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# Preoperative Posterior Tilt Increases the Risk of Later Conversion to Arthroplasty After Osteosynthesis for Femoral Neck Fracture

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ABSTRACT

*Background:* Femoral neck fractures (FNFs) are one of the most common injuries in the elderly. Treatment is either internal fixation or primary arthroplasty. The main aim of this study is to assess the risk factors associated with fixation failure leading to further arthroplasty in FNFs treated with cannulated screws.

*Methods:* Data on internal fixations of FNFs performed at Turku University Hospital between January 1, 2012 and December 31, 2017 were collected retrospectively from the patient database. Radiographical measurements were performed for preoperative displacement and posterior tilt, postoperative displacement, reduction quality, and implant shaft angle.

*Results:* Altogether 301 cases were included in the study. The overall reoperation rate was 25% and conversion to arthroplasty was performed in 16% of cases. In the multiple variant analysis, adjusted for age and gender, nondisplaced fractures with a 0°-20° preoperative posterior tilt had a significantly lower risk of later conversion to arthroplasty than did nondisplaced fractures with a ≤0° or ≥20° posterior tilt (odds ratio [OR] 4.0, 95% confidence interval [CI] 1.8-8.6, $P = .0005$) and displaced fractures (OR 7.2, 95% CI 3.0-17.4, $P < .0001$). No statistically significant association was found between preoperatively nondisplaced fractures with a <0° or ≥20° posterior tilt and displaced fractures (OR 0.6, 95% CI 0.2-1.3, $P = .2$).

*Conclusion:* Displaced fractures and fractures with a preoperative posterior tilt of <0° or ≥20° have a considerably increased risk of reoperation and conversion to arthroplasty. Primary arthroplasty should be considered as treatment for displaced FNFs and fractures with >20° or <0° posterior tilt, especially in fragile patients, to avoid further operations.



A femoral neck fracture (FNF) is one of the most common injuries in elderly patients, leading to increased morbidity and mortality [1,2]. Surgical intervention is the gold standard treatment for FNF and is associated with lower mortality and higher union rates compared to nonoperative treatment [3]. Operative treatment options for FNFs are internal fixation and arthroplasty. Internal fixation is associated with less blood loss, shorter duration of surgery, and fewer hospitalization days compared to arthroplasty [4,5]. However, especially among elderly patients, internal fixation has higher reoperation rates than arthroplasty, leading to higher healthcare costs and increased morbidity [6–8]. One of the most common reoperations after internal fixation is implant removal surgery, which is usually classified as minor surgery. Reoperations after arthroplasty are, in contrast, usually more severe and most commonly performed due to dislocation, periprosthetic fracture, and infection [9–11].

FNFs are divided into nondisplaced and displaced fractures according to Garden [12,13]. In the literature, displaced fracture and

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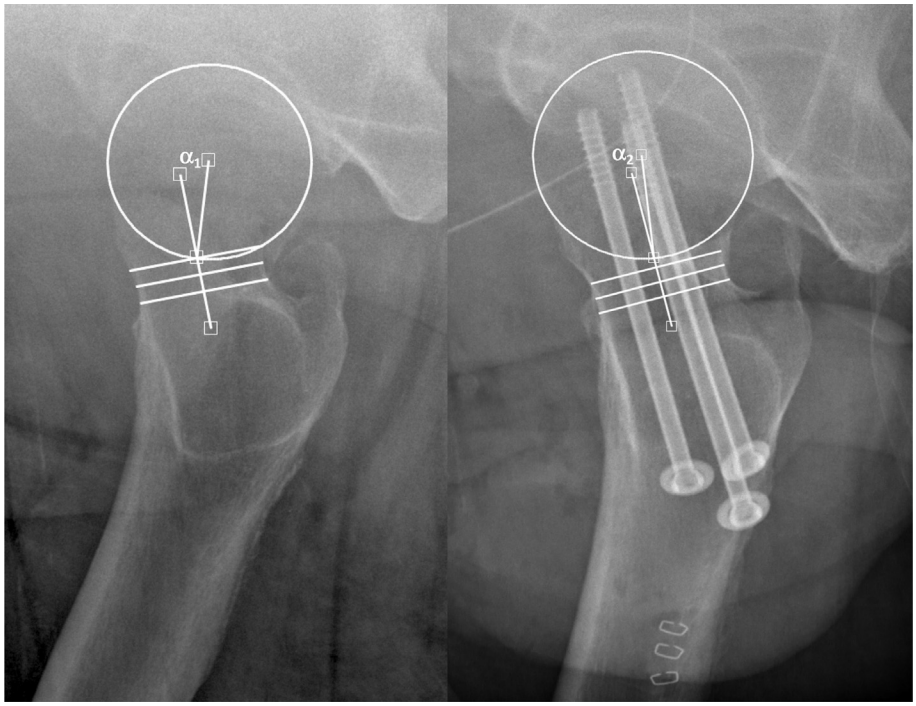


