ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA
www.aott.org.tr

Research Article

A new scoring system for predicting cut-out risk in patients with intertrochanteric femur fractures treated with proximal femoral nail anti-rotation

Burak Kulakoglu[1], Guzelali Ozdemir[2], Olgun Bingol[2], Taner Karlidag[2], Omer Halit Keskin[2], Atahan Durgal[2]

[1]*Department of Orthopaedics and Traumatology, Kilis State Hospital, Kilis, Turkey*
[2]*Department of Orthopaedics and Traumatology, Ankara City Hospital, Ankara, Turkey*

ARTICLE INFO

Article history:
Submitted January 11, 2023
Received in revised form March 15, 2023
Last revision received form September 17, 2023
Accepted September 28, 2023
Publication Date October 26, 2023

Keywords:
Intertrochanteric fractures
proximal femoral nailing
cut-out
scoring system

ORCID iDs of the authors:
B.K. 0000-0002-5590-8484;
G.O. 0000-0003-4279-0955;
O.B. 0000-0003-1720-1709;
T.K. 0000-0003-4250-0444;
O.H.K. 0000-0003-2402-8465;
A.D. 0000-0002-6980-6745.

ABSTRACT

Objective: The objectives of this study were to: (1) determine all the potential risk factors defined in the literature for cut-out after proximal femoral nail anti-rotation in managing intertrochanteric fractures and (2) make a reliable prediction about the likelihood of cut-out by developing a quantitative scoring system.

Methods: Four hundred eighty patients who were operated on for an intertrochanteric femur fracture were included in the study. The patients were evaluated retrospectively. Radiological parameters known to affect cut-out, including tip apex distance (TAD), calcar-referenced TAD (CalTAD), and reduction quality, were also used to evaluate the patients. Additionally, the classification of the fracture according to the cortical thickness index for osteoporosis, the Charlson comorbidity index for additional comorbidities, and the Arbeitsgemeinschaft Für Osteosynthesefragen classification were evaluated.

Results: The cut-out rate among all patients was 7.2%. Cut-out risk could be predicted by gender, TAD, CalTAD, and reduction quality. Female gender, TAD > 29.45, CalTAD > 31.75, and acceptable or poor reduction quality significantly increased the cut-out risk. Based on the chi-square analysis, it was determined that there was a significant relationship between the cut-out risk and the variables of TAD, CalTAD, reduction quality, gender, and fracture type (P=.000, P=.000, P=.000, P=.008, P=.016, respectively). Logistic regression analysis showed a strong correlation between the newly developed scoring system and the risk of cut-out. The risk of cut-out increased 8.1 times in individuals with a score of more than 2 (P < .001).

Conclusion: Female gender, TAD > 29.45, CalTAD > 31.75, and acceptable or poor reduction quality are the parameters found to be significant in determining the cut-out risk. With the newly developed scoring system, risks can be calculated for all situations that may occur according to the scores obtained by the patients. The cut-out risk increases significantly in patients with a score above 2 points.

Level of Evidence: Level III, Diagnostic Study.

Introduction

Intertrochanteric fractures (ITFs) account for approximately half of all hip fractures caused by low-energy mechanisms such as simple falls.[1] These fractures are associated with high morbidity and mortality.[2]

Intertrochanteric fractures are frequently fixed with interlocking proximal femoral nail anti-rotation (PFN-A) systems, and cut-out is the most common mechanical complication of fixation failure.[3-5] Cut-out is the result of the instability of a fracture due to varus collapse of the neck shaft angle while the implant is fixed, causing the screw to protrude out of the femoral head. It is seen in 0%-16% of cases reported in the literature.[6]

It has been shown that the risk of cut-out may vary according to the type of fracture, the quality of the intraoperative reduction, and different variables such as tip apex distance (TAD).[7] The recently defined calcar-referenced tip apex distance (CalTAD) has also been associated with the risk of cut-out.[8] Other studies have demonstrated that age, gender, and osteoporosis affect the risk of cut-out.[5,9-13] However, the specific rates of increases in risk as a result of the factors that cause cut-out have not been determined in the literature and a scoring system has not been established.

The aim of this study is to evaluate all potential risk factors defined in the literature for cut-out complications that may develop after PFN-A is applied for ITFs, to develop a quantitative scoring system to allow reliable predictions about cut-out occurrence, and to offer suggestions for its use in practice.

Material and methods

In this study, patients with ITFs admitted to Ankara City Hospital's Orthopedics and Traumatology Department between January 2019 and August 2021 were evaluated retrospectively. Patients' records were reviewed after the approval of the ethics committee (E1-20-1226) was obtained on November 11, 2020, from the Ankara City Hospital No. 1 Clinical Research Ethics Committee. All researchers participating in the study complied with the most recent version of the

Corresponding author:
Burak Kulakoglu
burakkulakoglu@gmail.com

Content of this journal is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

Cite this article as: *Kulakoglu B, Ozdemir G, Bingol O, Karlidag T, Keskin OH, Durgal A. A new scoring system for predicting cut-out risk in patients with intertrochanteric femur fractures treated with proximal femoral nail anti-rotation. Acta Orthop Traumatol Turc., 2023;57(5):258-266.*

DOI: 10.5152/j.aott.2023.23018

Declaration of Helsinki. Informed consent forms were obtained from all patients participating in the study.

