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Use of the trochanteric fixation nail advanced (TFNA) may increase the risk for nail breakage and early breakage time compared to other frequently used implants

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ABSTRACT

Background: Cephalomedullary nails (CMN) are widely used for fixation of unstable pertrochanteric fractures. In 2018, the Depuy Synthes Trochanteric Fixation Nail - Advanced (TFNA) implant was introduced at a level I academic trauma center. Subsequently, clinical concerns were raised about the use of the TFNA due to reports of nail breakage. The purpose of this study was to investigate the risk of nail breakage between TFNA and other nail models. Long term outcomes following nail failure were evaluated.

Methods: A retrospective cohort study was conducted using data of 1665 patients who had undergone a CMN procedure between 2014 and 2020. Data were handpicked from patient records. The nail breakage and breakage time of the TFNA were compared to the TFN, PFNA, Gamma3, and Intertan using cox regression analysis and logistic regression analysis. Long term outcomes were evaluated by assessing Oxford Hip Scores (OHS).

Results: The number of cephalomedullary nails were as follows: TFNA 754 (45.3 %), Gamma3 462 (27.7 %), PFNA 234 (14.1 %), TFN 211 (12.7 %), and Intertan 4 (0.2 %). A total of 21 (1.3 %) nails broke during the follow-up period. The TFNA broke the most often with 15 cases (2.0 %), followed by the Gamma3 with five cases (1.1 %) and the PFNA with one case (0.4 %). Overall, the mean (SD) nail breakage time was 222 (148) days. However, for the TFNA, Gamma3 and PFNA, the mean breakage times were 177 days (110), 292 (153) and 545, respectively. In logistic regression analysis we observed significant difference between TFNA and non-TFNA group. The odds ratio (OR) for nail breakage in TFNA group was 2.66 [95 % Ci, 1.01–6.99, $p = 0.047$]. The mean (SD) one year OHS for Total Hip Arthroplasty after nail breakage and overall OHS for re-osteosynthesis was 38.6 (9.8) and 36.3 (7.8), respectively.

Conclusions: Our study provides evidence suggesting that the TFNA may be associated with an increased risk of nail breakage compared to other nail models. It should be noted that implant breakage is a relatively infrequent complication. Long-term outcomes following secondary procedures were comparable between THA and re-osteosynthesis.

Level of evidence: Level IV

Introduction

Proximal femoral fractures are one of the most common fractures in the elderly [1]. Trochanteric fractures are commonly treated with cephalomedullary nailing. However, various complications related to cephalomedullary fixation have been reported. The overall complication rate in cephalomedullary nailing has been estimated to be 6.2 % [2]. Typical mechanical complications that can occur include broken nail, broken collum screw or blade, cut-out, cut-through, femoral shaft fracture, malunion, and nonunion [3,4]. Most complications in cephalomedullary nailing are due to technical reasons, such as malalignment of the fracture, malreduction, insufficient implant size, or inappropriate entry point [4]. In Finland, the total intramedullary nail removal rate for any reason has been reported at 5.4 %, with 1.8 % attributed to subsequent THA operation and 3.6 % to other types of operations [5].

Until 2018, Depuy Synthes provided Tampere University Hospital

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with Proximal Femoral Nail Antirotation (PFNA) intramedullary nails. However, after year 2018 a swift transition process took place in which the implants were first changed to the Titanium Trochanteric Fixation Nail System (TFN) and then to the TFN-ADVANCED® Proximal Femoral Nailing System (TFNA), which has a 2 mm smaller diameter on the proximal part of the nail. After introduction of the TFNA implant, recurrent implant failures raised concerns about the performance of the implant compared to other models. The main reason for this concern was multiple broken TFNA implants from the aperture of the collum screw of the intramedullary nail.

The literature concerning the possible increase in implant failure rates with TFNA implants is partially controversial. For ethical, treatment approach, and financial reasons, it is of great importance to understand whether the change of implant has resulted in increased failure rates.

The aim of the present study was to investigate whether doubts raised about the performance of the TFNA are well-founded. We hypothesized that the TFNA nails have higher risk for breakage compared to other nail types. In addition, long-term outcomes were assessed following nail breakage.

