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Survivorship of Total Hip Arthroplasty After Acute Hip Fracture and Failed Osteosynthesis Based on the Finnish Arthroplasty Register With a 4-Year Mean Follow-Up

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ABSTRACT

Background: Surgical treatment options for femoral neck fracture include arthroplasty and internal fixation (IF). An IF is associated with faster operation time, less blood loss, and fewer hospitalization days than arthroplasty. However, reoperation rates are significantly higher than treatment with total hip arthroplasty (fracture-THA). Most reoperations following IF include implant removal surgeries and conversions to THA (salvage-THA).
Methods: We assessed survivorship of 3,823 fracture-THA, 298 salvage-THA, and 73,141 THA performed for osteoarthritis based on the Finnish Arthroplasty Register using a Kaplan–Meier estimator. In addition, we conducted Cox regression analyses to assess risk factors for a revision operation after fracture-THA.
Results: Inferior Kaplan–Meier 7-year survivorship was observed in the fracture-THA (91.5%, 95% confidence interval (CI) [90.4 to 92.7]) and salvage THA (89.4%, 95% CI [84.8 to 94.1]) groups compared to the osteoarthritis-THA group (95.4%, 95% CI [95.2 to 95.5]). Survivorship between the fracture-THA group and the salvage-THA group was comparable. In the multivariate Cox regression analyses, for risk factors for revision due to infection, dislocation, or periprosthetic fracture, no statistically significant factors were identified.
Conclusion: We conclude that the 7-year survivorship of fracture-THA and salvage-THA is similar, but inferior than that of OA-THA.

Surgical treatment options for femoral neck fracture (FNF) include arthroplasty and internal fixation (IF). Arthroplasty is the most widely used method for displaced fractures in elderly patients, whereas an IF is a viable option for nondisplaced fractures and in young patients when the hip joint can be saved [1–3].

An IF is associated with faster operation time, less blood loss, and fewer hospitalization days than arthroplasty [4,5]. However, reoperation rates are higher than treatment with hemiarthroplasty or total hip arthroplasty (fracture-THA). Reoperation rates after IF vary between 16 and 33%; most reoperations following IFs are implant removal surgeries and conversions to THA (salvage-THA) [6–11]. Some studies have suggested that salvage THA has a higher risk for revision than fracture-THA; however, there is no consensus [12–15]. The revision rate after fracture-THA is lower than IF: revision rates vary between 2.4 and 5.8%, depending on follow-up time. Most revisions following fracture-THA are performed due to dislocation or infection. Although the overall revision rate is lower than IF, the revision procedures are more complex [8,13,16,17]. Several risk factors are associated with revision risk after fracture THA, such as posterior approach and uncemented stem [16].

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We aimed to compare survivorship and revision rates of fracture-THA, OA-THA (THA performed for osteoarthritis), and salvage THA based on the Finnish Arthroplasty Register (FAR) data. Our hypothesis was that fracture-THA and salvage-THA have inferior survivorship than OA-THA. Our secondary aim was to assess the risk factors for revision in fracture-THA patients.

Patients and Methods

Our retrospective registry study was based on prospectively collected data from the FAR, which gathers information on THA surgery in Finland. All healthcare units are required to deliver all essential information on performed THAs to the Finnish Institute for Health and Welfare, which is responsible for the FAR [18]. Since 2014, the updated register has included detailed implant data and variables, such as body mass index, American Society of Anesthesiologists class (ASA class), and surgical approach. As of 2023, over 95% of all primary THAs and 84% of all revisions have been reported to FAR [18].

We assessed the survivorship figures of fracture-THA and salvage-THA and compared them to those of the OA-THA group. The salvage-THA group included patients who had undergone THA as a salvage procedure after failed osteosynthesis for FNF. The Finnish Arthroplasty Register does not record data on the method of osteosynthesis used in the primary fixation. The primary endpoint was revision for any reason. We also assessed survivorship for infection, dislocation, and periprosthetic fracture as separate end points and analyzed the risk factors for revision in the fracture-THA group. The study patients underwent surgery between May 18, 2014, and May 7, 2023, and had a mean follow-up time of 4.0 years (range, 0 to 8.9).

Data on 3,823 fracture-THA, 298 salvage-THA, and 73,141 OA-THA patients were extracted (Figure 1). In all groups, the majority of the patients were women (63% in the fracture-THA group, 59% in the salvage-THA group, and 57% in the OA-THA group). In the fracture-THA and OA-THA groups, the majority were aged 66 to 75 years (44 and 38%, respectively); the most common age group was $\geq$ 76 in the salvage-THA group. Most of the patients in the fracture-THA and salvage-THA groups were ASA class III (47 and 52%, respectively), whereas the most common group was ASA class II in the OA-THA group (51%). In all groups, the posterior approach was the most commonly used (86% in all groups; Table 1).

Data Analyses

The unadjusted survival rates and their 95% confidence intervals (CIs) for OA-THA, fracture-THA, and salvage-THA patients were assessed using a Kaplan–Meier (KM) estimator. Survivorship was estimated according to revision for any reason, revision due to dislocation, revision due to infection, revision due to periprosthetic fracture, and mortality as events of interest. Following standard KM methodology, patients were censored at time of death when the event was revision for any reason. When analyzing revision due to a specific reason, patients were censored at time of death or at revision for another reason. When mortality was the event, no censoring was done.

Univariate and multivariate Cox proportional hazards regression models were fitted for fracture-THA patients who had a revision due to any reason as the event. We used the directional acyclic graph (DAG) presented by Panula et al. [19], in which the connection between different variables and revision risk was considered in the context of infection revisions for THA using a subset of the data. Building on this framework, we constructed new DAGs to model causal relationships specific to dislocations and fractures. First, we ran a univariate regression for all covariates (Supplementary Table 1). Then, we ran the analyses for ASA classification controlling for age; for intraoperative bleeding controlling for BMI, previous contributing surgeries, intraoperative fracture, and surgeon education; for general anesthesia controlling for age and ASA class; for intraoperative fracture controlling for BMI; and for fixation method controlling for sex and age [19].

For dislocation revision based on the new DAG, we ran the analyses for ASA classification controlling for age; for intraoperative complication controlling for BMI; for approach controlling for previous operation; and for head size controlling for ASA classification, age, BMI, approach, intraoperative complications, and previous operations (Supplementary Figure 1).

For fracture revision based on the new DAG, we ran the analyses for ASA classification controlling for age; for fixation method controlling for age, ASA classification, sex, and BMI; and for approach controlling for previous operations (Supplementary Figure 2).

The proportional hazards assumption was tested using a test based on scaled Schoenefeld residuals [20,21]. The assumption was violated only by BMI in the univariate analyses and general anesthesia in the multivariate analyses. For BMI, we ran a nonparametric log-rank test and found a *P* value of 0.80, which is consistent with the lack of statistical significance in the Cox analyses. For intraoperative fracture, the result was consistent with that of the univariate analyses in which the proportional hazard assumption was not violated (i.e., the hazard for reoperation was higher for patients who had an intraoperative fracture, but the hazard ratio (HR) was not statistically significant).