Regardless of gender and age, patients with postoperative follow-up of at least 6 months who were treated with short PFN-A (170-200 mm) were included in the study. Patients with pathological fractures, previous operations on the same hip, a history of neuromuscular disease, renal failure, polytrauma, inappropriate postoperative or preoperative radiographs, and treatment methods other than PFN-A were excluded from the study.

A total of 733 patients with ITFs were admitted to Ankara City Hospital's Orthopedics and Traumatology Department between January 2019 and August 2021, and 253 patients who did not meet the inclusion criteria were excluded from the study. Therefore, a total of 480 patients with ITFs were included in the study (Figure 1).

All patients in the current study underwent PFN-A (simplelock/interclaw PFN-A, Zimed Medical, Gaziantep, Turkey) with open or closed reduction. The procedure was performed while the patients were in the supine position. A traction table was used during surgery. The same orthopedic implant, a PFN-A, was used for all patients included in the study. No drain was placed in the surgical area and the duration of the surgery was recorded. Surgical duration was defined as beginning after the patient's anesthesia procedure was completed and ending when the surgical incision was sutured.

Demographic data including age, gender, side of operation, type of anesthesia, and American Society of Anesthesiologists score were collected. In addition, the fracture type, reduction quality, TAD, CalTAD, cortical thickness index (CTI), position of the screws in the femoral head, and Charlson comorbidity index (CCI) were also evaluated for all patients included in the study.

Age, gender, fracture type, reduction quality, position of the screws in the femoral head, TAD, CalTAD, CTI, and CCI were evaluated to determine whether they were independent risk factors for cut-out. Cutoff values were considered for all parameters, and calculations were performed to determine how many times each parameter increased the risk of cut-out. A newly developed scoring table was created according to these results.

Radiological evaluations

In this study, radiological parameters were evaluated with anteroposterior (AP) and lateral radiographs taken on the first postoperative day.

HIGHLIGHTS

- Cut- out is the most common mechanism of fixation failure in proximal femoral nail anti-rotation systems. This study aimed to evaluate the potential risk factors associated with nail cut-out, and to develop a quantitative scoring system to predict cut-out occurrence.
- The results showed that Female gender, tip apex distance of >29.45, calcar-referenced tip apex distance of >31.75, and acceptable or poor reduction quality significantly increase cut-out risk. Moreover, according to the new scoring system developed in this study, the risk of cut-out increases significantly in patients with scores above 2 points.
- The results indicate that the newly developed scoring system presented here can guide clinical practice. Routine follow-up and postoperative rehabilitation may be suitable for low-risk patients (0-1-2 points), but close follow-up and safer rehabilitation programs for high risk patients (3-4 points) is advisable. As the cut-out risk is very high for patients with a score of 5, revision surgery should be considered when their general conditions allow it.

Baumgaertner et al[5] reported that TAD could be defined as the sum of the distance between the screw tip and the apex of the femoral head in the AP view and lateral view. Figures 2 and 3 illustrate how TAD was measured in the present study using the following formula: $TAD=[X_{ap}\times(D_{true}/D_{ap})]+(X_{lat}\times(D_{true}/D_{lat})]$ (D: true known diameter of the lag screw).

The AP and lateral radiographs were also evaluated for CalTAD (Figure 4).[14] The CalTAD distance is defined as the sum of TAD distances in AP and lateral radiograph. In the AP view, the CalTAD value is the distance between the femoral head and the apex of the femoral head, where the line drawn parallel to the femoral neck passing through the calcar femoris intersects with the femoral head.

Reduction quality was evaluated based on 3 different ratings as defined by Baumgaertner et al.[5] Two criteria were evaluated from AP and lateral radiographs. The first of these was the alignment and the second was the displacement amount (Table 1). In the evaluation of alignment, the cervicodiaphyseal angle (Figure 5) should be between 120° and 135° in the AP view, and there should be less than 20° of angulation on the lateral radiograph. When assessing the amount of displacement, there should be less than 4 mm of displacement between each fragment on the AP and lateral radiographs. Reduction was considered good if both criteria were met, acceptable or moderate if only 1 was met, and poor if neither was met. The CTI was measured as the ratio of the cortical width minus the endosteal width to the cortical width 100 mm below the tip of the lesser trochanter (Figure 6).

The position of the screws in the femoral head was evaluated according to the quadrants of Cleveland and Bosworth.[15,16] The patients were divided into 2 groups, with 1 group having ideal positioning and 1 having suboptimal positioning, based on the quadrants of Cleveland and Bosworth. Within these groups, the location of the screws was analyzed in the ideal position (central/inferior in AP radiographs and central/posterior in lateral radiographs) as well as in other positions that were considered suboptimal.

