■ TRAUMA

Intramedullary nail versus sliding hip screw for stable and unstable trochanteric and subtrochanteric fractures

17,341 PATIENTS FROM THE NORWEGIAN HIP FRACTURE REGISTER

K. M. L. Grønhaug,
E. Dybvik,
K. Matre,
B. Östman,
J-E. Gjertsen

From Norwegian Hip Fracture Register, Bergen, Norway

Aims
The aim of this study was to investigate if there are differences in outcome between sliding hip screws (SHSs) and intramedullary nails (IMNs) with regard to fracture stability.

Methods
We assessed data from 17,341 patients with trochanteric or subtrochanteric fractures treated with SHS or IMN in the Norwegian Hip Fracture Register from 2013 to 2019. Primary outcome measures were reoperations for stable fractures (AO Foundation/Orthopaedic Trauma Association (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 (EuroQol five-dimension three-level index score), 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 American Society of Anesthesiologists score.

Results
Reoperation rate was lower after surgery with IMN for unstable fractures one year (HRR 0.82, 95% confidence interval (CI) 0.70 to 0.97; p = 0.022) and three years postoperatively (HRR 0.86, 95% CI 0.74 to 0.99; p = 0.036), compared with SHS. For individual fracture types, no clinically significant differences were found. Lower one-year mortality was found for IMN compared with SHS for stable fractures (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.

Cite this article: ***Bone Joint J*** **2022;104-B(2):274–282.**

Introduction
The choice of implant in the treatment of trochanteric fractures and subtrochanteric fractures has been debated for decades, without reaching consensus.[1,2]

The most common implants are extramedullary sliding hip screws (SHSs) and intramedullary nails (IMNs),[2] skewing towards IMN over the past two decades.[3] The IMN has historically had a higher risk of peri-implant fractures.[2] However, modern nail designs may have reduced this difference.[2,4] Accordingly, results from earlier studies comparing the two treatment methods may no longer be valid in the context of revised treatment recommendations.[4] Results from the available literature are contradictory. Recent studies have been unable to demonstrate any significant differences in outcome,[5,6] whereas others report a beneficial effect of IMNs in the treatment of unstable trochanteric and subtrochanteric fractures.[7,8] A

Correspondence should be sent to K. M. L. Grønhaug; email: kirstengroenhaug@gmail.com

doi:10.1302/0301-620X.104B2.BJJ-2021-1078.R1 $2.00

Bone Joint J
2022;104-B(2):274–282.

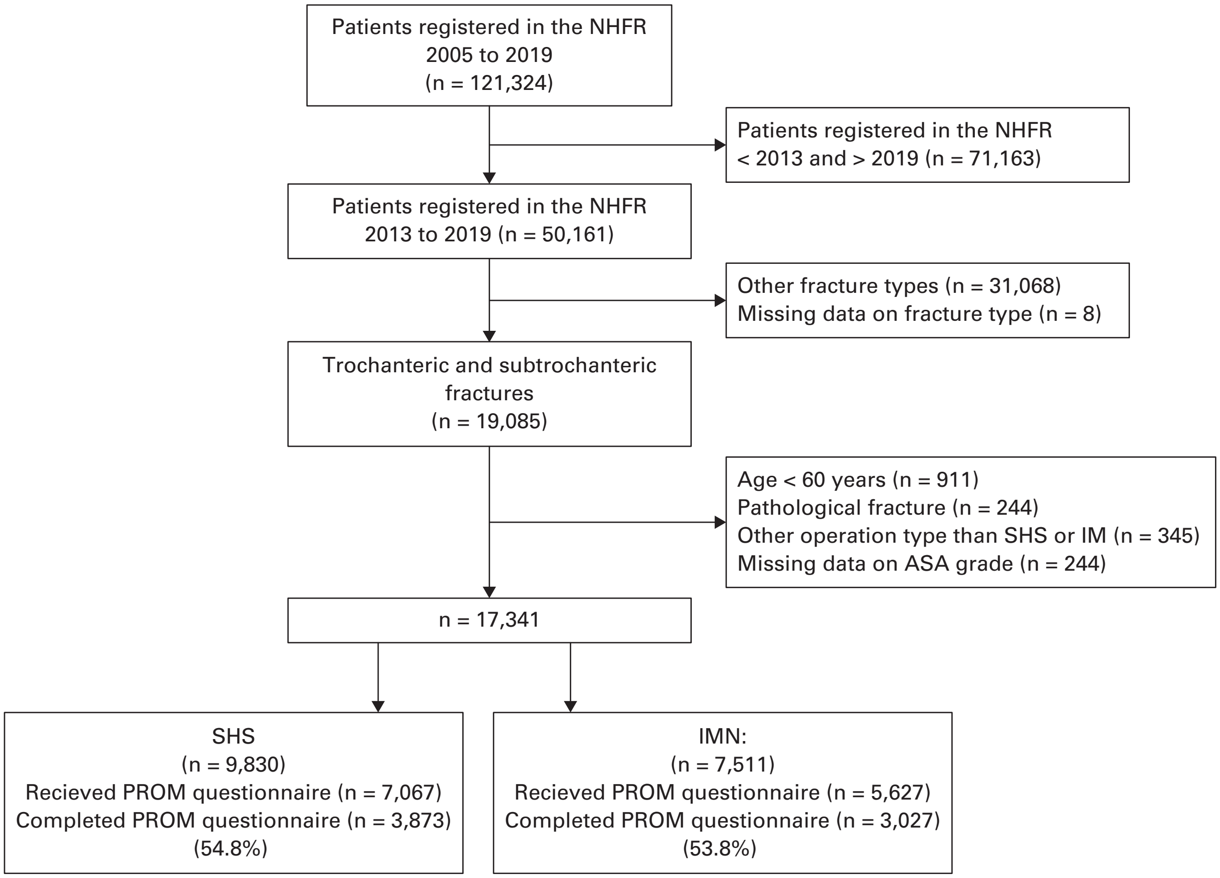

Fig. 1

Flowchart of the study population. ASA, American Society of Anesthesiologists; IMN, intramedullary nail; NHFR, Norwegian Hip Fracture Register; PROM, patient-reported outcome measure; SHS, sliding hip screw.