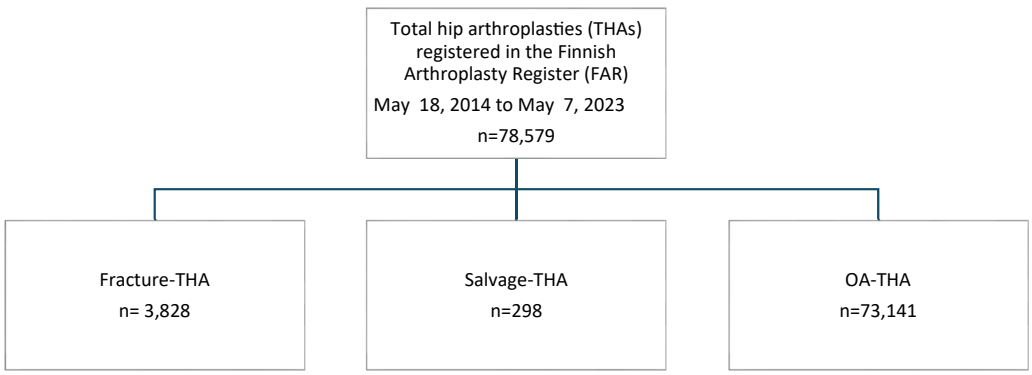

Figure 1. Flowchart indicating the number of patients in each group included in the study. Fracture-THA was defined as primary THA performed for an acute femoral neck fracture, salvage-THA as THA performed after failed internal fixation of a femoral neck fracture and OA-THA as primary THA performed for osteoarthritis. OA, osteoarthritis; THA, total hip arthroplasty.

Table 1
Demographic Data of Total Hip Arthroplasty Patients for Osteoarthritis (OA-THA), for Femoral Neck Fracture (Fracture-THA), and for Failed Osteosynthesis (Salvage-THA).

Characteristic	OA-THA n (%) n = 73,141	Fracture-THA n (%) n = 3,823	Salvage-THA n (%) n = 298
Age in years, n	73,141	3,823	298
≤55	8,784 (12)	286 (7)	58 (19)
56 to 65	18,376 (25)	836 (22)	55 (18)
66 to 75	27,940 (38)	1,682 (44)	85 (28)
≥76	18,041 (25)	1,019 (27)	100 (34)
Sex, n	73,141	3,823	298
Men	31,594 (43)	1,423 (37)	122 (41)
Women	41,547 (57)	2,400 (63)	176 (59)
Operated, n	73,132	3,823	298
Right	40,973 (56)	1,812 (47)	141 (47)
Left	32,159 (44)	2,011 (53)	157 (53)
The American Society of Anesthesiologists (ASA) classification, n	72,922	3,799	298
I	8,433 (12)	244 (6)	13 (4)
II	37,294 (51)	1,552 (41)	102 (34)
III	26,296 (36)	1,799 (47)	156 (52)
IV to V	899 (1)	204 (5)	27 (9)
BMI, n	68,865	3,276	277
≤20	1,170 (2)	299 (9)	34 (12)
21 to 25	16,243 (24)	1,421 (43)	112 (40)
26 to 30	28,313 (41)	1,125 (34)	82 (30)
31 to 35	16,373 (24)	347 (11)	38 (14)
>35	6,766 (10)	84 (3)	11 (4)
Hospital volume, n	73,141	3,823	298
Low (<240)	19,311 (26)	652 (17)	57 (19)
Medium (240 to 480)	24,770 (34)	1,165 (30)	79 (27)
High (>480)	29,060 (40)	2,006 (52)	162 (54)
Level of education (surg.), n	70,656	3,706	286
Specialist	67,909 (96)	3,353 (90)	275 (96)
Resident	2,521 (4)	317 (9)	9 (3)
Other	226 (0)	36 (1)	2 (1)
Level of education (assist.), n	70,077	3,669	283
No assistant	3,216 (5)	457 (12)	18 (6)
Specialist	6,942 (10)	608 (17)	37 (13)
Resident	17,625 (25)	1,249 (34)	76 (27)
Other	42,294 (60)	1,355 (37)	152 (54)
Surgical approach, n	72,877	3,798	298
Anterior (Smith-Peterson)	441 (1)	21 (1)	1 (0)
Antero-lateral (modified Hardinge)	9,547 (13)	516 (14)	42 (14)
Posterior	62,889 (86)	3,261 (86)	255 (86)
Interoperative bleeding, n	71,942	3,744	294
≤500 mL	61,272 (85)	2,996 (80)	151 (51)
>500 mL	10,670 (15)	748 (20)	143 (49)
Duration (minutes), n	69,337	3,621	280
<45	7,858 (11)	276 (8)	9 (3)
45 to 59	14,071 (20)	586 (16)	25 (9)
60 to 89	28,399 (41)	1,629 (45)	72 (26)
90 to 120	9,885 (14)	718 (20)	69 (25)
>120	9,124 (13)	412 (11)	105 (38)
Anesthesia (epidural), n	72,872	3,798	297
Yes	1,076 (1)	62 (2)	21 (7)
No	71,796 (99)	3,736 (98)	276 (93)
Anesthesia (nerve block), n	72,872	3,798	297
Yes	45 (0)	19 (1)	2 (1)
No	72,827 (100)	3,779 (99)	295 (99)
Anesthesia (spinal), n	72,872	3,798	297
Yes	68,026 (93)	3,475 (91)	263 (89)
No	4,846 (7)	323 (9)	34 (11)
Anesthesia (general)	72,872	3,798	297
Yes	5,261 (7)	350 (9)	34 (11)
No	67,611 (93)	3,448 (91)	263 (89)
Local infiltration analgesia (LIA)	72,917	3,801	297
No	59,923 (82)	3,352 (88)	235 (79)
Yes	12,994 (18)	449 (12)	62 (21)
Perioperative complication (fracture), n	71,999	3,726	287
No	71,407 (99)	3,658 (98)	275 (96)
Yes	592 (1)	68 (2)	12 (4)
Previous contrib. operations, n	69,009	3,557	272
No	68,714 (100)	3,513 (99)	139 (51)
Yes	295 (0)	44 (1)	133 (49)

(*continued on next page*)

Table 1 (*continued*)