Materials and methods

This study was conducted at Tampere University Hospital (TAUH), Finland, using retrospective cohort study. The Ethical Committee of Tampere University Hospital has waived the requirement for ethical committee evaluation of all retrospective studies using routinely collected health care data. This decision is based on the Medical Research Act (488/1999) and the Act on the Status and Rights of Patients (785/1992). Moreover, in accordance with Finnish legislation (the Act on the Secondary Use of Health and Social data (552/2019)), no ethical informed written consent was required due to the retrospective register-based study design and because the patients were not contacted [6]. Institutional permission was granted by the Head of Tampere University Hospital with permission code R21534. An extension of permission for the OHS questionnaires letters was granted later.

Patient data were handpicked by two authors from the electronic patient database for the years 2014 through 2020 using the Nordic Medico-Statistical Committee (NOMESCO) procedure codes which are shown in appendix. Individual patient records and radiological images were also reviewed. The first search included 2397 procedures performed in the treatment of a proximal femoral fracture.

The collected patient data included age, sex, the ICD-10 diagnostic codes (S72.0, S72.1, S72.2, S72.3, S72.4), date of accident, operation details, implant type, implant details, time to failure, complications, reoperation, previous hip fractures, ASA grade [7], any risk factors for comorbidity included in the Charlson comorbidity index (CCI) [8], use of alcohol during injury, anticoagulants, and smoking. Fractures were classified as high- and low-energy fractures. Low energy fractures were categorized by fall on the same level, fall from bed, or fall from stairs. High energy fractures were motor vehicle accidents, falling from heights, and crush accidents. Operation details included open or closed reduction, use of cable, and operation date. Helical blade bone cement augmentation or dynamic distal locking was never used on primary nailings. Complications were classified according to the Clavien-Dindo classification for surgical complications [9]. Fracture pattern was categorized according to the AO/OTA classification [10]. Implant details included screw or blade use on the proximal hip screw. A total of five implant types were included. DePuy synthes (Raynham, Massachusetts, U.S.) manufactured the TFNA, TFN and PFNA. Stryker (Kalamazoo, Michigan, U.S) manufactured the Gamma Trochanteric Nail 3 (Gamma3) and Smith&Nephew (Watford, England, UK) manufactured the Trigen Intertan Trochanteric Antegrade Nail.

Functional outcome data using the Oxford Hip Score (OHS) were obtained via mail. OHS is a joint specific 12-item patient-reported measure which evaluates the pain and function of the operated hip. A patient can give a score from a minimum of zero to a maximum of 48 points. A maximum 48 points indicates that there is no pain or functional restriction in the hip. A score of zero indicates the hip is painful and has major functional disability. The OHS is primarily used with THA patients [11].

In the present study, the inclusion criteria were all proximal femoral fractures in which cephalomedullary nailing was used.

All other implants used in the treatment of proximal femoral hip fracture were excluded. In addition, patients with pathological fracture were excluded.

Statistical analysis

In the sociodemographic table, differences between the nail breakage and no nail breakage groups were examined using the Pearson Chi-Square Test for categorical variables, and the Mann-Whitney U test for continuous variables to compare the differences between the groups. Nail breakage was treated as a time to event variable. To compare the risk of nail breakage between nail models, survival analysis using Cox proportional hazard regression was performed. The time to nail breakage from index fracture surgical procedure to the event of nail breakage was used as the follow up time. The nail model was used as the main independent variable where TFNA was the reference model. Covariates, including, sex, collum head part, open reduction, previous hip fracture, and smoking status were included in the model to account for potential confounding factors. Adjusted Hazard risks (aHRs) and corresponding 95 % confidence intervals (CIs) were calculated.

Furthermore, logistic regression analysis was conducted to assess the frequency of nail breakage among groups: TFNA and non-TFNA. In this analysis, the dependent variable was binary, indicating whether a nail breakage event occurred or not. The nail model was included as a categorical independent variable, and the same covariates as in the survival analysis were added to adjust for potential confounding factors. Odds ratios and their respective 95 % CIs were reported.

All statistical analyses were performed using IBM SPSS Statistics (version 27). The significance level was set at $p< 0.05$.

Results

After exclusion, 1665 patients from the original 2397 patients were included for further analysis. Of the 732 excluded patients, 629 (85.9 %) had undergone procedures other than cephalomedullary nailing. These procedures included plate fixation 405 (64 %), revision surgeries 90 (14 %) screw fixation 63 (10 %), semiendoprosthesis 48 (7.6 %) and other nails 23 (3.7 %). In addition, 101 (13.8 %) duplicates and two (0.03 %) pathological fractures were excluded.

In total, 1193 of the patients analyzed were women (71.6 %). The mean (SD) age was 81.1 (11.7) years. Patient demographics for the No Nail Break and Nail Break groups are shown in Table 1. Statistically significant differences between the two groups were observed in age, fracture type, open reduction, cable usage, and osteoporosis.