**Fig. 1.** Preoperative and postoperative shoot through lateral radiographs presenting posterior tilt measurements of a successful osteosynthesis. $\alpha_1$, 18.1°; $\alpha_2$, 7.7°.

inadequate fracture reduction have been shown to be risk factors for fixation failure and reoperations of FNFs treated with internal fixation [14–18]. The definition of posterior tilt was first introduced by Palm et al in 2009 and later further validated [19,20]. Posterior tilt of the femoral head of >20° on lateral view has been shown to be an individual predictor of failure in nondisplaced FNFs [20–22], although this has not been observed in all studies [23]. Lately, also the quality of reduction on lateral view has been studied and a correlation found between postoperative posterior tilt of the femoral head and reoperation [11,24].

The main aim of this study is to assess the risk factors associated with fixation failure leading to further arthroplasty in FNFs treated with cannulated screws. Our hypothesis is that fracture displacement, including preoperative posterior tilt of the femoral head, increases the risk of later conversion to arthroplasty.

## Patients and Methods

A retrospective review was conducted of all patients with acute FNF operated with cannulated screws at Turku University Hospital, Finland, between January 1, 2012 and December 31, 2017. The electronic patient record system (Uranus Miranda, CGI Finland) was searched using a combination of the FNF diagnosis code (ICD-10: S72.0) and surgical procedure code for cannulated screws (NOMESCO code, Finnish version, NFJ50). The gold standard technique for osteosynthesis was fixation with parallel cannulated screws. The operating surgeon decided the surgical technique and indications.

The data retrieved from the medical charts included patient's gender, age, fracture side, mechanism of injury, American Society of Anesthesiologists classification (ASA 1-5), and time to surgery. The mechanism of injury was divided into 2 groups: low-energy trauma (fall on the same level) and high-energy trauma (all other injury mechanisms) and was assessed from the electronic patient record system (accident code W01). Time to surgery was calculated from the hospital admission date to surgery date. Patients were divided into 3 groups: those operated on within 24 hours after hospital admission, between 24 and 48 hours, and more than 48 hours after admission.