Characteristic	OA-THA n (%) n = 73,141	Fracture-THA n (%) n = 3,823	Salvage-THA n (%) n = 298
Antibiotic prophylaxis, n	73,047	3,809	297
No	108 (0)	9 (0)	0 (0)
Cefuroxime	70,141 (96)	3,651 (96)	278 (94)
Clindamycine	2,084 (3)	91 (2)	12 (4)
Other	604 (1)	53 (1)	6 (2)
Vancomycine	110 (0)	5 (0)	1 (0)
Antithrombotic prophylaxis, n	72,856	3,778	296
No	812 (1)	123 (3)	4 (1)
Enoxaparin	51,026 (70)	2,927 (77)	235 (79)
Other	3,562 (5)	102 (3)	10 (3)
Rivaroksaban	10,222 (14)	160 (4)	27 (9)
Tinzaparin	7,110 (10)	454 (12)	19 (6)
Warafarin	124 (0)	12 (0)	1 (0)
Anticoagulants, n	72,364	3,773	296
No	5,050 (7)	329 (9)	20 (7)
Other	415 (1)	52 (1)	6 (2)
Tranexamic acid	66,899 (92)	3,392 (90)	270 (91)
Mechanical antithrombotic prophylaxis, n	66,128	3,381	253
No	46,203 (70)	2,825 (84)	187 (74)
Calf muscle pump, surgical stocking	100 (0)	2 (0)	0 (0)
Calf muscle pump	62 (0)	0 (0)	0 (0)
Surgical stocking	19,763 (30)	554 (16)	65 (26)
Antimicrobial incise drape, n	72,879	3,798	297
No	38,643 (53)	1,842 (48)	173 (58)
Yes	34,236 (47)	1,956 (52)	125 (42)
Femoral head size, n	69,861	3,492	267
28	2,222 (3)	525 (15)	49 (18)
32	13,829 (20)	661 (19)	50 (19)
36	52,582 (75)	1,643 (47)	140 (52)
>36	1,039 (1)	214 (6)	7 (3)
Other	189 (0)	113 (3)	9 (3)
Fixation method, n	72,340	3,750	294
Cemented	2,195 (3)	263 (7)	31 (11)
Cementless	45,106 (62)	878 (23)	125 (43)
Hybrid	25,251 (35)	2,683 (72)	135 (46)
Reverse	289 (0)	20 (1)	10 (3)
Bearing couple, n	63,546	2,884	221
Metal-on- ultra-highly crosslinked polyethylene (UHXLPE)	29,333 (46)	1,832 (64)	141 (64)
Ceramic-on-ceramic	3,707 (6)	34 (1)	10 (5)
Ceramic-on-UHXLPE	27,175 (43)	751 (26)	57 (26)
Ceramized metal-on-UHXLPE	2,805 (4)	63 (2)	7 (3)
Metal-on-metal	442 (1)	194 (7)	4 (2)
Other	84 (0)	10 (0)	2 (1)

All data analyses were conducted using the statistical software R version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). The level of statistical significance was set to $P < 0.05$.

Results

Revision for Any Reason

The incidence of revision surgeries over the 7-year follow-up was 6.5% in the fracture-THA group, 5.7% in the salvage-THA group, and 4.1% in the OA-THA group.

Inferior KM 7-year survivorship was observed in the fracture-THA (91.5%, 95% CI [90.4 to 92.7]) and salvage-THA (89.4%, 95% CI [84.8 to 94.1]) groups compared to the OA-THA group (95.4%, 95% CI [95.2 to 95.5]). Survivorship between the fracture-THA group and the salvage-THA group was comparable (Table 2 and Figure 2).

Revision for Dislocation, Infection, or Periprosthetic Fracture

Inferior 7-year survivorship with revision for dislocation as the end point was observed in the fracture-THA and salvage-THA groups compared to the OA-THA group. The 7-year survivorship was 97.4% in the fracture-THA group (95% CI [96.8 to 98.0]), 96.3% in the salvage-THA group (95% CI [93.9 to 98.8]), and 98.6% in the OA-THA group (95% CI [98.5 to 98.7]; Figure 3; Table 2).

The 7-year survivorship for infection revision was 97.5% (95% CI [96.8 to 98.2]) in the fracture-THA group and 93.1% (95% CI [89.0 to 97.5]) in the salvage-THA, which was inferior than 98.5% (95% CI [98.4 to 98.5]) in OA-THA (Figure 4; Table 2).

Survivorship was higher in the OA-THA group with revision for periprosthetic fracture as the endpoint for follow-up times over three years than the fracture-THA and salvage-THA groups. At seven years, the survivorship for the fracture-THA group was 97.5% (95% CI [96.7 to 98.3]), 98.5% (95% CI [96.9 to 100.0]) in the salvage-THA group and 99.1% (95% CI [99.0 to 99.2]) in the OA-THA group (Figure 5; Table 2).

Mortality

Throughout the follow-up period, higher mortality was observed in the fracture-THA and salvage-THA groups than in the OA-THA group. At one year, mortality was 5.6% (95% CI [93.7 to 95.2]) in the fracture-THA group, 6.7% (95% CI [90.5 to 96.2]) in the salvage-THA group, and 0.8% (95% CI [99.2 to 99.3]) in the OA-THA group. At seven years, mortality was 32.7% (95% CI [65.1 to 69.6]) in the fracture-THA group, 34.7% (95% CI [58.9 to 72.4]) in the

Table 2
Kaplan–Meier Survival Estimates for 1, 3, 5, and 7 Years for Different End Points in Total Hip Arthroplasty Patients for Osteoarthritis (OA-THA), for Femoral Neck Fracture (Fracture-THA) and for Failed Osteosynthesis (Salvage-THA).

End Point	Years	OA-THA	At Risk	Fracture-THA	At Risk	Salvage-THA	At Risk
Revision (for any reason)	1	0.971 [0.970, 0.972]	64,256	0.953 [0.946, 0.960]	3,193	0.936 [0.909, 0.965]	251
	3	0.963 [0.962, 0.965]	45,236	0.937 [0.929, 0.945]	2,072	0.917 [0.885, 0.949]	181
	5	0.958 [0.956, 0.960]	27,462	0.925 [0.915, 0.934]	1,159	0.910 [0.877, 0.945]	105
	7	0.954 [0.952, 0.955]	11,614	0.915 [0.904, 0.927]	440	0.894 [0.848, 0.941]	43
Revision (for dislocation)	1	0.993 [0.993, 0.994]	64,256	0.983 [0.979, 0.987]	3,193	0.982 [0.967, 0.998]	251
	3	0.990 [0.989, 0.991]	45,236	0.979 [0.974, 0.984]	2,072	0.970 [0.949, 0.991]	181
	5	0.988 [0.987, 0.989]	27,462	0.976 [0.971, 0.982]	1,159	0.963 [0.939, 0.988]	105
	7	0.986 [0.985, 0.987]	11,614	0.974 [0.968, 0.980]	440	0.963 [0.939, 0.988]	43
Revision (for infection)	1	0.987 [0.986, 0.988]	64,256	0.983 [0.979, 0.987]	3,193	0.964 [0.943, 0.985]	251
	3	0.986 [0.985, 0.986]	45,236	0.981 [0.976, 0.985]	2,072	0.955 [0.932, 0.979]	181
	5	0.985 [0.984, 0.986]	27,462	0.978 [0.973, 0.983]	1,159	0.949 [0.922, 0.976]	105
	7	0.985 [0.984, 0.985]	11,614	0.975 [0.968, 0.982]	440	0.931 [0.890, 0.975]	43
Revision (for periprosthetic fracture)	1	0.994 [0.993, 0.994]	64,256	0.992 [0.989, 0.995]	3,193	0.997 [0.990, 1.000]	251
	3	0.993 [0.992, 0.994]	45,236	0.987 [0.983, 0.991]	2,072	0.992 [0.982, 1.000]	181
	5	0.992 [0.991, 0.993]	27,462	0.980 [0.975, 0.986]	1,159	0.985 [0.969, 1.000]	105
	7	0.991 [0.990, 0.992]	11,614	0.975 [0.967, 0.983]	440	0.985 [0.969, 1.000]	43
Mortality	1	0.992 [0.992, 0.993]	66,553	0.944 [0.937, 0.952]	3,359	0.933 [0.905, 0.962]	269
	3	0.968 [0.966, 0.969]	47,198	0.871 [0.860, 0.883]	2,218	0.844 [0.802, 0.888]	198
	5	0.931 [0.928, 0.933]	28,990	0.781 [0.765, 0.797]	1,252	0.706 [0.648, 0.769]	114
	7	0.884 [0.880, 0.888]	12,393	0.673 [0.651, 0.696]	483	0.653 [0.589, 0.724]	47

salvage-THA group, and 11.6% (95% CI [88.0 to 88.8]) in the OA-THA group (Figure 6; Table 2).