The number of cephalomedullary nails used were TFNA 754 (45.3 %), Gamma3 462 (27.7 %), PFNA 234 (14.1 %), TFN 211 (12.7 %), and Intertan 4 (0.2 %). Of these, 21 (1.3 %) broke during the follow-up period with the mean (SD) age of 70.4 (18.3). In 17 of the 21 cases of nail breakage, the patients were women (81.0 %). Moreover, the nail that broke the most was the TFNA nail with a total of 15 broken nails (2.0 %). For the other nails, five breakings occurred with the Gamma3 (1.1 %) and one breakage with the PFNA (0.4 %). No instances of nail breakage were recorded for the other nail models during the follow-up period. The mean (SD) time for nail breakage was 222 (148) days. For the TFNA, Gamma3, and PFNA the mean breakage times were 177 (110), 292 days (153) and 545, respectively.

In cox regression analysis we failed to observe a statistically significant reduction in nail breakage when using other nail models than TFNA compared to other nail models. The adjusted hazard risk (aHR) for

Table 1
Patient sociodemographic details for nail break and No nail breakage Numbers are quantitative with percentages (%) unless otherwise specified. Statistical significance between the two groups presented as p values.

	No nail break	Nail break	p
Age, mean (SD, range)	81.3 (11.6, 21–104)	70.4 (18.3, 19–93)	<0.001 *
Females	1175 (71.5 %)	17 (81.0 %)	0.338
Right femur fracture	834 (50.7 %)	14 (66.7 %)	0.151
ASA class, mean (SD)	3.1 (0.61)	3.0 (0.64)	0.862
1	12 (0.7 %)	0	
2	172 (10.5 %)	3 (14.3 %)	
3	1048 (63.7 %)	14 (66.7 %)	
4	408 (24.8 %)	4 (19.0 %)	
CCI score, mean (SD, range)	5.6 (2.2, 0–16)	4.7 (2.7, 0–16)	0.111
Low energy fracture	1590 (96.7 %)	19 (90.5 %)	0.403
Implant type	1644	21	0.117
TFNA	739 (45 %)	15 (71.4 %)	
Gamma 3	457 (27.8 %)	5 (23.8 %)	
PFNA	233 (14.2 %)	1 (4.8 %)	
TFN	211 (12.8 %)	0	
Intertan	4 (0.2 %)	0	
Collum part helical	437 (26.6 %)	6 (28.6 %)	0.838
Open reduction	456 (27.7 %)	14 (66.7 %)	<0.001 *
Cable used	201 (12.2 %)	9 (42.9 %)	<0.001 *
Fracture type			<0.001
Simple pertrochanteric	979 (60.8 %)	5 (25.0 %)	*
Multifragmentary pertrochanteric	363 (22.5 %)	5 (25.0 %)	
Intertrochanteric / reverse oblique	234 (14.5 %)	9 (45.0 %)	
Subtrochanteric / diaphyseal	34 (2.1 %)	1 (5.0 %)	
Previous hip fracture	236 (14.4 %)	5 (23.8 %)	0.222
Osteoporosis	150 (9.1 %)	5 (23.8 %)	0.022*
Anticoagulation	466 (28.3 %)	5 (23.8 %)	0.645
Smoking	116 (7.1 %)	3 (14.3 %)	0.202
Trauma under the influence of alcohol	87 (5.3 %)	3 (14.3 %)	0.07
Days from trauma to operation (SD)	1.8 (1.3)	2.0 (1.9)	0.849
Discharge within 30 days	144 (8.8 %)	0	0.156

ASA, American Society of Anesthesiologists: physical status classification system; CCI, Charlson comorbidity index; SD, standard deviation; TFNA, Trochanteric fixation nail advanced; PFNA, Proximal femoral nail antirotation; TFN, Titanium trochanteric fixation nail system,.
Simple pertrochanteric fractures includes 31A1.1, 31A1.2 and 31A1.3; Multifragmentary fractures include 31A2.2 and 31A2.3; Intertrochanteric / reverse oblique fractures include 31A3.1, 31A3.2 and 31A3.3; Subtrochanter / diafyseal fractures include 32A, 32B and 32C type fractures.
* marks statistical significance.