Patients' preoperative and postoperative radiographs were analyzed retrospectively using the Carestream picture archiving and communication systems (PACS) software. Radiographic measurements included preoperative fracture displacement, preoperative posterior tilt, and quality of reduction. Preoperative fracture displacement was classified either as nondisplaced or displaced on the anteroposterior (AP) radiograph according to the Garden classification [12]. Posterior tilt was measured with the technique introduced by Palm et al [20] from the shoot-through lateral radiograph (Figs. 1 and 2) . Nondisplaced fractures (Garden 1 and 2) were then divided by posterior tilt into 2 groups (<20° and ≥20°). If an anterior tilt was detected, the case was included in the ≥20° group based on earlier literature [25]. Quality of reduction was determined by measuring postoperative posterior tilt, and the cases were divided into 3 groups: nondisplaced on AP view and 0°-10° posterior tilt, nondisplaced on AP view and ≥10° or ≤0° posterior tilt, and displaced on AP view. Postoperative displacement on AP view was determined by drawing the Shenton line on the radiograph; if the line was not intact, the case was considered displaced. A fracture was considered well reduced if there was a <10° posterior tilt and no displacement on AP view; otherwise, a fracture was considered inadequately reduced. As in the preoperative measurements, if an anterior tilt was detected, fracture was included in the ≥10° group. Implant shaft angles were measured from the most inferior screw and divided into 2 groups, ≤125° and >125°, based on previous literature [11]. All measurements were performed by one author (J.H.) and supervised by a musculoskeletal radiologist with 8 years' experience (V.H.). In the multiple regression analysis patients were divided into age groups <65 years (n = 77), 65-75 years (n = 74), and >75 years (n = 150), to diminish age bias.

Data on reoperations during follow-up were collected from the patient records. All reoperations were registered and included in

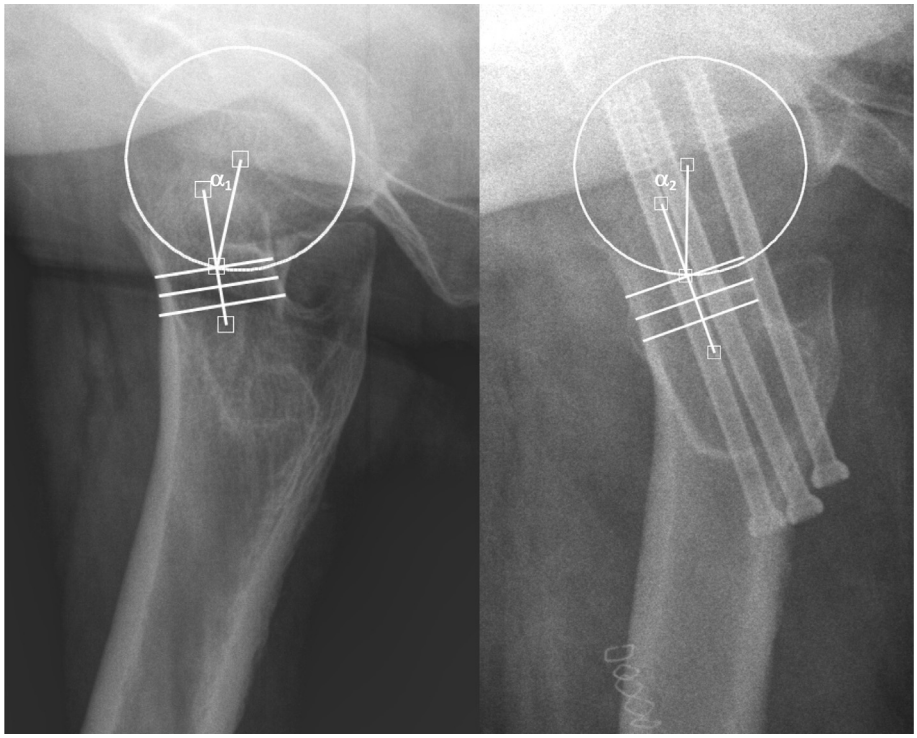


**Fig. 2.** Preoperative and postoperative shoot through lateral radiographs presenting posterior tilt measurements on a patient who underwent a later conversion to arthroplasty at 4 months. $\alpha_1$, 22.6°; $\alpha_2$, 20.0°.

the data. The main outcome of interest was conversion to arthroplasty, which was studied also as a separate endpoint.

*Statistical Methods*

Descriptive statistics are shown as the number of subjects and proportions for categorical variables. For normally distributed variables, means with standard deviations and range (min-max) are presented, and median with interquartile range and range (min-max) otherwise.

