Intramedullary nails in the treatment of trochanteric and subtrochanteric fractures

Kirsten Marie Larsen Grønhaug

Thesis for the degree of Philosophiae Doctor (PhD)
University of Bergen, Norway
2023

UNIVERSITY OF BERGEN

Intramedullary nails in the treatment of trochanteric and subtrochanteric fractures

Kirsten Marie Larsen Grønhaug

Thesis for the degree of Philosophiae Doctor (PhD)
at the University of Bergen

Date of defense: 15.09.2023

Year: 2023

Title: Intramedullary nails in the treatment of trochanteric and subtrochanteric fractures

Name: Kirsten Marie Larsen Grønhaug

Print: Skipnes Kommunikasjon / University of Bergen

Scientific environment

This PhD project has been a collaboration between the Department of Orthopaedic Surgery, Østfold Hospital Trust and the Norwegian Hip Fracture Register.

After completing my training as an orthopaedic surgeon, I was offered a position as consultant surgeon at Østfold Hospital trust, to work in the field of orthopaedic trauma surgery. After a few years of 100% clinical work my colleague Bengt Østman included me in a research project on the timing of hip hemiarthroplasty and the influence on prosthetic joint infection in collaboration with Sahlgrenska University Hospital in Gothenburg and McMaster University in Canada. After this exciting introduction to the world of orthopaedic research, he asked me to be first author in a study on subsequent femoral fractures after intramedullary nailing. This study became Paper I of my thesis and while working on the study we established contact with Jan-Erik Gjertsen at the Norwegian Hip Fracture Register (NHFR). Together we quickly agreed on two additional studies regarding the use of intramedullary nails in the treatment of trochanteric and subtrochanteric fractures. Research on intramedullary nailing was a well-tailored match with our department's treatment policy of hip fractures over the past two decades. I was accepted as a PhD candidate at the University in Bergen in 2019, with Jan-Erik Gjertsen, head of NFHR and Professor at Department of Clinical Medicine, University of Bergen as main supervisor and Bengt Østman, senior consultant and head of research at the Department of Orthopaedic surgery, Østfold Hospital Trust as co-supervisor. The Department of Research at Østfold Hospital trust lead by professor Whaleed Ghanima, has funded 20% of my position at the Department of Orthopaedics from 2019 – 2023 to complete the PhD.

UNIVERSITY OF BERGEN

"Your assumptions are your windows on the world. Scrub them off every once in a while, or the light won't come in."

Alan Alda

Acknowledgements

I would like to thank my colleague, friend and co-supervisor Dr. Bengt Østman for believing in me as a competent orthopaedic surgeon and researcher, particularly during the times I did not. I have learned so much during the surgery we have performed together and through the scientific work he has included me in. I admire his ability to stay true to method, inspire and teach. I have been allowed to ask the most basic questions and still been met with patience, understanding and brilliant answers. I would not have embarked on my journey towards a PhD had it not been for him.

My main supervisor Dr. Jan-Erik Gjertsen deserves ovations. He has, in spite of all his responsibilities as head of the NHFR, an active clinician and the father of two children, answered all my questions and reviewed every single manuscript draft swiftly and conscientiously be it day or night, working hours or holiday. Despite his experience and vast publication list, he is always patient, down to earth and welcoming. I deeply admire him, as a researcher, clinician, supervisor and person.

I also want to thank Mrs Eva Dybvik, statistician at the NHFR, who has been a patient and understanding teacher and co-author. She has guided me through the incomprehensible jungle of statistics and rescued me every time my very limited competence in computer science was about to put an end to the whole project.

Dr. Kjell Matre, director of the Department of Orthopaedic Surgery at Haukeland University Hospital has been a great inspiration and help, as he conducted analyses similar to those in Paper II in his own PhD. He always keeps the big picture in mind and has on several occasions pointed our research group in the right direction when we were preoccupied by less important details.

I wish to thank Dr. Kristian Samuelsson, professor at Sahlgrenska University Hospital for his contribution to Paper I and the collaboration with our department that started years before this PhD.

Dr. Asbjørn Sorteberg, head of Department of Orthopaedic Surgery at Østfold Hospital Trust, and Dr. Anders Lippert, Head of Division for Orthopaedic Trauma have given

me time and opportunity to work on this PhD alongside my clinical work. They have respected and protected my research time. They have supported and encouraged me and my fellow PhD candidates in our work, and at the same time allowed me to thrive and develop as an orthopaedic surgeon in my preferred field, orthopaedic trauma surgery.

I also want to thank my wonderful colleagues, past and present, home and abroad, for their friendship and inspiration.

Dr. Waleed Ghanima, professor and Head of Department of Research has enthusiastically supported the evolvement of an orthopaedic research community at our clinic. His department has provided me with 20% research time and economical support in the process of publishing the articles in this PhD.

I will, in my career as in all aspects of life, be grateful to my parents Søren and Elisabeth for their infinite love, support, patience and belief in me. They have inspired me throughout my life, and I still turn to them for comfort, help, enthusiastic discussions and confirmation.

Last, but not least, I want to thank my husband Gudmund. He has given me confidence, happiness, love and our wonderful children, Jakob and Pavel who welcomed me into their lives when we became a family and Pia and Kari, the new amazing arrivals to complete it. Gudmund has supported and inspired me through this PhD as he has through every day of our life together.

Contents

Scientific environment……..... **3**

Acknowledgement……..... **5**

Contents……..... **7**

List of abbreviations……..... **10**

List of publications…… **13**

Summary in English……..... **14**

Summary in Norwegian……..... **16**

1. Introduction and background…..... **18**

1.1 Epidemiology of hip fractures and importance of topic…… 18

1.1.1 Index fractures……..... 19

1.1.2 Subsequent fractures…… 20

1.1.3 Prevention of hip fractures……..... 21

1.2 Classification and stability assessment……..... 23

1.2.1 Classification of hip fractures…….. 23

1.2.2 Stability assessment…….. 28

1.3 Historical development of treatment strategies for trochanteric and subtrochanteric fractures…….... 29

1.4 Contemporary treatment……... 31

1.4.1 Intramedullary nails…… 31

1.4.2 Sliding hip screw……..... 33

1.4.3 Biomechanical considerations……. 34

1.4.4 Time trends for treatment of trochanteric and subtrochanteric fractures…….…..... 35

1.5 Complications after trochanteric and subtrochanteric fractures…… 37

1.5.1 Infection…… 38

1.5.2 Peri-implant fracture…… 41

1.5.3 Hardware failure……... 42

1.5.4 Cut-out…….. 43

1.5.5 Non-union……. 45

2. Aims of the studies……. 46

3. Patients and methods…… 47

3.1 Registration of hip fractures at Østfold Hospital Trust……. 47

3.2 The Norwegian Hip Fracture Register……..... 48

3.2.1 Registration of primary operations……..... 48

3.2.2 Registration of reoperations……. 48

3.2.3 Registration of patient-reported outcomes…….. 49

3.2.4 Mortality……... 50

3.3 Inclusion and exclusion of patients……... 51

3.4 Statistics…… 52

4. Summary of Papers I-III…….... 54

4.1 Paper I……... 54

4.2 Paper II……..... 56

4.3 Paper III……. 58

5. Discussion……... 60

5.1 Methodological considerations……..... 60

5.1.1 Retrospective studies…… 60

5.1.2 Register-based studies……..... 61

5.1.2.1 Strengths of register-based studies……... 61

5.1.2.2 Limitations of register-based studies……..... 62

5.1.3 Register-based studies versus RCTs……. 64

5.1.4 Limitations of the AO/OTA classification model……..... 66

5.2 Discussion of results……..... 67

5.2.1 Subsequent fractures following treatment with intramedullary nail 67

5.2.2 Choice of implants in trochanteric and subtrochanteric fractures.. 71

5.2.3 Comparison of intramedullary nails…… 77

6. Conclusions…… 82

7. Implications of studies…….. 84

8. Future perspectives……... 86

8.1 Validation of classification models of trochanteric and subtrochanteric fractures……. 86

8.2 The importance of intramedullary nail length……... 86

8.3 Peri-implant fractures…… 87

9. References…….. 88

Appendices……. 115

Appendix 1: Operation form, The Norwegian Hip Fracture Register

Appendix 2: Patient questionnaire, The Norwegian Hip Fracture Register

Papers I-III

List of abbreviations

AAOS	American Association of Orthopaedic Surgeons
ADL	Activities of Daily Living
ANOVA	ANalysis Of VAriance
AO/ASIF	Arbeitsgemeinschaft für Osteosynthesefragen / Association for Study of Internal Fixation
AO/OTA	Arbeitsgemeinschaft für Osteosynthesefragen / American Orthopaedic Trauma Association
ASA	American Society of Anesthesiologists
BMD	Bone Mineral Density
BMI	Body Mass Index
calTAD	calcar referenced Tip Apex Distance
CFS	Clinical Frailty Scale
CHS	Compression Hip Screw
CI	Confidence Interval
COS	Core Outcome Set
DFD	Danish Fracture Database
DHS	Dynamic Hip Screw
DMHFR	Danish Multidiciplinary Hip Fracture Register
EBM	Evidence Based Medicine
EQ-5D-3L	European Quality of Life 5 Dimensions 3 Level Version

EWGSOP	European Working Group on Sarcopenia in Older Persons
FLS	Fracture Liaison Services
HRR	Hazard Rate Ratio
HRQL	Health Related Quality of Life
IAFF	Infection After Fracture Fixation
ICD-10	International statistical Classification of Diseases and related health problems
IMN	Intramedullary Nail
IOF	International Osteoporosis Foundation
IQR	InterQuartile Range
MCID	Minimal Clinically Important Difference
mFI	modified Frailty Index
MRI	Magnetic Resonance Imaging
NAR	Norwegian Arthroplasty Register
NHFR	Norwegian Hip Fracture Register
NICE	National Institute for Health and Care Excellence
NCSP	NOMESKO Classification of Surgical Procedures
OHS	Oxford Hip Score
OR	Odds Ratio
PJI	Prosthetic Joint Infection
PROM	Patient Reported Outcome Measures

SD	Standard Deviation
SFR	Swedish Fracture Register
SHS	Sliding Hip Screw
Sffx	Subsequent femoral fracture
SSI	Surgical Site Infection
STROBE	STrengthening the Reporting of OBservational studies in Epidemiology
TAD	Tip Apex Distance
TSP	Trochanteric Support Plate
RCT	Randomised Controlled Trial
VAS	Visual Analogue Scale
WHO	World Health Organisation

List of publications

Paper I

Grønhaug KML, Dybvik E, Gjertsen JE, Samuelsson K, Östman B. Subsequent ipsi- and contralateral femoral fractures after intramedullary nailing of a trochanteric or subtrochanteric fracture: a cohort study on 2012 patients.
BMC Musculoskelet Disord. 2022 Apr 28;23(1):399.

Paper II

Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen JE.
Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures: 17,341 patients from the Norwegian Hip Fracture Register.
Bone Joint J. 2022;104-B(2):274-282.

Paper III

Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen JE. Comparison of intramedullary nails in the treatment of trochanteric and subtrochanteric fractures. An observational study of 13,363 fractures in the Norwegian Hip Fracture Register.
Submitted to JBJS Dec 2022

Summary in English

A hip fracture is a serious event in the geriatric patient, causing considerable morbidity and increased mortality. Choice of implant in the surgical treatment of trochanteric and subtrochanteric fractures has been debated for decades. The aim of this research project was to describe the impact of an intramedullary nail (IMN) in the event of a subsequent femoral fracture (Sffx), conduct an updated comparison of the sliding hip screw (SHS) and the IMN in stable versus unstable trochanteric and subtrochanteric fractures in Norway and compare the outcomes of different IMN designs.

In Paper I we investigated how an IMN affects the incidence, pattern and localisation of Sffxs in patients treated for a trochanteric or subtrochanteric fracture, without implants or sequelae after previous surgery in either femur. We conducted a retrospective cohort study of 2,012 patients treated at Østfold Hospital trust, all with documented native femora prior to the index fracture. All subsequent fractures were registered. Patients reaching any endpoint (Sffx, other complication requiring surgery, non-fracture related surgery, death) were censored. The total incidence of a Sffx was five times lower on the ipsilateral than the contralateral side following surgery with an IMN, and there was a tenfold increase in the risk of ipsilateral femoral shaft and distal metaphyseal fractures compared to fractures of the shaft and distal metaphysis in the contralateral side. We concluded that an IMN significantly changes the distribution of a Sffx, protecting the proximal femur but increasing the risk of a fracture distal to the implant.

In Paper II we compared the outcomes of SHS and IMN with emphasis on index fracture stability in a prospective cohort study using data from the Norwegian Hip Fracture Register (NHFR), including 17,341patients treated with a SHS or an IMN from 2013-2019. Primary outcome measure was reoperations in patients treated with an SHS or an IMN in stable versus unstable fractures, and secondary outcome measures were reoperations for individual fracture types, mortality and patient related outcome measures (PROMs) for stable versus unstable fractures. We detected a lower reoperation rate for IMN compared to SHS in unstable fractures, and no difference in

reoperation rate for stable fractures. When analysing individual fracture types there were minimal differences. Mortality was lower one year postoperatively in the group treated with an IMN in stable and unstable fractures alike. PROM data were incomplete, but we found a significant difference in EQ-5D-3L index score, mobility, pain and satisfaction one year postoperatively in favour of the IMN in unstable fractures.

In Paper III we compared reoperation rates for the different brands of IMNs in common use in Norway. We conducted a prospective cohort study including all trochanteric and subtrochanteric fractures treated with an IMN in general use over the past ten years and registered in the NHFR from 2007-2019, identifying 8,283 short nails and 4,949 long nails. Short and long nails were analysed separately. Primary outcome measure was reoperation rate for each brand of short and long nails for all fractures combined, and secondary outcome measure was reoperation rate for the different IMN brands regarding individual fracture types. We dicovered similar reoperation rates for the different types of short nails, and a higher reoperation rate for the TRIGEN TAN/FAN in all fractures combined and in AO/OTA A1, A2, and subtrochanteric fractures in subanalyses of individual fracture types.

The results of this thesis support the current international and national guidelines recommending the use of an IMN in the treatment of unstable trochanteric and subtrochanteric fractures. Peri-implant fractures are however, still a challenge, and the presence of an IMN significantly changes the distribution of a subsequent fracture. We have identified significant differences in reoperation rate between different brands of long IMNs, emphasizing the value of registers in thesurveillance of performance and outcomes of implants used in the treatment of trochanteric and subtrochanteric fractures.

Summary in Norwegian

Et hoftebrudd er en alvorlig og potensielt dødelig hendelse for et eldre, skrøpelig individ. Et slikt brudd fører svært ofte til økt hjelpebehov, varig nedsatt funksjon og overdødelighet. Valg av implantat i behandlingen av trokantære og subtrokantære brudd har vært diskutert over flere tiår. Målet med dette prosjektet var å beskrive hvordan en intramedullær nagle påvirker lokalisasjon og morfologi ved et nytt brudd i lårben, å gjennomføre en oppdatert sammenlikning av glideskrue og intramedullær nagle i behandlingen av henholdsvis stabile og ustabile trokantære og subtrokantære brudd, samt sammenlikne de ulike intramedullære naglene i utstrakt bruk i Norge.

I Artikkel I har vi undersøkt hvordan en intramedullær nagle påvirker forekomst, lokalisasjon og bruddmønster ved et nytt brudd hos pasienter behandlet for et trokantært eller subtrokantært brudd, uten tidligere implantat eller følgetilstand etter brudd i hverken motsatt eller samme lårben. Vi gjennomførte en retrospektiv kohortstude av 2012 pasienter behandlet ved Sykehuset Østfold, alle med dokumentert friske lårben før det første bruddet inntraff. Alle påfølgende brudd ble registrert. Pasienter som nådde et av følgende endepunkter: påfølgende lårbensbrudd, annen komplikasjon som ledet til reoperasjon, ikke bruddrelatert operasjon i et av lårbena eller død, ble fortløpende sensurert. Den samlede forekomsten av påfølgende brudd i et av lårbena var fem ganger lavere på samme side sammenliknet med motsatt side, mens det var ti ganger så høy forekomst av brudd i skaft og distale metafyse på samme side som implantatet sammenliknet med brudd i skaft og distale metafyse. Vår konklusjon var at en intramedullær nagle påvirker fordelingen av et påfølgende brudd i lårben i betydelig grad. Naglen ser ut til å beskytte mot brudd i øvre del av lårbenet, men øker risikoen for et brudd distalt for implantatet.

I Artikkel II har vi gjennomført en prospektiv kohortstudie der vi sammenliknet utfall av behandling med glideskrue og intramedullær nagle for trokantære og subtrokantære brudd, med tanke på bruddets stabilitet. Utvalget er hentet fra Nasjonalt Hoftebruddregister (NHBR). Vi inkluderte 17 341 pasienter behandlet med glideskrue eller intramedullær nagle og registrert i NHBR i tidsrommet 2013-2019. Det primære

utfallsmålet var reoperasjon etter behandling med glideskrue versus intramedullær nagle ved henholdsvis stabile og ustabile brudd. Sekundære utfallsmål var reoperasjon ved individuelle bruddtyper, mortalitet og pasientrapporterte utfall ved henholdsvis stabile og ustabile brudd. Vi fant lavere reoperasjonsrate ved bruk av intramedullær nagle enn glideskrue for ustabile brudd, og ingen forskjell i reoperasjonsrate for de to ulike implantatene for stabile brudd. Subanalyser av individuelle bruddtyper viste minimale forskjeller. Dødelighet ett år postoperativt var lavere i gruppen behandlet med intramedullær nagle, gjeldende for både stabile og ustabile brudd. Pasientrapporterte data var manglefulle, men vi fant signifikante forskjeller i EQ-5D-3L-indeks, smerte og tilfredshet ett år postoperativt i favør av behandling med intramedullær nagle.

I Artikkel III sammenliknet vi reoperasjonsrate for de ulike typene intramedullære nagler i utstrakt bruk i Norge. Vi gjennomførte en prospektiv kohortstudie der vi inkluderte alle trokantære og subtrokantære brudd behandlet med nagler brukt jevnlig de siste ti år og registrert i NHBR i tidsrommet 2007-2019, totalt 8283 korte nagler og 4949 lange nagler. Korte og lange nagler ble analysert hver for seg. Primært utfallsmål var reoperasjonsrate for de enkelte typer korte og lange nagler for alle bruddtyper samlet, og sekundært utfallsmål var reoperasjonsrate for de ulike korte og lange naglene for hver enkelt bruddtype. Vi fant sammenliknbare resultater for de ulike typene korte nagler, og høyere reoperasjonsrate for TRIGEN TAN/FAN både for alle brudd samlet og for AO/OTA A1, A2 og subtrokantære brudd ved subanalyser på ulike bruddtyper.

Resultatene i dette prosjektet støtter de gjeldende internasjonale og nasjonale retningslinjer, der en intramedullær nagle anbefales i behandlingen av trokantære og subtrokantære brudd. Implantatnære brudd er fremdeles en utfordring, og vi har funnet at en intramedullær nagle påvirker fordelingen av et påfølgende lårbensbrudd i betydelig grad. Vi har identifisert signifikante forskjeller i reoperasjonsrate ved bruk av ulike typer lange intramedullære nagler, noe som understreker verdien av registre for å overvåke implantater i bruk ved behandling av trokantære og subtrokantære brudd.

1 Introduction and background

1.1 Epidemiology of hip fractures and importance of topic

Hip fractures represent a major challenge on an individual as well as a socioeconomical level. North America and Europe, particularly the Scandinavian countries, have the highest incidence of hip fractures[1]. Today, approximately 9,000 hip fractures are treated in Norwegian hospitals each year[2], and with an ageing population the prevalence is likely to increase, nationally and internationally[3]. There has been a slight decline in age-specific incidence rates of hip fractures in the Western countries, including Norway[4-6], possibly due to improved treatment of osteoporosis and vitamin D deficiency, better general health and physical status, as illustrated in Figure 1. However, the increased life expectancy of a growing population counteracts the effect on the total number of fractures[3,7,8]. The Global Burden of Disease project has estimated an increase in years lived with disability due to a hip fracture of 62% between 1999 and 2019[7]. Approximately 18% of women and 6% of men will experience a hip fracture during their life span[9,10]. The one-year mortality rate is reported up to 25%[9], the risk of a subsequent femoral fracture up to 14%[11-13], and 50% of patients never return to their previous level of mobility[14,15]. The typical hip fracture patient is female, of advanced age and frail. Literature suggests that patients with a fragility fracture in the trochanteric area are even older, less mobile, and have more comorbidities than patients with a femoral neck fracture[14].

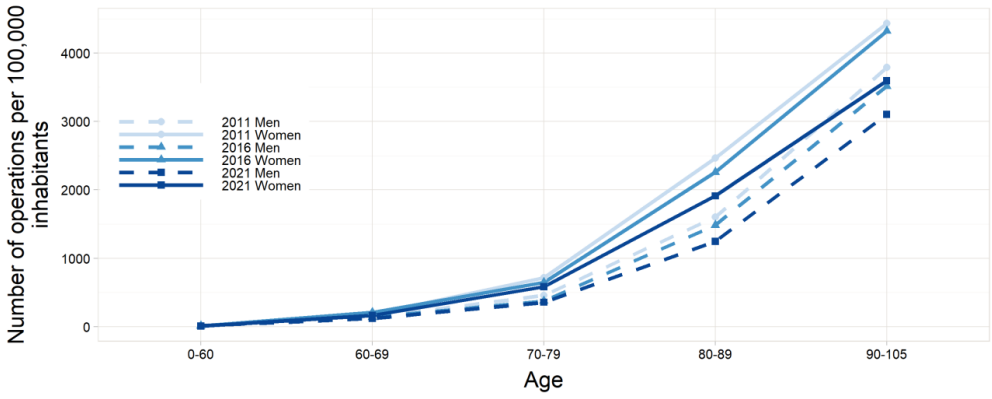


Figure 1: Incidence of hip fractures. Courtesy of Norwegian Hip Fracture Register (NHFR) (Reprinted with permission)

There is wide consensus concerning multidisciplinary approach to optimize treatment of hip fracture patients[16-20]. Still, debates concerning surgical techniques and implants in the treatment of different types of hip fractures remain, and the treatment of hip fractures vary greatly both nationally and internationally[21-30]. The scope of this PhD is to investigate intramedullary nails in modern surgical treatment of trochanteric and subtrochanteric fractures.

1.1.1 Index fractures

Risk factors for the index fragility fracture of the hip are well described in the available literature. Increasing age, female sex, institutionalization, osteoporosis, and increased fall tendency (due to cognitive impairment, frailty, sensorimotor, and sight disorders, multipharmacy) all increase the risk of an index hip fracture[31]. The vulnerable hip fracture patients run a great risk of adverse outcome following their hip fractures, particularly patients in nursing homes, suffering from severe osteoporosis, cognitive impairment, and sarcopenia[32-36]. Mortality is generally high in the geriatric population sustaining a hip fracture, but there is a significant excess post-fracture mortality of hip fracture patients compared to peers without hip fractures - attributable to the fracture itself and pre-fracture comorbidity[37-40]. A higher category of frailty, defined as the

reduced physiologic capacity of geriatric patients to react to acute stressors such as a hip fracture and measured using the clinical frailty scale (CFS)[41] and the modified frailty index (mFI)[42], leads to significantly increased mortality. This also applies to pre-fracture institutionalization, diagnosed dementia and delirium, malnutrition, sarcopenia and time to surgery beyond 24-48 hrs that are all independent risk factors for increased mortality and all related to other adverse outcomes of hip fracture surgery[35,43-47]. Kjærvik et al. recently published results from a large population-based and linked multiregister study concluding that patient and socioeconomic risk factors (non-modifiable factors) had a stronger association with mortality than healthcare-related (modifiable) risk factors[44].

1.1.2 Subsequent fractures

A patient surviving an index fragility fracture of the hip runs a substantially increased risk of a subsequent femoral fracture, estimated to be up to 14%[11,13,48,49]. To some extent, risk factors for the second fracture differ from the more investigated risk factors of the index fracture mentioned above, as these patients must be able to survive the stress of an initial hip fracture to be at risk for a subsequent femoral fracture. The Funen County Hip Fracture Study with a follow up of minimum 12 months reported that 50% of Sffxs occured within the first year, and after 12 months for men and 19 months for women the fracture risk diminished to levels similar to the index hip fracture[50]. The Framingham study, with a substantially longer follow up time of mean 4.2 years and extending to 51 years, found that only 2.5% of Sffxs occurred the first 12 months. A similar discrepancy compared to the Funen County Hip Fracture Study was found in a study based on data from the Danish Multidisciplinary Hip Fracture Register (DMHFR)[51]. The one-year mortality has been found to be significantly higher after a Sffx compared to an index femoral fracture, even when adjusting for baseline characteristics[12]. In the Framingham study, weight loss and poor perceived health were associated with a Sffx, while estrogen use, physical activity, and normal visual acuity were protective factors[11]. The majority of the Sffxs occur in the contralateral femur[52]. Previous studies have not specified the presence or absence of other implants or

sequelae in either femur prior to the index fracture, possibly affecting the risk and the pattern of contra- or ipsilateral Sffx. Bone Mineral Density (BMD) at the time of the primary fracture may not indicate who are at risk of a Sffx[53]. Bone loss after the first hip fracture may have a greater impact, as a rate of loss of 3–7% per year in the contralateral hip has been described[54,55], substantially higher than the general age-related bone loss of approximately 1% per year[56].

1.1.3 Prevention of hip fractures

The main focus of research in the field of orthopaedic surgery has historically been modes of treatment, as reflected in studies regarding hip fractures as well. Although optimalized treatment and follow up can improve outcomes after hip fracture surgery, 50% of these fragile patients will never return to their previous mobility, and frequently demand a higher level of care[14,15]. Initial treatment, postoperative in-hospital and community care, as well as treatment of complications present a major socioeconomic burden. Given the increasing incidence of hip fractures due to an ageing population, primary prevention has a much greater impact than any optimalization of treatment. As described above, the risk factors for hip fractures in the elderly are well documented[1,57]. The primary and secondary prevention of fragility fractures primarily by treating osteoporosis and reducing the risk of falls are of key importance to the current and future epidemiology of hip fracture[58].

Low bone density doubles the risk of a hip fracture[31]. In Norway, 240,000-300,000 individuals have BMD lower than the threshold of osteoporosis[59]. Several factors affect BMD. Some are non-amenable, like sex and age. Amenable risk factors are low Body Mass Index (BMI), inactivity, smoking, vitamin D-deficiency and long-term cortisone treatment[60,61], and low-threshold interventions may reduce the suffering and cost associated with fragility hip fractures considerably.

Several Randomized Controlled Trials (RCTs) as well as register- and population-based studies have reported a cost-effective, significant risk reduction of hip fractures

in postmenopausal women with the use of bisphosphonates[62-64]. Nevertheless, rates of testing, diagnosis and treatment among postmenopausal women are low.

The prevention of falls is an obvious measure to reduce hip fracture risk. In a Norwegian population > 75 years old, 50% of women reported that they had fallen once or more the past year, and 13% of the falls had resulted in a fracture[65]. In a WHO report, 30% of people > 65 years of age have one or more falls each year[66]. The National Institute for Health and Care Excellence (NICE) guidelines present a detailed multifactorial risk assessment including identification of falls history, assessment of gait, balance, mobility, sarcopenia, perceived functional ability, visual impairment, urinary incontinence, home hazards, cardiovascular history and medication. Based on the risk assessment, an individualized multifactorial intervention is recommended, including strength and balance training, home hazard intervention, vision correction and modification/withdrawal of medication. These measures require long term involvement of healthcare professionals, information and flexibility in implementation and execution of the programmes[58]. The effect of fall prevention measures has proven difficult to detect. High quality evidence indicates that exercise programs and modifications in the homes of frail elderly persons effectively reduces falls, whereas the quality of evidence supporting vitamin D supplementation, gait-stabilizing devices and psychotropic medication withdrawal is low[58,66]. External hip protectors have shown a significant reduction in hip fractures[67-69]. A Cochrane review from 2014 concludes with moderate evidence of effect, but emphasize that long term acceptance and adherence is poor, affecting the results of the included trials[70].

A prior fragility fracture doubles a patient's future fracture risk[13,71]. A low energy hip fracture may indicate osteoporosis and several guidelines recommend initiation of bisphosphonate treatment.[58,72-74]. There is evidence of cost-effective treatment with bisphosphonates in women between 65 and 80 years of age with a fragility fracture, whereas this treatment in men and the youngest and oldest female hip fracture patients can be debated[75]. The impact of other explanatory factors than BMD, such as age and impaired balance may be underestimated[75] To prevent a subsequent hip fracture, multi-national evidence-based models of post fracture care have been suggested[76]. In 2012,

the International Osteoporosis Foundation (IOF) launched the Capture the Fracture Campaign in order to reduce the incidence of subsequent fragility fractures worldwide. To achieve this goal Fracture Liaison Services (FLS) were introduced, and have been successfully implemented in several countries[72]. The core objectives of an FLS are case identification, risk stratification, initiation of treatment in accordance with guidelines and improvement of long-term adherence with therapy[72]. The general measures to prevent fractures are amenable to the subsequent fractures as well. Additionally the accelerated bone loss in the contralateral hip after an initial hip fracture may be prevented by exercise programmes[77]. Although limited, there is also evidence supporting supplementation of vitamin D and dietary protein to prevent subsequent fractures after the index hip fracture. In conclusion, multiple interventions are required, possibly life-long, to reduce the risk of a subsequent hip fracture.

1.2 Classification and stability assessment

1.2.1 Classification of hip fractures

An ideal classification system should be simple, valid, reliable and reproducible. It should indicate stability and dislocating forces at play and provide information regarding the risk and nature of complications. Furthermore, a classification system should communicate the pattern of injury and allow identification and comparison of similar fractures across borders, to facilitate research and the development of treatment guidelines.

Hip fractures can be coarsely divided into neck fractures, trochanteric fractures and subtrochanteric fractures based on anatomical site. Fractures of the head of the femur are considered a different entity, as it is usually seen in younger individuals suffering high energy trauma and rarely occur as a fragility fracture without prior avascular necrosis or other localized pathology[78].