Statistical analysis

Statistical analysis was performed using IBM Statistical Package for the Social Sciences Statistics software version 20.0 for Windows (IBM SPSS Corp.; Amonk, NY, USA). The results were evaluated within 95% CIs and $P < .05$ was considered significant. Descriptive statistics for categorical variables were given as percentages and frequencies, while descriptive statistics for numerical variables were expressed as mean, SD, median, and minimum–maximum values. For the cut-out risks of these variables, chi-square and logistic regression analysis techniques were used to obtain information about whether they were statistically independent risk factors, whether their cutoff values constituted risk factors, and how many times they increased the risk. Whether the variables determined to be cut-out risk factors were independent risk factors was evaluated by chi-square analysis. The cutoff values separating the groups that did and did not experience cut-out in terms of numerical variables were determined by receiver operating characteristic (ROC) curve analysis. The binary logistic regression analysis technique (method: enter), as an advanced statistical analysis technique, was used to reveal how much each variable affected the risk of cut-out, the cut-out probabilities, and the predictability of the cut-out risk with the scoring method developed using these probabilities.

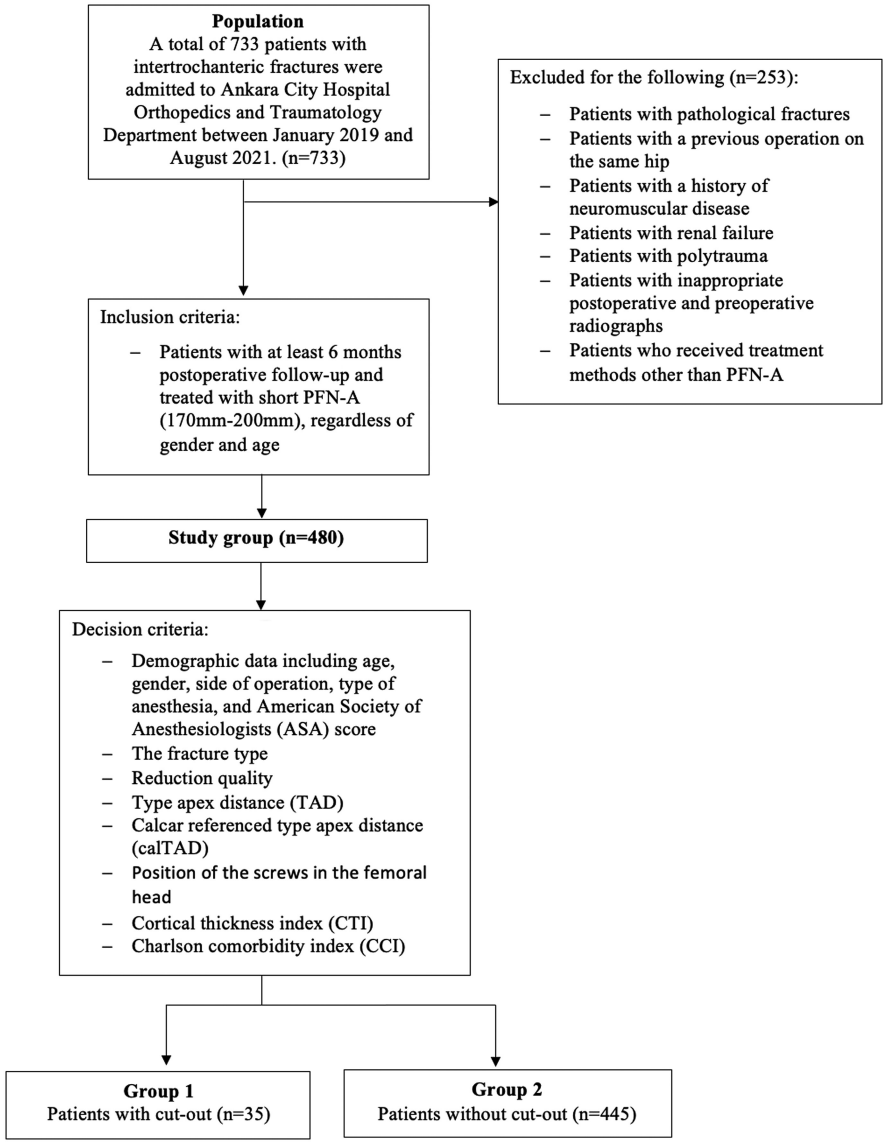

Figure 1. Flowchart. PFN-A, proximal femoral nail anti-rotation.

Results

A total of 480 individuals who met the criteria, from among 733 patients treated for ITFs in the relevant timeframe, were included in the study. Descriptive statistics for all patients included in the study are summarized in Table 2. The cut-out rate in the total sample was 7.2% (Table 2). The mean follow-up time of the patients included in the study was found to be 10.66 ± 3.88 months. The minimum follow-up period was 6 months, and the maximum follow-up period was 11 months.

Age, CCI, and CTI could not be categorized as variables with significant cutoff values according to the ROC analysis. However, the cutoff values obtained for TAD and CalTAD, which were statistically significant variables, were found to be 29.45 mm and 31.57 mm, respectively (Figure 7). According to ROC analysis, the normal limits were found to be <29.45 mm for TAD and <31.57 mm for CalTAD. The TAD values of 74.6% and CalTAD values of 63.8% of the 480 patients were within these normal limits (Table 2).

The position of the screws in the femoral head according to the Cleveland and Bosworth quadrants showed the following distributions by quadrants: superior–anterior (2.5%), superior–central (1.6%), superior–posterior (1.2%), central–anterior (8.9%), central–central (65.6%), central–posterior (3.1%), inferior–anterior (11.4%), inferior–central (12.9%), and inferior–posterior (2.9%) (Figure 8). In the group with ideal positioning, cut-out was observed in 15 of 406 patients, whereas in the suboptimal group, cut-out was observed in 20 of 74 patients. The association between suboptimal positions and the occurrence of cut-out complications was found to be statistically significant ($P < .001$). The suboptimal group had a higher risk of cut-out compared to the ideal group (Table 2).