Predictors for conversion to arthroplasty were modeled with logistic regression with the following independent variables: age, gender, ASA class, time to surgery, fracture side, mechanism of injury, and displacement. The multiple logistic regression model for the same dependent variable included age, gender, and displacement as independent variables. Predictors for any reoperation were modeled with logistic regression where age, gender, ASA class, time to surgery, fracture side, mechanism of surgery, reoperations, and implant shaft angle were independent variables. Odds ratios (OR) and their 95% confidence intervals (CIs) were calculated from this logistic regression model. The nonparametric Kaplan-Meier method was used with the cumulative incidence curve.

All statistical tests were performed as 2-sided, with a significance level set at 0.05. The analyses were performed using the SAS System, version 9.4 for Windows (SAS Institute Inc, Cary, NC).

## Results

The data contain information on 352 operations using cannulated screws performed on 341 patients during the study period. Six patients had both femoral necks fixated due to FNF and were included twice in the data as 2 separate cases. Fifty-one patients were excluded for various reasons (Fig. 3), leaving 301 cases eligible for the data analysis. Patient records were evaluated from injury to either time of death or conversion to arthroplasty, or until January 1, 2020, whichever occurred first. All patients had at least 1 follow-up visit with postoperative hip radiographs (supine AP) approximately 6 weeks after the primary surgery. Further follow-up visits were arranged if needed.

The mean age was 73 years (range 20-102). The amount of very young patients (20-40 years) was low (n = 6) and these patients were included in the youngest 20-65 age group. One hundred sixty-eight (56%) patients were women; 113 (38%) patients died during the follow-up period, 42 (14%) of them during the first year after surgery. The mechanism of injury was low-energy trauma for 276 (92%) patients (Table 1). The mean follow-up period was 3.3 years