Risk Factors for any Revision in the Fracture-THA Group

In the univariate analyses for risk factors for any revision, women were associated with a lower risk for revision (HR 0.70, 95% CI [0.54 to 0.89], $P = 0.004$). Patients aged 66 to 75 had a lower risk for revision than patients aged <55 (HR 0.59, 95% CI [0.38 to 0.99], $P = 0.02$). The posterior approach was associated with an increased risk of revision compared to the antero-lateral (modified Hardinge) approach (HR 1.64, 95% CI [1.06 to 2.51], $P = 0.03$). Hybrid fixation had lower revision rates than cementless fixation (HR 0.66, 95% CI [0.50 to 0.88], $P = 0.004$; Supplementary Table 1).

In addition, we performed competing risk analyses due to high mortality for all outcomes. There was no significant difference in survival rates (Supplementary Table 2).

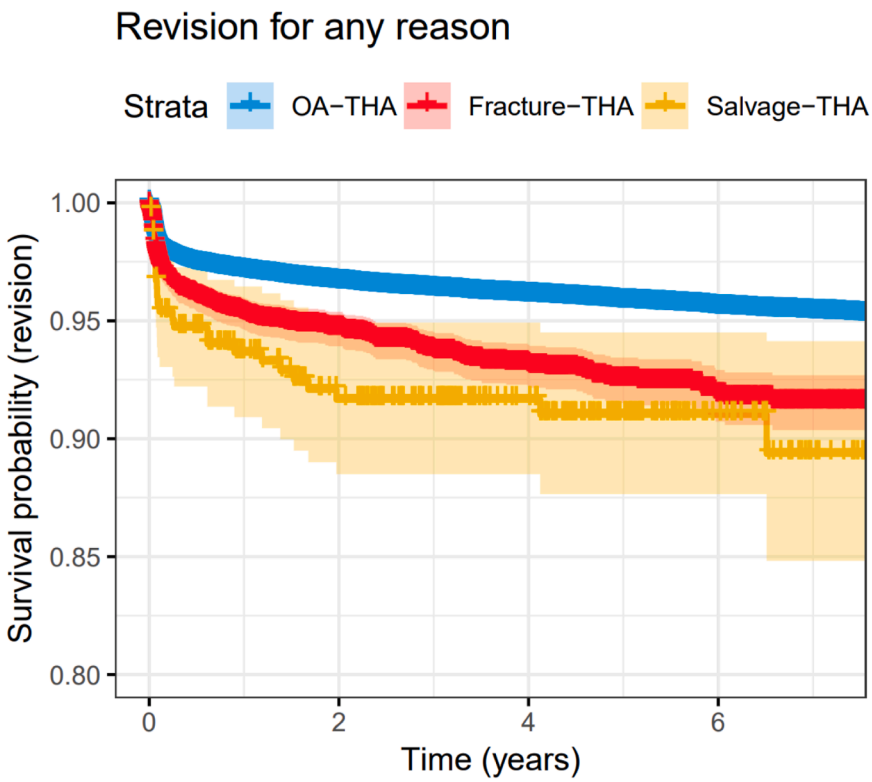

Figure 2. Kaplan–Meier estimates and their 95% confidence intervals of survival probability with revision for any reason as the endpoint. The strata are total hip arthroplasty (THA) due to osteoarthritis (OA-THA), femoral neck fracture (fracture-THA), and failed osteosynthesis of femoral neck fracture (salvage-THA).

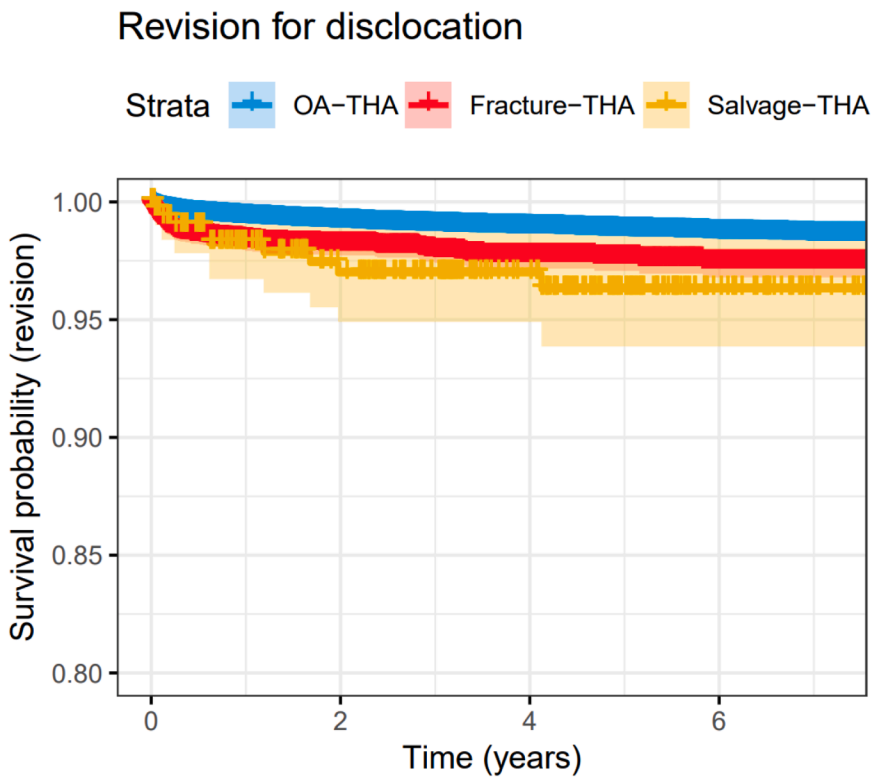

Figure 3. Kaplan–Meier estimates and their 95% confidence intervals of survival probability with revision due to dislocation as the endpoint. The strata are total hip arthroplasty (THA) due to osteoarthritis (OA-THA), femoral neck fracture (fracture-THA), and failed osteosynthesis of femoral neck fracture (salvage-THA).