PFNA was 0.050 [95 % Ci, 0.002–1.253; $p = 0.068$] and for Gamma 3 aHR 0.584 [95 % Ci, 0.152–2.25; $p = 0.434$]. None of the confounding factors showed statistical significance towards nail breakage. Cumulative hazard function shows PFNA broke later than other nail models. In logistic regression analysis we observed significant difference between TFNA and non-TFNA group. The odds ratio (OR) for nail breakage in TFNA group was 2.66 [95 % Ci, 1.01–6.99, $p = 0.047$]. In confounding factors open reduction seemed to increase the risk for nail breakage with odds ratio of 5.04 [95 % Ci, 2.00–12.7; $p < 0.001$]. Table 2, Table 3 and Fig 1.

The most common AO grade for implant breakage with six cases was 31A3.3 reverse oblique type fracture. The two second largest groups with four cases each were 31A2.3 multifragmentary fracture and 31A1.2 two-part fracture. Other fracture types included 31A1.3 lateral wall intact with three cases, 31A3.1 simple oblique with one case, three cases of diaphyseal fractures with two spiral fractures, and one oblique fracture. Other details relating to broken nails are shown in Table 4.

After nail breakage, all but two (9.5 %) patients underwent revision surgery. Revision procedures included eight total hip arthroplasties

Table 2
Factors explaining risk for nail breakage in cox regression analysis.

Factor	Group size	Hazard Ratio	P-value
Female	17	1.36 (0.3–6.17)	0.689
PFNA	1	0.050 (0.002–1.25)	0.068
Gamma3	5	0.584 (0.152–2.25)	0.434
Head part screw	15	0.331 (0.076–1.44)	0.141
Open reduction	14	1.575 (0.514–4.827)	0.427
Previous hip fracture	5	0.781 (0.186–3.279)	0.736
Smoking	3	0.232 (0.04–1.342)	0.103

PFNA, Proximal Femoral Nail Antirotation; Gamma3, Gamma Trochanteric Nail3;.

Table 3
Gatecorigal confounding factors explaining risk for nail breakage in Logistic regression analysis.

Factor	Group size	Odds Ratio	P-value
TFNA group	729	2.66 (1.01–6.99)	0.047*
Female	1163	1.84 (0.593–5.70)	0.292
Smoking	116	2.53 (0.689–9.32)	0.162
Open reduction	459	5.04 (2.00–12.7)	<0.001*
Previous hip fracture	234	1.89 (0.677–5.29)	0.224
Head part screw	1192	1.07 (0.408–2.83)	0.885

* marks statistical significance.

(38.1 %), six renailings (28.6 %), and five angled blade plates (23.8 %). Two patients had both PFNA, and LCP implanted during the reoperation. One patient underwent salvage, where renailing was later converted to THA due to nail breakage. Table 5

The OHS was obtained from 15 patients. The mean (SD) follow-up time for patient-reported outcomes was 2.8 (1.8) years. The mean (SD) OHS for THA one year after the operation was 38.6 (9.8). The overall mean (SD) OHS for re-osteosynthesis was 36.3 (7.8). Table 5

Discussion

A key finding of the present study is that the TFNA has a slightly higher risk for nail breakage compared to the PFNA (1.6 %) and the Gamma3 (0.9 %). The mean (SD) breakage times for the TFNA, Gamma3, PFNA were 177 days (110), 292 (153) and 545 days, respectively. The TFNA broke nearly four months prior to the Gamma3. Since only one PFNA nail broke during follow-up period it is hard to compare breakage times to other models.

In cox regression analysis we failed to observe statistically significant reduction in nail breakage compared to the TFNA. However, aHRs were in favor for reduced risk for nail breakage while using Gamma 3 or PFNA. Although the liability of the results suffers from low number of nail breakages. In logistic regression analysis we noticed a statistically significant increase in nail breakage while using TFNA nails compared to non-TFNA nails. In addition, open reduction increased the risk for nail breakage. Open reduction refers to complex fracture pattern and difficult revision thus higher risk for nail breakage is explanatory. Overall, the analysis of 21 nail breakage cases presents a statistical challenge due to the small sample size, which may affect the robustness of the findings.

Based on our data, there does not appear to be a clear association between fracture type and nail breakage. A significant proportion of the TFNA breakages occurred in 31A3.3 fractures. However, when examining the entire cohort, 3.2 % of patients with 31A3.3 fracture experienced nail breakage, regardless of the implant model. This relatively low overall incidence suggests that fracture morphology alone is unlikely to explain the observed differences in breakage rates between implants.

In the literature, the total risk for nail breakage reported is relatively low at between 0.06 % and 7 %, with most studies reporting a total risk of <2 % [12–15]. In this study, we found a slight increase in the risk for nail breakage when using the TFNA compared to the other nail models.