long IMN is now recommended as the implant of choice for AO Foundation/Orthopaedic Trauma Association (AO/OTA)[9] A3 trochanteric fractures and subtrochanteric fractures in several countries,[10] although the superiority of the IMN is still debatable. An association between increased 30-day mortality and IMNs in the treatment of trochanteric fractures has been proposed.[11] There are still reports describing higher risk of peri-implant fracture with IMN than SHS.[12] In this study, based on data from the Norwegian Hip Fracture Register (NHFR) from 2013 to 2019, we compared reoperation rates between SHS and IMN in stable fractures (AO/OTA A1) and unstable fractures (AO/OTA A2, A3, and subtrochanteric combined) one and three years postoperatively. Secondary aims were to compare reoperation rates between SHS and IMN in A2, A3, and subtrochanteric fractures separately, and to compare mortality and patient-reported outcomes after SHS and IMN for stable and unstable fractures one year after surgery.

Methods

This prospective cohort study is based on data from the NHFR. The reporting rate was 88% for primary osteosynthesis and 80% for reoperations in 2018.[13] The surgeon reports information on the patient, the fracture, and the operation in a one-page form. Patient-reported outcome measures (PROMs) questionnaires are sent to all patients four, 12, and 36 months postoperatively, where the four-month questionnaire also includes questions on preoperative status. Preoperative status and data from the 12-month questionnaire were included in the present study. Trochanteric fractures were classified according to the AO/OTA classification system as AO/OTA type A1 (simple two-part), A2 (multifragmentary), and A3 (intertrochanteric/reverse oblique).[9] Subtrochanteric fractures were defined as diaphyseal fractures with the centre of the fracture less than five cm distal to the lesser trochanter.[9] Further, we defined all A1 fractures as stable and A2, A3, and subtrochanteric fractures as unstable.[14]

We included patients with trochanteric or subtrochanteric fractures treated with a SHS with or without a trochanteric support plate (TSP), or a short or long IMN, treated from January 2013 to December 2019. Patients aged < 60 years, patients treated with other implants than SHS or IMN, patients with pathological fractures (other than osteoporosis), and patients with missing data (American Society of Anesthesiologists (ASA) classification,[15] fracture type, and type of implant) were excluded. Finally, 17,341 patients were included in the reoperation analysis. Of these, 9,830 (56.7%) were treated with a SHS and 7,511 (43.3%) with an IMN (Figure 1). Reoperations were categorized according to indication and type. Cause of reoperation was not readily available in patients receiving

Table I. Baseline characteristics of patients.

Variable	AO/OTA A1 fractures, n (%)			AO/OTA A2 fractures, n (%)			AO/OTA A3 fractures, n (%)			Subtrochanteric fractures, n (%)		
	SHS	IMN	p-value	SHS	IMN	p-value	SHS	IMN	p-value	SHS	IMN	p-value
Total	4,811	2,030		4,139	2,975		407	645		473	1,861	
Female	3,280 (68)	1,399 (69)	0.548*	3,042 (74)	2,187 (74)	0.988*	307 (75)	494 (77)	0.667*	355 (75)	1,392 (75)	0.909*
Mean age, yrs (SD)	83.0 (9.0)	83.0 (8.7)	0.990†	83.5 (8.6)	83.3 (8.7)	0.482†	83.6 (8.5)	82.9 (8.8)	0.182†	82.4 (9.7)	82.2 (9.3)	0.707†
Age group, yrs			0.022*			0.912*			0.456*			0.068*
60 to 74	924 (19)	347 (17)		692 (17)	515 (17)		67 (17)	123 (19)		114 (24)	406 (22)	
75 to 79	542 (11)	272 (13)		490 (12)	349 (12)		46 (11)	90 (14)		38 (8)	224 (12)	
80 to 84	922 (19)	389 (19)		779 (19)	548 (18)		68 (17)	103 (16)		76 (16)	341 (18)	
85 to 89	1,153 (24)	517 (26)		1,081 (26)	793 (27)		117 (29)	178 (28)		122 (26)	456 (25)	
> 90	1,270 (26)	505 (25)		1,100 (27)	770 (26)		109 (27)	151 (23)		123 (26)	434 (23)	
ASA grade			0.215*			0.389*			0.847*			0.334*
1	85 (2)	30 (2)		51 (1)	44 (2)		6 (2)	8 (1)		14 (3)	40 (2)	
2	1,555 (32)	617 (30)		1,261 (31)	911 (31)		118 (29)	199 (31)		146 (31)	571 (31)	
3	2,794 (58)	1,233 (61)		2,483 (60)	1,802 (61)		249 (61)	379 (59)		268 (57)	1,109 (60)	
4	377 (8)	150 (7)		344 (8)	218 (7)		34 (8)	59 (9)		45 (10)	141 (8)	
Cognitive impairment			0.007*			0.029*			0.875*			0.695*
Yes	1,280 (27)	550 (27)		1,137 (28)	748 (25)		104 (26)	161 (25)		117 (25)	420 (23)	
No	3,010 (63)	1230 (61)		2,537 (61)	1,927 (65)		267 (66)	417 (65)		311 (66)	1,255 (67)	
Uncertain	384 (8)	207 (10)		370 (9)	238 (8)		27 (7)	51 (8)		38 (8)	149 (8)	
Missing	137 (3)	43 (2)		95 (2)	62 (2)		9 (2)	16 (3)		7 (2)	37 (2)	
PROM preoperative, n	1,981	875		1,740	1,280		182	301		216	810	
Mean EQ-5D index score (SD)	0.71 (0.28)	0.70 (0.27)	0.448†	0.72 (0.27)	0.71 (0.28)	0.176†	0.69 (0.28)	0.74 (0.25)	0.034†	0.71 (0.29)	0.74 (0.27)	0.169†
Preoperative mobility (EQ-5D)			0.035*			0.283*			0.098*			0.576*
No problems	1,142 (56)	463 (51)		1,001 (56)	732 (56)		90 (48)	183 (58)		127 (58)	489 (58)	
Some problems	868 (43)	419 (47)		771 (43)	565 (43)		96 (51)	131 (41)		86 (39)	338 (40)	
Confined to bed	30 (2)	20 (2)		13 (1)	17 (1)		2 (1)	4 (1)		6 (3)	14 (2)	