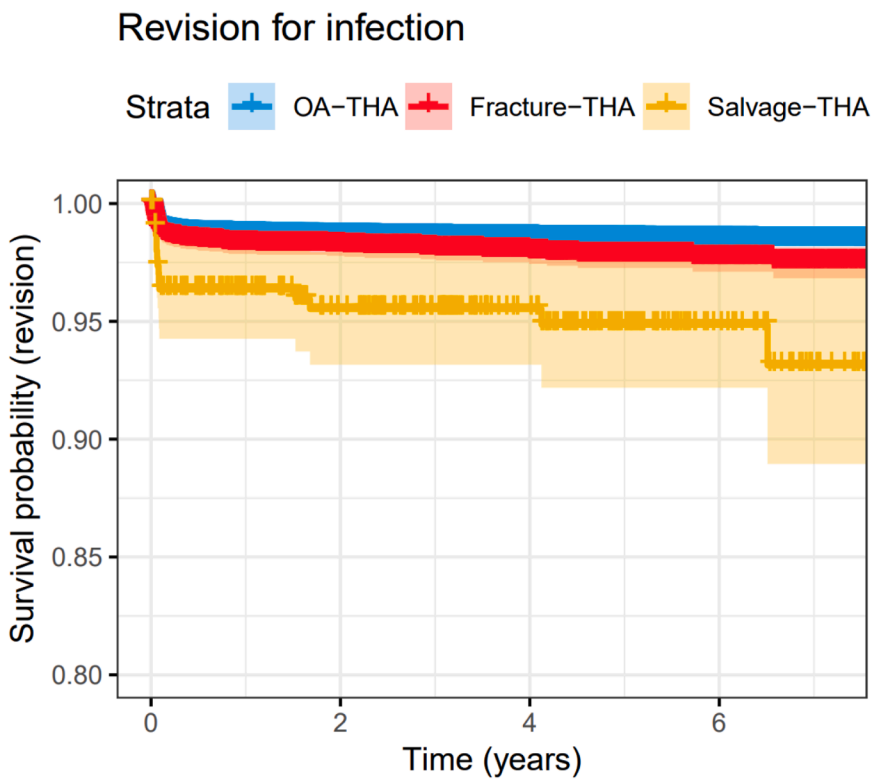

Figure 4. Kaplan–Meier estimates and their 95% confidence intervals of survival probability with revision due to infection as the endpoint. The strata are total hip arthroplasty (THA) due to osteoarthritis (OA-THA), femoral neck fracture (fracture-THA), and failed osteosynthesis of femoral neck fracture (salvage-THA).

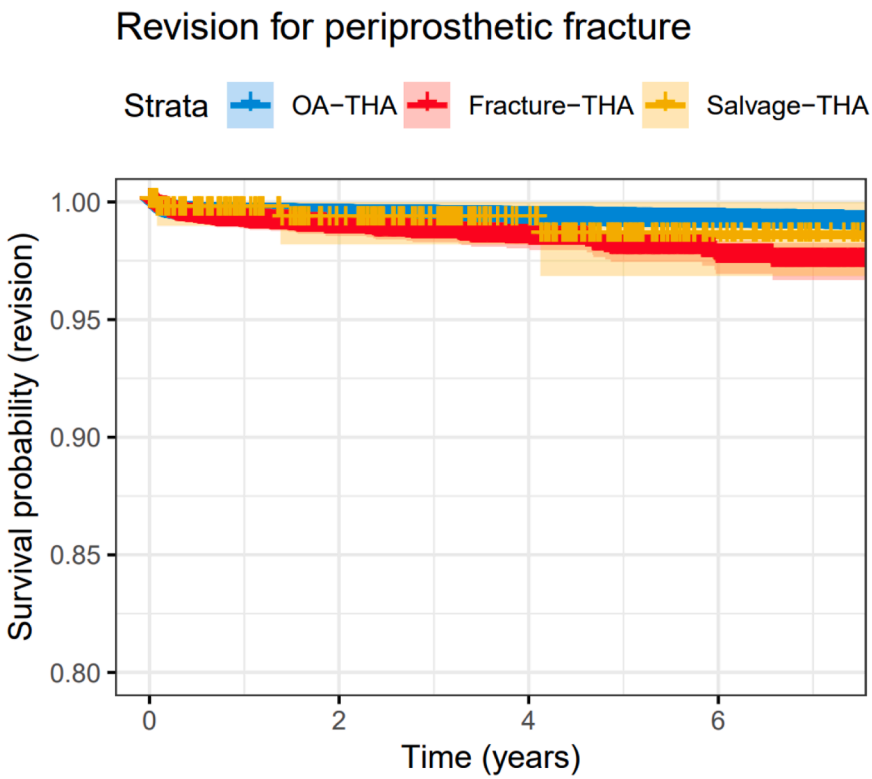

Figure 5. Kaplan–Meier estimates and their 95% confidence intervals of survival probability with revision due to periprosthetic fracture as the endpoint. The strata are total hip arthroplasty (THA) due to osteoarthritis (OA-THA), femoral neck fracture (fracture-THA), and failed osteosynthesis of femoral neck fracture (salvage-THA).

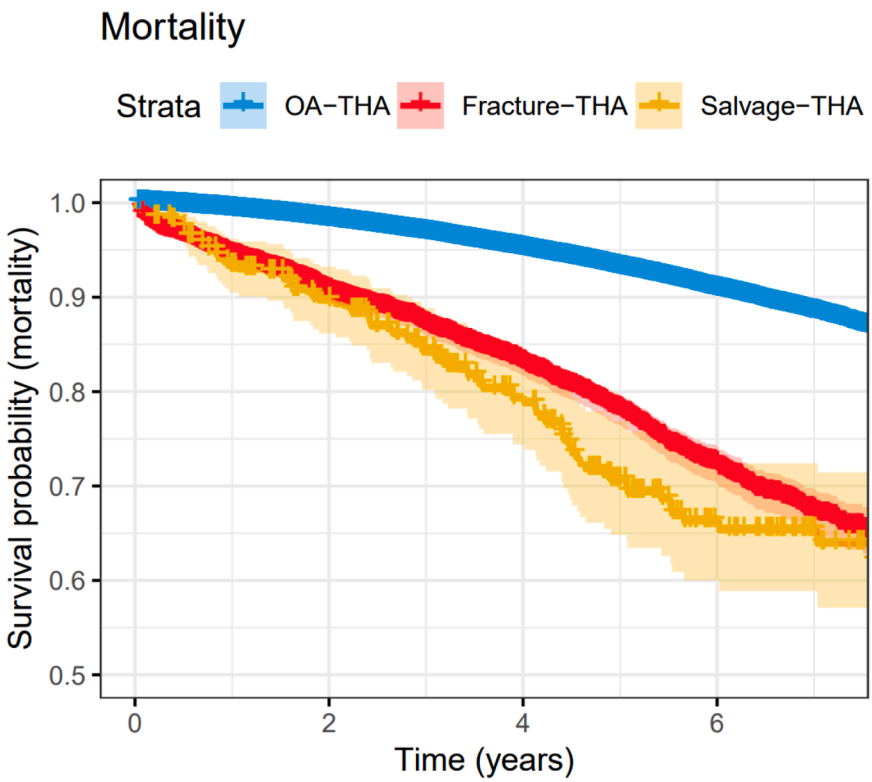

Figure 6. Kaplan–Meier estimates and their 95% confidence intervals of survival probability with mortality as the endpoint. The strata are total hip arthroplasty (THA) due to osteoarthritis (OA-THA), femoral neck fracture (fracture-THA), and failed osteosynthesis of femoral neck fracture (salvage-THA).

Risk Factors for Revision for Dislocation in the Fracture-THA Group

There was no statistical correlation found between the examined variables and revision rates due to dislocation in the multivariate Cox regression analyses (Supplementary Table 3).

Risk Factors for Revision for Infection in the Fracture-THA Group

Cemented fixation was associated with a lower risk of revision than cementless fixation (HR 0.66, 95% CI [0.27 to 1.62], $P = 0.03$); however, a wide CI was observed. There were no statistically significant values found between other variables and revision rates due to infection (Supplementary Table 4).