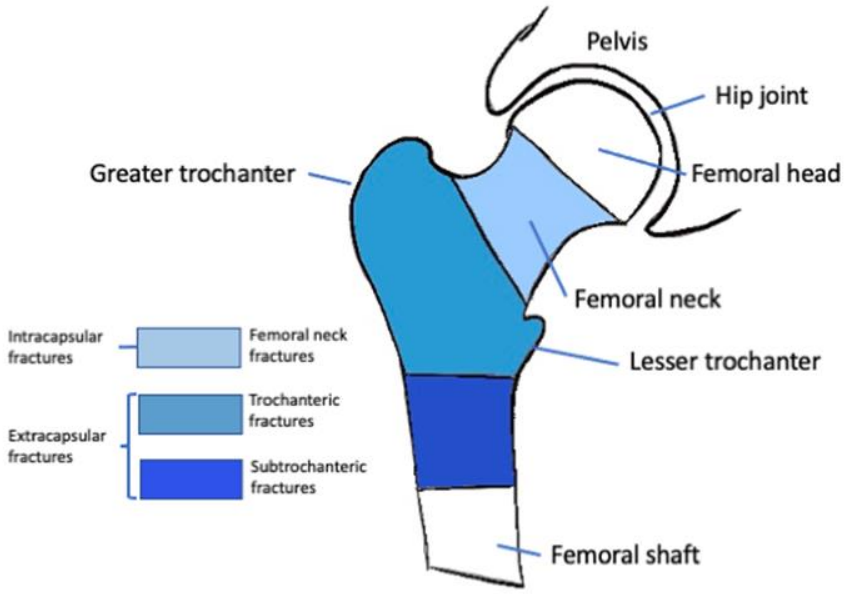


Figure 2: Classification of hip fractures. Courtesy of Eva Dybvik. (Reprinted with permission)

Fractures in the femoral neck are divided into intracapsular (medial) and extracapsular (basocervical fractures (Figure 2), decisive to choice of treatment. Intracapsular fractures are commonly classified according to Garden, originally describing severity of dislocation in the coronal plane (Figure 3). The reliability of the classification improves when the Garden classification is simplified, using the terms: 'non-displaced' (Garden I and II) or 'displaced' (Garden III and IV)[79,80]. Other classification systems have been introduced (Pauwel[81], Arbeitsgemeinschaft für Osteosynthesefragen / American Orthopaedic Trauma Association (AO/OTA)[82]) but the simplified Garden classification with the addition of dislocation assessment in the transverse plane appears reliable for practical purposes[79,83]. Posterior tilt is an independent risk factor of failure in Garden I and II fractures and studies indicate Garden I and II fractures with posterior tilt > 20 degrees should be considered displaced[84-87].

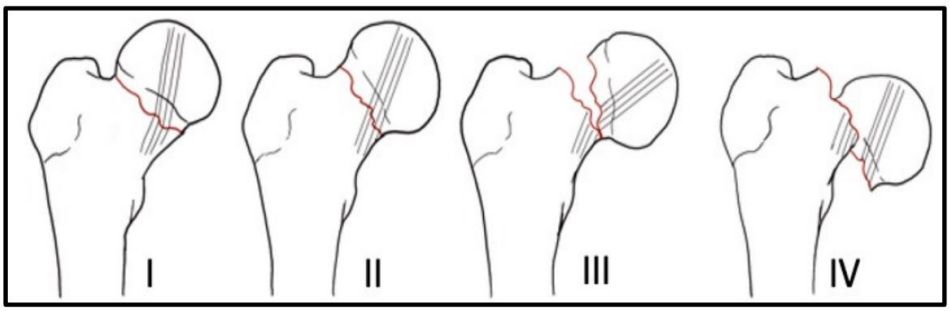


Figure 3: Garden classification of femoral neck fractures. Courtesy of Cato Kjærvik (Reprinted with permission)

Trochanteric fractures occur between the lateral border of the femoral neck and the inferior border of the minor trochanter. Several classification systems describing trochanteric and subtrochanteric fractures have been proposed, but all of them have their flaws[88]. The AO/OTA alphanumeric classification system was originally developed in 1980 by the Arbeitsgemeinschaft für Osteosynthesefragen (AO) and later adopted by the American Orthopedic Trauma Association (OTA)[82]. The unified classification model has been updated regularly, most recently in 2018, and defines simple, two-part trochanteric fractures with inherent stability as A1, multifragmentary trochanteric fractures with potential inherent instability as A2, and intertrochanteric (reverse oblique) fractures with inherent instability as A3. (Figure 4)

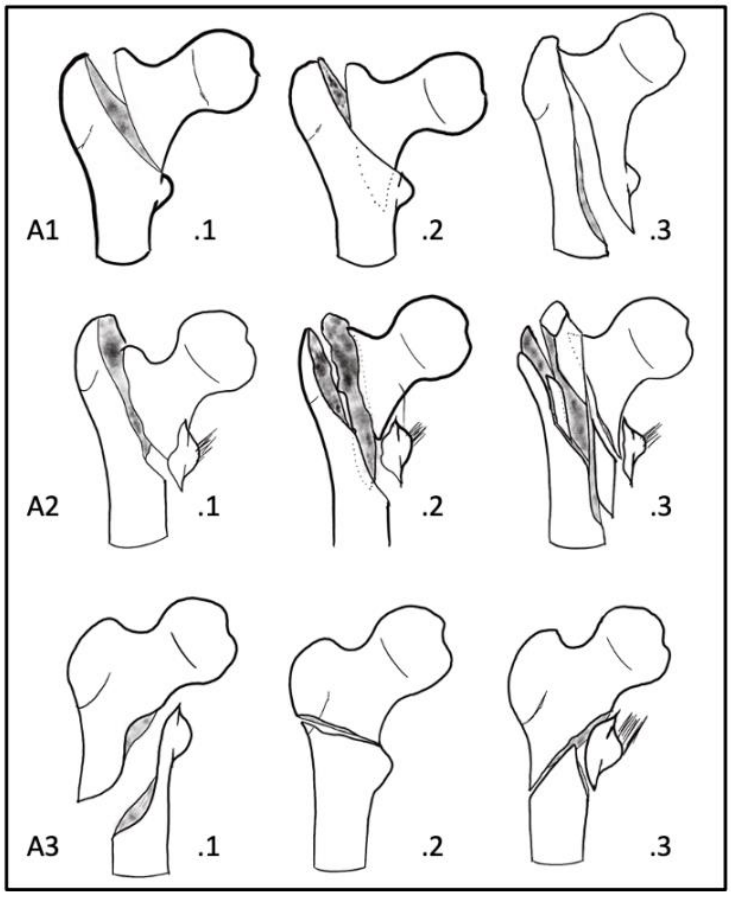


Figure 4: AO/OTA classification of trochanteric fractures. Courtesy of Cato Kjærvik (Reprinted with permission)

Numerous other classification systems have been suggested focusing on either stability and anatomical pattern (Evans[89], Ramadier[90], Decoulx[91], Nakano[92]) or maintaining reduction (Jensens modification of Evans[93], Tronzo[94]). All of these classification systems, including the AO/OTA, have challenges when it comes to inter- and intraobserver reliability, but AO/OTA and Evans-Jensen (Figure 5) appear to be the most reliable, reproducible and clinically useful systems[95,96]. In the Swedish Fracture Register (SFR) a recent validity study has been performed, indicating that the AO classification of femoral fractures in the SFR is accurate and that the data can be reliably used for further research studies[97].

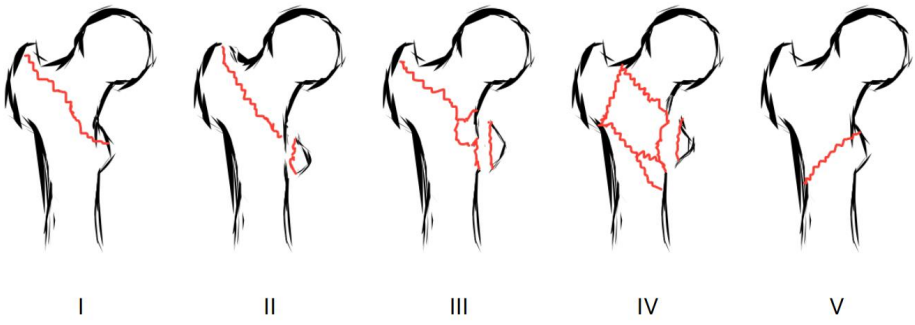


Figure 5: Evans-Jensen classification of trochanteric fractures (Author's illustration)

Subtrochanteric fractures are defined by the AO/OTA classification system as diaphyseal fractures with the centre of the fracture less than three cm distal to the lesser trochanter. Subtrochanteric fractures are unstable and divided into subgroups A1-A3, B1-B2 and C1-C3 according to grade of comminution and severity[82]. In the Norwegian Hip Fracture Register (NFHR), Seinsheimers definition of subtrochanteric fractures as located within five cm distal to the minor trochanter has been applied[98]. Subtrochanteric fractures have been described in several other classification systems as well[99], the Russel Taylor classification perhaps being the more renown (Figure 6). Debate concerning reproducibility and reliability of this classification system and the evolvement of modern implants have, however, decreased its clinical relevance[100-102].

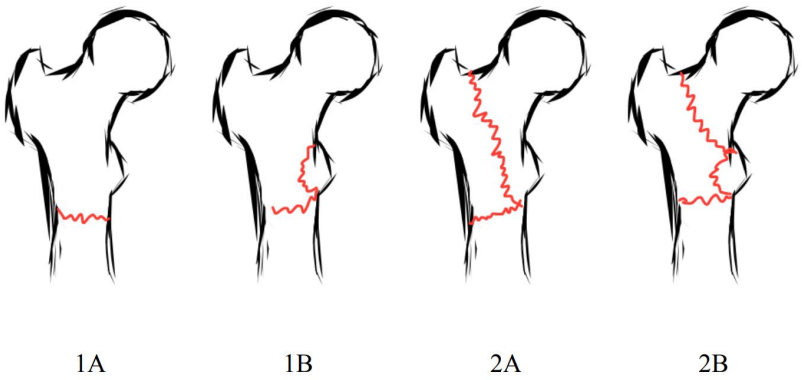


Figure 6: Russel-Taylor classification of subtrochanteric fractures (Author's illustration)

Different fracture characteristics present different challenges and systematic classification prior to surgical treatment is important to counteract dislocating forces and obtain sufficient reduction and stability. Furthermore, the AO/OTA classification system including subgroups provide a universal language important to scientific evaluation of treatment and interpretation of studies.

According to the NHFR approximately 54% of hip fractures are femoral neck fractures, 32% are trochanteric fractures, and 5% are subtrochanteric fractures. The remaining percentages represent combinations of fracture patterns, pathological fractures or missing information (Table 1).

	Number	%
Femoral neck fractures		
Garden 1+2	19,232	14.0
Garden 3+4	55,500	40.4
Basocervical	4,526	3.3
Trochanteric fractures		
AO/OTA A1	21,026	15.3
AO/OTA A2	20,947	15.2
AO/OTA A3	2,436	1.8
Subtrochanteric fractures	7,304	5.3
Other/missing data	6,595	4.7

Table 1: Distribution of hip fractures in the Norwegian Hip Fracture Register[2]

1.2.2 Stability assessment

Ability to determine fracture stability is the clinically most important role of the various classification systems. Stable fractures, A1 and A2.1 according to AO/OTA and type 1 and 2 according to Evans-Jensen, will withstand medial compressive forces after fixation. Unstable fractures, AO/OTA A2.2, A2.3 and A3, and Evans-Jensen type 3-5

fractures, with compromise of the posteromedial cortex, presence of subtrochanteric extension, or presence of a reversed obliquity fracture pattern, will collapse and/or displace under medial compressive forces despite axial reduction. Additionally, the importance of lateral wall integrity has been highlighted recently. Fractures with insufficiency of the lateral wall (thickness < 20.5 mm)[103] or lateral wall fracture[104] are considered unstable. Thus, lateral wall integrity should be included as a key component in the assessment of fracture stability in addition to posteromedial comminution, subtrochanteric extension, and presence of a reverse obliquity fracture pattern.

1.3 Historical development of treatment strategies for trochanteric and subtrochanteric fractures

Historically, intramedullary nailing as treatment method in trauma management in general was a controversial subject ever since the first cases were carried out in the 1800s, possibly inspired by the Aztecs use of wooden sticks for pseudarthrosis treatment described by the Spanish in the 1500s[105]. Only episodic cases are described until Gerhard Küntscher developed the principles of intramedullary constructs during World War II. Due to academic disagreement the concept of intramedullary nailing was not accepted in North America and Europe until the 1970s, but then developed into the preferred treatment for femoral shaft fractures[105]. With the evolvement of cephalomedullary nails for proximal femoral fractures, the indications for intramedullary nailing expanded. The predecessors of modern cephalomedullary nails, shown in Figure 7, were designed by Dr Arsène Grosse and Dr Ivan Kempf, and Dr Thomas Russell and Dr John Charles Taylor and further developed into the first generation of Gamma nails in the early 1990s[106-108].

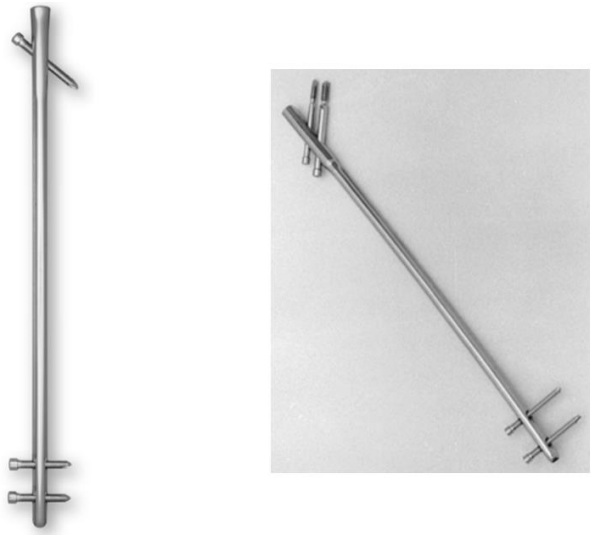


Figure 7: The Grosse-Kempf nail (Stryker Corporation, Kalamazoo, Michigan, USA)**, left and the Russell-Taylor nail** (Smith and Nephew, Hertfordshire, UK)**, right**

The first generations of IMNs for the treatment of trochanteric and subtrochanteric fractures were ridden with a high incidence of peri-implant fractures[109]. Further understanding of the biomechanical properties of the implant and bone led to the development of new generations of IMNs with a significantly lower risk of peri-implant fractures[110]. Modern nails all have an anatomical design, require reaming and allow distal locking.

The SHS has been used in the treatment of trochanteric and subtrochanteric fractures ever since the introduction by Ernst Pohl in 1951[111,112]. A similar dynamic construct intended for stabilization of femoral neck fractures had been designed by Robert Danis in 1934, but was never taken into use[113]. At the end of the 1950s, Pohls design inspired the development of the Richards classic hip screw and the first results were published in 1964[114]. This coincided with the recognition of high incidences of mechanical failure in the blade plates which were the treatment of choice of the Arbeitsgemeinschaft für Osteosynthesefragen / Association for Study of Internal Fixation (AO/ASIF) in the 1950s and 60s, leading to the development of the Ender nail in the 70s[115-118]. This implant turned out to yield a high percentage of complications as well, preparing the ground for the reintroduction of the SHS[119-122]. The AO/ASIF introduced their own

similar implant, including the option of a trochanteric support plate to counteract the inevitable medialization of the femoral shaft[123]. The SHS became the standard implant in the treatment of trochanteric fractures[124]. The implant is still in use although facing increasing competition from the IMN over the past two decades.

1.4 Contemporary treatment

Most proximal femoral fractures today are treated surgically, with the exception of moribund patients receiving only palliative care and trochanteric fractures only detected in MRI in patients able to mobilise with an acceptable level of pain. Series describing non-operative treatment of all other variations of proximal femoral fractures reveal unacceptable pain, very limited potential for recovery and high mortality. There is a close correlation between ability 31obilese and mortality[125-127]. The goal of operative treatment of all geriatric hip fractures is swift reduction and stabilisation of the fracture, allowing early mobilisation and load bearing. Prolonged bedrest and Insufficient analgesia increase the risk of several complications such as venous thrombosis, pneumonia, muscular atrophy, obstipation and delirium[17]. In the following, only the development of surgical treatment of trochanteric- and subtrochanteric fractures will be elaborated, as only this group of fractures are investigated in the individual studies of the thesis. Trochanteric and subtrochanteric fractures are usually treated with a SHS or an IMN[127]

1.4.1 Intramedullary nails

The IMN is introduced into the medullary canal through an entry point on the tip of the greater trochanter or slightly medial to it depending on the nail design. The IMN normally requires a less invasive approach than extramedullar implants and can be combined with other means of fixation such as cerclage wires and reposition plates[128,129]

One or two lag screws are inserted through the lateral cortex into the femoral neck, allowing compression at the fracture site in the case of a trochanteric fracture. Various designs have been developed over the past decades, such as an additional anti-rotation screw, an integrated anti-rotation screw allowing intraoperative compression of the fracture, and a blade design to increase bone density around the lag screw. Furthermore, implants have evolved from the first generation of straight unreamed nails into second and third generations of implants (Figure 8). Changes have been made with regard to choice of alloy, reaming and distal design, and the historically higher risk of peri-implant fractures compared to the SHS seems to have been reduced significantly[110,127,130,131]. In the treatment of stable trochanteric fractures, a short nail may be used, whereas a long nail is, in some guidelines, recommended in the treatment of unstable trochanteric and subtrochanteric fractures[58,132]. There is still debate regarding the benefits of a long nail in these particular settings, as well as the potential hazards of using a short nail in the treatment of unstable fractures[74,133-135].

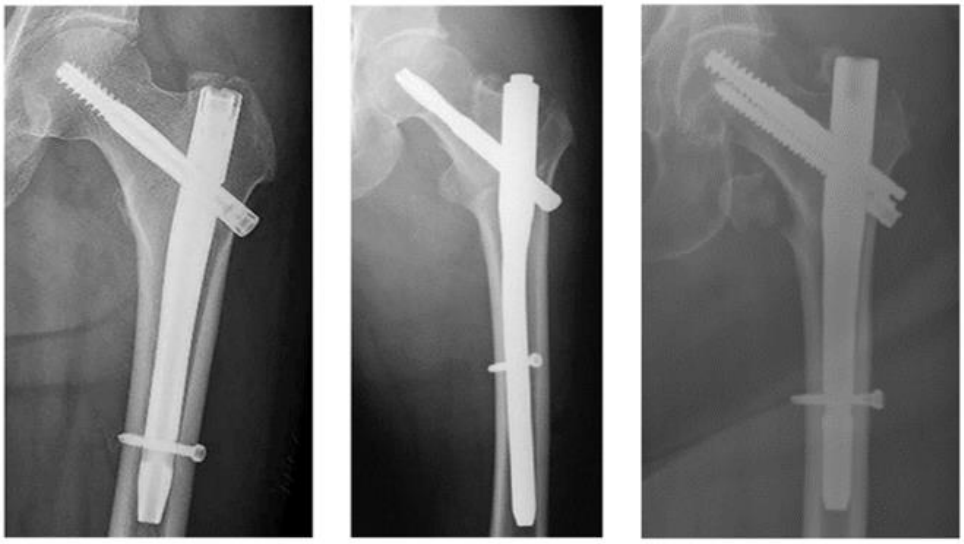


Figure 8: Examples of IMNs A) Gamma3 (Stryker Corporation, Kalamazoo, Michigan, USA), B) PFNA (DePuy Synthes, Oberdorf, Switzerland) and C) TRIGEN INTERTAN (Smith and Nephew, Hertfordshire, UK)

1.4.2 Sliding hip screw

The SHS consists of a lag screw connected to a plate through a barrel, allowing compression at the fracture site with load bearing of a trochanteric fracture, enhancing bone healing and reestablishment of medial cortical contact[136]. This implant requires an open, muscle-splitting approach, even when just detaching vastus lateralis from its insertion on the posterior surface of the femur. SHS implants from different manufacturers, examplified in Figure 9, present minor variations like lag screw thread design and locking options, but usually offer plate-barrel angles ranging from 130 – 150 degrees and 2-16-hole sideplates. 135 degrees plate-barrel angle and a four-hole sideplate is the standard implant. The sliding of the lag screw in the barrel of the SHS is influenced by angle, barrel length and lag screw length. In the case of an A3 or a subtrochanteric fracture, a trochanteric stabilizing plate (TSP) may be added in attempt to prevent medialization of the shaft[137,138]. The CHS system has the option of an integrated TSP.

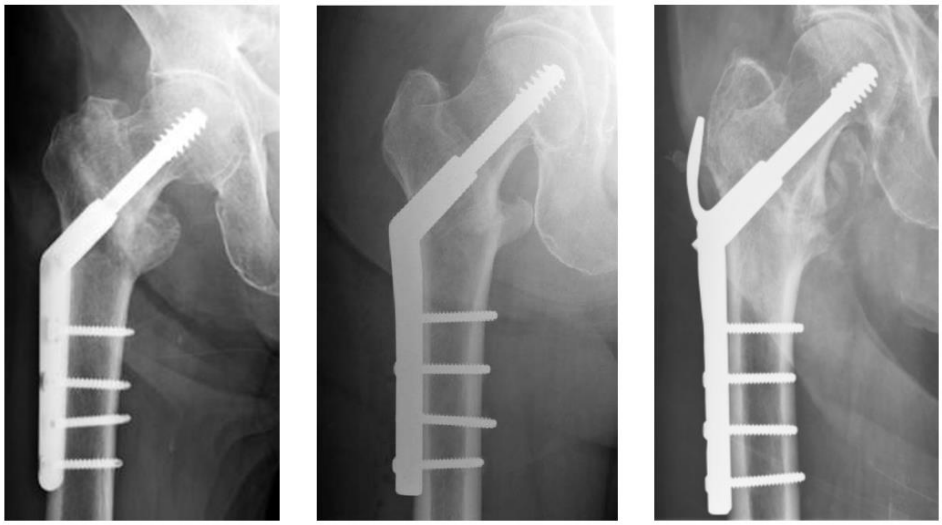


Figure 9: Examples of SHS: A) DHS (DePuy Synthes, Oberdorf, Switzerland), B) CHS (Smith and Nephew, Hertfordshire, UK) and C) CHS with TSP

1.4.3 Biomechanical considerations

The biomechanical properties of the IMN and the SHS differ in terms of their intra- versus extramedullary placement. The placement inside the medullary canal may prevent massive medialisation of the shaft, a challenge in the treatment of unstable A2 and reverse oblique fractures (A3). Femoral medialization is an individual risk factor for a poor outcome regarding pain and mobility one year postoperatively, healing complications and revision, and fractures treated with an SHS are significantly more prone to medialization[131]. The IMN also has the theoretical advantage of a shorter lever arm, which may lead to reduced stress on the implant. Biomechanical and clinical studies have not been able to unambiguously conclude that there is a difference in cut-out risk amenable to this feature[139], whereas the tip-apex-distance (TAD), as described by Baumgaertner and succeeding developments of this measure[140], correlates with cut-out-rate in IMN as well as in SHS[25,131,141,142]. Nevertheless, an IMN construct appears to be biomechanically stronger and more rigid than an SHS plate construct, leading to less subsidence[129]. Studies indicate that fracture reduction is paramount to ensure stability and uneventful healing of trochanteric and subtrochanteric fractures, regardless of implant chosen. Fractures with varus malalignment > 20 degrees angulation or > 4mm displacement have a significantly increased risk of failure, and tend to fail earlier than adequately reduced fractures[143]. Even though avoiding varus malreduction reduces the load on both IMN and SHS, biomechanical studies indicate an SHS construct may be more affected by varus malalignment and run a greater risk of failure[144]. Lateral wall patency is an important factor when using an SHS construct as well as an IMN, and the addition of a TSP to aid lateral wall reconstruction may reduce the risk of failure[137,145]. Previous studies conclude that a compromised lateral wall is a greater risk when using an SHS compared with an IMN[103,104]. Some modes of failure are amenable to the particular biomechanical properties of the IMN. The IMN seems to have a persistent increased risk of fractures adjacent to the implant[146,147], although not to the extent reported in studies before 2000[109,130,148]. Development of IMN design have reduced the incidence of peri-implant fractures[110,149-151], but some recent studies suggest there is still a higher risk associated with the use of an IMN[147,148].

This is likely due to the rigidity of the implant and the stress-shielding amenable to its intramedullary placement.

1.4.4 Time trends for treatment of trochanteric and subtrochanteric fractures

Nationally and internationally, there has been a significant change in the surgical treatment of trochanteric fractures over the past decade, skewing towards increased use of IMNs for all fracture types but particularly for AO/OTA A2, A3 and subtrochanteric fractures[2,24,152,153] (Figures 10-13). This trend is not necessarily founded in existing evidence[24,154]. The SHS is still the implant of choice in the treatment of stable trochanteric fractures (A1 and A2.1)[58,73,104]. Nevertheless, there has been a significant increase in the use of IMNs in these fractures as well, despite the lack of evidence for a better outcome[155,156]. American and European cost-effectiveness analyses claim the SHS should be the implant of choice in the treatment of stable fracture types[157,158 159,160].

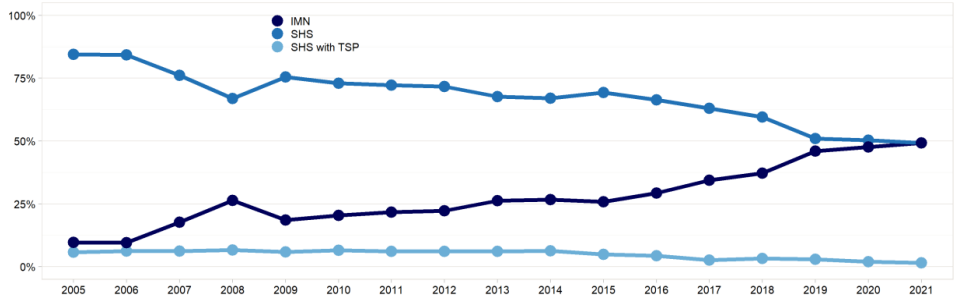


Figure 10: Time trends for treatment of AO/OTA A1 fractures in the NHFR[2] (Reprinted with permission from NHFR)

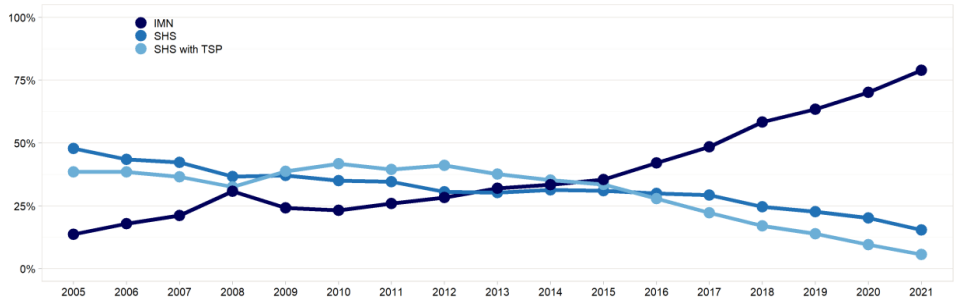


Figure 11: Time trends for treatment of AO/OTA A2 fractures in the NHFR[2] (Reprinted with permission from NHFR)

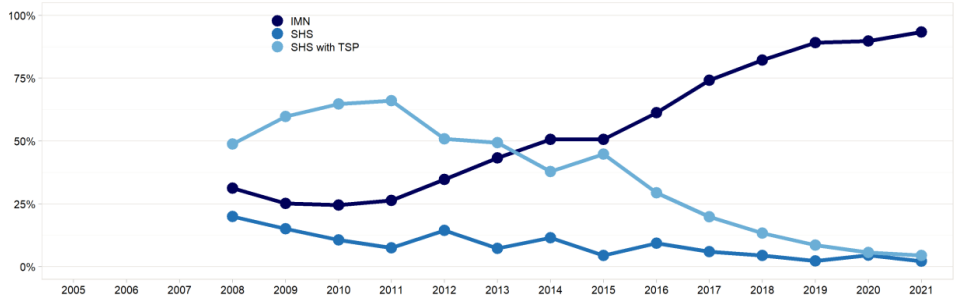


Figure 12: Time trends for treatment of AO/OTA A3 fractures in the NHFR[2] (Reprinted with permission from NHFR)

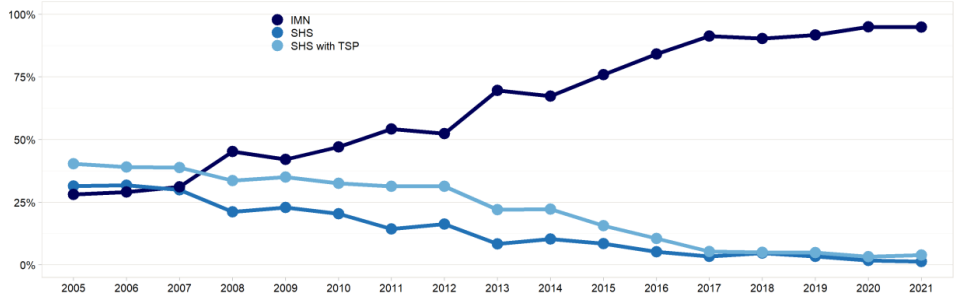


Figure 13: Time trends for treatment of subtrochanteric fractures in the NHFR[2] (Reprinted with permission from NHFR)

Furthermore, some studies, both RCTs and register based, have even detected higher rates of complications and mortality with the use of an IMN compared to a SHS in trochanteric fractures[161,162]. Although national and international guidelines now recommend the use of an IMN in the treatment of A3 and subtrochanteric fractures[73,74], the last Cochrane report for 2022 with a total of 76 studies (66 RCTs, 10 quasi-RCTs) could not confirm a clear benefit attributable to the IMN in terms of reoperation risk or mortality four months postoperatively. The 2022 Cochrane report describes a reduced risk of infection and non-union with the use of an IMN, but a persistent increased risk of peri-implant fractures[148]. However, more than half of the studies included were conducted before 2010, and the evolvement of the third generation of IMNs seem to have reduced their risk of complications. Furthermore, the Cochrane reviews only include RCTs and quasi-RCTs, and the lack of evidence supporting the current trend of increased use of IMNs may be attributable to the challenges an RCT faces in the investigation of rare outcomes such as reoperations following trochanteric and subtrochanteric fractures. Register-based studies have, contrary to the Cochrane report, indicated a benefit of an IMN in the treatment of A3 and subtrochanteric fractures[163]. The heterogeneity of A2 fractures complicates the interpretation of results in studies investigating the treatment of this particular group of fractures and warrants a more specific estimation of stability in the classification systems.

1.5 Complications after trochanteric and subtrochanteric fractures

A complication leading to a reoperation is a devastating event for a frail hip fracture patient, already facing excess mortality after the primary operation. In the 2022 NHFR annual report 3.4% of A1 fractures, 6.9% of A2 fractures, 10.5% of A3 fractures, and 9.5% of subtrochanteric fractures were registered with a reoperation[2]. More than one cause of reoperation may be given. The use of a hierarchy may conceal the true prevalence of coinciding complications, but is necessary when conducting a register-based study to ensure patients are only counted once. A selected list of causes of reoperations is given in Table 2, but as patients reoperated with a THA are registered

int the NAR, it is likely that particularly cut-out is largely underrepresented in this table, as this complication is likely to lead to a THA. Cause of reoperation is not specified to any further extent than "complication leading to THA) in the NAR.