Age, CCI, and CTI were not statistically significant in the ROC analysis ($P=.632$, $P=.586$, and $P=.112$, respectively). As a result of chi-square analysis, it was determined that there was a significant relationship between cut-out risk and the variables of TAD, CalTAD, reduction quality, position of the screws, gender, and fracture type ($P < .001$, $P < .001$, $P < .001$, $P < .001$, $P=.008$, and $P=.016$, respectively).

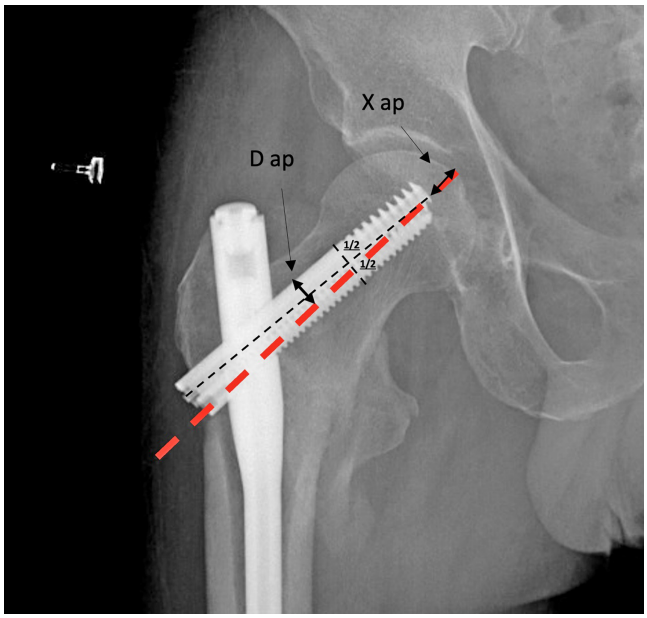

Figure 2. Measurement of tip apex distance from anteroposterior radiography. Ap, anteroposterior; D, true known diameter of the lag screw.

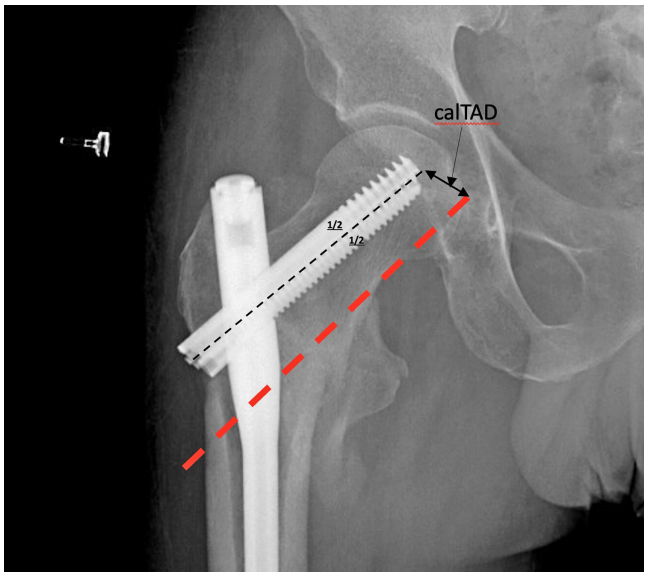

Figure 4. Measurement of calcar-referenced tip apex distance (CalTAD) on anteroposterior radiography

Univariate analysis

The cutoff values obtained at the end of ROC analysis for the variables of CCI, CTI, and age were found to be statistically insignificant (P=.632, P=.586, and P=.112, respectively), and it was not possible to determine whether they were risk factors for cut-out by chi-square testing. Therefore, the numerical values of these variables were included in the logistic regression analysis.

Multivariate analysis

Since fracture type, the position of the screws, and CCI were not statistically significant variables in explaining cut-out risk according to multivariate logistic regression analysis (P=.723, P=.995, and P=.781 respectively), these variables were removed and the model was analyzed again. In the appropriate model, gender, CalTAD, TAD, and reduction quality were found to be statistically significant variables in explaining cut-out risk (P < .005). In addition, the model was significant according to the omnibus test (P < .001) and sufficient according to the Hosmer and Lemeshow test, and it can be said that the model fits the data well (P=.727, >.05) (Table 3).

The resulting multivariate logistic regression model was obtained as follows:

$$Y_i = -7.996 + 2.342 \times X_{Gender1} + 1.538 \times X_{Tad1} + 2.795 \times X_{CalTad1} + 4.577 \times X_{Reduction2}$$

The probability of a patient experiencing cut-out is calculated with the formula

$$P_{yi} = \frac{e^{yi}}{\left(1 + e^{yi}\right)},$$

according to this model.[17] The probabilities of these different cases were calculated based on the multivariate logistic regression model (Table 4).

Newly developed scoring system

The categorical values of the variables were defined as scores. Using the scores of 4 variables, a patient can obtain a minimum of 0 and a maximum of 5 points with the newly developed scoring system (NDSS) (Table 4).