Risk Factors for Revision for Periprosthetic Fracture in the Fracture-THA Group

In the multivariate analyses, no statistically significant associations were observed among ASA class, surgical approach, or fixation method and revision for periprosthetic fracture (Supplementary Table 5).

Discussion

We found that fracture-THA patients had inferior 7-year survivorship overall and for dislocation, infections, and periprosthetic fractures compared to OA-THA patients. The overall 7-year survivorship of the salvage-THA group was also inferior to that of the OA-THA group, including when revision due to infection or dislocation was used as the end point. The survivorship of the fracture-THA and salvage-THA groups was comparable. However, care must be taken in extrapolating these results, as the number of patients in the salvage-THA group was low and, therefore, CIs were wide.

In the literature, revision rates for fracture-THAs varied between 2.8 and 5.8%, depending on follow-up time and the reoperations included as revision surgeries [8,13,16,17]. These revision rates align with our study. Similarly, a Dutch registry study with 12,159 fracture-THAs and 274,147 OA-THAs found higher revision rates for fracture-THA than OA-THAs. The 10-year KM survivorship for fracture-THAs was 94.2 and 95.3% for OA-THAs, and the risk of revision for fracture-THAs was 1.3 times higher than OA-THAs [13]. A study based on the Swedish hip register showed similar findings; in KM analyses, the revision rate for fracture-THA was 4.4 compared to 2.9% of THAs performed for other reasons [17]. In a Norwegian registry study, a risk 1.6 times higher was observed in fracture-THA than OA-THA, but no statistically significant difference was observed in subgroup analyses of the reason for revision surgery [15].

Salvage-THA has been thought to have an inferior outcome than OA-THA. We found inferior overall 7-year survivorship in the salvage-THA group compared to the OA-THA group, but it was similar to that of the fracture-THA group. Schmitz et al. reported a revision rate of 6.8% for salvage-THA after 10 years in a cohort of 4,310 salvage-THAs. They did not find any difference in survival between salvage-THA and fracture-THA [13]. A similar reoperation rate was published for salvage-THA in a study based on the Swedish Hip Arthroplasty Registry with 5,687 salvage-THAs, where the 7-year survival rate for salvage-THA was 95.3% [17]. Our findings align with these studies. However, the number of salvage-THA patients in our study was low compared to the fracture-THA patients; therefore, the 95% CIs were wide, and our results regarding salvage-THA should be extrapolated with caution. In contrast to our results, Mahmoud et al. found an increased risk for complications, including deep infection, dislocation, and periprosthetic fracture with salvage-THA compared to primary THA after FNF in a meta-analysis. However, due to the heterogeneity of the studies in the meta-analysis, the number of patients who had different outcomes in the analyses was low [14].

Fracture-THA patients had higher revision rates for dislocation throughout the follow-up period compared to OA-THA patients. In both groups, 86% of the patients were operated on using the posterior approach, so the groups were comparable according to approach [22]. A registry study of 269,280 patients from the Dutch hip registry found a higher revision rate with the posterior approach (1.1%) compared to straight lateral THAs (0.5%), anterolateral THAs (0.5%), and anterior THAs (0.3%). In addition, larger femoral head size was associated with lower revision rates, regardless of surgical approach [23]. In our study, 52% in the fracture-THA group and 76% in the OA-THA group had a femoral head size of 36 mm or larger. However, there was no association between femoral head size and revision rate in the fracture-THA group. However, patient-related matters in FNF patients, such as higher fall risk and frailty, might have contributed to elevated revision rates due to dislocation in FNF patients.

The 7-year survivorship for revision due to periprosthetic fracture in the fracture-THA group was inferior to that of the OA-THA group. There is some conflicting evidence regarding this. In a Norwegian registry study, Gjertsen et al. did not find any difference in revision rates for periprosthetic fractures between fracture-THA and OA-THA patients [15]. In Finland, unlike Norway, hybrid fixation in THA is more common, and reverse hybrid is not used at all. These differences may explain the differences between the countries [24]. Overall, FNF patients are usually frailer than OA patients; therefore, our results are consistent.

Several studies have reported an increased risk of revision for infection following fracture-THA compared to OA-THA. In accordance with our results, Norwegian and Dutch registry data show decreased survivorship of fracture-THA compared to OA-THA for revisions due to infection. However, both reported an increased risk for revision due to infection in the salvage-THA group compared to the OA-THA group [13,25]. In our study, the 7-years survivorship of salvage-THA was only 93.1%, but due to wide CIs, the difference with the fracture-THA group did not reach statistical significance.

A FNF is associated with high overall morbidity and mortality rates [26,27]. A Norwegian hip registry study reported a first-year mortality rate of 24.3% among hip fracture patients. However, the study included all patients who had an FNF diagnosis. This explains the high mortality rate, as all the frailest patients were included [28]. In our cohort, the first-year mortality rate was 6.7% in the fracture-THA group, which was significantly higher than the 0.8% in the OA-THA group. Usually, FNF patients are frailer and suffer from comorbidities compared to elective OA patients. For example, most OA-THA patients were in ASA class II, whereas ASA class III was the most common in the fracture-THA group. It is well known that THA is used in the treatment of the fittest and youngest group of fracture patients instead of hemiarthroplasty; this likely explains the relatively low mortality compared to hip fracture patients in general.

We found no statistically significant association with the posterior approach and revision for dislocation using the Cox regression multivariate analyses. In the literature, an association between the posterior approach and the risk of revision in both fracture-THAs and OA-THAs has been observed. Rogmark et al. found higher cumulative dislocation rates at 1 year in the posterior approach group compared to the lateral approach (8.3 versus 2.7%, respectively) [22,29]. However, the number of revision surgeries in our cohort was low, which might have caused bias in the analyses. We also found that hybrid fixation was associated with a decreased revision rate compared to cementless fixation in fracture patients

in the univariate analyses for revision for any reason. However, no statistically significant association was found in the analyses for periprosthetic fracture for fracture-THA. Hybrid THA is currently the most popular fixation method in Finland, whereas cemented THA is rare; only 263 cemented fracture-THAs were in the cohort. Previous studies have indicated that patients who have cementless stem fixation suffer more periprosthetic fractures [30–32].

This study has several potential limitations. Although register data were prospectively collected, they are observational by nature. The completeness of revision surgery for the FAR was 84% (FAR, 2023), meaning that at least 15% of revision surgeries were missing. However, we think that the completeness of fracture- and salvage-THA and OA-THA revisions is approximately the same. The number of salvage-THAs was understandably low, which undermined the comparisons. Furthermore, due to the registry dataset, we were unable to include hemiarthroplasties in the analyses. A strength of this study was the high number of fracture- and OA-THA patients in a national registry setup.

In conclusion, patients who had fracture-THA had inferior survival rates compared to OA-THA, and patients who had salvage-THA had lower survival rates than those who had THA due to OA. Furthermore, in the multivariate analyses of risk factors for revision due to infection, dislocation, or periprosthetic fracture, no statistically significant factors were identified.

CRediT authorship contribution statement

Jukka S. Honkanen: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Elina M. Ekman:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Joel Kostensalo:** Writing – review & editing, Writing – original draft, Software, Formal analysis, Data curation, Conceptualization. **Antti P. Eskelinen:** Writing – review & editing, Visualization, Conceptualization. **Keijo T. Mäkelä:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization. **Inari Laaksonen:** Writing – review & editing, Visualization, Supervision, Project administration, Methodology, Investigation, Conceptualization.