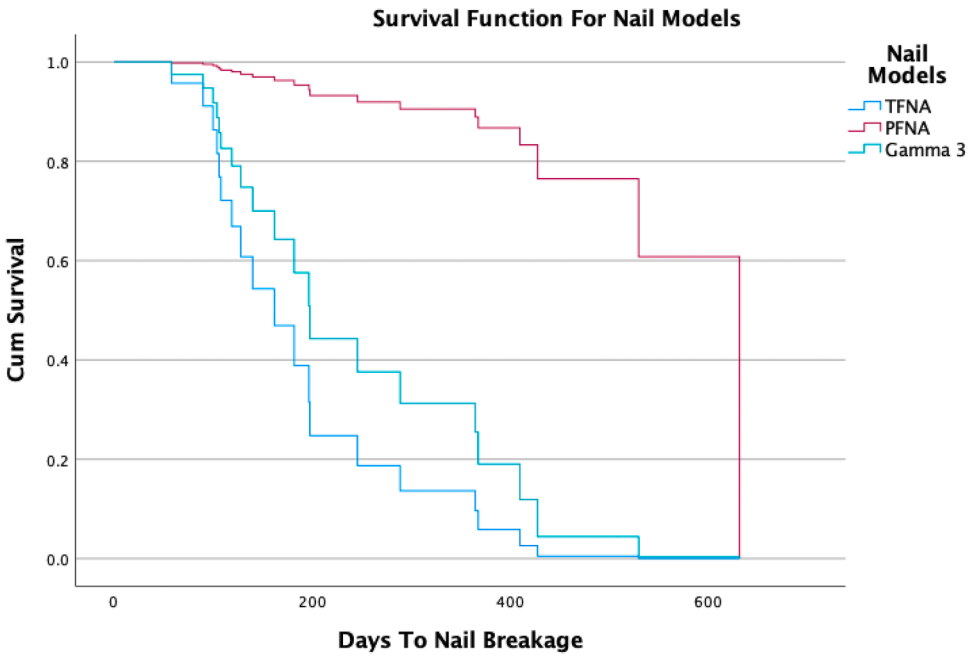

Fig. 1. Kaplan-Meier plot showing nails at risk for nail breakage during each timepoint during follow-up time.

The TFNA compared to its predecessor the PFNA, the proximal part of the nail in the aperture of the collum screw is 2 mm smaller in diameter. Therefore, we hypothesized that this may be the reason for the reduced metal strength and subsequently increased implant failure rates compared to PFNA and other nail models.

Multiple studies have investigated the performance of the TFNA. A recent study by an Australian group evaluated the TFNA implant using broken implants retrieved from 16 patients. The study revealed that changes to the nail design and/or alloy may have contributed to the observed cases of breakage. Average time for nail breakage was reported to be 5 months, which is in line with our findings [16]. A case-control study in The Netherlands compared implant failure between the TFNA (542) and the Gamma Trochanteric Nail 3 (Gamma3) (797). The results of that study showed a higher risk for fixation failure with the TFNA (14 %) than for the Gamma3 (7 %), with a hazard ratio (HR) of 2.0. Implant breakage rate was similar for both groups at 0.6 % [12]. A retrospective study from the United States compared nail breakage between the TFNA (14 730) and non-TFNA nails (8260) (the Gamma3 and the Zimmer Natural Nail (ZNN)) but found no significant difference in the nail breakage rate. However, breakage of the non-TFNA group's nail was reported to have occurred three weeks prior to that of the TFNA, which contrasts with the findings of all the other studies [13]. A study in the US compared the risk for revision between the TFN (4007) and the TFNA (3972). The nail breakage rate of the TFNA was 0.2 %, whereas the nail breakage rate of the TFN was 0.06 %. To date, this is the largest difference reported. However, no statistical significance was found in nail breakage or revision risk [14].

A retrospective study in the US compared the average time to nail breakage between 183 TFNA and 159 Gamma3 nails. The authors of the study observed that the TFNA broke on average two months prior to the Gamma3. The mean (SD) breakage time for the TFNA and the Gamma3 was 213 (180) days and 278 (181) days, respectively. Interestingly, in our study, we found a larger difference in breakage times between these two nails. In this study, the failed nails were inspected by the manufacturer, revealing that 19 out of 21 Gamma3 nails exhibited notching marks from drilling at the point of failure, whereas only one TFNA nail showed such marks according to the available reports. These findings suggest that early failures of TFNA occur without implant damage, whereas implant failure in Gamma3 nails is often iatrogenic [17]. A UK based study reported 6 implant breakages and found a mean (Range) breakage time for the TFNA of 325 (103–949) days, which differs somewhat from our findings [15].