	A1 n (%)	A2 n (%)	A3* n (%)	Sub-trochanteric n (%)
Infection	111 (0.5)	291 (1.4)	47 (1.9)	135 (1.8)
Peri-implant fracture	86 (0.4)	110 (0.5)	11 (0.4)	46 (0.6)
Hardware failure	181 (0.8)	396 (1.9)	74 (3.0)	190 (2.6)
Cut-out	66 (0.3)	114 (0.5)	17 (0.7)	26 (0.3)
Non-union	64 (0.3))	168 (0.8)	33 (1.3)	118 (1.6)

Table 2: Selected causes of reoperation per type of fracture in the NHFR[2] (List is not exhaustive and more than one cause is possible. Patients reoperated with THA not counted) *registration of A3 fractures started in 2008

1.5.1 Infection

Given the high prevalence of at least one major medical comorbidity in the hip fracture population, these patients are particularly vulnerable to surgical site infections (SSI)[164]. The rate of deep infection after hip fracture is reported to be between 1.3 and 3.6[165-167].

Although a relatively rare complication, the consequences are profound on an individual and socioeconomic level[165,168]. SSI is an independent risk factor for increased 90-day and one-year mortality in the general hip fracture population[165,168-170]. One-year mortality for patients with SSI is reported to be 35.4–50.0%, substantially higher than those without infection (24.1–30%)[165,168]. Furthermore, an SSI after hip fracture treatment significantly reduces the prospect of return to previous mobility and level of care[165,168,171]. For the individual hospital, prolonged length of stay and further

medical and surgical requirements adds a three- to four-fold cost of care[168,171]. Few studies have singled out trochanteric and subtrochanteric fractures when investigating rate and risk factors for post-operative infection in hip fracture patients[166], but existing literature suggests the risk of an SSI is lower for trochanteric fractures treated with osteosynthesis compared with femoral neck fractures treated with hemi- or total arthroplasty[166,167,169,172].

Definitions of SSI in fracture patients – "infection after fracture fixation" (IAFF) vary in the existing literature, causing difficulty estimating the incidence and impact of this complication, as well as creating treatment guidelines[173,174]. Periprosthetic joint infections (PJIs) are more unanimously defined, and guidelines are largely agreed upon. Many of the surgical and medical treatment concepts applied to IAFF have been adopted from PJI treatment algorithms[175,176]. IAFF and PJI do have similar clinical properties, but there are important distinctions between the elective arthroplasty patient and the trauma patient. Attempts have been made to create consensus and facilitate diagnosing and related research[173,174].

In a previous study based on NHFR data, risk factors for SSI in surgically treated hip fractures were cognitive impairment, an intraoperative complication, and increasing duration of surgery, but after controlling for observed confounding, the association between duration of surgery and early and delayed deep SSI was not statistically significant[169]. Other studies have both confirmed[177] and contradicted[170,178] this result. Age is related to increased risk of an SSI, but mainly due to the increasing comorbidity associated with advanced age. Charlson Comorbidity Index > 3 has been reported as an individual risk factor for SSI following hip fracture surgery[167], and an association between increasing ASA score and SSI has been described[179]. Nutritional deficiency has also been confirmed to be an independent risk factor of postoperative complications, including infection[180]. The relationship between BMI and SSI in hip fracture patients has been extensively studied, and there appears to be a significant increase in SSIs with increasing BMI in obese patients (BMI > 28)[170,181].

Choice of implant may affect the risk of an SSI in trochanteric and subtrochanteric fractures, namely an increased risk associated with an SHS compared with an IMN[177].

Previous register-based studies have found this to only apply to unstable trochanteric fractures and subtrochanteric fractures[156,163], and in the most recent Cochrane reviews comparing extra- and intramedullary devices in the treatment of extracapsular hip fractures no such distinction could be made[109,126].

Another topic of debate is the impact of surgeon and anaesthesiologist experience on risk of an SSI, where large register-based studies have come to contradicting conclusions[104,168,177,182].

Staphylococci (*Staph aureus*), methicillin-sensitive or -resistant, are the most common causative organisms in SSI following surgical treatment of hip fractures, regardless of implant[168,183 184,185]. Targeted systemic prophylactic antibiotics administered correctly is the single most important measure against SSIs, and significantly reduce the risk[186]. This is reflected in international and national treatment guidelines[73,74]. Prophylactic antibiotics should be administered within 60 minutes of the inscision[186-188]. There is less high-quality evidence determining the ideal duration of prophylaxis. Studies from arthroplasty surgery are commonly used to substantiate guidelines regarding prophylaxis in hip fracture treatment. The risk of SSI after THA decreases with every added dose up to four doses the first 24 hours, but there seems to be no further benefit of administration of prophylactic antibiotics beyond 24 hours[188], confirmed in other studies[189]. Some authors even claim one dose administered preoperatively may be sufficient in both arthroplasty surgery and in the treatment of closed fractures[190,191], although not reflected in current practice.

There is little evidence substantiating choice of antibiotic in prophylactic treatment. Furthermore, the pattern of resistance in microbes varies between continents and countries and international guidelines are not necessarily ideal for all countries[192]. In Norway too, the most common causative microbe is staphylococcus aureus, but the occurrence of methicillin resistance is much lower[193,194].

In the era of worldwide evolving antibiotic resistance, orthopaedic surgeons too have an individual responsibility to choose as narrow spectered antibiotics as possible, including prophylaxis, and pay respect to evidence based guidelines regarding duration.

1.5.2 Peri-implant fracture

In the treatment of trochanteric and subtrochanteric fractures, an implant will affect the acting forces in the case of a second trauma and may increase the risk of some fracture types and decrease the risk of others. The risk of a peri-implant fracture is higher after an initial trochanteric, subtrochanteric or femoral shaft fracture compared to a femoral neck fracture[195,196]. The choice of implant may influence the risk of an ipsilateral subsequent fracture[146,147]. Historically, the IMNs have been associated with more peri-implant fractures than the SHS[109,130,148], but modern nails seem to have reduced the discrepancy[110,149-151]. Nevertheless, even recent studies have detected a persistent higher risk of peri-implant fractures associated with the use of an IMN[147,148], and although the incidence has decreased with the evolution of new generations of IMNs, peri-implant fractures still represent a challenge to the orthopaedic surgeon. A peri-implant fracture will typically occur in the femoral shaft or distal metaphyseal area[146,196,197]. However, previous studies have not specified the presence or absence of other implants or sequelae in either femur prior to the index fracture, possibly affecting risk and distribution of fractures.

There is an ongoing discussion regarding the possible benefit of a long nail in the treatment of unstable intertrochanteric and subtrochanteric fractures. In the AAOS and NICE guidelines, no specification of nail length is given, whereas the Norwegian national guidelines recommend a long nail[58,74,132,198]. Most studies conclude that there is no significant difference in the rates of peri-implant fracture between short and long nails[135,199], but a recent study from the Danish Multidisciplinary Hip Fracture Registry (DMHFR) indicates there might be a benefit to long nails[133].

Distal locking may reduce the risk of peri-implant fracture in both short and long nails. Current evidence supports distal locking in axially or rotationally unstable fractures, including those with subtrochanteric extension or comminution, or in osteoporotic femora[200].

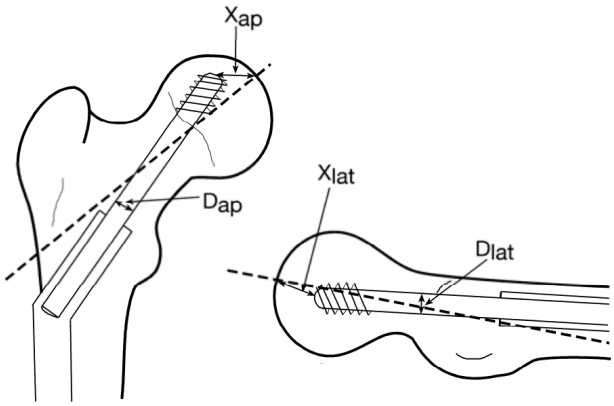
1.5.3 Hardware failure

Hardware failure is not consistently defined but can in general be argued to include implant fracture or dislocation, implant deformation, and component displacement like screw back-out. Predisposing factors are implant or component malposition, suboptimal surgical approach and implant design. In the NHFR data, hardware failure includes screw, nail and plate breakage, and excessive sliding of the lag screw in the SHS or IMN, causing significant shortening of the femoral neck. Failure modes of an SHS construct typically includes excessive sliding of the lag screw and pull-out of the screws securing the side-plate. Failure is associated with unstable fracture patterns with lateral wall incompetence, varus displacement, femoral shaft medialisation and shortening[145,201-203]. Biomechanically the SHS runs a greater risk of medialisation of the femoral shaft in unstable fractures with a compromised lateral wall, due to loss of integrity with osteoporosis or fracture, confirmed by several studies[103,104,203,204]. These fracture patterns lack the bony support to counteract the pull of the adductor muscles and allow the distal fragment to displace medially. The adjunct of a TSP has been advocated to reduce the risk of medialisation[137], but its value has been debated[138,205]. Breakage of the lag screw or the plate are rare complications but may occur if the sliding capability of the lag screw in the barrel of the SHS is affected[202,206,207]. More commonly, screw or plate breakage will occur in the case of concomitant non-union. The IMN has, with its intramedullary placement and thus shorter lever arm, a theoretically lower risk of medialisation of the femoral shaft, and a decreased tensile strain on the implant. The IMN has some unique failure modes. The z-effect phenomenon can occur in intramedullary nail designs with two separate or integrated lag screws. In these cases the inferior lag screw migrates laterally, and the superior lag screw migrates medially during loading. Biomechanical studies suggest an increased risk of the z-effect in unstable fracture patterns, as bone density of the femoral head exceeds that of the femoral neck[208]. Causes of the z-effect are not exhaustively defined, but appear to include loss of medial support, varus collapse, posterior or anterior entry point of the nail, and poor bone quality. Furthermore, one biomechanical study suggests a neck-shaft angle < 125 degrees predisposes of the z-effect[209]. A neck-shaft angle of < 125 degrees has also been linked to a significant increase in fixation failure for all

causes combined[210]. Nail or screw breakage are rare events, but described to be associated with unamenable factors like unstable fracture types, subtrochanteric fractures in particular, and pathological fractures[211], as well as amenable factors like varus malreduction, suboptimal implant positioning and damage to the lag screw aperture upon reaming[212-214]. Non-union due to biological or mechanical causes will in the case of treatment with either IMN and SHS cause fatigue and increase the risk of implant breakage[215-217].

1.5.4 Cut-out

Cut-out is, in the presence of an SHS or an IMN, defined as protrusion of the lag-screw through the femoral head surface as a consequence of varus collapse of the fracture. The prevalence of cut-out in the treatment of trochanteric and subtrochanteric fractures is in various studies estimated to be 1.85%–16.5%[142,218,219], and poses a challenge with the use of SHS and IMN alike. Tip-apex-distance (TAD), fracture classification, position of the screw in the femoral head, and fracture reduction are identified as predictors for screw cut-out[218]. TAD, described by Baumgaertner[140], is considered to be a reliable predictor of cut-out risk, relevant to the positioning of both IMN and SHS[220-222], and an optimal TAD is, in some studies, regarded the most important factor in the prevention of cut-out[223]. TAD is defined as the sum of the distances between the tip of the lag screw and the apex of the femoral head, as measured in an antero-posterior and lateral view, and adjusted for radiograph magnification by using the diameter of the lag screw as reference, illustrated in figure 14.



$$TAD = (X_{ap} x \frac{D_{true}}{D_{ap}}) + (X_{lat} x \frac{D_{true}}{D_{lat}})$$

Figure 14: Calculation of TAD D_{true}: actual diameter of lag screw (courtesy of dr Kjell Matre, reprinted with permission)

Clinical and biomechanical studies have attempted to determine the optimal range in TAD-value, where the risk of cut-out is minimized[140,221,224], and is suggested to not exceed 25 mm. With the development of more refined imaging techniques, the accuracy and relevance of the TAD has been questioned[225]. Furthermore, a recent biomechanical study[226], and a finite-element study[227] have shown that inferior middle and inferior posterior positions are preferrable, challenging the importance of a TAD > 25 mm cut-off for prediction of cut-out, as this suggests a higher rate of cut-out with a more inferior placement of the lag screw and implies a central–central placement is optimal. This may indicate that a calcar referenced tip-apex distance (CalTAD) is more accurate to predictt cut-out[142]. Screw placement is recommended central-inferiorly or anterior-inferiorly based on clinical, biomechanical and mathematical analyses[226-228]. Even when the TAD exceeds the recommended measure, these screw positions are still protective of cut-out[218]. Fracture classification is closely related to cut-out risk, even when adjusted for TAD and screw position. A3 fractures are significantly more at risk than A1 fractures[218], whereas the risk in A2 fractures is more difficult to assess in studies due to the heterogeneity of this group and the following uncertainty in subclassification of these fractures. The importance of screw placement and TAD in subtrochanteric fractures is debatable. A varus malreduction of the fracture has been

associated with a higher cut-out rate in fractures treated with either SHS and IMN[139,142,229].

More recent studies have found that a combination of the known risk factors of cut-out are more likely to cause cut-out than any single factor[142,222,230].

1.5.5 Non-union

Non-union describes a fracture where failure of normal fracture healing processes has occured and where there is no possibility of healing without further intervention[231]. In the 2022 NHFR report, non-union was reported as a cause of reoperation in 8.7% of A1 fractures, 11.5% of A2 fractures, 12.8% of A3 fractures and 17.0% of subtrochanteric fractures[2]. Several causes of reoperation may be given though, and non-union may be a consequence of, or a predisposing factor for other complications documented in previous literature, such as infection, hardware failure and cut-out[143,232]. Causes of non-union are multifactorial, including biological, mechanical and patient factors[231]. The trochanteric region is well vascularized and non-union as such relatively rare. Hypertrophic nonunions typically occur when there is adequate vascularity but inadequate stability, whereas atrophic non-union lack sufficient blood supply at the fracture site and additional stabilizing procedures may be futile[231,233]. Nonunions caused by surgeon induced fixed diastasis may have variable vascularity and stability[233]. Vitamin D and calcium deficiency, abnormalities in thyroid function and other hormonal systems are associated with delayed fracture healing and may increase risk of nonunion[234]. Revision options in the face of a nonunion following treatment for trochanteric or subtrochanteric fractures are revision nailing with or without bone grafting, arthroplasty with THA or HA, or revision fixation with a proximal femur locking- or blade-plate. Results of revision surgery after non-union, regardless of modality, are somewhat disheartening, with a high rate of re-revision and mortality[143]. Emphasis should be placed on the importance of initial reduction and stability, appropriate fixation method and maximising bone healing capabilities.

2 Aims of the studies

The overall aim of this thesis was to evaluate the outcomes of trochanteric and subtrochanteric fractures treated with an IMN, using data from a local quality database and the Norwegian Hip Fracture Register.

The specific aims of the three studies included in the thesis were:

Paper I:

- To investigate how an IMN affects the incidence, pattern, and localisation of subsequent femoral fractures in patients without implants or sequelae after previous surgery in either femur.

Paper II:

- To compare reoperation rates for SHS and IMN for stable fractures (A1) and unstable fractures (A2, A3, and subtrochanteric combined) one and three years postoperatively.
- To compare reoperation rates for SHS and IMN for A2, A3, and subtrochanteric fractures separately one and three years postoperatively.
- To compare mortality and patient-reported outcomes after SHS and IMN for stable and unstable fractures one year postoperatively.

Paper III:

- To compare reoperation rates between different IMNs used in the treatment of trochanteric and subtrochanteric fractures.
- To report reoperation rates for the various types of short and long nails regarding fracture type.

3 Patients and methods

3.1 Registration of hip fractures at Østfold Hospital Trust

In ***Paper I*** patients were identified by searching the hospital database at Østfold Hospital Trust using the International Statistical Classification of Diseases and Related Health Problems (ICD10) and the NOMESKO Classification of Surgical Procedures (NCSP) codes. Patients with ICD10 codes S72.1 (trochanteric fractures) or S72.2 (subtrochanteric fractures) and NCSP codes NFJ51 or NFJ52 (intramedullary nailing of trochanteric or subtrochanteric fractures respectively) were identified. Electronic health records and X-ray images were reviewed. Variables collected are shown in Appendix 1. Handwritten documentation provided by the surgeons postoperatively was reviewed and compared with the electronic health records. The American Society of Anesthesiologists Physical Status scoring system (ASA score) was used to assess the overall health status of the patient. Pre- and postoperative X-ray images, as well as all follow-up X-ray images taken of the proximal femur and the pelvis, were examined to identify, classify and localise index fractures and any subsequent fractures. Fracture type was registered according to the AO/OTA classification system[235]. Pelvic X-ray images visualising the contralateral hip and all follow-up X-ray images were included for all patients to identify any pre-existing implant, added implant, or sequelae in either proximal femur. The completeness of local data obtained from electronic health records was validated by comparison with data from the NHFR. Patients missing from either database were supplemented.

3.2 The Norwegian Hip Fracture Register

Papers II and III are based on data from the Norwegian Hip Fracture Register (NHFR).

The NHFR was established in January 2005 to collect information about patients treated for hip fractures in Norway[236]. Data collection is approved by the Norwegian Data Protection Authority. Until July 2021 patients' written consent was required for registration in the NHFR, whereas patients are now included without consent but can withdraw at any time. Registration completeness when compared to the Norwegian Patient Registry has been found to be 86% for primary osteosyntheses and 78% for reoperations after osteosyntheses[2]. All hospitals in Norway treating hip fractures report to the NHFR[2]. Regular reports from the NHFR are presented on their website.

3.2.1 Registration of primary operations

After each primary operation the surgeons fill in a standardized 1-page form with the unique identification number assigned to all Norwegian residents revealing age and sex, comorbidity according to the ASA classification, cognitive status, time of injury and type of fracture (Appendix 2). Trochanteric fractures are classified according to the AO/OTA classification system as AO/OTA type A1 (simple two-part), A2 (multifragmentary), and A3 (intertrochanteric/reverse oblique). Subtrochanteric fractures are defined as diaphyseal fractures with the centre of the fracture less than five cm distal to the lesser trochanter. Additionally, intraoperative details including timing and duration of surgery as well as type of surgery and implant are reported. Details of implants are given in product labels attached to the registration form. This allows identification of each implant on catalogue number level.

3.2.2 Registration of reoperations

All reoperations should be reported to the NHFR, also reoperations without exchange or removal of implants. Reoperations including failure of osteosynthesis, non-union,

avascular necrosis of the femoral head, local pain, malunion, superficial or deep infection, haematoma, cut-out, peri-implant fracture and "other" are recorded using the same form as for primary operations (Appendix 2) and can be linked to the primary operation using the unique identification number assigned for each Norwegian resident. More than one cause may be given for each reoperation in the NHFR. Two or more complications may very well present themselves concomitantly, like infection and non-union, infection and hardware failure, hardware failure and non-union and so on so forth. In ***Paper I*** all reoperations registered with peri-implant fracture as cause were counted, and reoperations for other causes censored. In ***Papers II and III*** hierarchies based on assumed severity of the different causes of reoperation was suggested to avoid counting each reoperation more than once. In ***Paper II*** infection, peri-implant fracture, mechanical complications (non-union, implant failure, cut-out), unspecified sequelae (treated with THA), pain alone, other, was chosen. Collapsing individual causes of mechanical complications into one group was done to create larger groups and thus give more robust statistical analyses. In ***Paper III*** we chose a more detailed hierarchy (infection, peri-implant fracture, hardware failure, cut-out, non-union, unspecified sequelae (treated with THA), pain alone, other) to possibly identify specific modes of failure linked to particular nail designs.

3.2.3 Registration of patient-reported outcomes

Patient-reported outcomes were included as secondary outcome in ***Paper II***. A standardized questionnaire including health-related quality of life (EQ-5D), a visual analogue scale (VAS) 0-100 for pain (0 = no pain, 100 = unbearable pain), and a VAS 0-100 for satisfaction (0 = least satisfied, 100 = most satisfied) is sent to the patients 4, 12, and 36 months postoperatively. The pre-fracture EQ-5D is collected in the questionnaire sent to patients 4 months postoperatively. The multi-item, generic EQ-5D questionnaire (EQ-5D-3L, EuroQol Group, Rotterdam, The Netherlands) consists of the following dimensions (walking ability, ability of self-care, ability to perform usual activities, pain/discomfort, and anxiety/depression), and is regarded as a useful and relevant outcome measure for this patient population. The EQ-5D-3L is a non-

disease-specific questionnaire offering the opportunity of assessment and comparison of patients' perceived outcomes from different populations. Index score is calculated based on the response for each dimension. A score of 1 indicates the best possible health state, and a score of 0 indicates a perceived health state of no more value to the patient than death. The preference scores (EQ-5D index scores) generated from a large European population were used[237]. The response rate for PROM questionaries is 57%[2]. Although most frequently analysed as an index score, level of function can be explored within each dimension and compared to reference groups. Such comparisons have been done between hip fracture patients and the peer population[238].

3.2.4 Mortality

In ***Paper II*** one-year mortality was a secondary outcome measure. In the NHFR, mortality data are collected from the Norwegian Population Register, allowing analyses on mortality associated with patients' baseline data, type of fracture, type of implant, time to surgery, duration of surgery and intraoperative complications. In the annual reports, one-year mortality of patients sustaining different fracture types is calculated for each individual hospital.

3.3 Inclusion and exclusion of patients

The inclusion and exclusion criteria for ***Papers I-III*** are summarized in Table 3.

	Inclusion criteria	Exclusion criteria
Paper I (local database)	**ICD10 codes:** *S72.1* (trochanteric fractures) *S72.2* (subtrochanteric fractures) **NCSP codes** *NFJ51* (intramedullary nailing of trochanteric fractures) *NFJ52* (intramedullary nailing of subtrochanteric fractures) **Preoperative X-ray images** without prior implants or sequelae in either femur	< 60 years of age Non-Norwegian citizens Primary care episode at a non-orthopaedic department Pre-existing implant in either femur High-energy trauma Multiple simultaneous fractures in the lower extremities Pathologic fracture (other than osteoporosis)
Paper II (NHFR data	Trochanteric and subtrochanteric fractures operated 2013-2019 Treatment with a short or long IMN or a SHS w/wo TSP	< 60 years of age Fractures treated with other implants than SHS or IMN Pathologic fracture (other than osteoporosis) Fractures with missing data
Paper III (NHFR data)	Trochanteric and subtrochanteric fractures operated 2007-2019 Treatment with a short or long IMN	< 60 years of age Fractures treated with other implants Pathologic fracture (other than osteoporosis) Fractures with missing data Implant used < n=150 Implant not in general use the past 10 years

Table 3: Inclusion and exclusion criteria in Papers I-III

3.4 Statistics

Pearson chi-square test was used for comparison of categorical variables and the independent t-test (Student's test) and Analysis of Variance (ANOVA) were used to compare mean values in continuous variables in independent groups. The significance level was set at 0.05 in ***all Papers***.

In ***Paper I*** data was summarised using frequencies and percentages for categorical variables. The mean, standard deviation (SD) and range were calculated for continuous variables. The mean time to subsequent fracture, range and 95% confidence interval (CI) were calculated. The odds ratio (OR) was calculated using robust variance estimates in logistic regression. The follow-up time was calculated from the primary operation until a new fracture-related operation on the ipsilateral side, fracture-related surgery on the contralateral side, other operation not related to a fracture, death, or 31 January 2020, whichever came first. The patients who reached any of the endpoints were censored along the way.

In ***Paper II*** hazard rate ratios (HRRs) of reoperations and hierarchical cause of reoperation were calculated using Cox regression analyses, adjusted for age, sex, and ASA classification[239]. Patients were followed from primary operation to reoperation, death, or 31 December 2019 (end of study), whichever occurred first. One-year mortality for SHS and IMN was calculated for stable and unstable fractures using Cox regression analysis adjusted for age, sex, and ASA classification. The proportional hazards assumption was tested using log-minus-log plots and was fulfilled. Patient-reported quality of life (EQ-5D-3L), pain (VAS 0-100), and satisfaction (VAS 0-100) twelve months postoperatively were analyzed using the independent sample t-test to compare means between SHS and IMN

In ***Paper III***, short and long nails were analysed separately. Median and interquartile range (IQR) was chosen to describe duration of surgery due to the extreme outliers that may represent errors in the registration process. HRRs of reoperations were calculated using Cox regression analysis, adjusted for age, sex, and ASA classification. Gamma3 was the most common nail in the analyses of both short and long nails and was used as

reference. Patients were followed from primary operation to reoperation, death, or December 31, 2019 (end of study), whichever occurred first.

The statistical analysis was performed using IBM SPSS Statistics, version 24 in ***Paper I***, version 26 in ***Paper II*** and version 29 in ***Paper III*** (IBM Corp, Armonk, NY, USA), the statistical package R version 3.4.0 (http://CRAN.R-project.org) in ***Papers I, II and III***, and, in ***Paper I***, Stata/SE (Version 16.0, StataCorp LLC, College Station, TX, USA).

The STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines were followed[240].

4 Summary of Papers I-III

4.1 Paper I

Grønhaug KML, Dybvik E, Gjertsen JE, Samuelsson K, Östman B.
Subsequent ipsi- and contralateral femoral fractures after intramedullary nailing of a trochanteric or subtrochanteric fracture: a cohort study on 2,014 patients.
BMC Musculoskelet Disord. 2022 Apr 28;23(1):399.

Background The incidence of a subsequent femoral fracture (Sffx) is significant among patients who have suffered an initial hip fracture. The pattern of an Sffx will be influenced by the presence and type of the given implant at the time of a second injury. An implant may increase the risk of some fracture types and decrease the risk of others. Previously published literature does not provide sufficient information regarding the impact of an intramedullary nail. Based on data from the hospital electronic health records we investigated how an intramedullary nail affects the incidence, pattern, and localization of subsequent femoral fractures in patients without implants or sequelae after previous surgery in either femur.

Patients and methods A cohort of 2,012 patients treated with a short or long intramedullary nail for the management of trochanteric or subtrochanteric fracture between January 2005 and December 2018 was retrospectively analysed. Subsequent presentations with ipsi- and contralateral femoral fractures were documented. Only patients with no previous femoral surgery were followed, and consecutive censoring of patients reaching either end-point (Sffxs, death, non-fracture complications or new implant) enabled analysis of the risk of a Sffx. Odds ratios (ORs) for subsequent femoral fracture were calculated using robust variance estimates in logistic regression. The information based on data from the hospital electronic health records was validated by comparison with data from the NHFR.

Results The mean age of the cohort was 82.4 years and 72.1% were female. The total number of patients presenting with subsequent femoral fractures was 299 (14.9%). The number of patients presenting with subsequent ipsilateral and contralateral femoral

fractures was 51 (2.5%) and 248 (12.3%) respectively (OR: 5.0, 95% CI: 3.7 to 6.9). Twenty-six (8.7%) of all subsequent femoral fractures occurred in the ipsilateral shaft, 14 (4.7%) in the ipsilateral metaphyseal area, one (0.33%) in the contralateral shaft, and three (1.0%) in the contralateral metaphysis (OR: 10, 95% CI: 3.6 to 29).

Conclusion An intramedullary nail significantly changes the fracture pattern in the event of a second low-energy trauma, reducing the risk of subsequent proximal ipsilateral femoral fractures and increasing the risk of subsequent ipsilateral femoral fractures in the shaft and distal metaphyseal area compared with the native contralateral femur. The overall risk of Sffx is substantially higher in the contralateral, native femur indicating the protective effect of the IMN regarding a proximal ipsilateral Sffx is much higher than the increased risk of sustaining an ipsilateral peri-implant fracture.

The increased incidence of ipsilateral versus contralateral Sffxs in the shaft and distal metaphyseal area following the implantation of an IMN in this study may indicate a redistribution of forces in the event of a second trauma to the femur, morphological changes in adjacent bone or altered falling pattern.

4.2 Paper II

Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen JE.
Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures in 17, 341 patients from the Norwegian Hip Fracture Register.
Bone Joint J. 2022;104-B(2):274-282.

Background The choice of implant in the treatment of trochanteric fractures and subtrochanteric fractures has been debated for decades without reaching consensus. The most common implants are extramedullary sliding hip screws (SHS) and intramedullary nails (IMN), skewing towards IMN over the past two decades. The primary aim of this study was to compare reoperation rates for SHS and IMN for stable fractures (A1) and unstable fractures (A2, A3, and subtrochanteric combined) one and three years postoperatively. Secondary aims were to compare reoperation rates for SHS and IMN for A2, A3, and subtrochanteric fractures separately one and three years postoperatively and to compare mortality and patient-reported outcomes after SHS and IMN for stable and unstable fractures one year after surgery.

Patients and methods Data from 17,341 patients registered in the Norwegian Hip Fracture Register with trochanteric or subtrochanteric fractures treated with SHS or IMN from 2013 to 2019 was assessed. Primary outcome measures were reoperations for stable fractures (AO/OTA type A1) and unstable fractures (AO/OTA type A2, A3 and subtrochanteric fractures). Secondary outcome measures were reoperations for A2, A3 and subtrochanteric fractures individually, one-year mortality, quality of life (EQ-5D-3L), pain (Visual Analogue Scale (VAS)), and satisfaction (VAS) for stable and unstable fractures. Hazard rate ratios (HRRs) for reoperation were calculated using Cox regression analysis with adjustments for age, sex and ASA-score.

Results Reoperation rate was lower after surgery with IMN for unstable fractures one year (HRR: 0.82, 95% CI: 0.70 to 0.97, p=0.02) and three years postoperatively (HRR: 0.86, 95% CI: 0.74 to 0.99, p=0.036), compared to SHS. For individual fracture types, no clinically significant differences were found. Lower 1-year mortality was found for

IMN compared to SHS for stable (HRR: 0.87, 95% CI: 0.78 to 0.96, p=0.007), and unstable fractures (HRR: 0.91, 95% CI: 0.84 to 0.98, p=0.014).

Conclusion This national register-based study indicates a lower reoperation rate for IMN than SHS for unstable trochanteric and subtrochanteric fractures, but not for stable fractures or individual fracture types. The choice of implant may not be decisive to the outcome of treatment for stable trochanteric fractures in terms of reoperation rate. One-year mortality rate for unstable and stable fractures was lower in patients treated with IMN. The lower one-year mortality rate for unstable and stable fractures in patients treated with IMN should be further investigated.

4.3 Paper III

Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen JE.
Comparison of intramedullary nails in the treatment of trochanteric and subtrochanteric fractures. An observational study of 13,363 fractures in the Norwegian Hip Fracture Register.
Submitted JBJS Am.

Background Different brands of intramedullary nails vary with respect to lag screw/blade design, single or double lag screw, proximal diameter, entry point, and for long nails, antecurvature. In this prospective, register based study we aimed to investigate if there are any differences in reoperation rate between the various brands of IMNs in widespread use for treatment of trochanteric and subtrochanteric fractures in Norway.