There are a maximum of 24 (2 × 2 × 2 × 3) different cases for the categorical values of the variables of gender (0, 1), TAD (0, 1), CalTAD (0, 1), and reduction quality (0, 1, 2) (Table 5). The risk of each condition for cut-out was calculated based on the multivariate logistic regression model. The risk of cut-out is 0.5% for patients with 0 points and 96.6% for those with 5 points. The cut-out risk ranges from 0.1% to

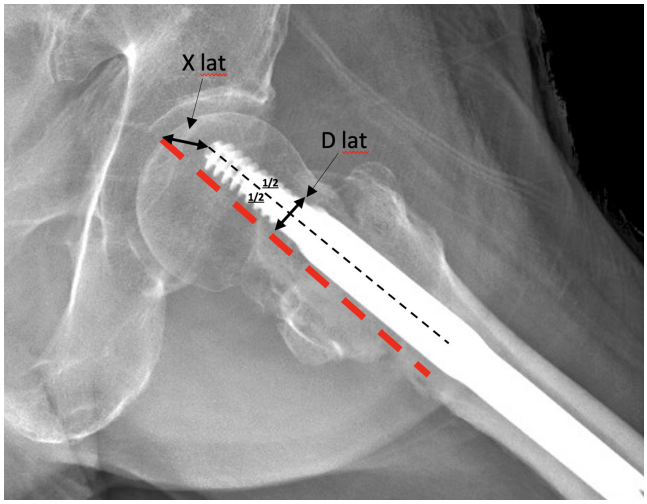

Figure 3. Measurement of the tip apex distance from lateral (lat) radiograph.

Table 1. Baumgaertner reduction criteria

Baumgaertner reduction criteria
1) Alignment
a. Anteroposterior view: normal or slight valgus neck shaft angle*
b. Lateral view: less than 20° of angulation
2) Displacement
a. Anteroposterior view: less than 4 mm of displacement of any fragments
b. Lateral view: less than 4 mm of displacement of any fragments

*Slight valgus means a valgus of no more than 10°.

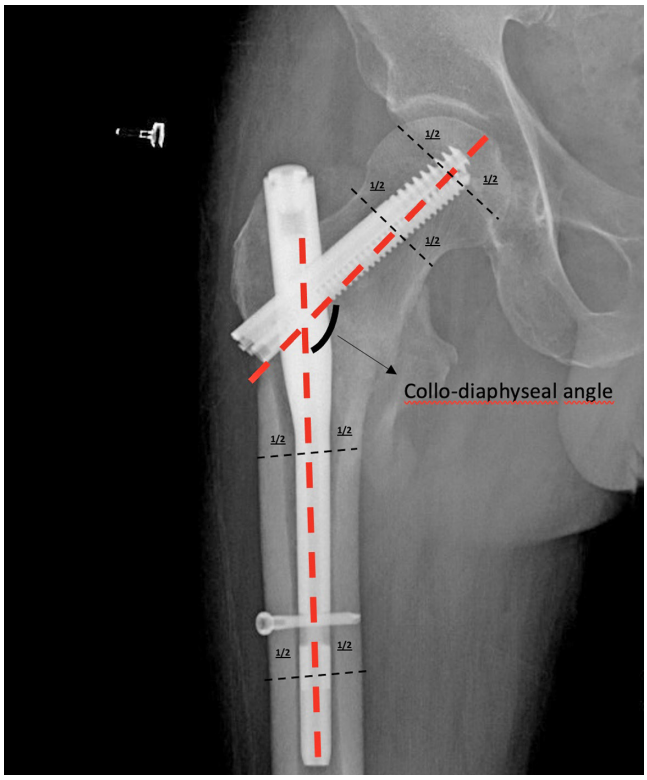

Figure 5. Measurement of neck shaft angle on anteriorposterior radiography.

Table 2. Number of cut-outs according to the categories of the variables

Variables	Category	Non-cut-out	Cut-out	Total
Gender	Male	205	8	213
	Female	240	27	267
	Total	445	35	480
Fracture type	31A1	227	9	236
	31A2	184	22	206
	31A3	34	4	38
	Total	445	35	480
TAD	Good (≤29.45)	352	6	358
	Poor (>29.45)	93	29	122
	Total	445	35	480
CalTAD	Good (≤31.75)	303	3	306
	Poor (>31.75)	142	32	174
	Total	445	35	480
Reduction quality	Excellent	347	6	353
	Acceptable	93	13	106
	Poor	5	16	21
	Total	445	35	480
The position of the screws	Ideal position	391	15	406
	Suboptimal position	54	20	74
	Total	445	35	480

CalTAD, calcar-referenced tip apex distance; TAD, tip apex distance.

0.7% for those with 1 point. It is between 0.8% and 6.1% for those with 2 points. It is between 6.9% and 43.2% for those with 3 points and between 58.3% and 84.8% for those with 4 points.

Among the total of 480 patients included in this study, 78 (16.2%) obtained 0 points, 203 (42.2%) 1 point, 131 (27.2%) 2 points, 36 (7.5%) 3 points, 22 (4.5%) 4 points, and 10 (2%) 5 points. The cut-out rates of these groups of patients according to scores of 0-1, 2, 3, 4, and 5 were 0.0%, 3.1%, 22.2%, 63.6%, and 90%, respectively (Table 6).