After nail breakage, THA was the most common operation performed. Renailing was the second most used method followed by angled blade plate. Similar findings for nail removal and reoperations have been reported [18,19]. The best treatment after nail breakage differs from patient to patient and may require more research. In our notice renailing after nail break was the least successful revision as the salvage procedures only occurred after renailing. For other reoperations, the OHS could not be assessed due to the small amount of data available. The OHS for those patients who suffered multiple nail breakages is usually obtained from patients who have undergone THA.

The present study took place in a level 1 trauma center which provided a relatively large sample size of 1665 patients, including a control group of multiple nail models. The sample size of the reference studies varied from 6 to 22 630 nails [12–17]. Patient data were collected individually by hand ensuring in-depth knowledge of each patient. At our center, nailing procedures are carried out by experienced orthopedic surgeons, traumatologists, or residents in orthopedics and traumatology who are at the end of their specialization program. Therefore, all procedures are performed by experienced surgeons. The standard of care did not change during the study period.

We acknowledge a few limitations in the present study. Poor reduction quality, particularly varus malalignment, increases the risk of nail breakage. In our study, we did not assess the reduction achieved for each fracture; therefore, a comparative analysis between poor reduction and nail breakage was not possible. However, the sample sizes for both the TFNA and non-TFNA groups are large, and the surgeries were predominantly performed by the same experienced surgeons. On average, it is unlikely that the quality of reduction has changed.

Additionally, having information on, implant size and tip-apex index for the 'No nail breakage' group, it would allow for a more comprehensive comparison between the nail breakage group. The lack of tip-apex index data is due to the retrospective nature of our study. Postoperative radiographs were taken without calibration markers, making Tip-apex index measurements unreliable. Additionally, our study focuses on nail breakage rather than cut-out risk, and there is no established correlation between the tip-apex index and nail breakage. Nail

Table 4
Details of broken nails.

Patient no	Age	Gender	Fracture type (AO)	Collum angle	Tip apex distance (TAD)	Time from injury to operation (days)	Implant type	Open reduction	Cable	Helical blade or screw	Time to failure (days)	Follow up time	Complications	Implant related complications
1	77	F	31A2.3	129°	15.5	1	TFNA long	Yes	Yes	Screw	106	2022	Collum screw breakage while standing	–
2	69	M	31A3.3	121°	14.1	2	TFNA short	No	No	Screw	409	2022	Collum screw breakage while walking	Nonunion
3	78	F	31A3.3	128°	15.9	0	TFNA long	Yes	No	Blade	118	2022	Collum blade breakage while walking	–
4	77	F	31A1.3	129°	15.9	2	TFNA, short	No	No	Screw	101	2022	IMN breakage miscellaneous*	–
5	75	F	31A1.2	126°	16.9	10	TFNA short	No	No	Screw	426	2022	Both IMN and screw breakage	–
6	74	F	31A2.3	126°	15.4	1	TFNA short	No	No	Screw	289	2022	Screw breakage	–
7	83	F	31A3.3	126°	14.8	1	TFNA, short	Yes	Yes	Screw	105	2022	IMN breakage	–
8	63	M	31A3.3	132°	17	4	TFNA long	Yes	Yes	Blade	161	2022	Collum screw breakage	Nonunion (No revision surgery)
9	19	F	31A1.2	125°	14	2	TFNA, short	Yes	Yes	Screw	172	2022	IMN breakage	–
10	30	F	31A1.2	122°	18.5	1	TFNA short	No	No	Screw	198	2022	IMN breakage	Nonunion
11	52	F	31A1.3	131°	32.1	0	TFNA short	No	No	Blade	183	2022	IMN breakage	–
12	93	F	32A1	122°	12.1	0	TFNA long	Yes	Yes	Screw	69	2022	IMN breakage	
13	89	M	31A2.3	126°	21.3	1	PFNA long	Yes	Yes	Blade	545	2022	IMN breakage and subtrochanteric fracture	–
14	82	F	31A3.1	125°	15.8	1	TFNA long	Yes	Yes	Blade	163	2022	IMN breakage, nonunion	Nonunion
15	76	F	31A3.3	128°	26	2	TFNA short	Yes	No	Screw	60	2022	IMN breakage due to falling	
16	73	F	31A3.3	128°	9.6	1	TFNA long	Yes	No	Blade	2 d for reoperation and 93 d until nail breakage	2022	Revision surgery for femur inversion and later IMN breakage	–
17	67	F	31A1.3	125°	16.4	2	Gamma3 short	Yes	No	Screw	548	2022	INM breakage, walking was getting harder and pain in gluteal area	–
18	82	F	32A1	127°	20.0	1	Gamma3 long	No	No	Screw	365	2022	IMN breakage and varus	–
19	89	F	31A2.3	129°	25.3	1	Gamma3 long	Yes	Yes	Screw	247	2022	IMN breakage	–
20	74	M	32A2	130°	15.8	1	Gamma3, long	Yes	Yes	Screw	195	2022	IMN breakage slowly getting more painful	–
21	66	F	31A1.2	129°	21.4	2	Gamma3 long	Yes	No	Screw	104	2022	IMN breakage and refracture	–