*Chi-squared test.
†Independent-samples *t*-test
AO/OTA, AO Foundation/Orthopaedic Trauma Association; ASA, American Society of Anaesthesiologists; EQ-5D, EuroQol five-dimension index score; IMN, intramedullary nail; PROM, patient-reported outcome measure; SD, standard deviation; SHS, sliding hip screw.

total hip arthroplasty (THA) as these operations are recorded in the Norwegian Arthroplasty Register (NAR), using a different form. Consequently, cause of reoperation recorded in the NAR was labelled "unspecified sequelae (THA)". More than one cause may be given for each reoperation in the NHFR. The following hierarchy was chosen to identify the most severe cause in each case: infection, peri-implant fracture, mechanical complications (nonunion, implant failure, cut-out), unspecified sequelae (treated with THA), pain alone, and other. Risk of reoperation at one and three years was calculated. One-year mortality was calculated and compared for patients treated with SHS and IMN. Patient reported outcome was compared one year postoperatively using the EuroQol five-dimesion three-level (EQ-5D-3L) index score,[16] a visual analogue scale (VAS) 0 to 100 for pain (0 = no pain and 100 = unbearable pain), and a VAS 0 to 100 for satisfaction (0 = least satisfied and 100 = most satisfied). Of the 17,341 patients included, 12,810 (73.9%) were still alive after one year. A 12-month questionnaire was sent to 12,694 patients (73.2%). Of these, 6,632 (52.2%) responded and were included in the PROM analysis. Stable fractures (A1) and unstable fractures (A2, A3, and subtrochanteric) were analyzed separately with regard to reoperation rates and PROM data. Further, subgroup analyses for each of the unstable fracture types were performed. SHS with and without a TSP were analyzed as one group, as were short and long IMNs.

We chose to compare SHS and IMN in the treatment of stable fractures and unstable fractures, as A3 and subtrochanteric fractures are less common and classification errors between A2, A3, and subtrochanteric fractures are frequent.[17,18] Erratic coding may obscure the true complication rates of implants used to treat different fracture subgroups.[14] To make the statistical analysis more robust and more clinically relevant, we considered A2, A3, and subtrochanteric as one group, acknowledging fracture instability as the common denominator.

Statistical analysis. Baseline data were analyzed using the chi-squared test and analysis of variance (ANOVA) for categorical variables, and the independent-samples *t*-test for continuous variables. Hazard rate ratios (HRRs) of reoperations and hierarchical cause of reoperation were calculated using Cox regression analysis, adjusted for age, sex, and ASA classification. Patients were followed from primary operation to reoperation, death, or until 31 December 2019 (end of study), whichever occurred first. One-year

Table II. Number and type of reoperations. More than one reoperation type may be performed per fracture.

Variable	Total	AO/OTA A1 fractures, n (%)		AO/OTA A2 fractures, n (%)		AO/OTA A3 fractures, n (%)		Subtrochanteric fractures, n (%)	
		SHS	IMN	SHS	IMN	SHS	IMN	SHS	IMN
Number	17,341	4,811	2,030	4,139	2,975	407	645	473	1,861
Reoperations three years	982 (5.7)	159 (3.3)	67 (3.3)	303 (7.3)	182 (6.1)	46 (11.3)	63 (9.8)	36 (7.6)	126 (6.8)
Total hip arthroplasty	319 (1.8)	58 (1.2)	18 (0.9)	110 (2.7)	59 (2.0)	13 (3.2)	19 (2.9)	11 (2.3)	31 (1.7)
Bipolar hemiarthroplasty	184 (1.2)	34 (0.7)	16 (0.8)	62 (1.5)	37 (1.2)	5 (1.2)	10 (1.6)	6 (1.3)	14 (0.8)
Re-osteosynthesis	257 (1.5)	29 (0.6)	23 (1.1)	66 (1.6)	45 (1.5)	18 (4.4)	17 (2.6)	14 (3.0)	45 (2.4)
Soft-tissue debridement	106 (0.6)	26 (0.5)	3 (0.1)	40 (1.0)	13 (0.4)	7 (1.7)	5 (0.8)	0 (0.0)	12 (0.6)
Removal of implant	86 (0.5)	12 (0.2)	2 (0.1)	26 (0.6)	19 (0.6)	3 (0.7))	7 (1.1)	1 (0.2)	16 (0.9)
Other	121 (0.7)	19 (0.4)	6 (0.3)	38 (0.9)	22 (0.7)	6 (1.5)	11 (1.7)	6 (1.3)	13 (0.7)

AO/OTA, AO Foundation/Orthopaedic Trauma Association; IMN, intramedullary nail; SHS, sliding hip screw.