Patients and methods Data from 13,363 trochanteric or subtrochanteric fractures treated with an IMN and registered in the Norwegian Hip Fracture Register (NHFR) between 2007 and 2019 was assessed. Primary outcome measure was risk of reoperation for various types of short and long IMNs. Secondly, reoperation rates for the selected nails regarding fracture type (AO/OTA type A1, A2, A3, and subtrochanteric fractures) were compared. Hazard rate ratios (HRRs) for reoperation were calculated using Cox regression analysis adjusted for age, sex, and ASA-score.

Results Mean age was 82.9 years and 72.8% were female. We included 8,414 short nails and 4,949 long nails. A1 fractures accounted for 29.8%, A2 for 40.6%, A3 for 7.2%, and subtrochanteric fractures for 22.4%. When comparing short nails regardless of fracture type, TRIGEN INTERTAN had an increased risk of reoperation one (HRR: 1.31, 95% CI: 1.03 to 1.66, p=0.028) and three years (HRR: 1.31, 95% CI: 1.06 to 1.61, p=0.011) postoperatively compared to Gamma3. For individual fracture types, we found no statistically significant differences in reoperation risk between the various types of short nails. Most failures occurred when the short TRIGEN INTERTAN was used in unstable fractures. When comparing long nails, TRIGEN TAN/FAN had an increased risk of reoperation one (HRR: 3.05, 95% CI: 2.10 to 4.42, p<0.001) and three

years (HRR: 2.54, 95% CI: 1.82 to 3.54, p<0.001) postoperatively compared with long Gamma3, persistent in A1, A2, and subtrochanteric fractures.

Conclusion This study indicates comparable reoperation rates for short nails in widespread use in Norway. The short TRIGEN INTERTAN nail was associated with a higher risk of reoperation, but mostly when used in unstable fractures contrary to recommendations of using a long nail for these fractures in the Norwegian interdisciplinary guidelines for treatment of hip fractures. In analyses of long nails, the TRIGEN TAN/FAN nail was associated with a higher risk of reoperation in the treatment of trochanteric and subtrochanteric fractures, applicable for both less and more experienced surgeons.

5 Discussion

5.1 Methodological considerations

5.1.1 Retrospective studies

Retrospective studies, considered inferior to prospective, randomized, and controlled clinical trials, can have strength and validity not necessarily recognized in the hierarchy of clinical data. A retrospective cohort study considers events that have already occurred. Health records of a certain group of patients are already collected and stored in a database, so it is possible to identify a group of patients – the cohort – and reconstruct their experience as if it had been prospectively followed up. Use of previously collected and stored records indicates that the retrospective cohort study is relatively inexpensive, and analyses often relatively quick and easy to perform. Furthermore, it enables the researcher to examine the temporal relationship between exposure and outcome. The information about patients may be collected without any thought for later research use and is usually not collected in a homogenous manner. In a retrospective study, it is likely that not all relevant risk factors have been recorded. The researcher will not be able to identify all exposure factors, covariates, and potential confounders, affecting the validity of a reported association between risk factor and outcome. In addition, it is likely that the measurement of risk factors and outcomes is not as accurate as in a prospective cohort study where documentation is done after defining a hypothesis and collection of information is structured. In ***Paper I*** a retrospective study design was applied to identify subsequent femoral fractures after initial treatment of a trochanteric or subtrochanteric fracture. An advantage to this design is its ability to study a rare outcome like a subsequent fracture, the ipsilateral fractures in particular. Furthermore, the retrospective design allows inclusion of a large population and long follow-up time. Important limitations were as described above, the inability of the retrospective design to identify relevant variables like BMD or fall pattern.

5.1.2 Register-based studies

The introduction of personal identification numbers in the Nordic countries in the 1960s paved the way for further development of medical registers in these countries, and their political stability and peaceful history have enabled them to establish reliable and relatively complete medical registries. The personal identification numbers allow linkage on an individual level between different registries, releasing an increasing amount of health-related data for epidemiological research. Registration systems like these are valuable as they offer a large number of recorded events, long follow up time, and a low influence of chance given the high number of observations in the data sets.

The main purpose of orthopaedic registers is collection of information regarding patients, implants, and procedures to monitor, and hopefully improve, outcome. Register-based studies require specific methodological considerations. Data collection in register-based studies differ from researcher collected data. Nevertheless, studies based on register data must be designed with the same scrutiny and critical approach to one's hypotheses as any other research.

In the following, the main strengths and limitations of register-based studies will be discussed.

5.1.2.1 Strengths of register-based studies

When conducting a register-based study, the relevant data have already been prospectively collected, minimizing cost and time spent. Sample size is much larger than what is possible in a traditional researcher-collected data set, yielding great statistical power and facilitating studies of less frequent outcomes and complications. When investigating rare outcomes, like reoperations after hip fracture surgery in ***Papers II and III***, a very high number of cases is required to reach sufficient statistical power. Accordingly, a RCT within a reasonable time frame would be very difficult to conduct. Linkage of different registers will enable calculation of completeness, ensuring the data regarding the population in question is representative. The NHFR has high completeness, minimizing the effects of selection bias, and allowing investigation of smaller sub-populations, such as patients with particular fracture types and implant

brands. Furthermore, the data have been collected prior to, and independent of, the study in question. This may reduce influence of any diagnostic process or treatment, that may represent obstacles in other research models. When investigating register data, valuable time has passed. Some complications develop months and years after exposure, surgery etc. Existing registers allow us to study long-term effects and outcomes, even when there is latency between exposure and manifestation of effect. Register-based studies can also be used to identify research questions suited for RCTs, and register data may even be used as a data pool for inclusion of patients into an RCT. Furthermore, given the large number of cases, register-based studies can supplement and substantiate results from RCTs. A study based on data from a register with high coverage and completeness will have high external validity as it describes the whole country, not just selected centres, surgeons or patients.

5.1.2.2 Limitations of register-based studies

Register-based studies certainly come with limitations that are important to recognize too. The most important limitation is that a register-based study can only describe associations, not causality. Data selection and content are not defined by the researcher and normally collected prior to the formulation of a particular research question, and the researcher is limited to use the pre-defined variables in the register. Certain information may be unavailable, like x-ray images in ***Papers II and III***. This prevented us from subclassification of fracture types influencing stability assessment of AO/OTA A2 fractures and verifying correct classification of fractures. Information in a register may be inaccurate, and the level of detail is limited. In health registers, coding of diagnoses and surgical procedures are used, and there may be variations in coding practice between health personnel, departments, institutions and even over time as coding systems are revised. The registers may lack information crucial to the interpretation of results and fail to identify and acknowledge confounders. Incomplete information regarding confounding factors, and the fact that register-based studies provide large samples and have great statistical power to detect small effect sizes, makes register-based studies prone to confounding. To reduce the risk of confounding in ***Papers II and III*** we adjusted for ASA, sex and age groups but there is a risk of residual confounding. Missingness is another important limitation in research methodology, also applicable to handling of data from the NHFR. An example in long-term medical studies is drop-out of participants because of deteriorating health or cognitive status, where the final dataset may include only the

healthiest individuals – attrition bias. We have no reason to believe we have a significant risk of attrition bias in ***Papers II and III*** as baseline data were comparable for all groups and mortality and loss to follow-up are assumed to be comparable in all groups. Evaluation of data quality is a limitation in register-based studies. Register data can be difficult to validate, as a golden standard cannot be established. Furthermore, the large amount of available data may lead to misleading post-hoc analyses. A research question posed after processing the data may be biased and lead to the wrong conclusions. Finally, clinically insignificant differences may reach statistical significance in register studies with large numbers of observations. The size of risk estimates must be interpreted, and clinical relevance taken into consideration upon conclusion.

In ***Paper II*** PROM-analyses were included. A core outcome set (COS) has been suggested for clinical trials investigating patients with hip fractures[241], including mortality, pain, activities of daily living, mobility and health related quality of life (HRQL). EQ-5D was recommended as measure of HRQL. The EQ-5D correlates with the hip specific PROM Oxford Hip Score (OHS)[238,242], and is regarded responsive for the hip fracture population, including proxy scores for patients with cognitive impairment[243,244]. When using PROMs the minimal clinically important difference (MCID) must be taken into consideration[245], which is estimated to be 0.06-0.07 for the EQ-5D index score[246]. The response rate from the patients receiving the 4-months questionnaire was only approximately 52% in ***Paper II***. We found a statistically significant higher EQ-5D-3L score at one year for patients with an A2 fracture treated with an IMN, but the difference only amounted to 0.04. Thus, we cannot conclude upon a clinically relevant difference in EQ-5D-3L score between treatment groups in our study, although statistically significant. Earlier studies have shown that the patients responding to the 4-months questionnaire are younger and healthier than the patients not responding, indicating selection bias. Furthermore, recall bias is likely as these data are collected 4 months postoperatively[247]. The PROM data reported in ***Paper II*** probably represent a best-case scenario as a recent study from the NHFR indicates that the frailest patients more seldom respond[248]. However, in their report based on two large prospective studies, Parsons et al provide evidence for the reliability of retrospective assessment of pre-injury health and functional status using the EQ-5D[238]. We decided to include PROM analyses despite a large amount of missing data, as we have no reason to believe there would be more non-responders in either group compared to the other. Nevertheless, after one year, 24% of the study

population had died, and only 52% of the remaining patients answered the questionnaire. With such a large amount of missing data we cannot draw any inferences based on PROM analyses.

When using health register data, validity must be evaluated. Validity can be described as completeness, holding two dimensions. The first dimension refers to the proportion of individuals in the population in question with the condition of interest that are correctly reported and entered in the register. Completeness can be calculated by comparison to another register or data source with high credibility, such as national patient registers containing all admitted patients in all hospitals. Such completeness analyses have been made in the NHFR[249]. Lower completeness for reoperations compared to primary operations implies that the reported risk of reoperation describes a best-case scenario. We have no reason to believe there is a systematic under-reporting of reoperations for any particular operation method in ***Paper II*** or for any particular type of IMN in ***Paper III***, and thus conclude the risk estimates can be trusted.

Another option to calculate completeness is to review hospital discharge reports, where all patients should be registered, but may be misclassified or lack classification. This is costly and time consuming, but a more accurate way of determining completeness of the register in question. The second dimension is validity of the variables, describing to what extent the variables in fact measure what they were intended to. In this sense, core measures for validity are sensitivity, specificity and positive and negative predictive value. An example relevant to ***Papers II and III*** is validity of fracture classification.

5.1.3 Register-based studies versus RCTs

Evidence-based medicine (EBM) categorizes various sources of information based upon their ability to provide reliable evidence. Meta-analyses and systematic reviews hover at the top of the hierarchy, followed by randomized clinical trials (RCTs), preferably blinded and controlled (Figure 15). RCTs are considered the golden standard of clinical research, providing the raw material for meta-analyses and systematic reviews. RCTs are designed to verify or falsify a pre-defined hypothesis and allow the researcher to infer causality from observed associations. Pre-defined inclusion and exclusion criteria and the process of randomization ensure homogenous study populations where the only difference between the intervention group and the control group is the intervention in question. Register-based studies are observational studies and are classified as low-level evidence according to the EBM hierarchy.

The Agency for Healthcare Research and Quality define a patient register as *"an organized system that uses observational study methods to collect uniform data (clinical and other) to evaluate specified outcomes for a population defined by a particular disease, condition, or exposure, and that serves one or more pre-defined scientific, clinical, or policy purposes."* Information from a register database reflect real-life clinical practice whereas in RCTs, intervention is decided by a protocol. In a register, information regarding a large number of various patients and over long periods of time is collected, allowing subgroup analyses. In an RCT, a limited number of similar patients are enrolled based on sample size calculation and power analyses, and followed for a limited period, most often with strict inclusion criteria, causing selection bias and low external validity. These studies have high internal validity. The large populations available in register-based studies can provide sufficient information to identify associations regarding rare diagnoses and outcomes with low prevalence and incidence. In these cases, RCTs will be too costly and time-consuming to perform. Rare adverse events are less likely to be captured in RCTs given their limited size and duration, and register-derived information is necessary for surveillance and documentation of safety. Medical decision-making will sometimes have to just rely on register-derived evidence, as RCTs may be impossible or unethical to perform. As discussed previously, there are limitations to register-based studies as well as to RCTs. The risk of bias is higher in a register-based study, such as ***Papers II and III***, than in an RCT and must be taken into careful consideration upon designing, conducting, and concluding. Methodological tools like Cox regression analysis and logistic regression allow adjustment for known confounders, but these are not exhaustive and a register-based study can never be as conclusive as an RCT. External validity, however, is higher in register-based studies.

In conclusion, well-designed RCTs and register-based observational studies both provide useful information and should both be considered when creating treatment guidelines.

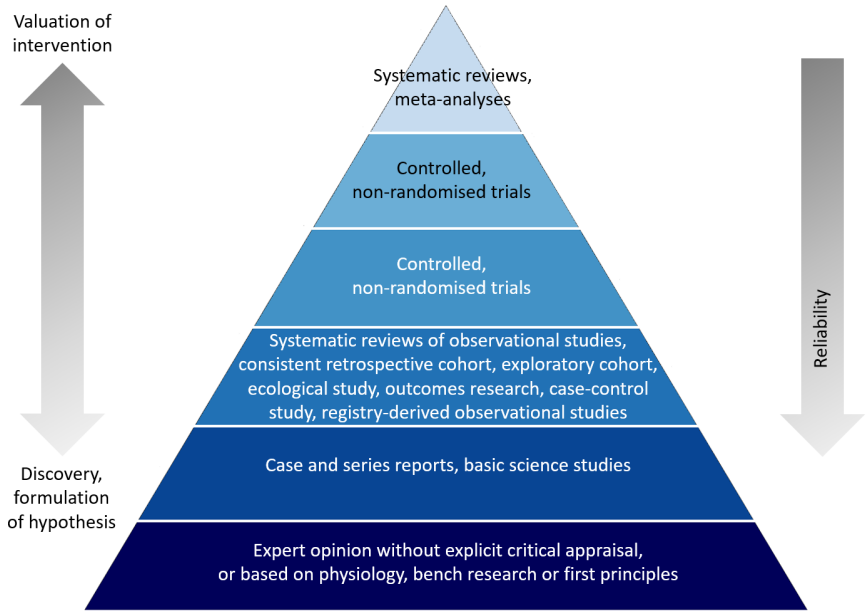


Figure 15: Pyramid of medical evidence hierarchy. Based on: Vandenbroucke JP. Observational Research, Randomized Trials and two views of medical science. PLoS Medicine 2008[250].

5.1.4 Limitations of the AO/OTA classification model

Detailed classification systems challenge accuracy in reporting when collecting fracture classification data at a largescale, like a national register. The AO/OTA classification is the most commonly used system and is also the classification chosen in the NHFR. After the initial publication in 1990 the system has been revised several times but has had persistent faults regarding inter- and intra-observer reliability[88,251]. In a clinical setting, particularly the AO/OTA A2 fracture type is challenging as it comprises of both relatively stable and unstable patterns. The AO/OTA classification system was revised in 2018 with the aim of re-classifying and further defining the 31-A2 group. Agreement for the subtypes of extracapsular fracture did not substantially improve; most centres achieved no better than "fair" agreement[252]. The AO/OTA classification remains sub-optimally reliable with only a "moderate" inter-observer reliability at group level with this falling to "fair" when sub-group classifications are made. Identification of stable and unstable injuries using the new AO/OTA system remains difficult and is challenging to apply with consistent accuracy[96]. There are indications of increased

diagnostic reliability when CT images with 3D reconstruction are available[253], but few centres routinely use CT-scans in the investigation of trochanteric and subtrochanteric fractures. In ***Papers II and III*** data on sub-classification of the AO/OTA A2 were unavailable. Accordingly, the AO/OTA A2 fractures in these papers may consist of both stable and unstable subtypes of fractures.

5.2 Discussion of results

5.2.1 Subsequent fractures following treatment with intramedullary nail

Patients surviving a hip fracture have a substantially increased risk of a Sffx, as described in several large epidemiological studies[13,195]. To be able to address this increased risk, orthopaedic surgeons need information regarding a multitude of factors, among these a deeper understanding of the biomechanical impact of the implants. A number of previous studies have investigated the occurrence and morphology of a second hip fracture in general[13,195] or described the incidence of peri-implant fractures distal to an IMN in particular[146,196,254], but no studies have eliminated the impact of previous implants or sequelae in either femur to isolate the impact of the IMN. In ***Paper I*** we attempted to achieve this distinction by excluding patients with pre-existing implants or fracture sequelae in either femur, and censoring patients receiving a new implant during follow-up. The distribution of Sffxs is illustrated in Figure 16.

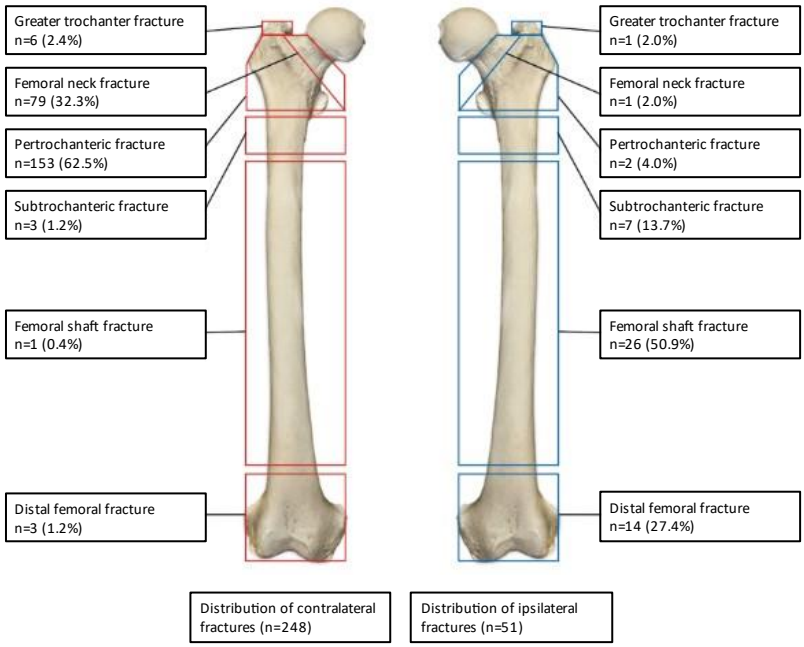


Figure 16: Distribution of subsequent femoral fractures (From ***Paper I***)

In ***Paper I***, we found a total incidence of a Sffx five times lower on the ipsilateral than on the contralateral side following trochanteric and subtrochanteric fractures treated with an IMN. The risk of femoral shaft and distal metaphyseal Sffx was ten times higher on the ipsilateral than on the contralateral side, given the much lower risk of a femoral shaft fracture than a proximal femur in a native femur. The occurrence of subsequent fractures has been investigated in large observational studies and register based studies[48,50,51], and the results of ***Paper I*** confirm their conclusion that the overall risk of a Sffx is significantly higher than the risk of an index hip fracture, particularly during the first 1-2 years. This also applies to Sffxs occurring after other types of low-energy fractures[48,255]. According to Center et al[52], the majority of Sffxs occur in the contralateral side, in agreement with our results. Bögl et al concluded upon overall reduced risk of reoperations and Sffx in particular with the use of IMN with femoral neck protection in the treatment of low energy femoral shaft fractures in a retrospective

study of 897 patients[256]. An increased risk of Sffx distal to an IMN similar to our findings was reported in the 2022 Cochrane review of surgical treatment of extracapsular hip fractures[126], a systematic review of 13,568 patients by Norris et al[146], and a register-based study from the Finnish Health Care Register by Yli-Kyyni et al[197]. Both the latter were published in 2012, thus including third generation IMNs. In ***Paper I***, we discovered an increased risk of a Sffx over a longer period compared to other register-based studies[50,197]. These studies report a substantially increased risk over the first 12-19 months, but thereafter a normalization of risk comparable to that of an index hip fracture. Schemitsch et al and Balasubramanian et al have reported a persistent higher risk of subsequent hip fracture for 5 years, although declining after a clustering during the first 1.5 years[48,257], in line with our results.

The incidence of ipsilateral Sffxs occurring in the shaft and distal metaphyseal area, are consistent with the existing literature[109,146,197]. In these previous studies, however, there is no information regarding previous implants or sequelae in either femur.

The increased risk of an ipsilateral Sffx in the shaft and distal metaphyseal area in the presence of a short versus a long IMN suggested in our material is in agreement with the results presented by Frisch et al in a retrospective cohort of 169 patients and a recent study from the Danish Multidisciplinary Hip Fracture Registry[133,258], but contradictory to the results in other retrospective cohort studies[199,259], recent systematic literature reviews[27,260] and a randomized prospective study of 220 patients[261]. The event of an ipsilateral Sffx is relatively rare and the low quantity analyzed in ***Paper I*** did not allow us to draw any interferences regarding differences between short and long IMNs.

Several variables are likely to contribute to the observed changes in distribution and morphology in the case of a Sffx following treatment with an IMN. All Sffxs ***in Paper I*** occurred following a low-energy trauma. The risk of a low-energy Sffx in the shaft, which is normally able to withstand substantial force even in osteoporotic individuals, is increased following the implantation of an IMN, indicate other explanatory factors in addition to general osteoporosis.

Factors amenable to the properties of the implant itself, like the modulus of elasticity are suggested to affect the incidence of adjacent fractures in biomechanical studies[262]. Ideally, the implant should counter bending, torsion and shear stress adequately, whilst allowing compression at the fracture site. The increased incidence of ipsilateral versus contralateral Sffxs in the shaft and distal metaphyseal area following the implantation of an IMN seen in ***Paper I*** may indicate a redistribution of forces in the event of a second trauma to the femur – protecting the proximal femur but increasing the risk of fracture distal to the IMN. Morphologic changes in adjacent bone may also increase the incidence of low-energy Sffxs distal to the implanted IMN, as seen in ***Paper I***. The implant bears the load following treatment of fractures in the lower extremity, causing bone resorption and localized osteopenia due to stress-shielding as described in association to other implants in fracture treatment as well[263-265]. Postoperative immobilization causes both localized and general reduction of bone mineral density (BMD) in the femur, confirmed in previous studies[53,266-268], and possibly contributes to the increased incidence of ipsilateral Sffxs in the shaft and distal metaphyseal area seen in ***Paper I***. Previous studies have targeted impaired balance and an increased risk of falling as major risk factors for index and subsequent hip fractures, and with a higher impact than low BMD[269-271]. This is reflected in guidelines for the secondary prevention of hip fractures[58,72]. Closely related to the increased risk of falling, sarcopenia, as defined by the European Working Group on Sarcopenia in Older Persons (EWGSOP): low muscle mass with low muscle strength or low physical performance, is typically seen in the frail hip fracture patient[269]. Sarcopenia inevitably develops further after the index hip fracture[272-274] due to lower activity, mobility, pain, and avoidance, thereby increasing the risk of falling and the risk of a Sffx[53].

Paper I provides a large sample size indicating high external validity. The retrospective design allows a long follow-up time reducing the risk of not identifying Sffxs occurring a long time after the index fracture. The exclusion of patients with pre-existing implants or sequelae in either femur allowed us to investigate the true impact of the IMN in this setting, and our data were validated by comparison to NHFR data. In ***Paper I***, information regarding BMD, sarcopenia or fall pattern before the index operation was

not available, but we assumed comparable BMD in both femurs as only patients without previous implants or sequelae in either femur at the time of index fracture were included and patients receiving other implants during follow-up were censored. The existing literature indicates that fracture type may affect the risk of a Sffx[196,275-277], but as ipsilateral Sffxs are less frequent, we did not have sufficient sample sizes to allow meaningful subanalyses of index fracture type or stability. ***Paper I*** only included patients treated with IMNs. A short Gamma3 accounted for 55.8% of implants used, followed by long Gamma3 (21.1%), and although we found a significant impact of the implant on the localization and incidence of a Sffx we cannot conclude whether this effect is specific only to IMNs, just Gamma3, or apply to other femoral implants as well, such as sliding hip screws or arthroplasty femoral stems.

5.2.2 Choice of implants in trochanteric and subtrochanteric fractures

The results in ***Paper II*** may indicate that IMN is the preferrable implant in the treatment of unstable fractures (A2, A3 and subtrochanteric fractures combined), as we found the IMN to be associated with lower reoperation rates than SHS. We found similar reoperation rates for SHS and IMN in the treatment of A1 fractures, but peri-implant fracture was a more prevalent cause of reoperation in patients with A1 fracture treated with an IMN. Otherwise, there were no clinically relevant differences in individual fracture types between SHS and IMN in terms of reoperation rates or PROM data. There was a lower 1-year mortality rate in patients treated with IMN compared to SHS for stable and unstable fractures alike.

The latest Cochrane review from 2022 confirms the conclusion of the 2010 report and continues the recommendation of an SHS for the majority of trochanteric fractures, mainly due to the higher incidence of peri-implant fractures associated with IMNs[109,148]. The 2022 report describes a higher incidence of infection after treatment with an SHS compared to an IMN, in line with the increased risk of infection following treatment with an SHS in unstable fractures found in ***Paper II***, but the overall risk of a complication was higher for patients treated with an IMN in their report, contrary to the results of our analyses of unstable fractures[148]. In the Cochrane reports only RCT

and quasi-RCTs are reviewed, whereas ***Paper II*** is a register-based study, and thus the results are not necessarily comparable. Some research questions, such as differences in rare outcomes like reoperations after trochanteric and subtrochanteric fractures, may be difficult to assess in RCTs. The necessary sample size of an RCT intended to detect significant differences in complications between implants in the treatment of these factures is estimated to be n >1,000. A recent propensity-matched comparative study of 8,000 patients with A1, A2 and A3 fractures did not identify any major differences between SHS and IMN[278]. Similar results were reported in a multicentre RCT comparing SHS and IMN (TRIGEN INTERTAN) in 684 patients with A1, A2, A3 and subtrochanteric fractures[279].

In ***Paper II*** we chose to focus on fracture stability indicated through classification rather than individual fracture type when investigating differences in reoperation rate between SHS and IMN. We believe this approach may be clinically more relevant and provide a more robust statistical analysis, as the stability assessment in the AO/OTA classification system is uncertain in the case of A2 fractures. Studies have reported moderate inter- and intra-observer reliability regarding stability assessment, even in the revised AO/OTA classification of 2018, indicating reservations when using this system in day-to-day decision making and analyses of register data[96,252]. As the A2 fractures are not further subclassified in the NHFR data and account for a considerable amount of investigated fractures, we chose to include A2 in the group of unstable fractures as suggested by Pervez[88]. In previous studies from the NHFR investigating the outcome of SHS versus IMN in the treatment of trochanteric and subtrochanteric fractures, lower reoperation rates were found in for SHS compared with IMN in type A1 fractures one and three years postoperatively[156], and higher reoperation rates for SHS compared with IMN in type A3 and subtrochanteric fractures combined[163]. A2 fractures were not included and remain a less properly defined entity in terms of stability and prediction of outcome. Lateral wall thickness appears to play a key role in the prediction of success with treatment, indicating the majority of A2 fractures should be considered unstable[103]. A2 fractures have been singled out in previous studies comparing IMN and SHS, but the results are conflicting[25,280,281]. The differences in reoperation rate for

individual fracture patterns found in the previous NHFR studies were not confirmed in ***Paper II***, but when analysing all unstable fractures pooled together, there was a statistically significant lower risk of reoperation with the use of IMN compared to SHS. Our results support the conclusion in the previous study from the NHFR that recommended the use of IMN in the treatment of A3 and subtrochanteric fractures[163]. In ***Paper II*** we included A2 fractures in the analysis of unstable fractures, thus also extending the recommendation to this group of fractures.

In ***Paper II*** subanalyses of cause of reoperation revealed more cases of infection as primary cause in patients with unstable fractures treated with SHS compared to those treated with IMN, persistent in subanalyses of A2 and A3 fractures. The risk of complications leading to revision with THA was also higher in patients with unstable fractures treated with an SHS, persistent in subanalyses on fracture type. This is contrary to a recent register-based study from the Swedish Fracture Register (SFR), concluding there is probably no difference in conversion rate to THA after IMN or SHS for extracapsular hip fractures, also including subanalyses regarding fracture type. That study did in fact find a higher risk of conversion to THA in A2 fractures treated with an IMN, although the authors did not perceive this difference as clinically important[282]. In the treatment of stable (A1) fractures, peri-implant fracture was a more prevalent cause of reoperation with the use of IMN, but the total reoperation rate was comparable between SHS and IMN. Peri-implant fractures were not overrepresented as cause of reoperation in A2, A3 and subtrochanteric fractures individually or pooled together. Existing literature is inconclusive regarding the possible beneficial effects of a long versus a short IMN[199]. Although a cephalomedullary device is recommended in international guidelines for the treatment of unstable intertrochanteric fractures, reverse obliquity fractures and subtrochanteric fractures, no recommendation regarding short or long IMN is given[58,73]. The Norwegian national guidelines include a specification of a long IMN in the treatment of A3 and subtrochanteric fractures[74]. Two meta-analyses from 2017[260] and 2020[134], and a retrospective study by Boone in 2014[283], among others have not found any differences in risk of reoperation between short and long IMNs in the treatment of unstable trochanteric fractures. There is, however, a recent study from the Danish Hip Fracture Register reporting higher risk of reoperation when a short IMN

is used in subtrochanteric fractures[133]. In ***Paper II*** we were not able to compare outcomes of long vs short nails, nor outcomes of SHS vs SHS with TSP, given the heterogeneity of the groups. A3 and subtrochanteric fractures were almost exclusively treated with a long IMN/SHS with TSP and A1 fractures almost exclusively treated with a short IMN/regular SHS.

In ***Paper II*** we focused on time to reoperation, and the results from Cox regression analyses are straightforward to interpret. The statistical interpretation from Kaplan-Meier and Cox analysis for analysis of reoperation have been advocated[284,285].

We found a lower mortality rate in patients treated with IMN compared to patients treated with SHS, applicable to both stable and unstable fractures. Previous studies have, contradictory to our result, found a higher mortality in patients treated with IMN compared to SHS[161,162], or claim choice of implant does not affect mortality[148,286]. The studies in question are not fully comparable. As opposed to the study of Whitehouse et al[161] our study included both trochanteric and subtrochanteric fractures, whereas they only included unstable A2 and A3 fractures. Pathological fractures were excluded, and our patients were treated during a later period. Wolf et al[162] only investigated A1 and A2 fractures in their register-based study where an IMN was associated with higher 30-day mortality. Pathological fractures were not explicitly excluded. A large register-based study from the Danish Fracture Database investigating mortality in trochanteric fractures (A1, A2, A3) concludes upon a higher crude mortality in patients treated with IMN compared to SHS at 30 days, 90 days and one year, but the differences were not significant after adjusting for confounders[287]. A recent study by Lynch-Wong et al found a lower 30-day mortality in patients treated with IMN compared to SHS, including all trochanteric fracture types but excluding subtrochanteric fractures[288]. The 2022 Cochrane report similarly concludes that there is probably no significant difference in mortality risk between patients treated for extracapsular hip fractures with IMN and SHS[148]. The discrepancy of results investigating mortality and choice of implant may indicate it is not the most important factor in predicting mortality in this group of patients.