It was observed that the scoring system based on these scores was statistically significant according to analyses conducted to determine the cut-out risk. The ROC analysis showed that the NDSS was reliable

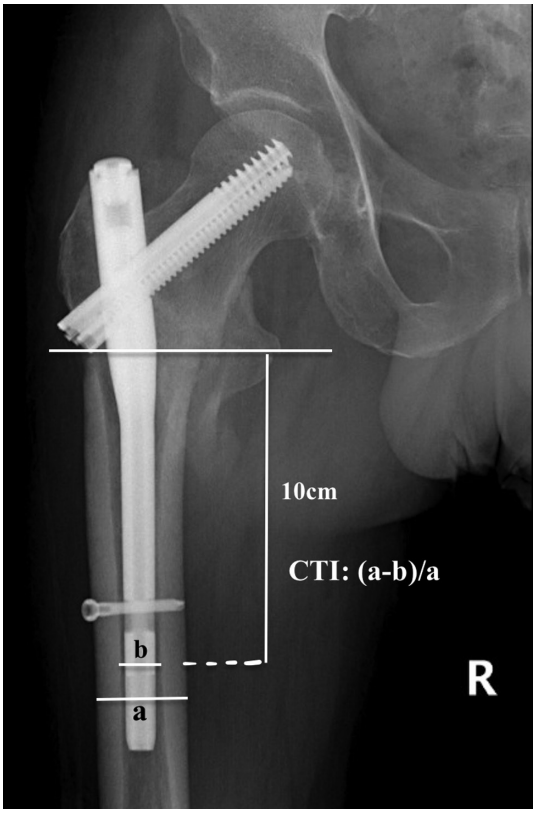

Figure 6. Measurement of cortical thickness index (CTI) on anterior posterior radiography.

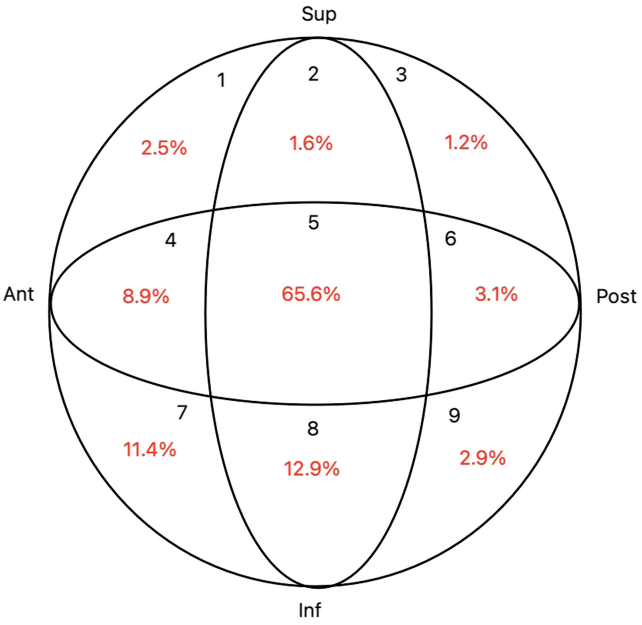

Figure 7. Receiver operating characteristic curve of numerical variables. Ant, anterior; inf, inferior; post, posterior; sup, superior.