Table III. Cause of reoperation after stable fractures (AO Foundation/Orthopaedic Trauma Association A1) one and three years postoperatively, hierarchically arranged.

Variable	SHS, n (%)	IMN, n (%)	HRR (95% CI)	p-value*
One year postoperatively				
All reoperations	116 (2.4)	54 (2.7)	1.09 (0.79 to 1.51)	0.604
Infection	25 (0.5)	5 (0.2)	0.46 (0.18 to 1.21)	0.116
Peri-implant fracture	6 (0.1)	15 (0.7)	5.94 (2.30 to 15.3)	< 0.001
Mechanical complications†	48 (1.0)	17 (0.8)	0.82 (0.47 to 1.43)	0.483
Unspecified sequelae (THA)‡	33 (0.7)	11 (0.5)	0.79 (0.40 to 1.56)	0.492
Other reason§	4 (0.1)	4 (0.2)	2.44 (0.61 to 9.78)	0.207
Pain alone	0 (0)	2 (0.1)	N/A	
Three years postoperatively				
All reoperations	159 (3.3)	67 (3.3)	1.00 (0.75 to 1.32)	0.982
Infection	27 (0.6)	5 (0.2)	0.43 (0.17 to 1.13)	0.086
Peri-implant fracture	7 (0.1)	17 (0.8)	5.80 (2.40 to 13.99)	< 0.001
Mechanical complications†	56 (1.2)	18 (0.9)	0.74 (0.44 to 1.26)	0.266
Unspecified sequelae (THA)‡	56 (1.2)	18 (0.9)	0.78 (0.46 to 1.32)	0.354
Other reason§	7 (0.1)	6 (0.3)	2.07 (0.70 to 6.16)	0.192
Pain alone	6 (0.1)	3 (0.1)	1.22 (0.31 to 4.88)	0.779

*Cox regression model adjusted for age group, sex, and American Society of Anesthesiologists grade is used as statistical method. Sliding hip screw is reference.
†Including hardware failure, cut-out, and nonunion.
‡Operation with THA recorded in the Norwegian Arthroplasty Register.
§All other reasons for reoperations, except pain alone.
CI, confidence interval; HRR, hazard rate ratio; IMN, intramedullary nail; N/A, not applicable; SHS, sliding hip screw; THA, total hip arthroplasty.

mortality for SHS and IMN was calculated for stable and unstable fractures using Cox regression analysis adjusted for age group, sex, and ASA classification. Further, the Cox model was used to construct survival curves for the different operation methods with adjustments for age group, 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 to 100), and satisfaction (VAS 0 to 100) 12 months postoperatively were recorded, and we used the independent-samples *t*-test to compare means between SHS and IMN. The significance level was set at a p-value < 0.05. The statistical analysis was performed using IBM SPSS Statistics v. 26 (IBM, USA) and the R statistical package (R Foundation for Statistical Computing, Austria).

The STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines were followed.[19]

Results

The study population included 9,830 patients operated with a SHS and 7,511 with an IMN. Overall, 6,984 patients (71%) with a SHS and 5,472 (73%) of those with an IMN were female, and the mean age was 83.2 years (standard deviation (SD) 8.85) and 82.9 years (SD 8.88), respectively. Approximately 70% of the patients were classified as ASA grade 3 or 4 in both treatment groups (Table I). A SHS with TSP was chosen in 7% of A1 fractures, 50% of A2 fractures, 82% of A3 fractures, and 68% of subtrochanteric fractures treated with a SHS. A long nail was chosen in 9% of A1 fractures, 29% of A2 fractures, 65% of A3 fractures, and 88% of subtrochanteric fractures treated with an IMN.

Reoperations. Number and type of reoperation for each fracture type are listed in Table II. No difference in overall risk of reoperation was found between SHS and IMN for stable fractures one year postoperatively (HRR 1.1, 95% confidence interval (CI) 0.79 to 1.51; p = 0.604) or three years postoperatively (HRR 1.0, 95% CI 0.75 to 1.32; p = 0.98), but peri-implant fracture was a more frequent cause of reoperation with the use of IMN (HRR 5.9, 95% CI 2.30 to 15.30; p < 0.001, and HRR 5.8, 95% CI 2.40 to 13.99; p < 0.001, respectively) (Table III). For unstable fractures, there was a lower overall risk of reoperation for IMN than for SHS one year postoperatively (HRR 0.82,

Table IV. Cause of reoperation after unstable fractures (AO Foundation/Orthopaedic Trauma Association A2, A3, and subtrochanteric) one and three years postoperatively, hierarchically arranged.

Variable	SHS, n (%)	IMN, n (%)	HRR (95% CI)	p-value*
One year postoperatively				
All reoperations	290 (5.8)	270 (4.9)	0.82 (0.70 to 0.97)	0.022
Infection	53 (1.1)	34 (0.6)	0.59 (0.38 to 0.90)	0.016
Peri-implant fracture	16 (0.3)	23 (0.4)	1.30 (0.69 to 2.46)	0.425
Mechanical complications†	132 (2.6)	127 (2.3)	0.85 (0.67 to 1.09)	0.192
Unspecified sequelae (THA)‡	81 (1.6)	57 (1.0)	0.60 (0.43 to 0.85)	0.003
Other reason§	8 (0.2)	17 (0.3)	1.93 (0.83 to 4.46)	0.127
Pain alone	0 (0)	12 (0.2)	N/A	
Three years postoperatively				
All reoperations	385 (7.7)	371 (6.8)	0.86 (0.74 to 0.99)	0.036
Infection	55 (1.1)	34 (0.6)	0.57 (0.37 to 0.87)	0.009
Peri-implant fracture	20 (0.4)	36 (0.7)	1.66 (0.96 to 2.87)	0.070
Mechanical complications†	150 (3.0)	153 (2.8)	0.91 (0.72 to 1.14)	0.389
Unspecified sequelae (THA)‡	130 (2.6)	100 (1.8)	0.67 (0.52 to 0.88)	0.003
Other reason§	12 (0.2)	22 (0.4)	1.66 (0.82 to 3.36)	0.158
Pain alone	18 (0.4)	26 (0.5)	1.27 (0.69 to 2.31)	0.444