F, Female; d, days; M, Male; IMN, intramedullary nail; TFNA, Trochanteric Fixation Nail; PFNA, Proximal Femoral Nail Antirotation - Advanced; Gamma3, Gamma Trochanteric Nail 3; -, none.

Table 5
Reoperations, salvage procedures and Oxford Hip Score.

Patient id	Reoperation date	Reoperation implant	Reoperation complications	Salvage	Oxford Hip Score	OHS years from latest operation
1	7.2.2020	Angled blade plate	–	–	25	2
2	8.10.2020	Angled blade plate	–	–	–	–
3	18.9.2020	Angled blade plate	–	–	41	4
4	15.9.2020	ZMR®/Continuum (ceramic-plastic)	–	–	45	1
5	10.8.2020	Mutars filia/G7®/freedom	–	–	20	1
6	19.8.2020	MS30-G7®, Freedom	–	–	29 -> 27	1 -> 2
7	5.6.2020	Angled blade plate	–	–	41	4
8		No reoperation	–	–	47	2
9	20.3.2020	Angled blade plate	–	–	–	–
10	18.2.2020	Short TFNA, Screw	Wound revision 9.2.2020, treated until 31.12.2020.	–	–	–
11	20.1.2020	Arcos Revisio Stem and G7®/ Freedom Acetabulum component	–	–	48	1
12	15.1.2019	Long TFNA blade with cable	–	–	29	3
13		No reoperation	–			
14	24.10.2018	Total endoprosthesis Mutars/ Regenerex/Freedom	–	–	37	1
15	28.8.2018	Long TFNA with blade	–	–	–	–
16	15.6.2018	Arcos/Freedom	–	–	43 -> 46	1 -> 4
17	8.1.2018	Gap 2/Advantage/ZMR Cemented	–	–	48	1
18	16.8.2017	Autologous bone graft, LCP, PFNA blade nailing	–	–	34	5
19	20.6.2017	Continuum/ZMR®/XLPE	–	–	–	–
20	18.5.2015	Long PFNA blade + LCP	–	–	48	7
21	20.09.2014	Long Gamma3	INM breakage due to nonunion	11/2015 Autologous caput bone graft and GAP2/ Trident/Exeter cemented. After THA two revision operations due to infections	20	5

MS, Morscher-spotorno; IMN, Intramedullary nail; THA, Total hip arthroplasty; Gamma3, Gamma Trochanteric Nail3; OHS; Oxford Hip Score; GAP2, graft augmentation prosthesis 2; LCP, pediatric LCP plate system; XLPE, crosslinked polyethylenes.

breakages consistently occur at the collum screw aperture, where nail thickness remains constant regardless overall size of the nail.

Furthermore, due to the retrospective nature of the study, the information retrieved from patient records might have been incomplete. Therefore, a multicenter study would have offered more patient data for analysis. As prospective data are not available, it is not possible to compare our findings to this data. In addition, the generalization of the findings of this study is not applicable to small volume centers.

Conclusion

Our study provides evidence suggesting that the TFNA may be associated with an increased risk of nail breakage compared to other nail models. However, further studies with larger population samples are needed to validate these findings. It is important to acknowledge that implant breakage is a relatively infrequent complication. Long-term outcomes following secondary procedures were comparable between THA and re-osteosynthesis.

Ethics statement

This retrospective study was approved by the head of Tampere University Hospital (Permission code. R21534). Due to the retrospective nature of the study, the requirement for informed consent was waived. The study was conducted in accordance with the Declaration of Helsinki. An extension of permission for the OHS questionnaires letters was granted later.