The choice of implant is an important issue that affects patient outcomes, at least for certain groups of patients and fractures, but other factors might be even more important. More emphasis should probably be placed on fracture reduction, correct implant positioning and pre- and postoperative care to reduce reoperation rates and improve patient satisfaction[74]. Furthermore, economic considerations inevitably play a role in choice of implants in all fracture treatment[157]. In a public healthcare system under increasing economic pressure world-wide as well as expectations of evidence based best practice guidelines including socioeconomic evaluations, orthopaedic surgeons cannot expect to be able to choose implant based on preference, habit or personal conviction.

The RCTs available investigating different treatment options for hip fractures in general, including trochanteric and subtrochanteric fractures, rarely include patient-relevant outcome measures like pain, activities of daily living (ADL), health-related quality of life and mobility[148]. The NHFR monitors PROMs using a visual analogue scale to describe pain and overall satisfaction, as well as the EQ-5D-3L containing dimensions describing mobility and ADL. The EQ-5D has evolved over time into a validated and relevant tool to measure softer, and less accessible outcomes for this patient population[238,289]. In ***Paper II***, patients with unstable fractures treated with an SHS reported lower EQ-5D-3L index score one-year post-fracture compared to patients treated with an IMN, and a lower VAS satisfaction score. The differences in mean EQ-5D-3L index score and mean VAS satisfaction score between the two groups were small, but a sizable number of patients in one of the groups may still have reported a clinically significant better outcome. The PROM values registered one year postoperatively do not correspond directly to the pre-fracture values provided in the four-month questionnaires, and do not represent a delta-value. Additional analyses to identify the number of patients returning to their pre-fracture EQ-5D-3L score, VAS satisfaction score and walking ability were performed, confirming the significant differences between patients treated with SHS versus IMN found in the crude comparison of PROM values one year postoperatively. Analyses of PROM data must be interpreted with great reservation, and we cannot draw any interferences because of the large amount of missing data. We chose to include the PROM analyses in ***Paper II***

as we do not have reason to believe the number of non-responders is skewed. Baseline data were similar for the compared groups and as described, the delta values when coupling pre-fracture PROMs and PROMs one year postoperatively for the patients having responded to both questionnaires confirmed the observed differences for the whole population, although the incomplete datasets cause great uncertainty. After one year, 24% of the study population had died, and only 52% of the remaining patients answered the questionnaire.

The large sample size studied in ***Paper II*** provides great statistical power and external validity as register data describes the average surgeon, hospital and patient. Large study populations and a long perspective are required to reveal statistically significant differences in implant performance, and an adequately powered RCT with sufficient follow-up time nearly impossible to perform. Register-based studies allow investigation of rare outcomes like reoperations and subanalyses of smaller groups like the A3 and subtrochanteric fractures but is prone to confounding as all relevant variables for all future studies cannot be foreseen when establishing a register. Furthermore, in order to achieve high completeness questionnaires have to be short and concise. Selection bias is not likely in ***Paper II*** as baseline characteristics were comparable for the two groups of patients, and choice of implant decided upon by tender at a regional level and not by the individual orthopaedic surgeon.

Register-based studies cannot claim to prove causality. Missingness is an issue in register-based research like ***Paper II*** and can only describe associations. In the NHFR as in other national registries, completeness regarding reoperations is lower than for primary operations, namely 80% versus 88%[290]. We do not have reason to believe there is a discrepancy in reporting of reoperations between implants although underreporting of complications certainly is a possible bias in ***Paper II***. All IMN and SHS brands were grouped together, respectively, and we cannot be ascertained our results are representative for all implant brands. Further, we must suspect fracture classification errors affecting interpretation of our results, as NHFR data do not contain x-ray images. Thus, we were not able to confirm correct classification of fracture type or identify combinations of fracture patterns. Previous studies have indicated that there is a fair

amount of classification errors, even with the most recently updated AO/OTA classification system[88,96,252]. In ***Paper II*** all A2 fractures were considered unstable, although A2-1 fractures have a stable fracture pattern. Subgroups of the AO/OTA fracture types cannot be identified in the NHFR data, and as all other subgroups of A2 fractures are unstable we believe including all A2 fractures is sound. This increases statistical power in our analyses and may be more clinically relevant.

5.2.3 Comparison of intramedullary nails

In ***Paper III***, the comparison of different short IMN brands in all fracture types combined revealed a slightly increased reoperation rate associated with the use of a short TRIGEN INTERTAN nail, but the clinical significance is questionable. Although most of these reoperations occurred in patients treated for A3 and subtrochanteric fractures no significant differences were detected in the analyses of individual fracture types, indicating similar outcomes. In the comparison of different long IMNs, there was a significantly increased risk of reoperation with use of a long TRIGEN TAN/FAN nail compared to the long Gamma3. Sub-analyses confirmed the increased risk of reoperation in A1, A2, and subtrochanteric fractures. Risk of reoperation increased further when the operating surgeon had less than three years of experience.

Previous studies have identified cut-out as the major cause of failure leading to reoperation[219,291]. In ***Paper III*** hardware failure was the most common cause of reoperation for short and long nails. This does not rule out the possibility of a concomitant cut-out, in line with existing literature. In the NHFR form, more than one cause of reoperation may be given. To avoid counting each reoperation more than once in ***Paper III***, the following hierarchy was chosen to identify the more serious cause: infection, peri-implant fracture, hardware failure, cut-out, non-union, unspecified sequelae (treated with THA and registered to the Norwegian Arthroplasty Register), pain alone, other. Thus, cut-out may have been present in addition to hardware failure, but not registered as main cause of reoperation.

To the best of our knowledge, ***Paper III*** is the first national register-based study investigating reoperation risk including all IMNs in general use. Previous studies have compared IMN and SHS[148,292], short and long nails[28,134,135,199,261,293-295] or two different nail designs[27,199,259,296]. A clear benefit to any particular IMN design or to a long nail in the treatment of unstable intertrochanteric and subtrochanteric fractures has not been established. The AAOS and NICE guidelines advocate the use of an IMN in the treatment of unstable fractures, but do not specifically recommend a long IMN[58,73]. The Norwegian national guidelines have a specification of a long IMN[74]. The slightly increased reoperation risk with the use of the short TRIGEN INTERTAN, primarily in unstable fracture patterns, seen in ***Paper III*** is far from conclusive, and the number of patients in some subgroups was too low to compare short and long nails in individual fracture types. Further research is certainly indicated, supported by recent study from the DMHFR suggesting there may be a benefit to long IMNs in unstable fracture patterns[133].

In order to obtain a stable construct allowing early weightbearing, adequate fracture reduction and correct positioning of the lag screw are crucial factors[204,293,297]. New variations of IMNs have been introduced over the past two decades and features like a helical blade and double or integrated lag screw have been investigated regarding risk of reoperation[293,294], but there is no clear evidence of superiority of any particular design. The helical blade is intended to increase adjacent bone density and reduce risk of cut-out. In ***Paper III*** the nail brands providing a helical blade (short and long PFNA) had comparable revision rates to the other brands, even when investigating risk of cut-out specifically. The introduction of double or integrated lag screws is intended to reduce the risk of failure due to rotational instability and fracture collapse, and although smaller series of patients and biomechanical studies may indicate an effect[298], definite clinical evidence to support this assumption is lacking[299,300]. In ***Paper III***, nail brands with double or integrated lag screws were included, namely the long TRIGEN TAN/FAN, the long T2 Recon nail, and short and long TRIGEN INTERTAN nails respectively. The results of our analyses did not indicate any significant benefit of these features, in fact the short TRIGEN INTERTAN and the long TRIGEN TAN/FAN had

a higher risk of reoperation when analysing all fracture types combined. There were no statistically significant differences in sub-analyses regarding individual fracture types, but as a long nail is recommended in the treatment of A3 and subtrochanteric fractures in the Norwegian guidelines[74], the number of such fractures treated with a short TRIGEN INTERTAN was low. Most failures occurred when used in unstable fracture patterns. This tendency could not be found in the subanalyses of other short nail brands. The TRIGEN TAN/FAN had a higher reoperation rate in all fracture types except A3. Hardware failure, theoretically including breakage of the nail or lag screws, exaggerated sliding and failure due to a z-effect, was the most frequently observed cause of reoperations in the short TRIGEN INTERTAN group and the long TRIGEN TAN/FAN group. The T2 Recon provides double lag screws, similar to the TRIGEN TAN/FAN, but did not have a higher rate of reoperations, indicating this particular feature may not explain the increased risk of reoperations.

The large sample size in ***Paper III*** provides high external validity and statistical power. Some fracture types are less common and certain IMN brands used less frequently, and although this causes uncertainty in the analysis of our register-based studies as well, a sufficiently powered RCT with a timeframe long enough to detect differences would be very difficult to perform. Analyses of data from the NHFR, given its high coverage and completeness[2], allowed analyses of subgroups and identification of statistically significant differences in baseline characteristics and rare outcomes like reoperations, and sample sizes were large enough to compare various brands of short and long nails used in the treatment of different fracture types. The risk of selection bias is low as baseline characteristics were similar for patients in the compared groups, and the choice of implant is undertaken by a tender process in the Norwegian health care system.

Registration completeness in the NHFR is calculated by comparison to information from the Norwegian National Population Register. Underreporting of complications is a possible bias in ***Paper III***, as registration completeness in the NHFR is lower for reoperations than for primary operations[290]. The coverage is high though, as 100% of Norwegian hospitals report to the NHFR, and systematic differences in the reporting of reoperations between implants is unlikely. There is a documented difference in

reporting practice between the hospitals in Norway[2], but none of the implants included in the analyses in ***Paper III*** were limited to one hospital alone. Furthermore, none of the implants were used exclusively in hospitals with low reporting percentage, reducing the risk of underreporting of reoperations related to particular implants.

Given the different designs of some of the implants included in ***Paper III***, one might expect unique hardware failure modes. Unfortunately, mechanical complications are not specified in any further detail in the NHFR than hardware failure, cut-out, and non-union, and more specific patterns of failure cannot be identified. Several factors related to surgical treatment, but not to choice of implant are associated with an increased risk of reoperation, like malreduction or suboptimal nail placement[204,291,297]. X-ray images are not available in the NHFR and we were not able to identify such confounders. Furthermore, the higher risk of reoperation found when a short TRIGEN INTERTAN nail was used by surgeons with more than three years of experience is likely to be influenced by unknown confounders. Challenging fracture patterns like reverse obliquity and subtrochanteric fractures are probably more often dealt with by more experienced surgeons. We did not have access to x-ray images and this possible distribution bias could neither be confirmed nor ruled out.

In the analyses in ***Paper III***, we found that some stable fractures (A1) had received a long IMN and some unstable fractures (A3 and subtrochanteric) a short IMN, eligible for all brands. The Norwegian national guidelines specifically recommend a long nail in the treatment of A3 and subtrochanteric fractures and an SHS or a short IMN in the treatment of A1 fractures[74]. The deviations identified in ***Paper III*** indicate variable adherence to these guidelines in the Norwegian orthopaedic population. Internationally recognized guidelines like the AAOS and NICE do not include specification of nail length[58,73]. Better outcome of a long IMN in reverse obliquity and subtrochanteric fractures compared to a short IMN has not been irrevocably confirmed in the existing literature[133,134,260,283]. We were not able to compare short and long IMNs in the treatment of different fracture types in ***Paper III***. We did find a slightly increased reoperation rate following treatment with the short TRIGEN INTERTAN, dominantly

A3 and subtrochanteric fractures, but there was no correlation between reoperation rate and individual fracture types for neither short TRIGEN INTERTAN nails nor any of the other short IMN brands. We cannot draw any interferences due to the limited number of short IMNs used in unstable fracture types.

In ***Paper III***, we were not able to establish if surgeon experience influences performance of the different nail brands, as the majority of operations were performed by surgeons with more than three years of experience. The NHFR data do not describe surgeon volume, but the learning curve is likely to be comparable for all IMN brands. Furthermore, we cannot be ascertained that reported experience does in fact reflect experience with hip fracture surgery in particular, although that is specified in the NHFR form. The operating surgeon may in some cases just have stated his or her experience in orthopaedic surgery. One previous study from Denmark has suggested that experienced surgeons have better outcomes when treating unstable trochanteric and subtrochanteric fractures[104,182], but this was not confirmed in a previous study based on NHFR data[182].

6 Conclusions

Paper I:

- An intramedullary nail significantly changes the fracture pattern in the case of a second low-energy trauma, reducing the risk of subsequent proximal ipsilateral femoral fractures and increasing the risk of subsequent ipsilateral femoral fractures in the shaft and distal metaphyseal area compared with the native contralateral femur.
- The overall risk of Sffx is substantially higher in the contralateral, native femur indicating the protective effect of the IMN with regard to a proximal ipsilateral Sffx is much higher than the increased risk of sustaining an ipsilateral peri-implant fracture.

Paper II:

- IMN had lower reoperation rate after one and three years than SHS for unstable trochanteric and subtrochanteric fractures, but not for stable fractures or individual fracture types.
- One-year mortality rate for unstable and stable fractures was lower in patients treated with IMN.
- Patients with unstable fractures treated with an SHS reported a lower EQ-5D-3L index score, inferior walking ability and were less satisfied one year postoperatively than patients treated with an IMN.

Paper III:

- Reoperation rates for different brands of short nails in widespread use in Norway were comparable.
- Use of a short TRIGEN INTERTAN was associated with a subtly increased risk of reoperation compared to the short Gamma3. Most failures occurred when used in unstable fractures contrary to national Norwegian guidelines for treatment of unstable intertrochanteric fractures, reverse obliquity and subtrochanteric fractures, where the recommendation of a long nail is specified, and the clinical importance of this difference is uncertain.
- The TRIGEN TAN/FAN nail was associated with a higher risk of reoperation compared to other long nails in the treatment of trochanteric and subtrochanteric fractures, applicable to both less and more experienced surgeons.

7 Implications of studies

This thesis elaborates on the use of intramedullary nails in the treatment of trochanteric and subtrochanteric fractures. In ***Paper I*** we identified a significant alteration of fracture incidence, localization and morphology indicating a significantly increased risk of a contralateral proximal femoral fracture and a significantly reduced incidence of ipsilateral proximal fractures. The incidence of ipsilateral fractures in the shaft and distal metaphysis was significantly increased, despite the fact that even an osteoporotic femoral shaft should be able to resist the applied forces in the case of a low energy trauma like a fall from standing height. Given the serious nature of peri-implant fractures, further biomechanical studies and clinical research to investigate why IMNs lead to increased fracture rates distal to the implant are called for, as well as similar studies investigating the risk of Sffx after other intra- and extramedullary implants in the treatment of proximal femoral fractures. The results of ***Paper II*** support the recommendations in national and international guidelines suggesting an IMN should be used in A3 and subtrochanteric fractures. Furthermore, we collapsed the presumed unstable fracture types and included A2 fractures in the group of unstable fracture patterns, as only A1 fractures can with certainty be regarded as stable. This decision may of course be questioned, but the existing literature confirms the uncertainty of stability assessment particularly in A2 fractures. Including A2 fractures in the group of unstable fractures might be more clinically relevant and provide a more robust statistical analysis.

The options for surgical treatment of trochanteric and subtrochanteric fractures has been extensively investigated and compared over the past two decades. Although the heterogeneity of A2 fractures still impedes a conclusion upon ideal treatment for this particular group, the orthopaedic community should probably focus on other factors than implant choice to improve outcome for these fragile patients – secondary fracture prevention, optimalisation of physical and mental health, nutrition and maintenance of physical and social activity after a hip fracture. This has also been suggested by senior researchers in the hip fracture register communities[301]. Nevertheless, all modes of treatment must be monitored, and with the development of large national registers with

high completeness and validity, we have a valuable tool for surveillance of outcome. New implants in fracture treatment are introduced regularly, as demonstrated in ***Paper III***, and not necessarily preceded by RCTs comparing them to existing implants as complications are relatively rare and reliable results are difficult to obtain through RCTs given their limited sample sizes and follow-up time. Thus, register-based studies will continue to be important sources in evidence-based treatment of hip fractures.

8 Future perspectives

8.1 Validation of classification models of trochanteric and subtrochanteric fractures

During the research resulting in ***Papers I-III*** we have become further aware of the uncertainty regarding accuracy in the classification of trochanteric and subtrochanteric fractures. In ***Paper I***, all x-ray images were reviewed, revealing several cases of misclassification. A1 fractures were seldom misclassified, but we detected considerable confusion regarding the classification of A2, A3 and subtrochanteric fractures. We have only reviewed images relevant to ***Paper I***, and thus only from patients treated at Østfold Hospital Trust. Previous studies have highlighted only moderate to fair inter- and intraobserver reliability in the AO/OTA classification system regarding proximal femur fractures, particularly with regards to stability assessment of A2 fractures[96,252]. This represents a non-negligible uncertainty when dealing with NHFR data, as we cannot be sure if the classification given in the form filled in by the surgeons is correct. This may have profound implications and we believe a validation of the classification model would be valuable. On the same note, the A2 fractures represent a large percentage of the total number of trochanteric fractures, and it is in this group the uncertainty of not just stability but also choice of implant is most evident. Given the higher cost of an IMN compared to an SHS it is important to determine whether there actually is an advantage to the IMN in this particular group.

8.2 The importance of intramedullary nail length

Nationally and internationally, there is at least a reasonable degree of agreement that A3 and subtrochanteric fractures fractures should be treated with an IMN[58,73,74]. There is still uncertainty regarding the indications of a short versus a long IMN in the existing literature[133,134,260,283]. Further studies to determine whether there is an advantage to a

long nail in any particular fracture types are necessary as there is an additional cost to these implants as well as longer operation time and blood loss.

8.3 Peri-implant fractures

In ***Paper I***, we aimed to investigate the true impact of an IMN by excluding patients with pre-existing implants or sequelae in either femur. Given the serious nature and consequences of a peri-implant fracture, similar studies regarding the impact of other extra- and intramedullar implants such as SHS and femoral stems would be valuable to guide and substantiate implant choice in the treatment of hip fractures.

References

1. Hernlund E, Svedbom A, Ivergård M, Compston J, Cooper C, Stenmark J, McCloskey EV, Jönsson B, Kanis JA. Osteoporosis in the European Union: medical management, epidemiology and economic burden. A report prepared in collaboration with the International Osteoporosis Foundation (IOF) and the European Federation of Pharmaceutical Industry Associations (EFPIA). *Arch Osteoporos*. 2013;8(1):136. doi:10.1007/s11657-013-0136-1

2. Furnes O, Gjertsen JE, Hallan G, Visnes H, Gundersen T, Fenstad AM, Dybvik E, Stenvik S, Kvinnesland I, Mulpuri KS, Solberg M. Annual report 2022: Norwegian Advisory unit on arthroplasty and hip fractures. http://nrlweb.ihelse.net/eng/Rapporter/Report2022_english.pdf2022.

3. Hagen G, Magnussen J, Tell G, Omsland T. Estimating the future burden of hip fractures in Norway. A NOREPOS study. *Bone*. Feb 2020;131:115156. doi:10.1016/j.bone.2019.115156

4. Søgaard AJ, Holvik K, Meyer HE, Tell GS, Gjesdal CG, Emaus N, Grimnes G, Schei B, Forsmo S, Omsland TK. Continued decline in hip fracture incidence in Norway: a NOREPOS study. *Osteoporos Int*. Jul 2016;27(7):2217-2222. doi:10.1007/s00198-016-3516-8

5. Støen RO, Nordsletten L, Meyer HE, Frihagen JF, Falch JA, Lofthus CM. Hip fracture incidence is decreasing in the high incidence area of Oslo, Norway. *Osteoporos Int*. Oct 2012;23(10):2527-34. doi:10.1007/s00198-011-1888-3

6. Meyer AC, Ek S, Drefahl S, Ahlbom A, Hedström M, Modig K. Trends in Hip Fracture Incidence, Recurrence, and Survival by Education and Comorbidity: A Swedish Register-based Study. *Epidemiology*. May 01 2021;32(3):425-433. doi:10.1097/EDE.0000000000001321

7. Collaborators GF. Global, regional, and national burden of bone fractures in 204 countries and territories, 1990-2019: a systematic analysis from the Global Burden of Disease Study 2019. *Lancet Healthy Longev*. Sep 2021;2(9):e580-e592. doi:10.1016/S2666-7568(21)00172-0

8. Omsland TK, Magnus JH. Forecasting the burden of future postmenopausal hip fractures. *Osteoporos Int*. Oct 2014;25(10):2493-6. doi:10.1007/s00198-014-2781-7

9. Johnell O, Kanis JA. An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. *Osteoporos Int*. Dec 2006;17(12):1726-33. doi:10.1007/s00198-006-0172-4

10. Veronese N, Maggi S. Epidemiology and social costs of hip fracture. *Injury*. Aug 2018;49(8):1458-1460. doi:10.1016/j.injury.2018.04.015

11. Berry SD, Samelson EJ, Hannan MT, McLean RR, Lu M, Cupples LA, Schaffer ML, Beiser AL, Kelly-Hayes M, Kiel DP. Second hip fracture in older men and women: the

Framingham Study. *Arch Intern Med*. Oct 08 2007;167(18):1971-6. doi:10.1001/archinte.167.18.1971

12. Batin S, Ozan F, Gurbuz K, Koyuncu S, Vatansever F, Uzun E. Evaluation of Risk Factors for Second Hip Fractures in Elderly Patients. *J Clin Med Res*. Mar 2018;10(3):217-220. doi:10.14740/jocmr3287w

13. Kanis JA, Johnell O, De Laet C, Johansson H, Oden A, Delmas P, Eisman J, Fujiwara S, Garnero P, Kroger H, McCloskey EV, Mellstrom D, Melton LJ, Pols H, Reeve J, Silman A, Tenenhouse A. A meta-analysis of previous fracture and subsequent fracture risk. *Bone*. Aug 2004;35(2):375-82. doi:10.1016/j.bone.2004.03.024S8756328204001309 [pii]

14. Bertram M, Norman R, Kemp L, Vos T. Review of the long-term disability associated with hip fractures. *Inj Prev*. Dec 2011;17(6):365-70. doi:10.1136/ip.2010.029579

15. Leibson CL, Tosteson AN, Gabriel SE, Ransom JE, Melton LJ. Mortality, disability, and nursing home use for persons with and without hip fracture: a population-based study. *J Am Geriatr Soc*. Oct 2002;50(10):1644-50. doi:10.1046/j.1532-5415.2002.50455.x

16. Griffin XL, Achten J, Parsons N, Costa ML, WHiTE collaborators. Does performance-based remuneration improve outcomes in the treatment of hip fracture? *Bone Joint J*. May 2021;103-B(5):881-887. doi:10.1302/0301-620X.103B5.BJJ-2020-1839.R1

17. Figved W, Myrstad M, Saltvedt I, Finjarn M, Flaten Odland LM, Frihagen F. Team Approach: Multidisciplinary Treatment of Hip Fractures in Elderly Patients: Orthogeriatric Care. *JBJS Rev*. Jun 2019;7(6):e6. doi:10.2106/JBJS.RVW.18.00136

18. Pioli G, Bendini C, Pignedoli P, Giusti A, Marsh D. Orthogeriatric co-management - managing frailty as well as fragility. *Injury*. Aug 2018;49(8):1398-1402. doi:10.1016/j.injury.2018.04.014

19. Steffensmeier A, Hoge C, Shah N, Matar R, Rice M, Grawe E, Held J, Budde B, Laughlin R, Sagi HC. Evaluation of a Novel Multidisciplinary Preoperative Workup Strategy for Geriatric Hip Fractures. *J Orthop Trauma*. Aug 01 2022;36(8):413-419. doi:10.1097/BOT.0000000000002342

20. Dakhil S, Thingstad P, Frihagen F, Johnsen LG, Lydersen S, Skovlund E, Wyller TB, Sletvold O, Saltvedt I, Watne LO. Orthogeriatrics prevents functional decline in hip fracture patients: report from two randomized controlled trials. *BMC Geriatr*. Mar 25 2021;21(1):208. doi:10.1186/s12877-021-02152-7

21. Ekhtiari S, Gormley J, Axelrod DE, Devji T, Bhandari M, Guyatt GH. Total Hip Arthroplasty Versus Hemiarthroplasty for Displaced Femoral Neck Fracture: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *J Bone Joint Surg Am*. Sep 16 2020;102(18):1638-1645. doi:10.2106/JBJS.20.00226

22. Frihagen F, Comeau-Gauthier M, Axelrod D, Bzovsky S, Poolman R, Heels-Ansdell D, Bhandari M, Sprague S, Schemitsch E, HEALTH Investigators. Who, if anyone,

may benefit from a total hip arthroplasty after a displaced femoral neck fracture?: a post hoc subgroup analysis of the HEALTH trial. *Bone Jt Open*. Aug 2022;3(8):611-617. doi:10.1302/2633-1462.38.BJO-2022-0074.R1

23. Bhandari M, Devereaux PJ, Einhorn TA, Thabane L, Schemitsch E, Koval KJ, Frihagen F, Poolman RW, Tetsworth K, Guerra-Farfan E, Madden K, Sprague S, Guyatt G, HEALTH Investigators. Hip fracture evaluation with alternatives of total hip arthroplasty versus hemiarthroplasty (HEALTH): protocol for a multicentre randomised trial. *BMJ Open*. Feb 13 2015;5(2):e006263. doi:10.1136/bmjopen-2014-006263

24. Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research C. Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of Orthopaedic Surgery Database. *J Bone Joint Surg Am*. Apr 2008;90(4):700-7. doi:10.2106/JBJS.G.00517

25. Barton TM, Gleeson R, Topliss C, Greenwood R, Harries WJ, Chesser TJ. A comparison of the long gamma nail with the sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur: a prospective randomized trial. *J Bone Joint Surg Am*. Apr 2010;92(4):792-8. doi:10.2106/JBJS.I.00508

26. Bohl DD, Basques BA, Golinvaux NS, Miller CP, Baumgaertner MR, Grauer JN. Extramedullary compared with intramedullary implants for intertrochanteric hip fractures: thirty-day outcomes of 4432 procedures from the ACS NSQIP database. *J Bone Joint Surg Am*. Nov 19 2014;96(22):1871-7. doi:10.2106/JBJS.N.00041

27. Dunn J, Kusnezov N, Bader J, Waterman BR, Orr J, Belmont PJ. Long versus short cephalomedullary nail for trochanteric femur fractures (OTA 31-A1, A2 and A3): a systematic review. *J Orthop Traumatol*. Dec 2016;17(4):361-367. doi:10.1007/s10195-016-0405-z

28. Gardner MJ, Silva MJ, Krieg JC. Biomechanical testing of fracture fixation constructs: variability, validity, and clinical applicability. *J Am Acad Orthop Surg*. Feb 2012;20(2):86-93. doi:10.5435/JAAOS-20-02-086

29. Kruse M, Mohammed J, Sayed-Noor A, Wolf O, Holmgren G, Nordström R, Crnalic S, Sköldenberg O, Mukka S. Peri-implant femoral fractures in hip fracture patients treated with osteosynthesis: a retrospective cohort study of 1965 patients. *Eur J Trauma Emerg Surg*. Feb 2022;48(1):293-298. doi:10.1007/s00068-020-01596-7

30. Evaniew N, Bhandari M. Cochrane in CORR ®: Intramedullary nails for extracapsular hip fractures in adults (review). *Clin Orthop Relat Res*. Mar 2015;473(3):767-74. doi:10.1007/s11999-014-4123-7

31. Berggren M, Stenvall M, Englund U, Olofsson B, Gustafson Y. Co-morbidities, complications and causes of death among people with femoral neck fracture - a three-year follow-up study. *BMC Geriatr*. Jun 03 2016;16:120. doi:10.1186/s12877-016-0291-5

32. Abraham DS, Barr E, Ostir GV, Hebel JR, Golden J, Gruber-Baldini AL, Guralnik JM, Hochberg MC, Orwig DL, Resnick B, Magaziner JS. Residual Disability, Mortality, and Nursing Home Placement After Hip Fracture Over 2 Decades. *Arch Phys Med Rehabil*. May 2019;100(5):874-882. doi:10.1016/j.apmr.2018.10.008

33. Bowers TM, Parker MJ. Assessment of outcome after hip fracture: development of a universal assessment system for hip fractures. *SICOT J*. 2016;2:27. doi:10.1051/sicotj/2016018

34. Dyer SM, Crotty M, Fairhall N, Magaziner J, Beaupre LA, Cameron ID, Sherrington C, FFN Rehabilitation Research Special Interest Group. A critical review of the long-term disability outcomes following hip fracture. *BMC Geriatr*. Sep 02 2016;16(1):158. doi:10.1186/s12877-016-0332-0

35. Forssten MP, Mohammad Ismail A, Ioannidis I, Wretenberg P, Borg T, Cao Y, Ribieiro Jr MAF, Mohseni S. The mortality burden of frailty in hip fracture patients: a nationwide retrospective study of cause-specific mortality. *Eur J Trauma Emerg Surg*. Dec 26 2022;doi:10.1007/s00068-022-02204-6

36. Mattisson L, Bojan A, Enocson A. Epidemiology, treatment and mortality of trochanteric and subtrochanteric hip fractures: data from the Swedish fracture register. *BMC Musculoskelet Disord*. Oct 12 2018;19(1):369. doi:10.1186/s12891-018-2276-3

37. Vestergaard P, Rejnmark L, Mosekilde L. Increased mortality in patients with a hip fracture-effect of pre-morbid conditions and post-fracture complications. *Osteoporos Int*. Dec 2007;18(12):1583-93. doi:10.1007/s00198-007-0403-3

38. Lunde A, Tell GS, Pedersen AB, Scheike TH, Apalset EM, Ehrenstein V, Sørensen HT. The Role of Comorbidity in Mortality After Hip Fracture: A Nationwide Norwegian Study of 38,126 Women With Hip Fracture Matched to a General-Population Comparison Cohort. *Am J Epidemiol*. Feb 01 2019;188(2):398-407. doi:10.1093/aje/kwy251

39. Lystad RP, Cameron CM, Mitchell RJ. Mortality risk among older Australians hospitalised with hip fracture: a population-based matched cohort study. *Arch Osteoporos*. Dec 2017;12(1):67. doi:10.1007/s11657-017-0359-7

40. Katsoulis M, Benetou V, Karapetyan T, Feskanich D, Grodstein F, Pettersson-Kymmer U, Eriksson S, Wilsgaard T, Jørgensen L, Ahmed LA, Schöttker B, Brenner H, Bellavia A, Wolk A, Kubinova R, Stegeman B, Bobak M, Boffetta P, Trichopoulo A. Excess mortality after hip fracture in elderly persons from Europe and the USA: the CHANCES project. *J Intern Med*. Mar 2017;281(3):300-310. doi:10.1111/joim.12586