*Cox regression model adjusted for age group, sex, and American Society of Anesthesiologists grade is used as statistical method. Sliding hip screw is reference.
†including hardware failure, cut-out, and nonunion.
‡Operation with THA recorded in the Norwegian Arthroplasty Register.
§All other reasons for reoperations, except pain alone.
CI, confidence interval; HRR, hazard rate ratio; IMN, intramedullary nail; N/A, not applicable; SHS, sliding hip screw; THA, total hip arthroplasty.

95% CI 0.70 to 0.97; p = 0.022) and three years postoperatively (HRR 0.86, 95% CI 0.74 to 0.87; p = 0.009). Further, the risk of reoperation due to infection one and three years postoperatively (HRR 0.6, 95% CI 0.38 to 0.90; p = 0.016, and HRR 0.6, 95% CI 0.37 to 0.89; p = 0.009, respectively), and the risk of reoperation with THA one and three years postoperatively (HRR 0.6, 95% CI 0.43 to 0.85; p = 0.003, and HRR 0.7, 95% CI 0.52 to 0.88; p = 0.003, respectively) were lower for IMN than for SHS (Table IV). Implant survival curves for SHS and IMN for stable fractures and unstable fractures are shown in Figure 2. When the unstable fracture types were investigated individually, SHS was found to have a higher risk of reoperation for any cause for A3 fractures at one year, and for A2 fractures at three years, compared to IMN. Otherwise no major difference in reoperation risk could be found between the two treatment methods when the fracture types were analyzed individually (Table V).

Mortality. One-year mortality was lower for IMN compared to SHS for stable fractures (HRR 0.87, 95% CI 0.78 to 0.96; p = 0.007), and for unstable fractures (HRR 0.91, 95% CI 0.84 to 0.98; p = 0.014).

PROMs data. Patients with unstable fractures treated with a SHS reported a lower mean EQ-5D-3L index score (0.55 (SD 0.26) vs 0.58 (SD 0.27); p = 0.001, chi-squared test), inferior walking ability based on the mobility dimension of the EQ-5D-3L (p < 0.001, chi-squared test), and were less satisfied with the result of the operation (mean VAS 32.5 (SD 22.5) vs 30 (SD 22.2); p < 0.001, chi-squared test) than patients treated with an IMN (Table VI). The differences found in EQ-5D-3L were persistent when calculating δ values. In patients with unstable fractures treated with SHS and IMN, 461 (22.6%) and 595 (25.6%) regained pre-fracture index score, respectively (p = 0.019, chi-squared test), while 785 (53%) and 1,038 (60%) regained pre-fracture walking ability, respectively (p < 0.001, chi-squared test).

Discussion

The results of this national, register-based cohort study may indicate that IMN in the treatment of unstable fractures (A2, A3, and subtrochanteric fractures combined) is associated with lower reoperation rates than SHS. Infection and unspecified sequelae leading to THA were more frequent causes of reoperation with the use of a SHS. We found similar reoperation rates for SHS and IMN in the treatment of A1 fractures, but peri-implant fracture was a more common 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 PROMs data. There was, however, a lower one-year mortality rate in patients treated with IMN compared with SHS for stable and unstable fractures alike.

The most recent Cochrane review in 2010 recommended SHS for the majority of trochanteric fractures, mainly due to the higher incidence of peri-implant fractures associated with IMNs.[2] There were indications that IMNs may have advantages in the treatment of intertrochanteric fractures (A3) and subtrochanteric fractures, but further studies are required. 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.[6] Similar results were reported in a multicentre, randomized controlled trial (RCT) comparing SHS and IMN (InterTAN) in 684 patients with A1, A2, A3, and subtrochanteric fractures.[20]

In the present study, we aimed to identify potential differences in reoperation rate between SHS and IMN in stable fractures (A1) and in unstable fractures (A2, A3, and subtrochanteric fractures combined), as such differences might be more clinically relevant and provide more robust statistical analysis. In previous studies from the NHFR, lower reoperation rates have been found for SHS than for IMN in type