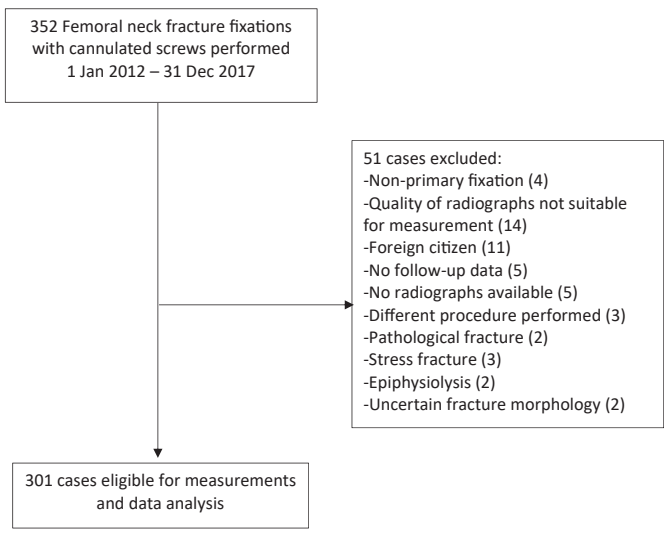


**Fig. 3.** Flowchart of patient selection.

**Table 1**
Characteristics of the Study Population.

| Variable | Total | Any Reoperation (%)[a] | Conversion to Arthroplasty (%)[a] |
|---|---|---|---|
| Total | 301 | 75 (24.9) | 49 (16.3) |
| Age (y) | | | |
| <65 | 77 | 26 (33.8) | 15 (19.5) |
| 65-75 | 74 | 24 (32.4) | 15 (20.3) |
| >75 | 150 | 25 (16.7) | 19 (12.7) |
| Gender | | | |
| Male | 133 | 38 (28.6) | 23 (17.3) |
| Female | 168 | 37 (22.0) | 26 (15.5) |
| Fracture laterality | | | |
| Right | 124 | 29 (23.4) | 20 (16.1) |
| Left | 177 | 46 (26.0) | 29 (16.4) |
| Mechanism of injury | | | |
| Low energy | 276 | 65 (23.6) | 42 (15.2) |
| High energy | 25 | 10 (40.0) | 7 (28.0) |
| ASA score | | | |
| 1-2 | 77 | 23 (29.9) | 15 (19.5) |
| 3 | 169 | 43 (25.4) | 26 (15.4) |
| 4–5 | 52 | 9 (17.3) | 8 (15.4) |
| Data missing | 3 | | |
| Time to surgery (h) | | | |
| <24 | 84 | 25 (29.8) | 17 (20.2) |
| 24-48 | 202 | 48 (23.8) | 31 (15.3) |
| >48 | 15 | 2 (13.3) | 1 (6.7) |
| Displacement | | | |
| Nondisplaced, posterior tilt 0°-20° | 192 | 28 (14.6) | 16 (8.3) |
| Nondisplaced, posterior tilt ≥20° or <0° | 62 | 22 (35.5) | 16 (25.8) |
| Displaced | 47 | 25 (53.2) | 17 (36.2) |
| Implant shaft angle | | | |
| ≤125° | 52 | 16 (30.8) | 9 (17.3) |
| >125° | 249 | 59 (23.7) | 40 (16.1) |
| Reduction | | | |
| Nondisplaced on AP view, posterior tilt 0°-10° | 209 | 39 (18.7) | 19 (9.1) |
| Nondisplaced on AP view, posterior tilt ≥10° or <0° | 88 | 34 (38.6) | 28 (31.8) |
| Displaced | 4 | 2 (50.0) | 2 (50.0) |
| Number of screws | | | |
| 2 | 2 | 0 | 0 |
| 3 | 275 | 72 (26.2) | 46 (16.7) |
| 4 | 23 | 3 (13.0) | 3 (13.0) |
| 5 | 1 | 0 | 0 |

AP, anteroposterior; ASA, American Society of Anesthesiologists.
[a] Percentage of the total for the given row in parentheses.

(range 0-8). In 75 (25%) cases the patient underwent any reoperation type during follow-up: a total of 49 (16%) underwent conversion to arthroplasty, 22 (7%) had implants removed, 2 (0.7%) underwent a revision surgery due to infection, and 2 (0.7%) underwent reosteosynthesis with another fixation device. Four patients underwent conversion to arthroplasty after implant removal surgery and were included in the conversion-to-arthroplasty group. The mean time to the conversion to arthroplasty was 12 months after the osteosynthesis (range 0.02-5.4 years). In 40 cases conversion to arthroplasty was performed with total hip arthroplasty and in 9 cases with hemiarthroplasty. Dual mobility cups were not used.

### *Risk of Conversion to Arthroplasty*

Fracture displacement and inadequate reduction were associated with a statistically significant increase in risk of conversion to arthroplasty. In the univariate analysis, nondisplaced fractures and a 0°-20° preoperative posterior tilt were less likely to lead to arthroplasty than were displaced fractures (OR 0.2, 95% CI 0.1-0.4, $P < .0001$) or fractures with a preoperative posterior tilt of <0° or ≥20° (OR 0.3, 95% CI 0.1-0.6). Also, adequately reduced fractures had a lower risk of conversion to arthroplasty compared to postoperatively displaced fractures (OR 0.1, 95% CI 0.01-0.8, $P = .03$). Patients with a preoperative posterior tilt of ≥20° or <0° but with adequate reduction had a significantly higher risk of later conversion to arthroplasty compared to patients with an adequate preoperative and postoperative posterior tilt (OR 3.4, 95% CI 1.3-8.8, $P = .01$). Furthermore, patients with a 0°-20° preoperative posterior tilt but inadequate reduction had a statistically significantly increased risk of arthroplasty compared to patients with an adequate preoperative and postoperative posterior tilt (OR 3.4, 95% CI 1.2-9.7, $P = .02$).