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Appendix

Supplementary Table 1
Univariable Analysis for Possible Risk Factors for Revision for Any Reason in Femoral Neck Fracture Patients Treated With Total Hip Arthroplasty (Fracture-THA).

Characteristic	Hazard Ratio	95% CI	*P*-Value
Age, n			
≤55	Reference		
56 to 65	0.76	[0.49, 1.20]	0.24
66 to 75	0.59	[0.38, 0.99]	0.02
≥76	0.73	[0.46, 1.13]	0.16
Sex, n			
Male	Reference		
Female	0.70	[0.54, 0.89]	0.004
Operated, n			
Right	Reference		
Left	1.15	[0.90, 1.48]	0.27
The American Society of Anesthesiologists (ASA) classification, n			
I	Reference		
II	1.16	[0.63, 2.12]	0.64
III	1.63	[0.90, 2.93]	0.11
IV–V	1.23	[0.53, 2.84]	0.63
Body mass index (BMI), n			
≤20	Reference		
21 to 25	1.00	[0.61, 1.65]	0.99
26 to 30	0.95	[0.57, 1.57]	0.83
31 to 35	0.94	[0.51, 1.74]	0.85
>35	1.52	[0.66, 3.47]	0.32
Hospital volume, n			
Low (<240)	Reference		
Medium (240 to 480)	0.91	[0.63, 1.31]	0.62
High (>480)	0.87	[0.64, 1.21]	0.41
Level of education (surg.), n			
Specialist	Reference		
Resident	0.94	[0.60, 1.49]	0.78
Other	-	-	-
Level of education (assist.), n			
No assistant	Reference		
Specialist	0.94	[0.53, 1.68]	0.84
Resident	1.49	[0.92, 2.42]	0.11
Other	1.51	[0.93, 2.45]	0.09
Surgical approach, n			
Anterolateral (modified Hardinge)	Reference		
Anterior (Smith-Peterson)	3.23	[0.97, 10.76]	0.06
Posterior	1.64	[1.06, 2.51]	0.03
Interoperative bleeding, n			
≤500 mL	Reference		
>500 mL	1.27	[0.95, 1.70]	0.11
Duration (minutes), n			
<45	Reference		
45 to 59	1.56	[0.82, 2.97]	0.17
60 to 89	1.35	[0.74, 2.44]	0.33
90 to 120	1.38	[0.73, 2.59]	0.32
>120	1.07	[0.53, 2.18]	0.85
Anesthesia (epidural), n			
Yes	1.70	[0.80, 3.62]	0.17
No	Reference		
Anesthesia (nerve block), n			
Yes	2.30	[0.57, 9.25]	0.24
No	Reference		
Anesthesia (spinal), n			
Yes	1.06	[0.67, 1.67]	0.82
No	Reference		
Anesthesia (general)			
Yes	0.97	[0.63, 1.51]	0.90
No	Reference		
Anesthesia (LIA), n			
Yes	0.97	[0.63, 1.51]	0.90
No	Reference		
Perioperative complication (fracture), n			
Yes	1.68	[0.79, 3.56]	0.18
No	Reference		
Previous contrib. operations, n			
Yes	2.16	[0.96, 4.86]	0.06
No	Reference		
Antibiotic prophylaxis, n			
No	-	-	-
Cefuroxime	Reference		
Clindamycine	1.31	[0.65, 2.65]	0.45
Other	0.25	[0.04, 1.80]	0.17
Vancomycine	3.17	[0.45, 22.62]	0.249
Antithrombotic prophylaxis, n			
Enoxaparin			
No	0.49	[0.18, 1.31]	0.15
Other	0.94	[0.42, 2.11]	0.87
Rivaroksaban	0.64	[0.32, 1.30]	0.22
Tinzaparin	0.87	[0.57, 1.35]	0.54
Warafarin	-	-	-
Anticoagulants, n			
No	Reference		
Other	0.62	[0.15, 2.67]	0.52
Tranexamic acid	1.23	[0.77, 1.96]	0.40
Mechanical antithrombotic prophylaxis, n			
No	Reference		
Calf muscle pump. surgical stocking	-	-	-
Calf muscle pump	-	-	-
Surgical stocking	1.02	[0.72, 1.44]	0.91
Antimicrobial incise drape, n			
No	Reference		
Yes	1.22	[0.94, 1.57]	0.13
Femoral head size, n			
28	0.94	[0.63, 1.41]	0.77
32	Reference		
36	1.04	[0.74, 1.47]	0.83
>36	0.96	[0.50, 1.86]	0.91
Other	0.75	[0.34, 1.65]	0.47
Fixation method, n			
Cementless	Reference		
Cemented	1.22	[0.78, 1.89]	0.37
Hybrid	0.66	[0.50, 0.88]	0.004
Reverse	-	-	-
Bearing couple, n			
Metal-on- ultra-highly crosslinked polyethylene (UHXLPE)	Reference		
Ceramic-on-ceramic	0.72	[0.18, 2.90]	0.64
Ceramic-on-UHXLPE	0.69	[0.48, 1.00]	0.05
Ceramized metal-on-UHXLPE	0.39	[0.10, 1.59]	0.19
Metal-on-metal	0.68	[0.33, 1.40]	0.30
Other	1.66	[0.23, 11.88]	0.61

LIA, local infiltration analgesia.

Supplementary Table 2
Competing Risk Results (i.e., No Censoring at Mortality) in Total Hip Arthroplasty Patients for Osteoarthritis (OA-THA), for Femoral Neck Fracture (Fracture-THA) and for Failed Osteosynthesis (Salvage-THA).

End Point	Years	OA-THA			Fracture-THA			Salvage-THA		
Revision (for any reason)	1	0.971	[0.970, 0.972]	64,256	0.954	[0.947, 0.960]	3,193	0.937	[0.910, 0.965]	251
	3	0.963	[0.962, 0.965]	45,236	0.939	[0.931, 0.947]	2,072	0.919	[0.888, 0.950]	181
	5	0.958	[0.957, 0.960]	27,462	0.929	[0.920, 0.938]	1,159	0.914	[0.881, 0.946]	105
	7	0.954	[0.953, 0.956]	11,614	0.922	[0.912, 0.932]	440	0.903	[0.864, 0.942]	43
Revision (for dislocation)	1	0.993	[0.993, 0.994]	64,256	0.984	[0.980, 0.988]	3,193	0.983	[0.968, 0.998]	251
	3	0.990	[0.989, 0.991]	45,236	0.980	[0.975, 0.984]	2,072	0.971	[0.951, 0.991]	181
	5	0.988	[0.987, 0.989]	27,462	0.977	[0.972, 0.982]	1,159	0.966	[0.943, 0.988]	105
	7	0.986	[0.985, 0.987]	11,614	0.976	[0.970, 0.981]	440	0.966	[0.943, 0.988]	43
Revision (for infection)	1	0.987	[0.986, 0.988]	64,256	0.983	[0.979, 0.987]	3,193	0.964	[0.943, 0.985]	251
	3	0.986	[0.985, 0.987]	45,236	0.981	[0.977, 0.986]	2,072	0.956	[0.933, 0.980]	181
	5	0.985	[0.984, 0.986]	27,462	0.979	[0.974, 0.984]	1,159	0.951	[0.925, 0.976]	105
	7	0.985	[0.984, 0.986]	11,614	0.977	[0.971, 0.982]	440	0.939	[0.906, 0.973]	43
Revision (for periprosthetic fracture)	1	0.994	[0.993, 0.994]	64,256	0.992	[0.989, 0.995]	3,193	0.997	[0.990, 1.000]	251
	3	0.993	[0.992, 0.994]	45,236	0.987	[0.984, 0.991]	2,072	0.993	[0.983, 1.000]	181
	5	0.992	[0.991, 0.993]	27,462	0.982	[0.977, 0.987]	1,159	0.987	[0.972, 1.000]	105
	7	0.991	[0.990, 0.992]	11,614	0.978	[0.972, 0.984]	440	0.987	[0.972, 1.000]	43

Supplementary Table 3
Multivariable Analysis for Revision for Dislocation in Femoral Neck Fracture Patients Treated With Total Hip Arthroplasty (Fracture-THA).