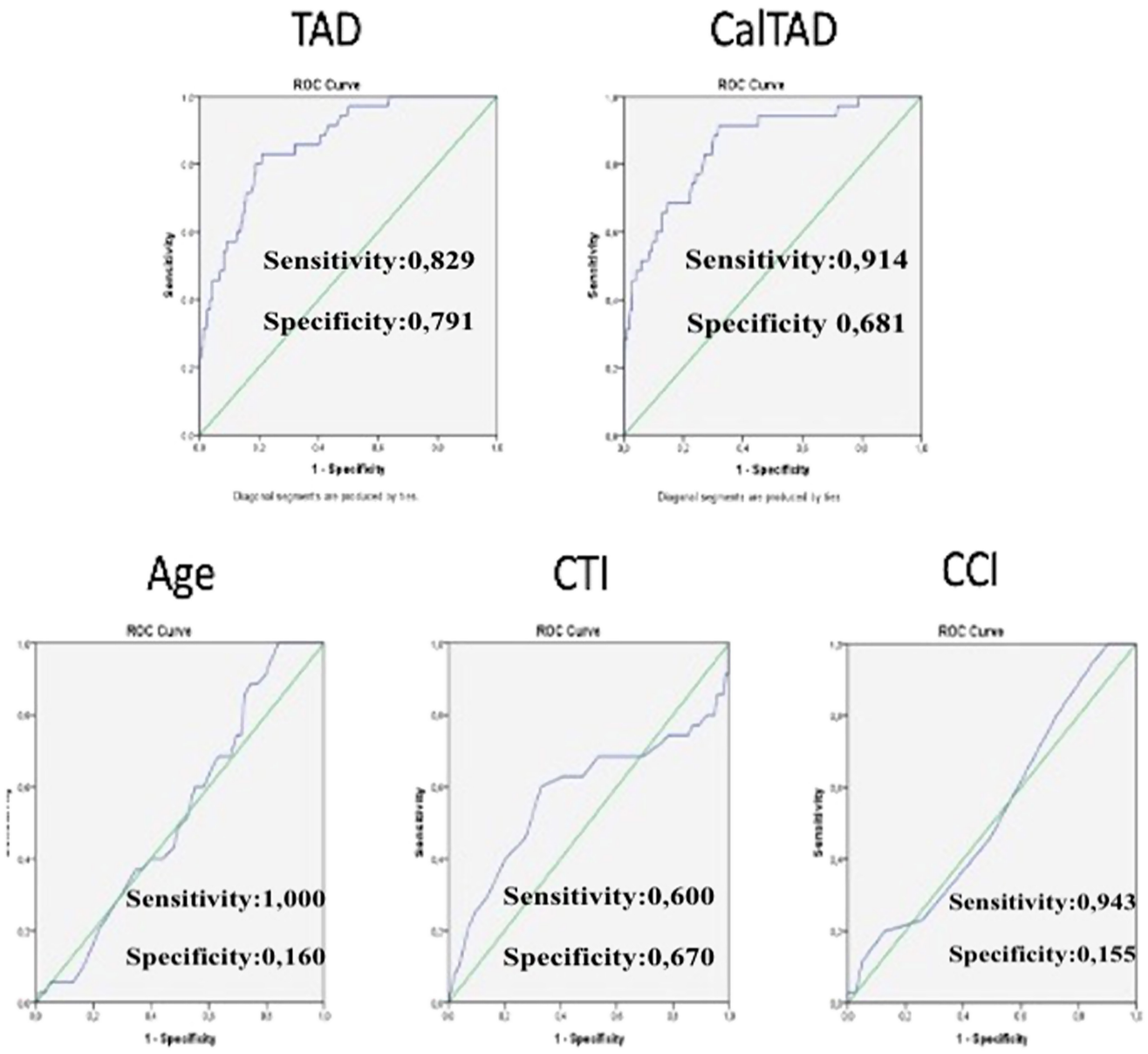

Figure 8. Distribution of the position of the screws in the Cleveland and Bosworth quadrants within our patient sample. CalTAD, calcar-referenced tip apex distance; CCI, Charlson comorbidity index; CTI, cortical thickness index; TAD, tip apex distance.

in estimating cut-out risk (area under the curve: 0.958, 95% CI: 0.931-0.984, $P < .001$, NDSS best cutoff value: 2.5). In chi-square analysis, 3 cells (25.0%) had expected counts of less than 5. Therefore, the Fisher's exact test was used instead of the Pearson chi-square test. The Fisher's exact test showed a significant relationship between the NDSS and cut-out risk (Fisher's exact test: 135,325, $P < .001$). Logistic regression analysis showed that there was a strong correlation between the NDSS and the risk of cut-out, with the risk of cut-out increasing 8.1 times for individuals with scores above 2 (exp (*B*): 8.1; 95% CI: 4.804-13.752, $P < .001$).

Table 3. Multivariate logistic regression results of factors associated with cut-out

Variables/factors	*B*	Exp(*B*)	*P*
Female (gender)	2.342	10.405	.000
TAD (>29.45)	1.538	4.655	.010
CalTAD (>31.75)	2.795	16.366	.001
Reduction quality (acceptable)	1.726	5.618	.002
Reduction quality (poor)	4.577	97.200	.000
Fixed	−7.996	0.000	.000
Significance tests		**Chi-square**	***P***
Hosmer and Lemeshow test		3629	.727
Omnibus testing for model coefficients		141 373	.000

Note: Gender, TAD, CalTADCalTAD, reduction quality, and fracture type are categorized (dashed) variables. CCI is a nominal (continuous) variable.
B, coefficient of the explanatory variables; CalTAD, calcar-referenced tip apex distance; CCI, Charlson comorbidity index; exp(*B*), odds ratio; *P*, significant level; TAD, tip apex distance.

Table 4. Newly developed scoring system

Variables in the model	Category	Score
Gender	Male	0
	Female	1
TAD mm	Good (≤29.45)	0
	Poor (>29.45)	1
CalTAD mm	Good (≤31.75)	0
	Poor (>31.75)	1
Reduction quality	Excellent	0
	Moderate	1
	Poor	2

Table 5. All situations that occur according to the points a patient can get

Possible situations	Gender [0,1] (1)	CalTAD [0,1] (2)	TAD [0,1] (3)	Reduction quality [0,1,2] (4)	Total (score points) (1)+(2)+(3)+(4)	Number of individuals per group	Patients with cut-out	Patients without cut-out	The probability of being cut-out (%)
1. situation	0	0	0	0	0	78	0	0	0.0
2. situation	0	0	1	0	1	11	0	0	0.1
3. situation	0	0	0	1	1	15	0	0	0.2
4. situation	1	0	0	0	1	146	0	0	0.3
5. situation	0	1	0	0	1	31	0	0	0.7
6. situation	0	0	1	1	2	6	0	0	0.8
7. situation	1	0	1	0	2	8	0	0	1.3
8. situation	1	0	0	1	2	36	2	34	1.9
9. situation	0	1	1	0	2	40	1	39	2.5
10. situation	0	0	0	2	2		0	0	3.2
11. situation	0	1	0	1	2	15	0	0	3.6
12. situation	1	1	0	0	2	26	1	25	6.1
13. situation	1	0	1	1	3	2	0	0	6.9
14. situation	0	1	1	1	3	10	1	9	12.5
15. situation	0	0	1	2	3		0		13.2
16. situation	1	1	1	0	3	13	4	9	19.8
17. situation	1	1	0	1	3	8	3	5	26.8
18. situation	1	0	0	2	3	3	0	0	28.3
19. situation	0	1	0	2	3	1	0	1	43.2
20. situation	1	1	1	1	4	14	7	7	58.3
21. situation	1	0	1	2	4	1	1	0	60.1
22. situation	0	1	1	2	4	6	6	0	74.3
23. situation	1	1	0	2	4		0		84.8
24. situation	1	1	1	2	5	10	9	1	96.6

CalTAD, calcar-referenced tip apex distance; TAD, tip apex distance.