41. Rockwood K, Song X, MacKnight C, Bergman H, Hogan DB, McDowell I, Mitnitski A. A global clinical measure of fitness and frailty in elderly people. *CMAJ*. Aug 30 2005;173(5):489-95. doi:10.1503/cmaj.050051

42. Subramaniam S, Aalberg JJ, Soriano RP, Divino CM. New 5-Factor Modified Frailty Index Using American College of Surgeons NSQIP Data. *J Am Coll Surg*. Feb 2018;226(2):173-181.e8. doi:10.1016/j.jamcollsurg.2017.11.005

43. Avenell A, Smith TO, Curtain JP, Mak JC, Myint PK. Nutritional supplementation for hip fracture aftercare in older people. *Cochrane Database Syst Rev*. Nov 30 2016;11(11):CD001880. doi:10.1002/14651858.CD001880.pub6

44. Kjærvik C, Gjertsen JE, Stensland E, Saltyte-Benth J, Soereide O. Modifiable and non-modifiable risk factors in hip fracture mortality in Norway, 2014 to 2018 : a linked multiregistry study. *Bone Joint J*. Jul 2022;104-B(7):884-893. doi:10.1302/0301-620X.104B7.BJJ-2021-1806.R1

45. Forssten MP, Ioannidis I, Mohammad Ismail A, Bass GA, Borg T, Cao Y, Mohseni S. Dementia is a surrogate for frailty in hip fracture mortality prediction. *Eur J Trauma Emerg Surg*. Oct 2022;48(5):4157-4167. doi:10.1007/s00068-022-01960-9

46. Åhman R, Siverhall PF, Snygg J, Fredrikson M, Enlund G, Björnström K, Chew MS. Determinants of mortality after hip fracture surgery in Sweden: a registry-based retrospective cohort study. *Sci Rep*. Oct 24 2018;8(1):15695. doi:10.1038/s41598-018-33940-8

47. Kjaervik C, Gjertsen JE, Engeseter LB, Stensland E, Dybvik E, Soereide O. Waiting time for hip fracture surgery: hospital variation, causes, and effects on postoperative mortality : data on 37,708 operations reported to the Norwegian Hip fracture Register from 2014 to 2018. *Bone Jt Open*. Sep 2021;2(9):710-720. doi:10.1302/2633-1462.29.BJO-2021-0079.R1

48. Schemitsch E, Adachi JD, Brown JP, Tarride JE, Burke N, Oliveira T, Slatkovska L. Hip fracture predicts subsequent hip fracture: a retrospective observational study to support a call to early hip fracture prevention efforts in post-fracture patients. *Osteoporos Int*. Jan 2022;33(1):113-122. doi:10.1007/s00198-021-06080-5

49. Holt G, Smith R, Duncan K, Hutchison JD, Gregori A, Reid D. Outcome after sequential hip fracture in the elderly. *J Bone Joint Surg Am*. Oct 03 2012;94(19):1801-8. doi:10.2106/JBJS.J.01539

50. Nymark T, Lauritsen JM, Ovesen O, Röck ND, Jeune B. Short time-frame from first to second hip fracture in the Funen County Hip Fracture Study. *Osteoporos Int*. 2006;17(9):1353-7. doi:10.1007/s00198-006-0125-y

51. Ryg J, Rejnmark L, Overgaard S, Brixen K, Vestergaard P. Hip fracture patients at risk of second hip fracture: a nationwide population-based cohort study of 169,145 cases during 1977-2001. *J Bone Miner Res*. Jul 2009;24(7):1299-307. doi:10.1359/jbmr.090207

52. Center JR, Bliuc D, Nguyen TV, Eisman JA. Risk of subsequent fracture after low-trauma fracture in men and women. *JAMA*. Jan 24 2007;297(4):387-94. doi:10.1001/jama.297.4.387

53. Dretakis KE, Dretakis EK, Papakitsou EF, Psarakis S, Steriopoulos K. Possible predisposing factors for the second hip fracture. *Calcif Tissue Int*. Apr 1998;62(4):366-9. doi:10.1007/s002239900446

54. Karlsson M, Nilsson JA, Sernbo I, Redlund-Johnell I, Johnell O, Obrant KJ. Changes of bone mineral mass and soft tissue composition after hip fracture. *Bone*. Jan 1996;18(1):19-22. doi:10.1016/8756-3282(95)00422-x

55. Dirschl DR, Henderson RC, Oakley WC. Accelerated bone mineral loss following a hip fracture: a prospective longitudinal study. *Bone*. Jul 1997;21(1):79-82. doi:10.1016/s8756-3282(97)00082-3

56. Karlsson MK, Obrant KJ, Nilsson BE, Johnell O. Bone mineral density assessed by quantitative ultrasound and dual energy X-ray absorptiometry. Normative data in Malmö, Sweden. *Acta Orthop Scand*. Apr 1998;69(2):189-93. doi:10.3109/17453679809117626

57. Johnell O, Kanis JA. An estimate of the worldwide prevalence, mortality and disability associated with hip fracture. *Osteoporos Int*. Nov 2004;15(11):897-902. doi:10.1007/s00198-004-1627-0

58. Centre NCG. The Management of Hip Fracture in Adults. London: National Clinical Guideline Centre: London: National Clinical Guideline Centre Available from: www.ncgc.ac.uk; 2011.

59. Meyer HE, Berntsen GK, Søgaard AJ, Langhammer A, Schei B, Fønnebø V, Forsmo S, Tell GS, NOREPOS Resaearch Group. Higher bone mineral density in rural compared with urban dwellers: the NOREPOS study. *Am J Epidemiol*. Dec 01 2004;160(11):1039-46. doi:10.1093/aje/kwh337

60. Johnell O, Gullberg B, Kanis JA, Allander E, Elffors L, Dequeker J, Dilsen G, Gennari C, Lopes Vaz A, Lyritis G. Risk factors for hip fracture in European women: the MEDOS Study. Mediterranean Osteoporosis Study. *J Bone Miner Res*. Nov 1995;10(11):1802-15. doi:10.1002/jbmr.5650101125

61. Emaus N, Wilsgaard T, Ahmed LA. Impacts of body mass index, physical activity, and smoking on femoral bone loss: the Tromsø study. *J Bone Miner Res*. Sep 2014;29(9):2080-9. doi:10.1002/jbmr.2232

62. Ström O, Lauppe R, Ljunggren Ö, Spångeus A, Ortsäter G, O'Kelly J, Åkesson K. Real-world effectiveness of osteoporosis treatment in the oldest old. *Osteoporos Int*. Aug 2020;31(8):1525-1533. doi:10.1007/s00198-020-05380-6

63. Yusuf AA, Cummings SR, Watts NB, Feudjo MT, Sprafka JM, Zhou J, Guo H, Balasumbrian A, Cooper C. Real-world effectiveness of osteoporosis therapies for fracture reduction in post-menopausal women. *Arch Osteoporos*. Mar 21 2018;13(1):33. doi:10.1007/s11657-018-0439-3

64. Abrahamsen B, Eiken P, Prieto-Alhambra D, Eastell R. Risk of hip, subtrochanteric, and femoral shaft fractures among mid and long term users of alendronate: nationwide cohort and nested case-control study. *BMJ*. Jun 28 2016;353:i3365. doi:10.1136/bmj.i3365

65. Bergland A, Wyller TB. Risk factors for serious fall related injury in elderly women living at home. *Inj Prev*. Oct 2004;10(5):308-13. doi:10.1136/ip.2003.004721

66. Secretariat MA. Prevention of falls and fall-related injuries in community-dwelling seniors: an evidence-based analysis. *Ont Health Technol Assess Ser*. 2008;8(2):1-78.

67. Kannus P, Parkkari J, Niemi S, Pasanen M, Palvanen M, Järvinen M, Vuori I Prevention of hip fracture in elderly people with use of a hip protector. *N Engl J Med*. Nov 23 2000;343(21):1506-13. doi:10.1056/NEJM200011233432101

68. van Schoor NM, Smit JH, Twisk JW, Bouter LM, Lips P. Prevention of hip fractures by external hip protectors: a randomized controlled trial. *JAMA*. Apr 16 2003;289(15):1957-62. doi:10.1001/jama.289.15.1957

69. Lauritzen JB, Petersen MM, Lund B. Effect of external hip protectors on hip fractures. *Lancet*. Jan 02 1993;341(8836):11-3. doi:10.1016/0140-6736(93)92480-h

70. Santesso N, Carrasco-Labra A, Brignardello-Petersen R. Hip protectors for preventing hip fractures in older people. *Cochrane Database Syst Rev*. Mar 31 2014;(3):CD001255. doi:10.1002/14651858.CD001255.pub5

71. Söreskog E, Ström O, Spångéus A, Åkesson KE, Borgström F, Banefelt J, Toth E, Libanati C, Charokopou M Risk of major osteoporotic fracture after first, second and third fracture in Swedish women aged 50 years and older. *Bone*. May 2020;134:115286. doi:10.1016/j.bone.2020.115286

72. Akesson K, Marsh D, Mitchell PJ, McLellan AR, Stenmark J, Pierroz DD, Kyer C, Cooper C, IOF Fracture Working Group Capture the Fracture: a Best Practice Framework and global campaign to break the fragility fracture cycle. *Osteoporos Int*. Aug 2013;24(8):2135-52. doi:10.1007/s00198-013-2348-z

73. Surgeons AAoO. American Academy of Orthopaedic Surgeons Management of Hip Fractures in Older Adults Evidence-Based Clinical Practice Guideline. Published 12/03/2021. American Academy of Orthopaedic Surgeons.

74. Ranhoff AH, Saltvedt I, Frihagen F, Raeder J, Maini S, Sletvold O. Interdisciplinary care of hip fractures.: Orthogeriatric models, alternative models, interdisciplinary teamwork. *Best Pract Res Clin Rheumatol*. 04 2019;33(2):205-226. doi:10.1016/j.berh.2019.03.015

75. Järvinen TL, Michaëlsson K, Jokihaara J, Collins GS, Perry TL, Mintzes B, Musini V, Erviri J, Wright JM, Sievänen H Overdiagnosis of bone fragility in the quest to prevent hip fracture. *BMJ*. May 26 2015;350:h2088. doi:10.1136/bmj.h2088

76. Boudou L, Gerbay B, Chopin F, Ollagnier E, Collet P, Thomas T. Management of osteoporosis in fracture liaison service associated with long-term adherence to treatment. *Osteoporos Int*. Jul 2011;22(7):2099-106. doi:10.1007/s00198-011-1638-6

77. Zerahn B, Olsen C, Stephensen S, Kanstrup IL, Schwarz Lausten G. Bone loss after hip fracture is correlated to the postoperative degree of mobilisation. *Arch Orthop Trauma Surg*. 1998;117(8):453-6. doi:10.1007/s004020050291

78. Enocson A, Wolf O. Pipkin fractures: epidemiology and outcome. *Eur J Trauma Emerg Surg*. Oct 2022;48(5):4113-4118. doi:10.1007/s00068-022-01951-w

79. Van Embden D, Rhemrev SJ, Genelin F, Meylaerts SA, Roukema GR. The reliability of a simplified Garden classification for intracapsular hip fractures. *Orthop Traumatol Surg Res*. Jun 2012;98(4):405-8. doi:10.1016/j.otsr.2012.02.003

80. Cazzato G, Oliva MS, Masci G, Vitiello R, Smimmo A, Matrangolo MR, Palmacci O, D'Adamio S, Ziranu A Femoral neck fracture: the reliability of radiologic classifications. *BMC Musculoskelet Disord*. Jan 25 2022;22(Suppl 2):1063. doi:10.1186/s12891-022-05007-3

81. Pauwels F. Der schenkelhalsbruch: ein mechanisches Problem. Springer Berlin Heidelberg; 1965.

82. Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and Dislocation Classification Compendium-2018. *J Orthop Trauma*. Jan 2018;32 Suppl 1:S1-S170. doi:10.1097/BOT.0000000000001063

83. Dolatowski FC, Adampour M, Frihagen F, Stavem K, Erik Utvåg S, Hoelsbrekken SE. Preoperative posterior tilt of at least 20° increased the risk of fixation failure in Garden-I and -II femoral neck fractures. *Acta Orthop*. Jun 2016;87(3):252-6. doi:10.3109/17453674.2016.1155253

84. Clement ND, Green K, Murray N, Duckworth AD, McQueen MM, Court-Brown CM. Undisplaced intracapsular hip fractures in the elderly: predicting fixation failure and mortality. A prospective study of 162 patients. *J Orthop Sci*. Jul 2013;18(4):578-85. doi:10.1007/s00776-013-0400-7

85. Biz C, Tagliapietra J, Zonta F, Belluzzi E, Bragazzi NL, Ruggieri P. Predictors of early failure of the cannulated screw system in patients, 65 years and older, with non-displaced femoral neck fractures. *Aging Clin Exp Res*. Mar 2020;32(3):505-513. doi:10.1007/s40520-019-01394-1

86. Kalsbeek J, van Walsum A, Roerdink H, Schipper I. More than 20° posterior tilt of the femoral head in undisplaced femoral neck fractures results in a four times higher risk of treatment failure. *Eur J Trauma Emerg Surg*. Apr 2022;48(2):1343-1350. doi:10.1007/s00068-021-01673-5

87. Okike K, Udogwu UN, Isaac M, Sprague S, Swiontkowski MF, Bhandari M, Slobogean GP, FAITH Investigators Not All Garden-I and II Femoral Neck Fractures in the Elderly Should Be Fixed: Effect of Posterior Tilt on Rates of Subsequent Arthroplasty. *J Bone Joint Surg Am*. Oct 16 2019;101(20):1852-1859. doi:10.2106/JBJS.18.01256

88. Pervez H, Parker MJ, Pryor GA, Lutchman L, Chirodian N. Classification of trochanteric fracture of the proximal femur: a study of the reliability of current systems. *Injury*. Oct 2002;33(8):713-5. doi:10.1016/s0020-1383(02)00089-x

89. Evans EM. The treatment of trochanteric fractures of the femur. *J Bone Joint Surg Br*. May 1949;31B(2):190-203.

90. Ramadier JO, Duparc J, Rougemont D, De Ferrari G. [Surgical treatment of trochanteric and juxta-trochanteric fractures]. *Rev Chir Orthop Reparatrice Appar Mot*. Dec 1956;42(6):759-82; discussion, 782-6.

91. Decoulx P, Lavarde G. [Fractures of the trochanteric region. A statistical study of 2,612 cases]. *J Chir (Paris)*. 1969;98(1):75-100.

92. Nakano T. Proximal femoral fracture. Seikeigeka (Orthopaedics)2014. p. 842-850.

93. Jensen JS. Classification of trochanteric fractures. *Acta Orthop Scand*. Oct 1980;51(5):803-10. doi:10.3109/17453678008990877

94. Tronzo RG. The use of an endoprosthesis for severely comminuted trochanteric fractures. *Orthop Clin North Am*. Oct 1974;5(4):679-81.

95. Andersen E, Jørgensen LG, Hededam LT. Evans' classification of trochanteric fractures: an assessment of the interobserver and intraobserver reliability. *Injury*. Nov 1990;21(6):377-8. doi:10.1016/0020-1383(90)90123-c

96. Chan G, Hughes K, Barakat A, Edres K, daAssuncao R, Page P, Dawe E Inter- and intra-observer reliability of the new AO/OTA classification of proximal femur fractures. *Injury*. Jun 2021;52(6):1434-1437. doi:10.1016/j.injury.2020.10.067

97. Knutsson SB, Wennergren D, Bojan A, Ekelund J, Möller M. Femoral fracture classification in the Swedish Fracture Register - a validity study. *BMC Musculoskelet Disord*. May 08 2019;20(1):197. doi:10.1186/s12891-019-2579-z

98. F. S. Subtrochanteric fractures of the femur. J Bone Joint Surg Am.1978. p. 300-6.

99. Loizou CL, McNamara I, Ahmed K, Pryor GA, Parker MJ. Classification of subtrochanteric femoral fractures. *Injury*. Jul 2010;41(7):739-45. doi:10.1016/j.injury.2010.02.018

100. Rizkalla JM, Nimmons SJB, Jones AL. Classifications in Brief: The Russell-Taylor Classification of Subtrochanteric Hip Fracture. *Clin Orthop Relat Res*. Jan 2019;477(1):257-261. doi:10.1097/CORR.0000000000000505

101. İmerci A, Aydogan NH, Tosun K. Evaluation of inter- and intra-observer reliability of current classification systems for subtrochanteric femoral fractures. *Eur J Orthop Surg Traumatol*. Apr 2018;28(3):499-502. doi:10.1007/s00590-017-2065-y

102. Guyver PM, McCarthy MJ, Jain NP, Poulter RJ, McAllen CJ, Keenan J. Is there any purpose in classifying subtrochanteric fractures? The reproducibility of four

classification systems. *Eur J Orthop Surg Traumatol*. May 2014;24(4):513-8. doi:10.1007/s00590-011-0780-3

103. Hsu CE, Shih CM, Wang CC, Huang KC. Lateral femoral wall thickness. A reliable predictor of post-operative lateral wall fracture in intertrochanteric fractures. *Bone Joint J*. Aug 2013;95-B(8):1134-8. doi:10.1302/0301-620X.95B8.31495

104. Palm H, Jacobsen S, Sonne-Holm S, Gebuhr P, Group HFS. Integrity of the lateral femoral wall in intertrochanteric hip fractures: an important predictor of a reoperation. *J Bone Joint Surg Am*. Mar 2007;89(3):470-5. doi:10.2106/JBJS.F.00679

105. Bekos A, Sioutis S, Kostroglou A, Saranteas T, Mavrogenis AF. The history of intramedullary nailing. *Int Orthop*. May 2021;45(5):1355-1361. doi:10.1007/s00264-021-04973-y

106. Kempf I, Grosse A, Beck G. Closed locked intramedullary nailing. Its application to comminuted fractures of the femur. *J Bone Joint Surg Am*. Jun 1985;67(5):709-20.

107. Cole JD, Ansel LJ. Intramedullary nail and lag-screw fixation of proximal femur fractures. Operative technique and preliminary results. *Orthop Rev*. Feb 1994;Suppl:35-44.

108. Russell TA. Intramedullary nailing: evolutions of femoral intramedullary nailing: first to fourth generations. *J Orthop Trauma*. Dec 2011;25 Suppl 3:S135-8. doi:10.1097/BOT.0b013e318237b2eb

109. Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. *Cochrane Database Syst Rev*. Sep 8 2010;(9):CD000093. doi:10.1002/14651858.CD000093.pub5

110. Bhandari M, Schemitsch E, Jonsson A, Zlowodzki M, Haidukewych GJ. Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. *J Orthop Trauma*. Jul 2009;23(6):460-4. doi:10.1097/BOT.0b013e318162f67f

111. Bartoníček J, Rammelt S. The history of internal fixation of proximal femur fractures Ernst Pohl-the genius behind. *Int Orthop*. Nov 2014;38(11):2421-6. doi:10.1007/s00264-014-2320-3

112. Pohl E. Verbindungsvorrichtung für gelenkanahe Knochenbrüche. 1951.

113. Danis R. Théorie et pratique de l'ostéosynthèse. Soulisse-Martin; 1949.

114. Clawson DK. Trochanteric fractures treated by the sliding screw plate fixation method. *J Trauma*. Nov 1964;4:737-52. doi:10.1097/00005373-196411000-00001

115. Pankovich AM, Tarabishy IE. Ender nailing of intertrochanteric and subtrochanteric fractures of the femur. *J Bone Joint Surg Am*. 1980;62(4):635-45.

116. Kuderna H, Böhler N, Collon DJ. Treatment of intertrochanteric and subtrochanteric fractures of the hip by the Ender method. *J Bone Joint Surg Am*. Jul 1976;58(5):604-11.

117. Ender H. Treatment of pertrochanteric and subtrochanteric fractures of the femur with Ender pins. Hip1978.

118. Ender J. Die Fixierung trochanterer Brüche mit runden elastischen Condylennageln. Acta Chir Austriaca1970. p. 40-42.

119. Levy RN, Siegel M, Sedlin ED, Siffert RS. Complications of Ender-pin fixation in basicervical, intertrochanteric, and subtrochanteric fractures of the hip. *J Bone Joint Surg Am*. Jan 1983;65(1):66-9.

120. Jones CW, Morris J, Hirschowitz D, Hart GM, Shea J, Arden GP. A comparison of the treatment of trochanteric fractures of the femur by internal fixation with a nail plate and the Ender technique. *Injury*. Aug 1977;9(1):35-42. doi:10.1016/0020-1383(77)90047-x

121. Hall G, Ainscow DA. Comparison of nail-plate fixation and Ender's nailing for intertrochanteric fractures. *J Bone Joint Surg Br*. Feb 1981;63-B(1):24-8. doi:10.1302/0301-620X.63B1.7204468

122. Sahlstrand T. The Richards compression and sliding hip screw system in the treatment of intertrochanteric fractures. *Acta Orthop Scand*. 1974;45(2):213-9. doi:10.3109/17453677408989142

123. Regazzoni P. The dynamic hip screw implant system. Springer, Berlin1985.

124. Ecker ML, Joyce JJ, Kohl EJ. The treatment of trochanteric hip fractures using a compression screw. *J Bone Joint Surg Am*. Jan 1975;57(1):23-7.

125. Shin ED, Sandhu KP, Wiseley BR, Hetzel S, Winzenreid AE, Simske NN, Johnson KP, Goodspeed DC, Doro CJ, Whiting PS Mortality Rates Following Non-Operative Geriatric Hip Fracture Treatment: A Matched Cohort Analysis. *J Orthop Trauma*. Dec 21 2022;doi:10.1097/BOT.0000000000002549

126. Lewis SR, Macey R, Stokes J, Cook JA, Eardley WG, Griffin XL. Surgical interventions for treating intracapsular hip fractures in older adults: a network meta-analysis. *Cochrane Database Syst Rev*. Feb 14 2022;2(2):CD013404. doi:10.1002/14651858.CD013404.pub2

127. Lewis SR, Macey R, Lewis J, Stokes J, Gill JR, Cook JA, Eardley WG, Parker MJ, Griffin XL Surgical interventions for treating extracapsular hip fractures in older adults: a network meta-analysis. *Cochrane Database Syst Rev*. Feb 10 2022;2(2):CD013405. doi:10.1002/14651858.CD013405.pub2

128. Rosenblum SF, Zuckerman JD, Kummer FJ, Tam BS. A biomechanical evaluation of the Gamma nail. *J Bone Joint Surg Br*. May 1992;74(3):352-7. doi:10.1302/0301-620X.74B3.1587875

129. Curtis MJ, Jinnah RH, Wilson V, Cunningham BW. Proximal femoral fractures: a biomechanical study to compare intramedullary and extramedullary fixation. *Injury*. Mar 1994;25(2):99-104. doi:10.1016/0020-1383(94)90111-2

130. Queally JM, Harris E, Handoll HH, Parker MJ. Intramedullary nails for extracapsular hip fractures in adults. *Cochrane Database Syst Rev*. Sep 12 2014;(9):CD004961. doi:10.1002/14651858.CD004961.pub4

131. Bretherton CP, Parker MJ. Femoral Medialization, Fixation Failures, and Functional Outcome in Trochanteric Hip Fractures Treated With Either a Sliding Hip Screw or an Intramedullary Nail From Within a Randomized Trial. *J Orthop Trauma*. Dec 2016;30(12):642-646. doi:10.1097/BOT.0000000000000689

132. Brox WT, Roberts KC, Taksali S, et al The American Academy of Orthopaedic Surgeons Evidence-Based Guideline on Management of Hip Fractures in the Elderly. *J Bone Joint Surg Am*. Jul 15 2015;97(14):1196-9. doi:10.2106/JBJS.O.00229

133. Viberg B, Eriksen L, Højsager KD, Højsager FD, Lauritsen J, Palm H, Overgaard S Should Pertrochanteric and Subtrochanteric Fractures Be Treated with a Short or Long Intramedullary Nail?: A Multicenter Cohort Study. *J Bone Joint Surg Am*. Dec 15 2021;103(24):2291-2298. doi:10.2106/JBJS.20.01904

134. Page PRJ, Poole WEC, Shah K, Upadhyay PK. Short or long intramedullary devices for hip fracture? A systematic review of the evidence. *J Orthop*. Nov-Dec 2020;22:377-382. doi:10.1016/j.jor.2020.08.030

135. Kleweno C, Morgan J, Redshaw J, Harris M, Rodriguez E, Zurakowski D, Vrahas M, Appleton P Short versus long cephalomedullary nails for the treatment of intertrochanteric hip fractures in patients older than 65 years. *J Orthop Trauma*. Jul 2014;28(7):391-7. doi:10.1097/BOT.0000000000000036

136. Chirodian N, Arch B, Parker MJ. Sliding hip screw fixation of trochanteric hip fractures: outcome of 1024 procedures. *Injury*. Jun 2005;36(6):793-800. doi:10.1016/j.injury.2005.01.017

137. Madsen JE, Naess L, Aune AK, Alho A, Ekeland A, Strømsøe K. Dynamic hip screw with trochanteric stabilizing plate in the treatment of unstable proximal femoral fractures: a comparative study with the Gamma nail and compression hip screw. *J Orthop Trauma*. May 1998;12(4):241-8. doi:10.1097/00005131-199805000-00005

138. Alm CE, Gjertsen JE, Basso T, Matre K, Röhrl, Madsen JE, Frihagen F Trochanteric stabilizing plate in the treatment of trochanteric fractures: a scoping review. *Acta Orthop*. Dec 2021;92(6):733-738. doi:10.1080/17453674.2021.1954305

139. Pervez H, Parker MJ, Vowler S. Prediction of fixation failure after sliding hip screw fixation. *Injury*. Oct 2004;35(10):994-8. doi:10.1016/j.injury.2003.10.028

140. Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM. The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. *J Bone Joint Surg Am*. Jul 1995;77(7):1058-64. doi:10.2106/00004623-199507000-00012

141. Helwig P, Faust G, Hindenlang U, Hirschmüller A, Konstantinidis L, Bahrs C, Südkamp N, Schneider R Finite element analysis of four different implants inserted in different positions to stabilize an idealized trochanteric femoral fracture. *Injury*. Mar 2009;40(3):288-95. doi:10.1016/j.injury.2008.08.016

142. Kashigar A, Vincent A, Gunton MJ, Backstein D, Safir O, Kuzyk PR. Predictors of failure for cephalomedullary nailing of proximal femoral fractures. *Bone Joint J*. Aug 2014;96-B(8):1029-34. doi:10.1302/0301-620X.96B8.33644

143. Tucker A, Warnock M, McDonald S, Cusick L, Foster AP. Fatigue failure of the cephalomedullary nail: revision options, outcomes and review of the literature. *Eur J Orthop Surg Traumatol*. Apr 2018;28(3):511-520. doi:10.1007/s00590-017-2059-9

144. Marmor M, Liddle K, Buckley J, Matityahu A. Effect of varus and valgus alignment on implant loading after proximal femur fracture fixation. *Eur J Orthop Surg Traumatol*. May 2016;26(4):379-83. doi:10.1007/s00590-016-1746-2

145. Gupta RK, Sangwan K, Kamboj P, Punia SS, Walecha P. Unstable trochanteric fractures: the role of lateral wall reconstruction. *Int Orthop*. Feb 2010;34(1):125-9. doi:10.1007/s00264-009-0744-y

146. Norris R, Bhattacharjee D, Parker MJ. Occurrence of secondary fracture around intramedullary nails used for trochanteric hip fractures: a systematic review of 13,568 patients. *Injury*. Jun 2012;43(6):706-11. doi:10.1016/j.injury.2011.10.027

147. Müller F, Galler M, Zellner M, Bäuml C, Marzouk A, Füchtmeier B. Peri-implant femoral fractures: The risk is more than three times higher within PFN compared with DHS. *Injury*. Oct 2016;47(10):2189-2194. doi:10.1016/j.injury.2016.04.042

148. Lewis SR, Macey R, Gill JR, Parker MJ, Griffin XL. Cephalomedullary nails versus extramedullary implants for extracapsular hip fractures in older adults. *Cochrane Database Syst Rev*. Jan 26 2022;1(1):CD000093. doi:10.1002/14651858.CD000093.pub6

149. Mingo-Robinet J, Torres-Torres M, Martínez-Cervell C, Del Olmo JAA, Laso JAR, Aguando-Hernandez H, Buron-Alvares I Comparative study of the second and third generation of gamma nail for trochanteric fractures: review of 218 cases. *J Orthop Trauma*. Mar 2015;29(3):e85-90. doi:10.1097/BOT.0000000000000190

150. Pascarella R, Fantasia R, Maresca A, Bettuzzi C, Amendola L, Violini S, Cuoghi F, Sangiovanni P, Cerbasi S, Boriani S, Tigani DS How evolution of the nailing system improves results and reduces orthopedic complications: more than 2000 cases of trochanteric fractures treated with the Gamma Nail System. *Musculoskelet Surg*. Apr 2016;100(1):1-8. doi:10.1007/s12306-015-0391-y

151. Georgiannos D, Lampridis V, Bisbinas I. Complications following Treatment of Trochanteric Fractures with the Gamma3 Nail: Is the Latest Version of Gamma Nail Superior to Its Predecessor? *Surg Res Pract*. 2014;2014:143598. doi:10.1155/2014/143598

152. Alm CE, Frihagen F, Dybvik E, Matre K, Madsen JE, Gjertsen J-E. Implants for trochanteric fractures inNorway: the role of the trochantericstabilizing plate—a study on 20,902fractures from the Norwegian hip fractureregister 2011–2017. Journal of Orthopaedic Surgery and Research 2021.