Characteristic	Hazard Ratio	95% CI	*P*-Value
The American Society of Anesthesiologists (ASA) classification, n			
I	Reference		
II	0.95	[0.32; 2.78]	0.93
III	2.28	[0.81; 6.40]	0.12
IV to V	0.990	[0.18; 5.53]	0.99
Intraoperative complications (fracture)			
No	Reference		
Yes	1.02	[0.97, 1.08]	0.17
Surgical approach			
Anterolateral	Reference		
Anterior	-	-	-
Posterior	2.96	[0.15; 7.67]	0.24
Femoral head size			
32	Reference		
28	0.57	[0.26, 1.25]	0.16
36	0.54	[0.29, 1.01]	0.06
>36	1.46	[0.58, 3.67]	0.43
Other	0.50	[0.12, 2.17]	0.35

CI, confidence interval.

Supplementary Table 4
Multivariable Analysis for Revision for Infection in Femoral Neck Fracture Patients Treated With Total Hip Arthroplasty (Fracture-THA).

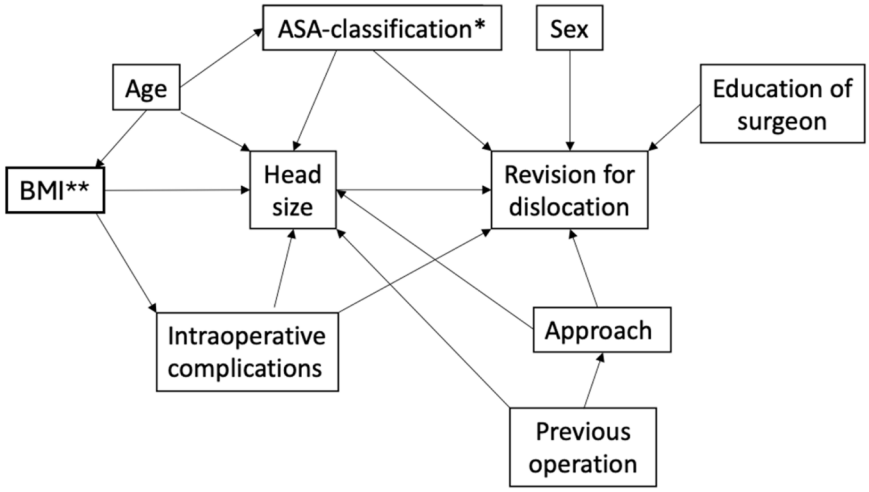
Characteristic	Hazard Ratio	95% CI	*P*-Value
Simultaneous bilateral operation			
No	Reference		
Yes	0.99	[0.97, 1.02]	0.46
The American Society of Anesthesiologists (ASA) classification, n			
I	Reference		
II	2.07	[0.49, 8.78]	
III	3.38	[0.81, 14.11]	
IV to V	2.36	[0.38, 14.51]	
Interoperative bleeding, n			
≤500 mL	Reference		
>500 mL	1.61	[0.90, 2.86]	0.11
Duration (minutes), n			
<45	Reference		
45 to 59	1.55	[0.41, 5.86]	0.51
60 to 89	1.58	[0.47, 5.28]	0.46
90 to 120	0.84	[0.22, 3.25]	0.8
>120	0,97	[0.23, 4.02]	0.06
Anesthesia (general)			
Yes	0,34	[0.99, 1.98]	0.06
No	Reference		
Perioperative complication, (fracture), n			
Yes	1,97	[0.48, 8.06]	0.35
No	Reference		
Fixation method, n			
Cementless	Reference		
Cemented	0,66	[0.27, 1.62]	0.03
Hybrid	0,74	[0.33, 1.62]	0.45
Reverse	-	-	-

CI, confidence interval.

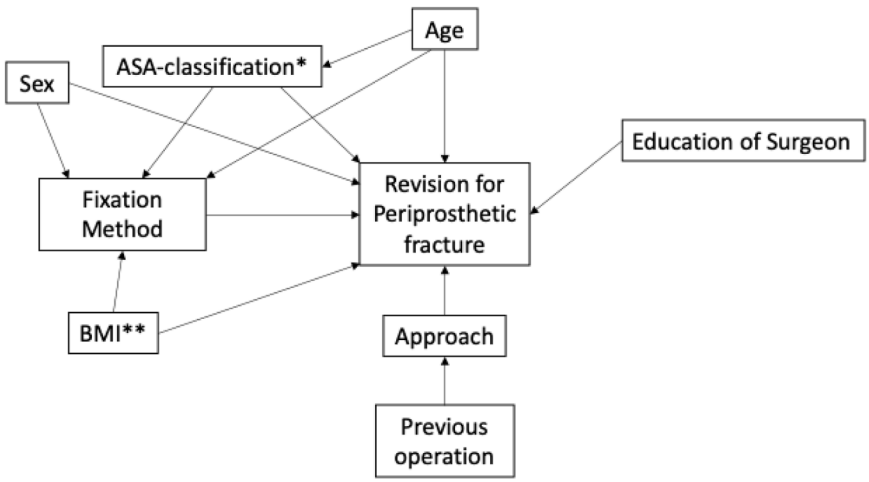
Supplementary Table 5
Multivariable Analysis for Revision for Periprosthetic Fracture in Femoral Neck Fracture Patients Treated with Total Hip Arthroplasty (Fracture-THA).

Characteristic	Hazard Ratio	95% CI	*P*-Value
The American Society of Anesthesiologists (ASA) classification, n			
I	Reference		
II	1.18	[0.35, 4.00]	0.79
III	1.66	[0.50, 5.57]	0.41
IV to V	2.01	[0.39, 10.34]	0.40
Surgical approach			
Anterolateral	Reference		
Anterior	5.63	[0.63, 50,43]	0.06
Posterior	2.20	[0.69, 11.70]	0.24
Fixation method			
Cementless	Reference		
Cemented	0.56	[0.16, 1.96]	0.37
Hybrid	0.56	[0.30, 1.04]	0.07
Reverse	-	-	-

CI, confidence interval.



Supplementary Figure 1. Directional acyclic graph (DAG) for revision for dislocation. *The American Society of Anesthesiologists classification, ** Body mass index.



Supplementary Figure 2. Directional acyclic graph (DAG) for revision for dislocation. *The American Society of Anesthesiologists classification, ** Body mass index.