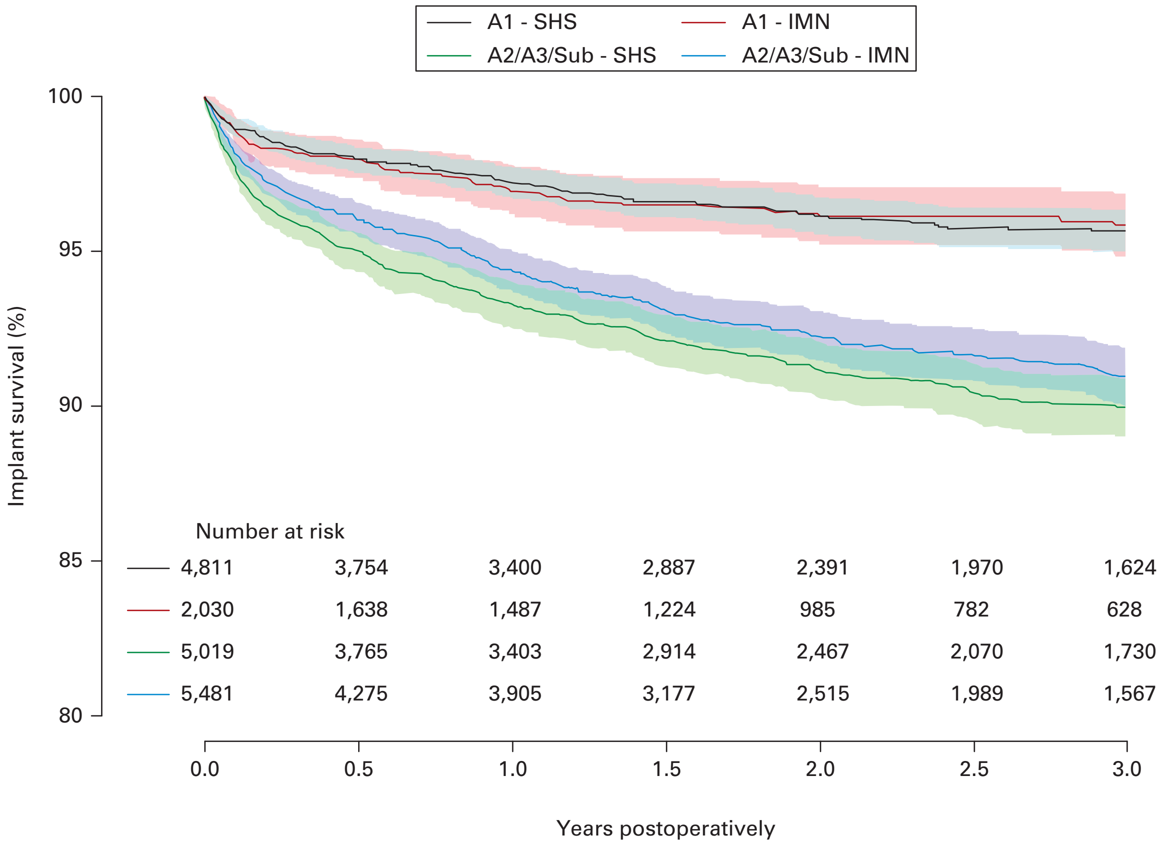

Fig. 2

Implant survival curves calculated from using Cox regression analysis for sliding hip screw (SHS) and intramedullary nail (IMN) in stable (AO Foundation/Orthopaedic Trauma Association (AO/OTA) A1) fractures versus unstable (A2, A3, and subtrochanteric) fractures.

Table V. Risk of reoperation for sliding hip screw (SHS) and intramedullary nail (IMN) for AO Foundation/Orthopaedic Trauma Association (AO/OTA) A1, A2, A3, and subtrochanteric fractures individually.

Variable	SHS		IMN		HRR (95% CI)*	p-value*
	Total, n	Reoperation, n	Total, n	Reoperation, n		
Reoperations one year						
AO/OTA A1	4,811	116	2,030	54	1.09 (0.79 to 1.51)	0.604
AO/OTA A2	4,139	221	2,975	135	0.83 (0.67 to 1.03)	0.093
AO/OTA A3	407	41	645	45	0.65 (0.43 to 1.00)	0.050
Subtrochanteric fractures	473	28	1,861	90	0.79 (0.52 to 1.21)	0.276
Reoperations three years						
AO/OTA A1	4811	159	2,030	67	1.00 (0.75 to 1.33)	0.982
AO/OTA A2	4,139	303	2,975	182	0.83 (0.69 to 1.00)	0.050
AO/OTA A3	407	46	645	63	0.83 (0.57 to 1.21)	0.332
Subtrochanteric fractures	473	36	1,861	126	0.89 (0.61 to 1.29)	0.538

*Hazard rate ratio calculated using Cox regression with sliding hip screw as reference. Adjusted for age, sex, and American Society of Anesthesiologists grade.
CI, confidence interval; HRR, hazard rate ratio.

A1 fractures one and three years postoperatively,[21] and higher reoperation rates for SHS compared with IMN in type A3 and subtrochanteric fractures combined.[8] A2 fractures were not included in these studies. In our study, we were unable to reproduce the differences in reoperation rate regarding individual fracture patterns, but we found a statistically significant lower risk of reoperation with the use of IMN in the treatment of the unstable fractures pooled together. Our results support the conclusion reported in a previous study from the NHFR that recommended the use of IMN in the treatment of A3 and subtrochanteric fractures.[8] We included A2 fractures in the analysis of unstable fractures, thus also extending the recommendation to this group of fractures. Previous studies have highlighted only moderate to fair inter- and intraobserver reliability in the AO classification system regarding proximal femur fractures, particularly with regard to stability assessment

Table VI. Pain, satisfaction, and quality of life 12 months after primary operation.