In the multiple variant analysis, adjusted for age and gender, nondisplaced fractures with a 0°-20° preoperative posterior tilt had a significantly lower risk of later conversion to arthroplasty compared to nondisplaced fractures with a ≤0° or ≥20° posterior tilt (OR 4.0, 95% CI 1.8-8.6, $P = .0005$) and displaced fractures (OR 7.2, 95% CI 3.0-17.4, $P < .0001$). No statistically significant association was found between preoperatively nondisplaced fractures with <0° or ≥20° posterior tilt and displaced fractures (OR 0.6, 95% CI 0.2-1.3, $P = .2$) (Table 2).

The trauma mechanism did not have an effect on the risk of later arthroplasty (OR 0.5, 95% CI 0.2-1.2, $P = .1$). Age, ASA class, time to surgery, gender, fracture side, or implant shaft angle did not have a statistically significant association with conversion to arthroplasty (Table 2).

### *Risk of Undergoing Any Reoperation*

Patients with a nondisplaced fracture and posterior tilt of 0°-20° had a lower risk of reoperation compared with patients with displaced fractures (OR 0.2, 95% CI 0.08-0.3, $P < .0001$).

**Table 2**
Analysis of Risk of Conversion to Arthroplasty.

| Variable | Univariate Analysis | | | Multivariate Analysis | | |
|---|---|---|---|---|---|---|
| | OR | 95% CI | *P* Value | OR | 95% CI | *P* Value |
| Age (y) | | | | | | |
| <65 | 1.7 | 0.8-3.5 | .2 | 0.9 | 0.4-2.1 | .7 |
| 65-75 | 1.8 | 0.8-3.7 | .1 | 1.4 | 0.6-3.1 | .4 |
| >75 | 1 | | | 1 | | |
| Gender | | | | | | |
| Male | 1.1 | 0.6-2.1 | .7 | 0.8 | 0.4-1.6 | .5 |
| Female | 1 | | | 1 | | |
| Fracture laterality | | | | | | |
| Right | 0.98 | 0.5-1.8 | .95 | | | |
| Left | 1 | | | | | |
| Mechanism of injury | | | | | | |
| Low energy | 0.5 | 0.2-1.2 | .1 | | | |
| High energy | 1 | | | | | |
| ASA score | | | | | | |
| 1-2 | 1.3 | 0.5-3.4 | .6 | | | |
| 3 | 1.0 | 0.4-2.4 | 1.0 | | | |
| 4-5 | 1 | | | | | |
| Time to surgery (h) | | | | | | |
| <24 | 1.4 | 0.7-2.7 | .3 | | | |
| 24-48 | 1 | | | | | |
| >48 | 0.4 | 0.05-3.1 | .4 | | | |
| Displacement | | | | | | |
| Nondisplaced, posterior tilt 0°-20° | 0.2 | 0.07-0.4 | <.0001[a] | 1 | | |
| Nondisplaced, posterior tilt ≥20° or <0° | 0.6 | 0.3-1.4 | .2 | 3.0 | 1.8-8.6 | .0005[a] |
| Displaced | 1 | | | 7.2 | 3.0-17.4 | <.0001[a] |
| Implant shaft angle | | | | | | |
| ≤125° | 1.1 | 0.5-2.4 | .8 | | | |
| >125° | 1 | | | | | |
| Reduction | | | | | | |
| Nondisplaced on AP view, posterior tilt 0°-10° | 0.1 | 0.01-0.8 | .03[a] | | | |
| Nondisplaced on AP view, posterior tilt ≥10° or <0° | 0.5 | 0.06-3.5 | .5 | | | |
| Displaced | 1 | | | | | |

AP, anteroposterior; ASA, American Society of Anesthesiologists; CI, confidence interval; OR, odds ratio.
[a] Statistically significant.

