.

1—Own home 2—Sheltered housing 3—Institutional care 4—Nursing home 5—Permanent hospital patient 6—Rehabilitation unit 7—Acute hospital 8—Other 9—Died

| 30. | Date of re-operation |

| 31. | Type of re-operation |

1—Removal implant 2—Removal of internal fixation 3—Total hip arthroplasty 4—Nevus cell nevus 5—Glioblastoma/malignant astrocytoma 6—Re-implantation 7—Reduction dislocation 8—Other (specify)

| 32. | Reason for re-operation |

1—Fracture displacement 2—Loss of position of osteosynthesis material without fracture displacement 3—Additional fracture around the implant 4—Non-union (nonunited). Non-union normally takes 3-6 months to occur so fracture displacement or loss of position of implant before this time should normally be coded as 1 or 2 5—Necrosis of head (segmental collapse, avascular necrosis in a fracture that has healed) 6—Local pain or tenderness at operation site or prominent implant causing discomfort with healed fracture 7—Wound infection 8—Wound haematoma 9—Dislocation of arthroplasty 10—Breakage of the implant 11—Debridement of the implant 12—Elective removal of implant. Fracture healed and no significant symptoms 13—Other (specify)

| 33. | Date of discharge or death in hospital |

| 34. | Discharged to (code as question 29) |

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Codes for "Admitted from"

1=Own home. Independent living accommodation although the person may receive assistance from relatives and outside agencies at home. Own, rented house, family member's home.

2=Sheltered housing, warden controlled accommodation, special flat. Partly independent living accommodation where major assistance is given.

3=Institutional care. Long term/permanent placement in a full service residential home, home for the elderly or infirm where meals are provided but the patient is mobile and generally able to carry out basic activities of daily living (dressing, washing, feeding, toileting). A social provision with minimum nursing input.

4=Housing home. Long term/permanent placement in an institutional home which has provision of nursing facilities to provide assistance in the basic activities of daily living of dressing, washing and toileting.

5=Permanent hospital inpatient. Long term/permanent placement of a patient in hospital which has nursing and medical support and for which there are no plans for discharge.

6=Rehabilitation unit. Short term/temporary placement in either a community rehabilitation unit, temporary nursing care, geriatric assessment unit, respite care, convalescent home.

7=Acute hospital. Short term/temporary placement.

8=Other (specify)

9= Died (only applies when answering question 19, 34)
Original articles

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


Original articles are not included in the electronic version of the dissertation.

Reprinted with kind permission of the Finnish Surgical Society and Springer Science and Business Media.
980. Palosaari, Kari (2008) Quantitative and semiquantitative imaging techniques in detecting joint inflammation in patients with rheumatoid arthritis. Phase-shift water-fat MRI method for fat suppression at 0.23 T, contrast-enhanced dynamic and static MRI, and quantitative 99mTc-nanocolloid scintigraphy
981. Perkiömäki, Marja Riitta (2008) Craniofacial shape and dimensions as indicators of orofacial clefting and palatal form. A study on cleft lip and palate and Turner syndrome families
Ismo Saarenpää

EXTRACAPSULAR HIP FRACTURES—ASPECTS OF INTRAMEDULLARY AND EXTRAMEDULLARY FIXATION