153. Rogmark C, Spetz CL, Garellick G. More intramedullary nails and arthroplasties for treatment of hip fractures in Sweden. *Acta Orthop*. Oct 2010;81(5):588-92. doi:10.3109/17453674.2010.506631

154. Smith L, Albersheim M, Blaschke BL, Parikh HR, Solfelt DA, vanHeest AE, Cunningham BP Trend and Economic Implications of Implant Selection in the Treatment of Intertrochanteric Hip Fractures: A Review of the American Board of Orthopaedic Surgery Database From 2007 to 2017. *J Am Acad Orthop Surg*. Sep 15 2021;29(18):789-795. doi:10.5435/JAAOS-D-20-00470

155. Baldock TE, Dixon JR, Koubaesh C, Johansen A, Eardley WGP. Variation of implant use in A1 and A2 trochanteric hip fractures : a study from the National Hip Fracture Database of England and Wales. *Bone Jt Open*. Oct 2022;3(10):741-745. doi:10.1302/2633-1462.310.BJO-2022-0104.R1

156. Matre K, Havelin LI, Gjertsen JE, Espehaug B, Fevang JM. Intramedullary nails result in more reoperations than sliding hip screws in two-part intertrochanteric fractures. *Clin Orthop Relat Res*. Apr 2013;471(4):1379-86. doi:10.1007/s11999-012-2728-2

157. Swart E, Makhni EC, Macaulay W, Rosenwasser MP, Bozic KJ. Cost-effectiveness analysis of fixation options for intertrochanteric hip fractures. *J Bone Joint Surg Am*. Oct 01 2014;96(19):1612-20. doi:10.2106/JBJS.M.00603

158. Alessio-Mazzola M, Traverso G, Coccarello F, Sanguineti F, Formica M. Dynamic hip screw versus intramedullary nailing for the treatment of A1 intertrochanteric fractures: A retrospective, comparative study and cost analysis. *Jt Dis Relat Surg*. 2022;33(2):314-322. doi:10.52312/jdrs.2022.646

159. Forte ML, Virnig BA, Eberly LE, Swiontkowski MF, Feldman R, Bhandari M, Kane RL Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. *J Bone Joint Surg Am*. May 2010;92(5):1105-14. doi:10.2106/JBJS.I.00295

160. Aros B, Tosteson AN, Gottlieb DJ, Koval KJ. Is a sliding hip screw or im nail the preferred implant for intertrochanteric fracture fixation? *Clin Orthop Relat Res*. Nov 2008;466(11):2827-32. doi:10.1007/s11999-008-0285-5

161. Whitehouse MR, Berstock JR, Kelly MB, Gregson CL, Judge A, Sayers A, Chesser TJ Higher 30-day mortality associated with the use of intramedullary nails compared with sliding hip screws for the treatment of trochanteric hip fractures: a prospective national

registry study. *Bone Joint J*. 01 2019;101-B(1):83-91. doi:10.1302/0301-620X.101B1.BJJ-2018-0601.R2

162. Wolf O, Mukka S, Ekelund J, Rogmark C, Möller M, Hailer NP. Increased mortality after intramedullary nailing of trochanteric fractures: a comparison of sliding hip screws with nails in 19,935 patients. *Acta Orthop*. Jan 03 2022;93:146-150. doi:10.2340/17453674.2021.862

163. Matre K, Havelin LI, Gjertsen JE, Vinje T, Espehaug B, Fevang JM. Sliding hip screw versus IM nail in reverse oblique trochanteric and subtrochanteric fractures. A study of 2716 patients in the Norwegian Hip Fracture Register. *Injury*. Jun 2013;44(6):735-42. doi:10.1016/j.injury.2012.12.010

164. Roche JJ, Wenn RT, Sahota O, Moran CG. Effect of comorbidities and postoperative complications on mortality after hip fracture in elderly people: prospective observational cohort study. *BMJ*. Dec 10 2005;331(7529):1374. doi:10.1136/bmj.38643.663843.55

165. Partanen J, Syrjälä H, Vähänikkilä H, Jalovaara P. Impact of deep infection after hip fracture surgery on function and mortality. *J Hosp Infect*. Jan 2006;62(1):44-9. doi:10.1016/j.jhin.2005.04.020

166. Masters J, Metcalfe D, Ha JS, Judge A, Costa ML. Surgical site infection after hip fracture surgery: a systematic review and meta-analysis of studies published in the UK. *Bone Joint Res*. Sep 2020;9(9):554-562. doi:10.1302/2046-3758.99.BJR-2020-0023.R1

167. Kristensen NK, Lange J, Frøslev T, Pedersen AB. Risk of reoperation due to surgical site infection in 74,771 hip fracture patients: a Danish nationwide cohort study. *Acta Orthop*. Sep 21 2022;93:760-766. doi:10.2340/17453674.2022.4580

168. Edwards C, Counsell A, Boulton C, Moran CG. Early infection after hip fracture surgery: risk factors, costs and outcome. *J Bone Joint Surg Br*. Jun 2008;90(6):770-7. doi:10.1302/0301-620X.90B6.20194

169. Pollmann CT, Dahl FA, Røtterud JHM, Gjertsen JE, Årøen A. Surgical site infection after hip fracture - mortality and risk factors: an observational cohort study of 1,709 patients. *Acta Orthop*. Jun 2020;91(3):347-352. doi:10.1080/17453674.2020.1717841

170. Liu X, Dong Z, Li J, Feng Y, Cao G, Song X, Yang J Factors affecting the incidence of surgical site infection after geriatric hip fracture surgery: a retrospective multicenter study. *J Orthop Surg Res*. Nov 21 2019;14(1):382. doi:10.1186/s13018-019-1449-6

171. Pollard TC, Newman JE, Barlow NJ, Price JD, Willett KM. Deep wound infection after proximal femoral fracture: consequences and costs. *J Hosp Infect*. Jun 2006;63(2):133-9. doi:10.1016/j.jhin.2006.01.015

172. Halonen LM, Stenroos A, Vasara H, Kosola J. Peri-implant fracture: a rare complication after intramedullary fixation of trochanteric femoral fracture. *Arch*

Orthop Trauma Surg. Dec 2022;142(12):3715-3720. doi:10.1007/s00402-021-04193-4

173. Metsemakers WJ, Morgenstern M, McNally MA, McFayden I, Scarborough M, Athanasou NA, Ochsner PE, Kuehl R, Rasche M, Borens O, Xie Z, Velkes S, Hungerer S, Kates SL, Zalavras C, Giannoudis PV, Richards RG, Verhofstad MHJ Fracture-related infection: A consensus on definition from an international expert group. *Injury*. Mar 2018;49(3):505-510. doi:10.1016/j.injury.2017.08.040

174. Metsemakers WJ, Kortram K, Morgenstern M, Moriarty TF, Meex I, Kuehl R, Nijs S, Richards RG, Raschke M, Borens O, Kates SL, Zalavras C, Giannoudis PV, Verhofstad MHJ Definition of infection after fracture fixation: A systematic review of randomized controlled trials to evaluate current practice. *Injury*. Mar 2018;49(3):497-504. doi:10.1016/j.injury.2017.02.010

175. Berríos-Torres SI, Umscheid CA, Bratzler DW, et al. Centers for Disease Control and Prevention Guideline for the Prevention of Surgical Site Infection, 2017. *JAMA Surg*. Aug 01 2017;152(8):784-791. doi:10.1001/jamasurg.2017.0904

176. Osmon DR, Berbari EF, Berendt AR, et al. Diagnosis and management of prosthetic joint infection: clinical practice guidelines by the Infectious Diseases Society of America. *Clin Infect Dis*. Jan 2013;56(1):e1-e25. doi:10.1093/cid/cis803

177. Harrison T, Robinson P, Cook A, Parker MJ. Factors affecting the incidence of deep wound infection after hip fracture surgery. *J Bone Joint Surg Br*. Feb 2012;94(2):237-40. doi:10.1302/0301-620X.94B1.27683

178. de Jong L, Klem TMAL, Kuijper TM, Roukema GR. Factors affecting the rate of surgical site infection in patients after hemiarthroplasty of the hip following a fracture of the neck of the femur. *Bone Joint J*. Aug 2017;99-B(8):1088-1094. doi:10.1302/0301-620X.99B8.BJJ-2016-1119.R1

179. Meyer AC, Eklund H, Hedström M, Modig K. The ASA score predicts infections, cardiovascular complications, and hospital readmissions after hip fracture - A nationwide cohort study. *Osteoporos Int*. Nov 2021;32(11):2185-2192. doi:10.1007/s00198-021-05956-w

180. Pimlott BJ, Jones CA, Beaupre LA, Johnston DW, Majumdar SR. Prognostic impact of pre-operative albumin on short-term mortality and complications in patients with hip fracture. *Arch Gerontol Geriatr*. 2011;53(1):90-4. doi:10.1016/j.archger.2010.06.018

181. Akinleye SD, Garofolo G, Culbertson MD, Homel P, Erez O. The Role of BMI in Hip Fracture Surgery. *Geriatr Orthop Surg Rehabil*. 2018;9:2151458517747414. doi:10.1177/2151458517747414

182. Authen AL. Surgeon's experience level and risk of reoperation after hip fracture surgery: an observational study on 30,945 patients in the Norwegian Hip Fracture Register 2011–2015. In: Dybvik E, editor. Volume 89, 2018 - Issue 5: Acta Orthopaedica; 2018. p. 496-502.

183. Lee J, Singletary R, Schmader K, Anderson DJ, Bolognesi M, Kaye KS. Surgical site infection in the elderly following orthopaedic surgery. Risk factors and outcomes. *J Bone Joint Surg Am*. Aug 2006;88(8):1705-12. doi:10.2106/JBJS.E.01156

184. Fletcher N, Sofianos D, Berkes MB, Obremskey WT. Prevention of perioperative infection. *J Bone Joint Surg Am*. Jul 2007;89(7):1605-18. doi:10.2106/JBJS.F.00901

185. Mackay DC, Harrison WJ, Bates JH, Dickenson D. Audit of deep wound infection following hip fracture surgery. *J R Coll Surg Edinb*. Feb 2000;45(1):56-9.

186. Gillespie WJ, Walenkamp GH. Antibiotic prophylaxis for surgery for proximal femoral and other closed long bone fractures. *Cochrane Database Syst Rev*. Mar 17 2010;2010(3):CD000244. doi:10.1002/14651858.CD000244.pub2

187. Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. *N Engl J Med*. Jan 30 1992;326(5):281-6. doi:10.1056/NEJM199201303260501

188. Engesaeter LB, Lie SA, Espehaug B, Furnes O, Vollset SE, Havelin LI. Antibiotic prophylaxis in total hip arthroplasty: effects of antibiotic prophylaxis systemically and in bone cement on the revision rate of 22,170 primary hip replacements followed 0-14 years in the Norwegian Arthroplasty Register. *Acta Orthop Scand*. Dec 2003;74(6):644-51. doi:10.1080/00016470310018135

189. Nelson CL, Green TG, Porter RA, Warren RD. One day versus seven days of preventive antibiotic therapy in orthopedic surgery. *Clin Orthop Relat Res*. Jun 1983;(176):258-63.

190. Slobogean GP, O'Brien PJ, Brauer CA. Single-dose versus multiple-dose antibiotic prophylaxis for the surgical treatment of closed fractures. *Acta Orthop*. Apr 2010;81(2):256-62. doi:10.3109/17453671003587119

191. Tang WM, Chiu KY, Ng TP, Yau WP, Ching PT, Seto WH. Efficacy of a single dose of cefazolin as a prophylactic antibiotic in primary arthroplasty. *J Arthroplasty*. Sep 2003;18(6):714-8. doi:10.1016/s0883-5403(03)00201-8

192. Hansen S, Schwab F, Asensio A, Carsauw H, Heczko P, Klavs I, Lyytikäinen, Palomar M, Riesenfeld-Orn I, Savey A, Szilagyi E, Valinteliene R, Fabry J, Gastmeier P Methicillin-resistant Staphylococcus aureus (MRSA) in Europe: which infection control measures are taken? *Infection*. Jun 2010;38(3):159-64. doi:10.1007/s15010-010-0001-8

193. Elstrøm P, Kacelnik O, Bruun T, Iversen B, Hauge SH, Aavitsland P. Meticillin-resistant Staphylococcus aureus in Norway, a low-incidence country, 2006-2010. *J Hosp Infect*. Jan 2012;80(1):36-40. doi:10.1016/j.jhin.2011.10.004

194. Control ECfDPa. Surgical site infections. Annual epidemiological report for 2016. ECDC: ECDC; 2016.

195. Lönnroos E, Kautiainen H, Karppi P, Hartikainen S, Kiviranta I, Sulkava R. Incidence of second hip fractures. A population-based study. *Osteoporos Int*. Sep 2007;18(9):1279-85. doi:10.1007/s00198-007-0375-3

196. Robinson CM, Adams CI, Craig M, Doward W, Clarke MC, Auld J. Implant-related fractures of the femur following hip fracture surgery. *J Bone Joint Surg Am*. Jul 2002;84(7):1116-22. doi:10.2106/00004623-200207000-00004

197. Yli-Kyyny TT, Sund R, Juntunen M, Salo JJ, Kroger HP. Extra- and intramedullary implants for the treatment of pertrochanteric fractures -- results from a Finnish National Database Study of 14,915 patients. *Injury*. Dec 2012;43(12):2156-60. doi:10.1016/j.injury.2012.08.026

198. Socci AR, Casemyr NE, Leslie MP, Baumgaertner MR. Implant options for the treatment of intertrochanteric fractures of the hip: rationale, evidence, and recommendations. *Bone Joint J*. Jan 2017;99-B(1):128-133. doi:10.1302/0301-620X.99B1.BJJ-2016-0134.R1

199. Lindvall E, Ghaffar S, Martirosian A, Husak L. Short Versus Long Intramedullary Nails in the Treatment of Pertrochanteric Hip Fractures: Incidence of Ipsilateral Fractures and Costs Associated With Each Implant. *J Orthop Trauma*. Mar 2016;30(3):119-24. doi:10.1097/BOT.0000000000000420

200. Kanakaris NK, Tosounidis TH, Giannoudis PV. Nailing intertrochanteric hip fractures: short versus long; locked versus nonlocked. *J Orthop Trauma*. Apr 2015;29 Suppl 4:S10-6. doi:10.1097/BOT.0000000000000286

201. Olsson O, Ceder L, Hauggaard A. Femoral shortening in intertrochanteric fractures. A comparison between the Medoff sliding plate and the compression hip screw. *J Bone Joint Surg Br*. May 2001;83(4):572-8. doi:10.1302/0301-620x.83b4.11302

202. Gundle R, Gargan MF, Simpson AH. How to minimize failures of fixation of unstable intertrochanteric fractures. *Injury*. Nov 1995;26(9):611-4. doi:10.1016/0020-1383(95)00125-s

203. Parker MJ. Trochanteric hip fractures. Fixation failure commoner with femoral medialization, a comparison of 101 cases. *Acta Orthop Scand*. Aug 1996;67(4):329-32. doi:10.3109/17453679609002325

204. Davis TR, Sher JL, Horsman A, Simpson M, Porter BB, Checketts RG. Intertrochanteric femoral fractures. Mechanical failure after internal fixation. *J Bone Joint Surg Br*. Jan 1990;72(1):26-31. doi:10.1302/0301-620X.72B1.2298790

205. Haddon J, Buciuto R, Johnsen LG. A prospective randomized trial of 100 patients using trochanteric support plates; worth their mettle? *Injury*. Mar 2019;50(3):733-737. doi:10.1016/j.injury.2019.01.035

206. Wu CC, Shih CH. Biomechanical analysis of the dynamic hip screw in the treatment of intertrochanteric fractures. *Arch Orthop Trauma Surg*. 1991;110(6):307-10. doi:10.1007/BF00443464

207. Cameron HU, Graham JD. Retention of the compression screw in sliding screw plate devices. *Clin Orthop Relat Res*. 1980;(146):219-21.

208. Strauss EJ, Kummer FJ, Koval KJ, Egol KA. The "Z-effect" phenomenon defined: a laboratory study. *J Orthop Res*. Dec 2007;25(12):1568-73. doi:10.1002/jor.20457

209. Pires RE, Santana EO, Santos LE, Giordano V, Balbachevsky D, Dos Reis FB. Failure of fixation of trochanteric femur fractures: Clinical recommendations for avoiding Z-effect and reverse Z-effect type complications. *Patient Saf Surg*. Jun 22 2011;5:17. doi:10.1186/1754-9493-5-17

210. Hoffmann MF, Khoriaty JD, Sietsema DL, Jones CB. Outcome of intramedullary nailing treatment for intertrochanteric femoral fractures. *J Orthop Surg Res*. Nov 12 2019;14(1):360. doi:10.1186/s13018-019-1431-3

211. Chitnis AS, Ray B, Sparks C, Grebenyuk Y, Vanderkarr M, Holy CE. Intramedullary Nail Breakage and Mechanical Displacement in Patients with Proximal Femoral Fractures: A Commercial and Medicare Supplemental Claims Database Analysis. *Med Devices (Auckl)*. 2021;14:15-25. doi:10.2147/MDER.S288188

212. Li P, Zhang Z, Zhou F, Lv Y, Guo Y, Tian Y. Characteristics of intramedullary nail breakage in pertrochanteric femur fractures: a summary of 70 cases. *J Orthop Surg Res*. Nov 17 2021;16(1):676. doi:10.1186/s13018-021-02826-3

213. von Rüden C, Hungerer S, Augat P, Trapp O, Bühren V, Hierholzer C. Breakage of cephalomedullary nailing in operative treatment of trochanteric and subtrochanteric femoral fractures. *Arch Orthop Trauma Surg*. Feb 2015;135(2):179-185. doi:10.1007/s00402-014-2121-6

214. Klima ML. Comparison of Early Fatigue Failure of the TFNa and Gamma 3 Cephalomedullary Nails in the United States From 2015 to 2019. *J Orthop Trauma*. Feb 01 2021;35(2):e39-e44. doi:10.1097/BOT.0000000000001864

215. Elliott DS, Newman KJ, Forward DP, Hahn DM, Ollivere B, Kojima K, Handley R, Rossiter ND, Wixted JJ, Smith RM, Moran CG A unified theory of bone healing and nonunion: BHN theory. *Bone Joint J*. Jul 2016;98-B(7):884-91. doi:10.1302/0301-620X.98B7.36061

216. Krappinger D, Wolf B, Dammerer D, Thaler M, Schwendinger P, Lindtner RA. Risk factors for nonunion after intramedullary nailing of subtrochanteric femoral fractures. *Arch Orthop Trauma Surg*. Jun 2019;139(6):769-777. doi:10.1007/s00402-019-03131-9

217. Foster AL, Moriarty TF, Zalavras C, Morgenstern M, Jaiprakash A, Crawford R, Burch MA, Boot W, Tetsworth K, Miclau T, Ochsner P, Schuetz MA, Richards RG, Metsemakers WJ The influence of biomechanical stability on bone healing and fracture-related infection: the legacy of Stephan Perren. *Injury*. Jan 2021;52(1):43-52. doi:10.1016/j.injury.2020.06.044

218. De Bruijn K, den Hartog D, Tuinebreijer W, Roukema G. Reliability of predictors for screw cutout in intertrochanteric hip fractures. *J Bone Joint Surg Am*. Jul 18 2012;94(14):1266-72. doi:10.2106/JBJS.K.00357

219. Bojan AJ, Beimel C, Taglang G, Collin D, Ekholm C, Jönsson A. Critical factors in cut-out complication after Gamma Nail treatment of proximal femoral fractures. *BMC Musculoskelet Disord*. Jan 02 2013;14:1. doi:10.1186/1471-2474-14-1

220. Lobo-Escolar A, Joven E, Iglesias D, Herrera A. Predictive factors for cutting-out in femoral intramedullary nailing. *Injury*. Dec 2010;41(12):1312-6. doi:10.1016/j.injury.2010.08.009

221. Hsueh KK, Fang CK, Chen CM, Su YP, Wu HF, Chiu FY. Risk factors in cutout of sliding hip screw in intertrochanteric fractures: an evaluation of 937 patients. *Int Orthop*. Dec 2010;34(8):1273-6. doi:10.1007/s00264-009-0866-2

222. John B, Sharma A, Mahajan A, Pandey R. Tip-apex distance and other predictors of outcome in cephalomedullary nailing of unstable trochanteric fractures. *J Clin Orthop Trauma*. Oct 2019;10(Suppl 1):S88-S94. doi:10.1016/j.jcot.2019.04.018

223. Fujii T, Nakayama S, Hara M, Koizumi W, Itabashi T, Saito M. Tip-Apex Distance Is Most Important of Six Predictors of Screw Cutout After Internal Fixation of Intertrochanteric Fractures in Women. *JB JS Open Access*. Dec 28 2017;2(4):e0022. doi:10.2106/JBJS.OA.16.00022

224. Rubio-Avila J, Madden K, Simunovic N, Bhandari M. Tip to apex distance infemoral intertrochanteric fractures: a systematic review. *J Orthop Sci*. Jul 2013;18(4):592-8. doi:10.1007/s00776-013-0402-5

225. Goffin JM, Jenkins PJ, Ramaesh R, Pankaj P, Simpson AH. What is the relevance of the tip-apex distance as a predictor of lag screw cut-out? *PLoS One*. 2013;8(8):e71195. doi:10.1371/journal.pone.0071195

226. Kuzyk PR, Zdero R, Shah S, Olsen M, Waddell JP, Schemitsch EH. Femoral head lag screw position for cephalomedullary nails: a biomechanical analysis. *J Orthop Trauma*. Jul 2012;26(7):414-21. doi:10.1097/BOT.0b013e318229acca

227. Goffin JM, Pankaj P, Simpson AH. The importance of lag screw position for the stabilization of trochanteric fractures with a sliding hip screw: a subject-specific finite element study. *J Orthop Res*. Apr 2013;31(4):596-600. doi:10.1002/jor.22266

228. Parker MJ. Cutting-out of the dynamic hip screw related to its position. *J Bone Joint Surg Br*. Jul 1992;74(4):625. doi:10.1302/0301-620X.74B4.1624529

229. Parker MJ. Valgus reduction of trochanteric fractures. *Injury*. May 1993;24(5):313-6. doi:10.1016/0020-1383(93)90053-9

230. Murena L, Moretti A, Meo F, Saggioro E, Barbati G, Ratti C, Canton G. Predictors of cut-out after cephalomedullary nail fixation of pertrochanteric fractures: a

retrospective study of 813 patients. *Arch Orthop Trauma Surg*. Mar 2018;138(3):351-359. doi:10.1007/s00402-017-2863-z

231. Brinker MR, O'Connor DP. The Biological Basis for Nonunions. *JBJS Rev*. Jun 14 2016;4(6)doi:10.2106/JBJS.RVW.15.00078

232. Olszewski D, Streubel PN, Stucken C, Ricci WM, Hoffmann MF, Jones CB, Sietsema DL,Tornetta 3rd P. Fate of Patients With a "Surprise" Positive Culture After Nonunion Surgery. *J Orthop Trauma*. Jan 2016;30(1):e19-23. doi:10.1097/BOT.0000000000000417

233. Nauth A, Lee M, Gardner MJ, et al. Principles of Nonunion Management: State of the Art. *J Orthop Trauma*. Mar 2018;32 Suppl 1:S52-S57. doi:10.1097/BOT.0000000000001122

234. Copuroglu C, Calori GM, Giannoudis PV. Fracture non-union: who is at risk? *Injury*. Nov 2013;44(11):1379-82. doi:10.1016/j.injury.2013.08.003

235. Marsh JL, Slongo TF, Agel J, Broderick JS, Creevey W, DeCoster TA, Prokuski L, Sirkin MS,Ziran B, Henley B, Audigé L. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma*. Nov-Dec 2007;21(10 Suppl):S1-133. doi:00005131-200711101-00001 [pii] 10.1097/00005131-200711101-00001

236. Gjertsen JE, Engesaeter LB, Furnes O, Havelin LI, Steindal K, Vinje T, Fevang JM The Norwegian Hip Fracture Register: experiences after the first 2 years and 15,576 reported operations. *Acta Orthop*. Oct 2008;79(5):583-93. doi:10.1080/17453670810016588

237. Greiner W, Weijnen T, Nieuwenhuizen M, Oppe S, Badia X, Busschbach, Buxton M, Dolan P, Kind P, Krabbe P, Ohinmaa, Parkin D, Roset M, Sintonen H, Tsuchiya A, de Charro F. A single European currency for EQ-5D health states. Results from a six-country study. *Eur J Health Econ*. Sep 2003;4(3):222-31. doi:10.1007/s10198-003-0182-5

238. Parsons N, Griffin XL, Achten J, Costa ML. Outcome assessment after hip fracture: is EQ-5D the answer? *Bone Joint Res*. 2014;3(3):69-75. doi:10.1302/2046-3758.33.2000250

239. Cox D. Regression models and life tables (with discussion). J R Statist Soc B1972. p. 187–220.

240. von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. Dec 2014;12(12):1495-9. doi:10.1016/j.ijsu.2014.07.013

241. Haywood KL, Griffin XL, Achten J, Costa ML. Developing a core outcome set for hip fracture trials. *Bone Joint J*. Aug 2014;96-B(8):1016-23. doi:10.1302/0301-620X.96B8.33766

242. Pinedo-Villanueva RA, Turner D, Judge A, Raftery JP, Arden NK. Mapping the Oxford hip score onto the EQ-5D utility index. *Qual Life Res*. Apr 2013;22(3):665-75. doi:10.1007/s11136-012-0174-y

243. Bryan S, Hardyman W, Bentham P, Buckley A, Laight A. Proxy completion of EQ-5D in patients with dementia. *Qual Life Res*. Feb 2005;14(1):107-18. doi:10.1007/s11136-004-1920-6

244. Tidermark J, Bergström G. Responsiveness of the EuroQol (EQ-5D) and the Nottingham Health Profile (NHP) in elderly patients with femoral neck fractures. *Qual Life Res*. Mar 2007;16(2):321-30. doi:10.1007/s11136-006-9004-4

245. Jaeschke R, Singer J, Guyatt GH. Measurement of health status. Ascertaining the minimal clinically important difference. *Control Clin Trials*. Dec 1989;10(4):407-15. doi:10.1016/0197-2456(89)90005-6

246. Walters SJ, Brazier JE. Comparison of the minimally important difference for two health state utility measures: EQ-5D and SF-6D. *Qual Life Res*. Aug 2005;14(6):1523-32. doi:10.1007/s11136-004-7713-0

247. Lingard EA, Wright EA, Sledge CB, Group KO. Pitfalls of using patient recall to derive preoperative status in outcome studies of total knee arthroplasty. *J Bone Joint Surg Am*. Aug 2001;83(8):1149-56. doi:10.2106/00004623-200108000-00003

248. Gjertsen JE, Baste V, Fevang JM, Furnes O, Engesæter LB. Quality of life following hip fractures: results from the Norwegian hip fracture register. *BMC Musculoskelet Disord*. Jul 07 2016;17:265. doi:10.1186/s12891-016-1111-y

249. Espehaug B, Furnes O, Havelin LI, Engesaeter LB, Vollset SE, Kindseth O. Registration completeness in the Norwegian Arthroplasty Register. *Acta Orthop*. Feb 2006;77(1):49-56. doi:10.1080/17453670610045696

250. Vandenbroucke JP. Observational research, randomised trials, and two views of medical science. *PLoS Med*. Mar 11 2008;5(3):e67. doi:10.1371/journal.pmed.0050067

251. Schipper IB, Steyerberg EW, Castelein RM, van Vugt AB. Reliability of the AO/ASIF classification for pertrochanteric femoral fractures. *Acta Orthop Scand*. Feb 2001;72(1):36-41. doi:10.1080/000164701753606662

252. Masters J, Metcalfe D, Parsons NR, Achten J, Griffin XL, Costa ML, WHiTE Collaborative Investigators. Interpreting and reporting fracture classification and operation type in hip fracture: implications for research studies and routine national audits. *Bone Joint J*. Oct 2019;101-B(10):1292-1299. doi:10.1302/0301-620X.101B10.BJJ-2019-0213.R1

253. Iguchi M, Takahashi T, Matsumura T, Ae R, Hiyama S, Nakashima M, Takeshita K. Addition of 3D-CT evaluation to radiographic images and effect on diagnostic reliability of current 2018 AO/OTA classification of femoral trochanteric fractures. *Injury*. Nov 2021;52(11):3363-3368. doi:10.1016/j.injury.2021.09.031

254. Saudan M, Lübbeke A, Sadowski C, Riand N, Stern R, Hoffmeyer P. Pertrochanteric fractures: is there an advantage to an intramedullary nail?: a randomized, prospective study of 206 patients comparing the dynamic hip screw and proximal femoral nail. *J Orthop Trauma*. Jul 2002;16(6):386-93. doi:10.1097/00005131-200207000-00004

255. van Geel TA, van Helden S, Geusens PP, Winkens B, Dinant GJ. Clinical subsequent fractures cluster in time after first fractures. *Ann Rheum Dis*. Jan 2009;68(1):99-102. doi:10.1136/ard.2008.092775

256. Bögl HP, Zdolsek G, Michaëlsson K, Höijer J, Schilcher J. Reduced Risk of Reoperation Using Intramedullary Nailing with Femoral Neck Protection in Low-Energy Femoral Shaft Fractures. *J Bone Joint Surg Am*. Sep 2020;102(17):1486-1494. doi:10.2106/JBJS.20.00160

257. Balasubramanian A, Zhang J, Chen L, Wenkert D, Daigle SG, Grauer A, Curtis JR. Risk of subsequent fracture after prior fracture among older women. *Osteoporos Int*. Jan 2019;30(1):79-92. doi:10.1007/s00198-018-4732-1

258. Frisch NB, Nahm NJ, Khalil JG, Les CM, Guthrie ST, Charters MA. Short Versus Long Cephalomedullary Nails for Pertrochanteric Hip Fracture. *Orthopedics*. Mar 01 2017;40(2):83-88. doi:10.3928/01477447-20161116-01

259. Hou Z, Bowen TR, Irgit KS, Matzko ME, Andreychik CM, Horwitz DS, Smith WR. Treatment of pertrochanteric fractures (OTA 31-A1 and A2): long versus short cephalomedullary nailing. *J Orthop Trauma*. Jun 2013;27(6):318-24. doi:10.1097/BOT.0b013e31826fc11f

260. Zhang Y, Zhang S, Wang S, Zhang W, Liu P, Ma J, Pervaiz N, Wang J. Long and short intramedullary nails for fixation of intertrochanteric femur fractures (OTA 31-A1, A2 and A3): A systematic review and meta-analysis. *Orthop Traumatol Surg Res*. Sep 2017;103(5):685-690. doi:10.1016/j.otsr.2017.04.003

261. Shannon SF, Yuan BJ, Cross WW, Barlow JD, Torchia ME, Holte PK, Sems SA. Short Versus Long Cephalomedullary Nails for Pertrochanteric Hip Fractures: A Randomized Prospective Study. *J Orthop Trauma*. Oct 2019;33(10):480-486. doi:10.1097/BOT.0000000000001553

262. Poitout DG. *Biomechanics and biomaterials in orthopedics*. Second ed. Springer-Verlag; 2016.

263. Allen MJ, Turner AS, Sairyo K, Ferrara L. Basic Science Symposium III: Animal Models for Orthopaedic Implant Evaluation. *SAS J*. 2008;2(4):195-200. doi:10.1016/SASJ-2008-Symposium42008-Symposium4 [pii]

264. Sha M, Guo Z, Fu J, Li J, Yuan CF, Shi L, Li SJ. The effects of nail rigidity on fracture healing in rats with osteoporosis. *Acta Orthop*. Feb 2009;80(1):135-8. doi:10.1080/17453670902807490

265. Utvag SE, Reikeras O. Effects of nail rigidity on fracture healing. Strength and mineralisation in rat femoral bone. *Arch Orthop Trauma Surg*. 1998;118(1-2):7-13. doi:10.1007/s004020050301

266. Bong MR, Kummer FJ, Koval KJ, Egol KA. Intramedullary nailing of the lower extremity: biomechanics and biology. *J Am Acad Orthop Surg*. Feb 2007;15(2):97-106. doi:15/2/97 [pii]10.5435/00124635-200702000-00004

267. Hagino H, Sawaguchi T, Endo N, Ito Y, Nakano T, Watanabe Y. The risk of a second hip fracture in patients after their first hip fracture. *Calcif Tissue Int*. Jan 2012;90(1):14-21. doi:10.1007/s00223-011-9545-6

268. Park KC, Lim SJ, Song YS, Hwang KT. Factors affecting peri-implant fracture following locking plate for osteoporotic distal femur fractures. *Orthop Traumatol Surg Res*. Dec 2017;103(8):1201-1204. doi:S1877-0568(17)30249-9 [pii]10.1016/j.otsr.2017.08.008

269. Cederholm T, Cruz-Jentoft AJ, Maggi S. Sarcopenia and fragility fractures. *Eur J Phys Rehabil Med*. Feb 2013;49(1):111-7. doi:R33133172 [pii]

270. Lang T, Cauley JA, Tylavsky F, Bauer D, Cummings S, Harris TB. Computed tomographic measurements of thigh muscle cross-sectional area and attenuation coefficient predict hip fracture: the health, aging, and body composition study. *J Bone Miner Res*. Mar 2010;25(3):513-9. doi:10.1359/jbmr.090807

271. Moore AZ, Caturegli G, Metter EJ, Makrogiannis S, Resnick SM, Harris TB, Ferrucci L. Difference in muscle quality over the adult life span and biological correlates in the Baltimore Longitudinal Study of Aging. *J Am Geriatr Soc*. Feb 2014;62(2):230-6. doi:10.1111/jgs.12653

272. Kortebein P, Symons TB, Ferrando A, Paddon-Jones D, Ronsen O, Protas E, Conger S, Lombeida J, Wolfe R, Evans WJ. Functional impact of 10 days of bed rest in healthy older adults. *J Gerontol A Biol Sci Med Sci*. Oct 2008;63(10):1076-81. doi:63/10/1076 [pii]10.1093/gerona/63.10.1076

273. McGuire MT, Jeffery RW, French SA, Hannan PJ. The relationship between restraint and weight and weight-related behaviors among individuals in a community weight gain prevention trial. *Int J Obes Relat Metab Disord*. Apr 2001;25(4):574-80. doi:10.1038/sj.ijo.0801579

274. Suesada MM, Martins MA, Carvalho CR. Effect of short-term hospitalization on functional capacity in patients not restricted to bed. *Am J Phys Med Rehabil*. Jun 2007;86(6):455-62. doi:10.1097/PHM.0b013e31805b7566 00002060-200706000-00005 [pii]

275. Lonnroos E, Kautiainen H, Karppi P, Hartikainen S, Kiviranta I, Sulkava R. Incidence of second hip fractures. A population-based study. *Osteoporos Int*. Sep 2007;18(9):1279-85. doi:10.1007/s00198-007-0375-3

276. Schroder HM, Petersen KK, Erlandsen M. Occurrence and incidence of the second hip fracture. *Clin Orthop Relat Res*. Apr 1993;(289):166-9.