Variable	SHS	IMN	Mean difference (95% CI)	p-value
EQ-5D-3L index score, n; mean (SD)				
Stable fractures	1,746; 0.59 (0.27)	692; 0.58 (0.27)	0.01 (-0.02 to 0.02)	0.958*
Unstable fractures	1,776; 0.55 (0.26)	2,052; 0.58 (0.27)	-0.04 (-0.05 to -0.02)	< 0.001*
EQ-5D-3L mobility for stable fractures, n (%)				0.505†
No problems	485 (26.9)	221 (29.1)		
Some problems	1,243 (68.9)	482 (66.6)		
Confined to bed	77 (4.3)	31 (4.3)		
EQ-5D-3L mobility for unstable fractures, n (%)				< 0.001†
No problems	377 (20.4)	571 (26.6)		
Some problems	1,372 (74.3)	1,488 (69.4)		
Confined to bed	97 (5.3)	84 (3.9)		
VAS score for pain, n; mean (SD)				
Stable fractures	1,777; 24.2 (21.1)	704; 24.3 (21.2)	-0.1 (-1.9 to 1.7)	0.914*
Unstable fractures	1,820; 27.3 (21.2)	2,104; 25.8 (21.0)	1.5 (0.2 to 2.8)	0.029*
VAS score for satisfaction; n; mean (SD)				
Stable fractures	1,773; 27.9 (21.5)	710; 27.5 (21.3)	0.5 (-1.4 to 2.3)	0.631*
Unstable fractures	1,821; 32.5 (22.5)	2,110; 30.0 (22.2)	2.5 (1.1 to 4.0)	< 0.001*

*Independent-samples *t*-test
†Chi-squared test.
CI, confidence interval; EQ-5D-3L, EuroQol five-dimension three-level index score; IMN, intramedullary nail; SD, standard deviation; SHS, sliding hip screw; VAS, visual analogue scale.

of A2 fractures. This implies caution with use in day-to-day decision-making or in registry data interpretation.[17,18]

Infection was a more prevalent cause of reoperation in patients with unstable fractures treated with SHS compared to those treated with IMN in our study. This also applied to the separate analysis of A2 and A3 fractures. Peri-implant fracture was a more prevalent cause of reoperation with the use of IMN in A1 fractures, but not in A2, A3, and subtrochanteric fractures individually or pooled together. Some authors claim that long nails reduce the risk of peri-implant fracture, but the literature is inconclusive regarding the protective effect of long versus short IMNs.[22] A3 and subtrochanteric fractures were almost exclusively treated with long nails/SHS with TSP and A1 fractures almost exclusively treated with short nails/regular SHS. Therefore, due to inherent bias, we were not able to compare outcomes of long versus short nails in this study, nor variations between SHS versus SHS with TSP.

The high overall mortality in this population may pose a challenge in the statistical analyses. We focus on time to reoperation and we argue that the results from Cox regression are straight forward to interpret for these analyses. The statistical interpretation from Kaplan-Meier and Cox analysis for analysis of reoperation have been advocated.[23] Furthermore, using Fine and Gray models to condition on mortality may introduce collider bias and misinterpretation of the results.[24]

We found a lower mortality rate in patients treated with IMN compared to patients treated with SHS, applicable to stable and unstable fractures. This is contradictory to Whitehouse et al,[11] reporting a 12.5% increase in 30-day mortality risk after IMN. These results are not readily comparable. Our population was collected during a later period, the percentage of females was higher, we included both trochanteric and subtrochanteric fractures and we excluded pathological fractures.

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.[25] Furthermore, economic considerations inevitably play a role in choice of implants in all fracture treatment.[26]

The EQ-5D-3L has been extensively studied and is regarded as a useful and relevant outcome measure for this patient population.[27,28] We found a lower mean EQ-5D-3L index score at one year for patients with unstable fractures treated with a SHS compared to an IMN, and a lower VAS satisfaction score. Although the differences in mean EQ-5D-3L index score and mean VAS satisfaction score between the two groups were small, a sizable number of patients in one of the groups may still have reported a clinically significant better outcome. Accordingly, we performed additional analyses to identify the number of patients returning to their pre-fracture EQ-5D-3L score, VAS satisfaction score, and walking ability, confirming the differences.

Complications after a trochanteric or subtrochanteric fracture are rare,[20] and large study populations are required to reveal statistically significant differences in implant performance or population characteristics. Some primary fracture patterns are uncommon, such as the A3 and the subtrochanteric fracture, and a sufficiently powered RCT is difficult to implement within a reasonable period. A large register-based study such as this one addresses some of these issues. In our study, patient characteristics at baseline were similar for the two groups, and selection bias unlikely. In the Norwegian healthcare system, the individual hospital chooses the implant, rather than the orthopaedic surgeon. This also reduces the risk of selection bias. Finally, register data from a national database describe the results of the average representative surgeon and hospital, and may reveal differences lost to RCTs performed in individual centres and by a limited number of surgeons.

This study has several limitations. Register-based studies such as ours can only describe associations, and do not aspire to prove causality. The completeness of registration of reoperations in the NHFR is lower than for primary operations,[13] at 80% versus 88%. Under-reporting of complications is a possible bias, but we have no reason to suspect a difference in reporting between the implant types. IMNs and SHSs were assessed as two implant groups. Accordingly, our results might not apply equally to all implant dimensions and brands. Further, NHFR data do not provide radiological evidence of the primary fracture, and there might be classification errors obscuring the true complication rates of implants used to treat different fracture subgroups.[14,17,18] We have included all A2 fractures in the group of unstable fractures, as subclassification was not possible based on the NHFR data. A2-1 fractures are often considered stable, whereas the majority of A2 fractures are unstable and may pose as great a challenge to the orthopaedic surgeon as an A3 or subtrochanteric fracture. Additionally, combinations of fracture patterns are common but not mentioned in the NHFR data. Finally, analyses of PROM data must be used with caution. 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, but we chose still to include these results as we have no reason to believe there are more non-responders in either group.

In 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.

Take home message

- Lower reoperation rate for unstable fractures treated with intramedullary nail (IMN) compared with sliding hip screw (SHS).
- Comparable outcomes in SHS and IMN in stable fractures and individual fracture types.
- Lower one-year mortality rates in patients treated with IMN In the treatment of unstable fractures, the use of SHS was more likely to lead to infection, and complications that required total hip arthroplasty.
- In the treatment of stable fractures, IMN was associated with increased prevalence of peri-implant fracture as a cause for reoperation.