Patients aged under 65 years and those aged 65-75 years had a higher risk of reoperation compared to patients over 75 (OR 2.5, 95% CI 1.3-4.8, $P = .004$ and OR 2.4, 95% CI 1.3-4.6, $P = .01$, respectively). Implant shaft angle was a decreasing risk factor for reoperation as a continuous variable (OR 0.96, 95% CI 0.9-0.99, $P = .01$) but did not have a significant association within groups (≤125° and >125°). The mechanism of injury did not have an effect on the risk of reoperation (OR 0.5, 95% CI 0.2-1.1, $P = .07$). No statistically significant association was found among reduction, time to surgery, ASA class, gender, or fracture side and reoperations (Table 3).

## Discussion

We found that preoperative FNF displacement, including a posterior tilt of <0° or ≥20°, increased the risk both of later conversion to arthroplasty and any reoperation after internal fixation of FNF. Also, inadequate reduction was associated with higher conversion-to-arthroplasty and reoperation rates. No significant association was found among conversion to arthroplasty and age, gender, implant shaft angle, time to surgery, fracture side, or mechanism of injury.

The total reoperation rate in our study population was 25%, and 16% of the patients underwent conversion to arthroplasty. These findings are similar to those of previous studies, which have reported reoperation rates between 16% and 33% [9,11,20,22–24,26]. Reoperation rates have been found to vary in the literature depending on which operations were defined as relevant reoperations [11,26]. In our study, every reoperation was included and conversion to arthroplasty was studied as a separate endpoint. Most of the reoperations were conversions to arthroplasty and implant removal surgeries, as in the previous studies [11,26]. Only 4 reoperations were performed for other reasons.

Eighty-four percent of the patients did not require later conversion to arthroplasty. While assessing the later risk of conversion to arthroplasty, preoperative displacement, including suboptimal posterior tilt, and inadequate postoperative reduction were associated with an increased risk of conversion. Eight percent of the patients with nondisplaced FNF and a posterior tilt between 0° and 20° underwent later conversion to arthroplasty compared with 26% of patients with nondisplaced FNF and a posterior tilt of <0° or ≥20°. Furthermore, there was no difference in risk of conversion to arthroplasty between patients with nondisplaced FNF with a <0° or ≥20° posterior tilt and patients with displaced FNF, suggesting that the effect of posterior tilt on later failure of internal fixation is as important as displacement on the AP radiograph. Comparable to our results, Okike et al [22] reported an increased risk of later conversion to arthroplasty in patients with a posterior tilt of ≥20°. Stockton et al [26] reported a conversion-to-arthroplasty rate of 14% in patients aged 18-50 years. Given that most FNF patients are elderly and fragile, any delay in rehabilitation due to a suboptimal choice of primary operation could lead to an inferior outcome. Therefore, based on our results and earlier literature, fragile patients with a preoperative posterior tilt of ≥20° are likely to benefit from arthroplasty as the primary operation to avoid reoperations.

A preoperative posterior tilt of <0° or ≥20° in nondisplaced FNFs was also associated with an increased risk of reoperation for any reason. Comparable to the risk of conversion to arthroplasty, there was no statistically significant difference in risk of

**Table 3**
Analysis of Risk of Reoperation.

| Variable | OR | 95% CI | *P* Value |
|---|---|---|---|
| Age (y) | | | |
| <65 | 2.5 | 1.3-4.8 | .004[a] |
| 65-75 | 2.4 | 1.3-4.6 | .008[a] |
| >75 | 1 | | |
| Gender | | | |
| Male | 1.4 | 0.8-2.4 | .2 |
| Female | 1 | | |
| Fracture laterality | | | |
| Right | 0.9 | 0.5-1.5 | .6 |
| Left | 1 | | |
| Mechanism of injury | | | |
| Low energy | 0.5 | 0.2-1.1 | .07 |
| High energy | 1 | | |
| ASA score | | | |
| 1-2 | 2.0 | 0.9-4.9 | .1 |
| 3 | 1.6 | 0.7-3.6 | .2 |
| 4-5 | 1 | | |
| Time to surgery (h) | | | |
| <24 | 1.4 | 0.8-2.3 | .3 |
| 24-48 | 1 | | |
| >48 h | 0.5 | 0.1-2.3 | .4 |
| Displacement | | | |
| Nondisplaced, posterior tilt 0°-20° | 0.2 | 0.08-0.3 | <.0001[a] |
| Nondisplaced, posterior tilt ≥20° or <0° | 0.5 | 0.2-1.0 | .07 |
| Displaced | 1 | | |
| Implant shaft angle | | | |
| ≤125° | 1.4 | 0.7-2.8 | .3 |
| >125° | 1 | | |
| Reduction | | | |
| Nondisplaced on AP view, posterior tilt 0°-10° | 0.2 | 0.03-1.7 | .1 |
| Nondisplaced on AP view, posterior tilt ≥10° or <0° | 0.6 | 0.09-4.7 | .7 |
| Displaced | 1 | | |