277. Shabat S, Gepstein R, Mann G, Kish B, Fredman B, Nyska M. The second hip fracture--an analysis of 84 elderly patients. *J Orthop Trauma*. Oct 2003;17(9):613-7. doi:10.1097/00005131-200310000-00003

278. Warren JA, Sundaram K, Hampton R, McLaughlin J, Patterson B, Higuera CA, Piuzzi NS. Cephalomedullary nailing versus sliding hip screws for Intertrochanteric and basicervical hip fractures: a propensity-matched study of short-term outcomes in over 17,000 patients. *Eur J Orthop Surg Traumatol*. Feb 2020;30(2):243-250. doi:10.1007/s00590-019-02543-y

279. Matre K, Vinje T, Havelin LI, Gjertsen JE, Furnes O, Espehaug B, Kjellevold SH, Fevang J . TRIGEN INTERTAN intramedullary nail versus sliding hip screw: a prospective, randomized multicenter study on pain, function, and complications in 684 patients with an intertrochanteric or subtrochanteric fracture and one year of follow-up. *J Bone Joint Surg Am*. Feb 6 2013;95(3):200-8. doi:10.2106/JBJS.K.01497

280. Müller F, Doblinger M, Kottmann T, Füchtmeier B. PFNA and DHS for AO/OTA 31-A2 fractures: radiographic measurements, morbidity and mortality. *Eur J Trauma Emerg Surg*. Oct 2020;46(5):947-953. doi:10.1007/s00068-019-01251-w

281. Zhu Q, Xu X, Yang X, Chen X, Wang L, Liu C, Lin P. Intramedullary nails versus sliding hip screws for AO/OTA 31-A2 trochanteric fractures in adults: A meta-analysis. *Int J Surg*. Jul 2017;43:67-74. doi:10.1016/j.ijsu.2017.05.042

282. Pyrhönen HS, Lagergren J, Wolf O, Bojan A, Mukka S, Möller M, Rogmark C. No Difference in Conversion Rate to Hip Arthroplasty After Intramedullary Nail or Sliding Hip Screw for Extracapsular Hip Fractures: An Observational Cohort Study of 19,604 Individuals. *J Bone Joint Surg Am*. Oct 05 2022;104(19):1703-1711. doi:10.2106/JBJS.22.00316

283. Boone C, Carlberg KN, Koueiter DM, Baker KC, Sadowski J, Wiater PJ, Nowinski GP, Grant KD. Short versus long intramedullary nails for treatment of intertrochanteric femur fractures (OTA 31-A1 and A2). *J Orthop Trauma*. May 2014;28(5):e96-e100. doi:10.1097/BOT.0b013e3182a7131c

284. Sayers A, Evans JT, Whitehouse MR, Blom AW. Are competing risks models appropriate to describe implant failure? *Acta Orthop*. Jun 2018;89(3):256-258. doi:10.1080/17453674.2018.1444876

285. Lie SA, Fenstad AM, Lygre SHL, Kroken G, Dybvik E, Gjertsen JE, Hallan G, Dale H, Furnes O. Kaplan-Meier and Cox Regression Are Preferable for the Analysis of Time to Revision of Joint Arthroplasty: Thirty-One Years of Follow-up for Cemented

and Uncemented THAs Inserted From 1987 to 2000 in the Norwegian Arthroplasty Register. *JB JS Open Access*. 2022;7(1)doi:10.2106/JBJS.OA.21.00108

286. Carow J, Carow JB, Coburn M, Kim BS, Büking B, Bliemel C, Bollheimer LC, Werner CJ, Bach JP, Knobe M. Mortality and cardiorespiratory complications in trochanteric femoral fractures: a ten year retrospective analysis. *Int Orthop*. Nov 2017;41(11):2371-2380. doi:10.1007/s00264-017-3639-3

287. Valen AK, Viberg B, Gundtoft PH, Wæver D, Thorninger R. Mortality in patients with trochanteric hip fractures (AO/OTA 31-A) treated with sliding hip screw versus intramedullary nail: A retrospective national registry study of 9547 patients from the Danish Fracture Database. *Injury*. Mar 12 2023;doi:10.1016/j.injury.2023.03.008

288. Lynch Wong M, Baker G, McCusker D, Zhang SD, Charlwood AP. A five-year review comparing 30-day mortality following intramedullary nailing versus sliding hip screw for trochanteric hip fractures. *Injury*. Jun 2022;53(6):2189-2194. doi:10.1016/j.injury.2022.03.025

289. Griffin XL, Parsons N, Achten J, Fernandez M, Costa ML. Recovery of health-related quality of life in a United Kingdom hip fracture population. The Warwick Hip Trauma Evaluation--a prospective cohort study. *Bone Joint J*. Mar 2015;97-B(3):372-82. doi:10.1302/0301-620X.97B3.35738

290. Furnes O, Gjertsen JE, Hallan G, Visnes H, Gundersen T, Fenstad AM, Dybvik E, Stenvik S, Kvinnesland I, Mulpuri KS, Solberg M. Annual report 2020: Norwegian Advisory unit on arthroplasty and hip fractures. http://nrlweb.ihelse.net/eng/Rapporter/Report2019_english.pdf2019.

291. Ciufo DJ, Zaruta DA, Lipof JS, Judd KT, Gorczyca JT, Ketz JP. Risk Factors Associated With Cephalomedullary Nail Cutout in the Treatment of Trochanteric Hip Fractures. *J Orthop Trauma*. Nov 2017;31(11):583-588. doi:10.1097/BOT.0000000000000961

292. Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen JE. Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures : 17,341 patients from the Norwegian Hip Fracture Register. *Bone Joint J*. Feb 2022;104-B(2):274-282. doi:10.1302/0301-620X.104B2.BJJ-2021-1078.R1

293. Schipper IB, Steyerberg EW, Castelein RM, van der Heijden F, den Hoed PT, Kerver AJH, Van Vugt AB. Treatment of unstable trochanteric fractures. Randomised comparison of the gamma nail and the proximal femoral nail. *J Bone Joint Surg Br*. Jan 2004;86(1):86-94.

294. Stern LC, Gorczyca JT, Kates S, Ketz J, Soles G, Humphrey CA. Radiographic Review of Helical Blade Versus Lag Screw Fixation for Cephalomedullary Nailing of Low-Energy Peritrochanteric Femur Fractures: There is a Difference in Cutout. *J Orthop Trauma*. Jun 2017;31(6):305-310. doi:10.1097/BOT.0000000000000853

295. Zehir S, Şahin E, Zehir R. Comparison of clinical outcomes with three different intramedullary nailing devices in the treatment of unstable trochanteric fractures. *Ulus Travma Acil Cerrahi Derg*. Dec 2015;21(6):469-76. doi:10.5505/tjtes.2015.28227

296. Vaughn J, Cohen E, Vopat BG, Kane P, Abbood E, Born C. Complications of short versus long cephalomedullary nail for intertrochanteric femur fractures, minimum 1 year follow-up. *Eur J Orthop Surg Traumatol*. May 2015;25(4):665-70. doi:10.1007/s00590-014-1557-2

297. Den Hartog BD, Bartal E, Cooke F. Treatment of the unstable intertrochanteric fracture. Effect of the placement of the screw, its angle of insertion, and osteotomy. *J Bone Joint Surg Am*. Jun 1991;73(5):726-33.

298. Santoni BG, Diaz MA, Stoops TK, Lannon S, Ali A, Sanders RW. Biomechanical Investigation of an Integrated 2-Screw Cephalomedullary Nail Versus a Sliding Hip Screw in Unstable Intertrochanteric Fractures. *J Orthop Trauma*. Feb 2019;33(2):82-87. doi:10.1097/BOT.0000000000001351

299. Sivakumar A, Edwards S, Millar S, Thewlis D, Rickman M. Reoperation rates after proximal femur fracture fixation with single and dual screw femoral nails: a systematic review and meta-analysis. *EFORT Open Rev*. Jul 05 2022;7(7):506-515. doi:10.1530/EOR-21-0067

300. Lang NW, Arthold C, Joestl J, Gormasz A, Boesmueller S, Hajdu S, Sarahrudi K. Does an additional antirotation U-Blade (RC) lag screw improve treatment of AO/OTA 31 A1-3 fractures with gamma 3 nail? *Injury*. Dec 2016;47(12):2733-2738. doi:10.1016/j.injury.2016.10.032

301. Rogmark C. Further refinement of surgery will not necessarily improve outcome after hip fracture. *Acta Orthop*. Apr 2020;91(2):123-124. doi:10.1080/17453674.2019.1706936

Appendices

Appendix 1: Operation form, Norwegian Hip Fracture Register

Appendix 2: Patient questionnaire, Norwegian Hip Fracture Register

NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland universitetssjukehus
Møllendalsbakken 7
5021 BERGEN
Tlf: 55973742

F.nr. (11 sifre).....

Navn:.....

(Skriv tydelig ev. pasientklistrelapp – **spesifiser sykehus**.)

Sykehus:.....

HOFTEBRUDD

PRIMÆRE OPERASJONER PÅ BRUDD I PROKSIMALE FEMURENDE og ALLE REOPERASJONER, inkludert lukket reponering av hemiproteser. Ved primæroperasjon med totalprotese og ved reoperasjon til totalprotese brukes kun hofteproteseskjema. Alle produktklistrelapper settes i merket felt på baksiden av skjemaet.

AKTUELLE OPERASJON
☐1 Primæroperasjon ☐ 2 Reoperasjon

SIDE (ett kryss) (Bilateral opr.= 2 skjema)
☐1 Høyre ☐2 Venstre

OPR TIDSPUNKT (dd.mm.åå) |__|__| |__|__| |__|__| kl |__|__|

BRUDD TIDSPUNKT (dd.mm.åå) |__|__| |__|__| |__|__| kl |__|__|
Dersom det er usikkerhet om bruddtidspunkt, fyll ut neste punkt.

TID FRA BRUDD TIL OPERASJON I TIMER
☐1 0-6 ☐2 >6-12 ☐3 >12-24 ☐4 >24-48 ☐5 >48

KOGNITIV SVIKT
☐0 Nei ☐1 Ja (Se test på baksiden) ☐2 Usikker

ASA-KLASSE (se bakside av skjema for definisjon)
☐1 Frisk
☐2 Asymptomatisk tilstand som gir økt risiko
☐3 Symptomatisk sykdom
☐4 Livstruende sykdom
☐5 Moribund

TYPE PRIMÆRBRUDD (ÅRSAK TIL PRIMÆROPERASJON) (Kun ett kryss)
Se baksiden for klassifikasjon
☐1 Lårhalsbrudd udislokert (Garden 1 og 2)
☐2 Lårhalsbrudd dislokert (Garden 3 og 4)
☐3 Lateralt lårhalsbrudd
☐4 Pertrokantært tofragment (AO klassifikasjon A1)
☐5 Pertrokantært flerfragment (AO klassifikasjon A2)
☐9 Intertrokantært (AO klassifikasjon A3)
☐6 Subtrokantært
☐7 Annet, spesifiser.....

TYPE PRIMÆROPERASJON (Kun ett kryss)
(Fylles ut bare ved primæroperasjon - eget skjema for totalproteser)
(Fest produktklistrelapp på baksiden eller spesifiser nøyaktig produkt)
☐1 To skruer eller pinner
☐2 Tre skruer eller pinner
☐3 Bipolar hemiprotese
☐4 Unipolar hemiprotese
☐5 Glideskrue og plate
☐6 Glideskrue og plate med trokantær støtteplate
☐7 Vinkelplate
☐8 Kort margnagle uten distal sperre
☐9 Kort margnagle med distal sperre
☐10 Lang margnagle uten distal sperre
☐11 Lang margnagle med distal sperre
☐12 Annet, spesifiser.....

Navn / størrelse og katalognummer.....

ÅRSAK TIL REOPERASJON (Flere enn ett kryss kan brukes)
☐1 Osteosyntesesvikt/havari
☐2 Ikke tilhelet brudd (non-union/pseudartrose)
☐3 Caputnekrose (segmentalt kollaps)
☐4 Lokal smerte pga prominerende osteosyntesemateriale
☐5 Brudd tilhelet med feilstilling
☐6 Sårinfeksjon – overfladisk
☐7 Sårinfeksjon – dyp
☐8 Hematom
☐9 Luksasjon av hemiprotese
☐10 Osteosyntesematerialet skåret gjennom caput
☐11 Nytt brudd rundt implantat
☐12 Løsning av hemiprotese
☐13 Annet, spesifiser.....

TYPE REOPERASJON (Flere enn ett kryss kan brukes)
(Fest produktklistrelapp på baksiden eller spesifiser nøyaktig produkt)
☐1 Fjerning av implantat (Brukes når dette er eneste prosedyre)
☐2 Girdlestone (= fjerning av implantat og caput)
☐3 Bipolar hemiprotese
☐4 Unipolar hemiprotese
☐5 Re-osteosyntese
☐6 Debridement for infeksjon
☐7 Lukket reposisjon av luksert hemiprotese
☐8 Åpen reposisjon av luksert hemiprotese
☐9 Annet, spesifiser.....

Navn / størrelse og katalognummer.....

FIKSASJON AV HEMIPROTESE
(For totalprotese sendes eget skjema til hofteproteseregisteret)
☐1 Usementert ☐1 med HA ☐2 uten HA
☐2 Sement med antibiotika Navn.....
☐3 Sement uten antibiotika Navn.....

PATOLOGISK BRUDD (Annen patologi enn osteoporose)
☐0 Nei ☐1 Ja, type.....

TILGANG TIL HOFTELEDDET VED HEMIPROTESE (Kun ett kryss)
☐1 Fremre (mellom sartorius og tensor)
☐2 Anterolateral (mellom gluteus medius og tensor)
☐3 Direkte lateral (transgluteal)
☐4 Bakre (bak gluteus medius)
☐5 Annet, spesifiser.....

ANESTESITYPE
☐1 Narkose ☐2 Spinal ☐3 Annet, spesifiser.....

PEROPERATIVE KOMPLIKASJONER
☐0 Nei ☐1 Ja, hvilke(n).....

OPERASJONSTID (hud til hud).....minutter.

ANTIBIOTIKAPROFYLAKSE ☐0 Nei ☐1 Ja

	Navn	Dosering	Varighet i timer
Medikament 1			……timer
Medikament 2			……timer
Medikament 3			……timer

TROMBOSEPROFYLAKSE
☐0 Nei ☐1 Ja: Første dose ☐1 Preoperativt ☐2 Postoperativt
Medikament 1 ..... Dosering opr.dag.....
Dosering videre ..... Varighet ..... døgn
Medikament 2 ..... Dosering ..... Varighet ..... døgn

FAST TROMBOSEPROFYLAKSE
☐0 Nei ☐1 Ja, type: .....

FIBRINOLYSEHEMMER
☐0 Nei ☐1 Ja, medikament : ..... Dosering .....

OPERATØRERFARING
Har en av operatørene mer enn 3 års erfaring i hoftebruddkirurgi? ☐0 Nei ☐1 Ja

Lege.....
Legen som har fylt ut skjemaet (navnet registreres ikke i databasen).

RETTLEDNING

Registreringen gjelder alle operasjoner for hoftebrudd (lårhals, pertrokantære og subtrokantære) og alle reoperasjoner, også reposisjoner, på pasienter som er primæroperert og reoperert for hoftebrudd. **Ved primæroperasjon med totalprotese og ved reoperasjon til totalprotese sendes bare skjema til hofteproteseregisteret.**
Ett skjema fylles ut for hver operasjon. Originalen sendes Haukeland universitetssjukehus og kopien lagres i pasientens journal. Pasientens fødselsnummer (11 sifre) og sykehuset må være påført. Aktuelle ruter markeres med kryss. Pasienten skal på eget skjema gi samtykke til registrering i Nasjonalt hoftebruddregister.

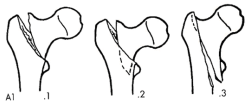
Kommentarer til enkelte punkt:
OPERASJONS- OG BRUDDTIDSPUNKT
Operasjonstidspunkt (dato og klokkeslett) må føres opp på alle primæroperasjoner. Det er også sterkt ønskelig at dato og klokkeslett for *bruddtidspunkt* føres opp. Dette bl.a. for å se om tid til operasjon har effekt på prognose. (Hvis en ikke kjenner klokkeslettet for bruddtidspunkt lar en feltet stå åpent. En må da prøve å angi omtrentlig tidsrom fra brudd til operasjon på neste punkt).
Ved reoperasjon er ikke klokkeslett nødvendig.

KOGNITIV SVIKT
Kognitiv svikt kan eventuelt testes ved å be pasienten tegne klokken når den er 10 over 11. En pasient med kognitiv svikt vil ha problemer med denne oppgaven.

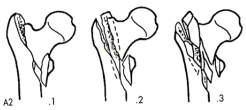
ASA-KLASSE (ASA=American Society of Anesthesiologists)
ASA-klasse 1: Friske pasienter som røyker mindre enn 5 sigaretter daglig.
ASA-klasse 2: Pasienter med en asymptomatisk tilstand som behandles medikamentelt (f.eks hypertensjon) eller med kost (f.eks diabetes mellitus type 2) og ellers friske pasienter som røyker 5 sigaretter eller mer daglig.
ASA-klasse 3: Pasienter med en tilstand som kan gi symptomer, men som holdes under kontroll medikamentelt (f.eks moderat angina pectoris og mild astma).
ASA-klasse 4: Pasienter med en tilstand som ikke er under kontroll (f.eks hjertesvikt og astma).
ASA-klasse 5: Moribund/døende pasient

GARDENS KLASSIFISERING AV LÅRHALSBRUDD
Garden 1: Ikke komplett brudd av lårhalsen (såkalt innkilt)
Garden 2: Komplett lårhalsbrudd uten dislokasjon
Garden 3: Komplett lårhalsbrudd med delvis dislokasjon. Fragmentene er fortsatt i kontakt, men det er feilstilling av lårhalsens trabekler. Caputfragmentet ligger uanatomisk i acetabulum.
Garden 4: Komplett lårhalsbrudd med full dislokasjon. Caputfragmentet er fritt og ligger korrekt i acetabulum slik at trabeklene er normalt orientert.

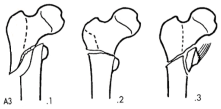
AO KLASSIFIKASJON AV TROKANTÆRE BRUDD



A1: Pertrokantært tofragment brudd



A2: Pertrokantært flerfragment brudd



A3: Intertrokantært brudd


Subtrokantært brudd*

*Subtrokantært brudd: Bruddsentrum er mellom nedre kant av trokanter minor og 5 cm distalt for denne.

REOPERASJONSÅRSAK
Dyp infeksjon defineres som infeksjon som involverer fascie, protese, ledd eller periprotetisk vev.

IMPLANTAT
Implantattype må angis entydig. Produktklistrelapp er ønskelig for å angi katalognummer for osteosyntesematerialet eller protesen som er brukt.

PEROPERATIVE KOMPLIKASJONER
Vi ønsker også å få meldt dødsfall på operasjonsbordet og peroperativ transfusjonstrengende blødning.

ANTIBIOTIKAPROFYLAKSE
Her føres det på hvilket antibiotikum som er blitt benyttet i forbindelse med operasjonen. Det anføres dose, antall doser og profylaksens varighet. F.eks. Medkament 1: Keflin 2g x 4, med varighet 4,5 timer.

TROMBOSEPROFYLAKSE
Medikament, dose og antatt varighet av profylaksen skal angis separat for oprerasjonsdagen og senere. Det skal også oppgis om pasienten står fast på tromboseprofylakse (AlbylE, Marevan, Plavix ol).

FIBRINOLYSEHEMMER
Her føres det på om en benytter blødningsreduserende legemidler i forbindelse med operasjonen (f.eks. Cyklokapron).

Kontaktpersoner vedrørende registreringsskjema er:
Overlege Jan-Erik Gjertsen, Ortopedisk klinikk, Haukeland universitetssjukehus. Tlf. 55 97 56 86 (email: jan-erik.gjertsen@helse-bergen.no)
Konsulent Nasjonalt Hoftebruddregister: Randi Furnes. Tlf. 55 97 37 42 (email: nrl@helse-bergen.no)
Internett: http://nrlweb.ihelse.net/

NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 7
5021 BERGEN

PASIENTSPØRRESKJEMA NASJONALT HOFTEBRUDDREGISTER

1. Dato for utfylling av skjema: |__|__| |__|__| |__|__|

2. Spørreskjemaet er besvart av:

☐ [1] Meg selv

eller ved hjelp av….(kryss av i ruten som gjelder)

☐ [2] Slektning (ektefelle, barn)
☐ [3] God venn eller annen nærstående
☐ [4] Annen privat person
☐ [5] Hjemmesykepleier/hjemmehjelp
☐ [6] Annen person, angi hvem:_____

NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 7
5021 BERGEN

I de neste 5 spørsmålene ønsker vi å vite hvordan livssituasjonen din var FØR du fikk hofte/lårhalsbruddet som du ble operert for.

3. Hvordan opplevde du gangevnen din?

- ☐ [1] Jeg hadde ingen problemer med å gå omkring
- ☐ [2] Jeg hadde litt problemer med å gå omkring
- ☐ [3] Jeg var sengeliggende

4. Hvordan klarte du personlig stell?

- ☐ [1] Jeg hadde ingen problemer med personlig stell
- ☐ [2] Jeg hadde litt problemer med å vaske meg eller kle meg
- ☐ [3] Jeg klarte ikke å vaske meg eller kle meg

5. Hvordan klarte du dine vanlige gjøremål (f.eks. arbeid, studier, husarbeid, familie- og fritidsaktiviteter)?

- ☐ [1] Jeg hadde ingen problemer med å utføre mine vanlige gjøremål
- ☐ [2] Jeg hadde litt problemer med å utføre mine vanlige gjøremål
- ☐ [3] Jeg var ute av stand til å utføre mine vanlige gjøremål

6. Smerter eller ubehag?

- ☐ [1] Jeg hadde verken smerte eller ubehag
- ☐ [2] Jeg hadde moderat smerte eller ubehag
- ☐ [3] Jeg hadde sterk smerte eller ubehag

7. Angst eller depresjon?

- ☐ [1] Jeg var verken engstelig eller deprimert
- ☐ [2] Jeg var noe engstelig eller deprimert
- ☐ [3] Jeg var svært engstelig eller deprimert

NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 7
5021 BERGEN

I de 5 neste spørsmålene ønsker vi å vite hvordan livssituasjonen din er NÅ:

8. Hvordan opplever du gangevnen din?

- ☐ [1] Jeg har ingen problemer med å gå omkring
- ☐ [2] Jeg har litt problemer med å gå omkring
- ☐ [3] Jeg er sengeliggende

9. Hvordan klarer du personlig stell?

- ☐ [1] Jeg har ingen problemer med personlig stell
- ☐ [2] Jeg har litt problemer med å vaske meg eller kle meg
- ☐ [3] Jeg klarer ikke å vaske meg eller kle meg

10. Hvordan klarer du dine vanlige gjøremål (f.eks. arbeid, studier, husarbeid, familie- og fritidsaktiviteter)?

- ☐ [1] Jeg har ingen problemer med å utføre mine vanlige gjøremål
- ☐ [2] Jeg har litt problemer med å utføre mine vanlige gjøremål
- ☐ [3] Jeg er ute av stand til å utføre mine vanlige gjøremål

11. Smerter eller ubehag?

- ☐ [1] Jeg har verken smerte eller ubehag
- ☐ [2] Jeg har moderat smerte eller ubehag
- ☐ [3] Jeg har sterk smerte eller ubehag

12. Angst eller depresjon?

- ☐ [1] Jeg er verken engstelig eller deprimert
- ☐ [2] Jeg er noe engstelig eller deprimert
- ☐ [3] Jeg er svært engstelig eller deprimert

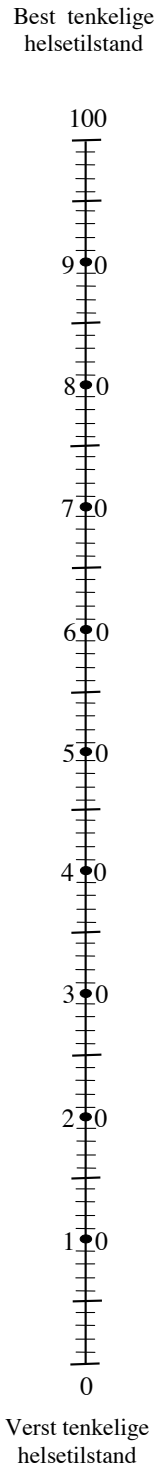
NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 7
5021 BERGEN

13. Din helsetilstand i dag.

For å hjelpe folk til å si hvor god eller dårlig en helsetilstand er, har vi laget en skala (omtrent som et termometer) hvor den beste tilstanden du kan tenke deg er merket 100 og den verste tilstanden du kan tenke deg er merket 0.

Vi vil gjerne at du viser på denne skalaen hvor god eller dårlig helsetilstanden din er i dag, etter din oppfatning. Vær vennlig å gjøre dette ved å trekke en linje fra boksen nedenfor til det punktet på skalaen som viser hvor god eller dårlig din helsetilstand er i dag.

Din egen helsetilstand i dag



NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 7
5021 BERGEN

SMERTE

14. Sett ett kryss på den streken som du synes tilsvarer din gjennomsnittlige smerteopplevelse fra den opererte hoften den siste måneden:

Ingen smerte — Maksimal smerte

I--------I--------I--------I--------I--------I--------I--------I--------I--------I

lett | moderat | middels | sterk | uutholdelig

TILFREDSHET

15. Sett ett kryss på den streken som du synes tilsvarer hvor fornøyd du er med operasjonsresultatet:

Fornøyd — Misfornøyd

I--------I--------I--------I--------I--------I--------I--------I--------I--------I

svært fornøyd | fornøyd | middels fornøyd | misfornøyd | svært misfornøyd

NASJONALT HOFTEBRUDDREGISTER
Nasjonalt Register for Leddproteser
Helse Bergen HF, Ortopedisk klinikk
Haukeland Universitetssykehus
Møllendalsbakken 7
5021 BERGEN

16. Har du besvær fra den andre hoften?

☐ 1 Ja ☐ 2 Nei

17. Er det andre årsaker til at du har problemer med å gå?
(For eksempel smerter fra andre ledd, ryggsmerter, hjerte-karsykdom eller andre sykdommer som påvirker gangevnen din)

☐ 1 Ja ☐ 2 Nei

18. Har du hatt nye operasjoner i den samme hoften som ble operert for hoftebrudd?

☐ 1 Ja ☐ 2 Nei

Takk for at du tok deg tid til å svare på spørsmålene. Dine svar er svært nyttige for oss. Vennligst send spørreskjemaet i retur til oss i den ferdig frankerte svarkonvolutten.

Papers I-III

Paper I:

Grønhaug KML, Dybvik E, Gjertsen J-E, Samuelsson K, Östman B. Subsequent ipsi- and contralateral femoral fractures after intramedullary nailing of a trochanteric or subtrochanteric fracture: a cohort study on 2012 patients. BMC Musculoskelet Disord. 2022 Apr 28;23(1):399

Paper II:

Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen J-E. Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures: 17,341 patients from the Norwegian Hip Fracture Register. Bone Joint J. 2022 Feb;104-B(2):274-282

Paper III:

Grønhaug KML, Dybvik E, Matre K, Östman B, Gjertsen J-E. Comparison of Intramedullary Nails in the Treatment of Trochanteric and Subtrochanteric Fractures: An Observational Study of 13,232 Fractures in the Norwegian Hip Fracture Register. J Bone Joint Surg Am. 2023 Aug 16;105(16):1227-1236

Graphic design: Communication Division, UiB / Print: Skipnes Kommunikasjon AS

uib.no

ISBN: 9788230858752 (print)
9788230860441 (PDF)