References

1. **Nyholm AM**, **Palm H**, **Malchau H**, **Troelsen A**, **Gromov K**. Lacking evidence for performance of implants used for proximal femoral fractures - A systematic review. *Injury*. 2016;47(3):586–594.
2. **Parker MJ**, **Handoll HH**. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. *Cochrane Database Syst Rev*. 2010;8(9):CD000093.
3. **Anglen JO**, **Weinstein JN**, **American Board of Orthopaedic Surgery Research Committee**. 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*. 2008;90-A(4):700–707.
4. **Bhandari M**, **Schemitsch E**, **Jönsson 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*. 2009;6:460–464.
5. **Reindl R**, **Harvey EJ**, **Berry GK**, **Rahme E**. Intramedullary versus extramedullary fixation for unstable intertrochanteric fractures: A prospective randomized controlled trial. *J Bone Joint Surg Am*. 2015;97-A(23):1905–1912.
6. **Warren JA**, **Sundaram K**, **Hampton R**, **et al**. 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*. 2020;30(2):243–250.
7. **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*. 2019;33(2):82–87.
8. **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*. 2013;44(6):735–742.
9. **Marsh JL**, **Slongo TF**, **Agel J**, **et al**. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma*. 2007;21(10 Suppl):S1-133.
10. **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*. 2015;97-A(14):1196–1199.
11. **Whitehouse MR**, **Berstock JR**, **Kelly MB**, **et al**. 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*. 2019;101-B(1):83–91.
12. **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*. 2016;47(10):2189–2194.
13. **Furnes O**, **Gjertsen J-E**, **Fenstad AM**, **et al**. Annual report 2020. Norwegian National Advisory Unit on Arthroplasty and Hip Fractures; Norwegian Arthroplasty Register; Norwegian Cruciate Ligament Register; Norwegian Hip Fracture Register; Norwegian Paediatric Hip Register. 2020. http://nrlweb.ihelse.net/eng/Rapporter/Report2019_english.pdf2019 (date last accessed 15 November 2021).
14. **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*. 2002;33(8):713–715.
15. **Dripps RD**. New classification of physical status. *Anaesthesiol*. 1963;24:111.
16. **Brooks R**. EuroQol: the current state of play. *Health Policy*. 1996;37(1):53–72.
17. **Chan G**, **Hughes K**, **Barakat A**, **et al**. Inter- and intra-observer reliability of the new AO/OTA classification of proximal femur fractures. *Injury*. 2021;52(6):1434–1437.
18. **Masters J**, **Metcalfe D**, **Parsons NR**, **et al**. Interpreting and reporting fracture classification and operation type in hip fracture: implications for research studies and routine national audits. *Bone Joint J*. 2019;101-B(10):1292–1299.
19. **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*. 2014;12(12):1495–1499.
20. **Matre K**, **Vinje T**, **Havelin LI**, **et al**. 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*. 2013;95-A(3):200–208.
21. **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*. 2013;471(4):1379–1386.
22. **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*. 2016;30(3):119–124.
23. **Sayers A**, **Evans JT**, **Whitehouse MR**, **Blom AW**. Are competing risks models appropriate to describe implant failure? *Acta Orthop*. 2018;89(3):256–258.
24. **Buzkova P**, **Barzilay JI**, **Mukamal KJ**. Assessing risk factors of non-fatal outcomes amid a competing risk of mortality: the example of hip fracture. *Osteoporos Int*. 2019;30(10):2073–2078.
25. **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*. 2019;33(2):205–226.
26. **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*. 2014;96-A(19):1612–1620.
27. **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.
28. **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*. 2015;97-B(3):372–382.

Author information:
K. M. L. Grønhaug, MD, Orthopaedic Surgeon, Department of Orthopaedic Surgery, Østfold Hospital Trust, Grålum, Norway; Department of Clinical Medicine, University of Bergen, Bergen, Norway.

E. Dybvik, MSc, PhD, Senior Statistician, Norwegian Hip Fracture Register, Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen, Norway.

K. Matre, MD, PhD, Orthopaedic Surgeon
J-E. Gjertsen, MD, PhD, Orthopaedic Surgeon
Department of Clinical Medicine, University of Bergen, Bergen, Norway; Norwegian Hip Fracture Register, Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen, Norway.

B. Östman, MD, PhD, Orthopaedic Surgeon, Department of Orthopaedic Surgery, Østfold Hospital Trust, Grålum, Norway.

Author contributions:
K. M. L. Grønhaug: Conceptualization, Methodology, Visualization, Formal analysis, Writing – original draft, Writing – review & editing.
E. Dybvik: Visualization, Formal analysis, Writing – review & editing.
K. Matre: Conceptualization, Methodology, Visualization, Formal analysis, Writing – review & editing.
B. Östman: Conceptualization, Methodology, Visualization, Formal analysis, Writing – review & editing.
J-E. Gjertsen: Conceptualization, Methodology, Visualization, Formal analysis, Writing – review & editing.

Funding statement:
No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

ICMJE COI statement:
The authors declare that they have no conflicts of interest.

Acknowledgements:
The authors thank all the Norwegian orthopedic surgeons who have loyally reported to the register.

Ethical review statement:
The NHFR has permission from the Norwegian Data Inspectorate to collect patient data based on written consent from the patients. (Permission issued January 3, 2005; reference number 2004/1658-2 SVE/-) Informed consent from patients was entered in the medical records at each hospital.

This article was primary edited by G. Scott.