AP, anteroposterior; ASA, American Society of Anesthesiologists; CI, confidence interval; OR, odds ratio.
[a] Statistically significant.

reoperation between this group and patients with displaced FNF. Insufficient postoperative reduction was associated with a higher rate of conversion to arthroplasty. Adequate reduction was seen in 52% of displaced fractures and fractures with a preoperative posterior tilt of <0° and >20°. However, only 40 patients with nondisplaced fracture and an adequate posterior tilt had insufficient reduction; thus the preoperative displacement level might be a covariate with the reduction results. The posterior tilt groups were chosen to correspond with prior literature. They had different limits preoperatively and postoperatively, which could explain the insufficient reduction of preoperatively nondisplaced fractures. Some were considered inadequately reduced even though the posture remained intact. Nonetheless, good reduction should be aimed at during surgery.

Furthermore, when assessing all reoperations, we found an association between age and reoperation rate; younger patients had an increased risk of reoperation but not of conversion to arthroplasty. Similar results showing younger patients having an increased risk of reoperation have been published earlier [11,27] but did not report separately on the risk of later conversion. Palm et al and Dolatowski et al, on the other hand, did not find an association between age and reoperation [20,28]. Implant removal surgery is typically performed on younger patients with high activity demands [27]. Additionally, the trauma mechanism is more often high energy in the younger population. This may explain the association between age and reoperations. We did not find a statistically significant association between time to surgery and reoperation, in contrast with prior literature [11,24]. In many previous studies, surgical delay has been defined in periods of 12 hours as opposed to 24-hour stretches in our study, potentially impacting the statistical analysis.

FNF has been reported to lead to increased mortality and morbidity [1,2]. In this study, a total of 38% of patients died during follow-up and 14% of patients during the first year after surgery. Most fractures studied were low energy, which might indicate that the patients were frail and explain the observed high mortality rate. Preoperative mobility, cognitive impairment, and surgical delay have been found to be associated with risk of death after FNF surgery [29,30]. Also, increasing age and high ASA score have been named as possible preoperative predictors of death [24,30]. We did not investigate the impact of these factors or further risk factors for death on FNF patients, as these factors do not affect the reoperation rate.

We acknowledge that our study has some limitations. First, the data were collected retrospectively; thus patient selection for internal fixation was determined by patient- and surgeon-related factors after hospital admission. It is possible that the patient selection has caused some bias to the results. However, we have tried to minimize this effect by including age and gender in the multiple variant model. Second, we did not have patient-reported outcome measures, as Turku University Hospital does not routinely collect patient-reported outcome measures on trauma patients. Patients treated with arthroplasty have been reported to be more satisfied and reported less pain compared to internal fixation [9]. Additionally, our outcome of interest was reoperation; some patients might have been dissatisfied with their hip, without undergoing reoperation or conversion to arthroplasty.

We conclude that given the considerably high percentage of reoperations and later arthroplasties after osteosynthesis of FNF, fractures with a posterior tilt of >20° or <0° should be treated as a displaced fracture. Primary arthroplasty should be considered as treatment for displaced FNFs and fractures with a >20° or <0° posterior tilt, especially in fragile patients, to avoid further operations.

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