CRediT authorship contribution statement

Leevi Karjalainen: Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Antti AJ. Ylitalo:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Investigation, Conceptualization. **Miika Lähdesmäki:** Methodology, Investigation, Data curation, Conceptualization. **Antti Eskelinen:** Supervision, Resources, Project administration. **Ville M. Mattila:** Validation, Resources, Project administration, Conceptualization. **Jussi P. Repo:** Writing – review & editing, Supervision, Resources, Project administration, Investigation, Conceptualization.

Declaration of competing interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2025.112410.

References

[1] Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury 2006; 37(8):691–7. Aug.
[2] Bojan AJ, Beimel C, Speitling A, Taglang G, Ekholm C, Jönsson A. 3066 consecutive gamma nails. 12 years experience at a single centre. BMC Musculoskelet Disord 2010;11(1):133. Dec 26.
[3] Klima ML. Mechanical complications after intramedullary fixation of extracapsular hip fractures. J. Am. Acad. Orthop. Surg. 2022;30(24):e1550–62. Dec 15.
[4] Mavrogenis AF, Panagopoulos GN, Megaloikonomos PD, Igoumenou VG, Galanopoulos I, Vottis CT, et al. Complications after hip nailing for fractures. Orthopedics 2016;39(1). Jan.
[5] Ponkilainen VT, Huttunen TT, Kannus P, Mattila VM. Hardware removal rates after surgical treatment of proximal femur fractures. Arch Orthop Trauma Surg 2020; 140(8):1047–54. Aug 21.
[6] Medical research act [Internet]. 2010 Vol. 488/1999. [cited 2022 Feb 27]. available from: https://www.finlex.fi/fi/laki/kaannokset/1999/en19990488.pdf.
[7] https://www.asahq.org/standards-and-guidelines/asa-physical-status-classification-system [Internet]. 2014 [cited 2023 Jan 30]. ASA physical status classification system. available from: ASA physical status classification system.

[8] Charlson M. Charlson comorbidity index (CCI) [Internet]. 2005 [cited 2022 Feb 27]. available from: https://www.mdcalc.com/charlson-comorbidity-index-cci#use-cases.
[9] Dindo D, Demartines N, Clavien PA. Classification of surgical complications. Ann Surg 2004 Aug;240(2):205–13.
[10] Meinberg EG, Agel J, Roberts CS, Karam MD, Kellam JF. Fracture and dislocation classification compendium-2018. J Orthop Trauma 2018;32:S1–170. Jan 1.
[11] LONKKA TOIMINTAKYKYKYSELY Oxford hip score (OHS). 2022.
[12] Schmitz PP, Hannink G, Reijmer J, Somford MP, Van Susante JLC. Increased failure rates after the introduction of the TFNA proximal femoral nail for trochanteric fractures: implant related or learning curve effect? Acta Orthop 2022;93:234–40. Jan 11.
[13] Wallace A, Amis J, Cafri G, Coplan P, Wood J. Comparative safety of the TFN-ADVANCED proximal femoral nailing system. J. Bone Jt. Surg. 2021;103(17):1637–45. Sep 1.
[14] Goodnough LH, Chang RN, Fasig BH, Prentice HA, Paxton EW, Diekmann GR, et al. Risk of revision after hip fracture fixation using DePuy synthes trochanteric fixation nail or trochanteric fixation nail advanced. J. Bone Jt. Surg. 2022 Mar 25.
[15] Nayar SK, Ranjit S, Adebayo O, Hassan SM, Hambidge J. Implant fracture of the TFNA femoral nail. J Clin Orthop Trauma 2021;22:101598. Nov.
[16] Lambers A, Rieger B, Kop A, D'Alessandro P, Yates P. Implant fracture analysis of the TFNA proximal femoral nail. J. Bone Jt. Surg. - Am. 2019;101(9):804–11. Vol. May 1.
[17] Klima ML. Comparison of early fatigue failure of the TFNa and gamma 3 cephalomedullary nails in the United States from 2015 to 2019. J Orthop Trauma 2021;35(2):e39–44. Feb.
[18] Cruz-Sánchez M, Torres-Claramunt R, Alier-Fabregó A, Martínez-Díaz S. Salvage for nail breakage in femoral intramedullary nailing. Injury 2015;46(4):729–33. Apr.
[19] Li P, Zhang Z, Zhou F, Lv Y, Guo Y, Tian Y. Characteristics of intramedullary nail breakage in pertrochanteric femur fractures: a summary of 70 cases. J Orthop Surg Res 2021;16(1):676. Dec 17.