Patients with 0, 1, and 2 points can be defined as having low risk (0%-6.1%), while patients with more than 2 points can be defined as having high risk (6.9%-96.6%).

Discussion

In the literature, the incidence of cut-out is reported to vary between 1.4% and 19% after intramedullary and extramedullary fixation depending on the implant used.[18-20] Although the incidence of cut-out after Gamma-3 nailing varies between 1.6% and 4.3% in the literature,[21-24] rates can reach up to 12.5%.[11,25] However, the incidence of cut-out after PFN-A applications was reported to be 8.2%.[26] All patients in the present study were treated with PFN-A, and the cut-out rate was 7.2% (35 patients). The most important finding of this study is that the risk of cut-out was 96.6% among patients with NDSS scores of 5, and these patients should be followed before discharge and revision surgery should be considered without delay when their general conditions allow it.

Tsai et al,[11] in their study investigating the risk of cut-out after the treatment of ITFs with Gamma-3 nails, stated that female gender significantly increased the risk of cut-out. They explained this by the fact that bone mineral density, proximal femur geometry, and bone strength in women differ compared to men.[11] As in the current study, female gender is generally considered an important factor for cut-out risk. Especially among elderly women, the parameters that increase risk during surgery should be reconsidered and more attention should be paid.

Baumgaertner et al[5] reported that TAD is an important factor for cut-out risk, and TAD values above 25 mm increase the risk significantly. However, the literature is controversial in this regard, and the cutoff values used for TAD vary.[11,17,18,24-26] Andruszkow et al[23] emphasized that TAD values above 25 mm are the most important factor increasing the risk of cut-out in cases of both stable and unstable ITFs.[27-28] In another study, it was shown that TAD is the most important factor that increases the risk among all considered factors.[29] Another recent study, however, demonstrated that TAD did not play a role in determining cut-out risk.[30] After the ROC analysis conducted in the current study, it was concluded that values above 29.45 mm significantly increased the risk of cut-out. Based on these findings, we suggest considering TAD after PFN-A applications performed for ITFs.

Another important parameter that has emerged in recent years is CalTAD.[14] Kuzyk et al[14] conducted a biomechanical study and reported that positioning the screw leading to the femoral head inferiorly in the AP radiograph and centrally in the lateral radiograph provided better stability against axial and torsional forces. The cut-off values for the CalTAD also vary.[17,31-33] More recently, Cai et al[34] observed that CalTAD values were more significant than TAD in efforts to prevent postoperative complications. In another study, Puthezhath et al[35] emphasized that CalTAD was a better parameter than TAD in determining cut-out risk. As in these studies, values above 31.75 mm were found to significantly increase the risk of

Table 6. Rate of cut-out according to scoring

Score	Cut-out				Total	Cut-out rate by score
	–	%	+	%		
0	78	17.5	0	0.0	78	0.0
1	203	45.6	0	0.0	203	0.0
2	127	28.5	4	11.4	131	3.1
3	28	6.3	8	22.9	36	22.2
4	8	1.8	14	40.0	22	63.6
5	1	0.2	9	25.7	10	90.0
Total	445	100.0	35	100.0	480	7.3

cut-out after ROC analysis in the current study. In addition, we think that the effect of CalTAD on cut-out risk is higher than that of TAD.

Studies have shown that nonanatomical reduction increases the risk of cut-out.[9,36,37] Reduction quality was found to be the most important parameter determining cut-out risk in our study.

The positioning of screws in the femoral head, as determined by the Cleveland and Bosworth quadrants, was shown to affect the occurrence of cut-out complications in previous studies, highlighting its significant importance.[15,16] In our study, it has been demonstrated that screws placed in the ideal position (central/inferior in AP radiographs, central/posterior in lateral radiographs) significantly reduce the risk of cut-out. Therefore, positioning should be carefully considered during surgical procedures. However, the logistic regression analyses performed in our study failed to successfully predict the risk of cut-out development and were therefore not included in the new scoring system.

Nguyen et al[12] reported that CTI as measured on AP radiographs of the proximal femur had the ability to predict bone mineral density and Fracture Risk Assessment Tool score at a statistically significant level and that these variables were correlated. They also showed that CTI was a reliable parameter for estimating osteoporosis and fracture risk, especially in women.[12] It has been reported that the Singh index, which is another method used to determine osteoporosis, has poor reliability and poor diagnostic value in screening for proximal femur osteoporosis.[38] In the current study, CTI as measured on AP radiographs was used to evaluate whether patients had osteoporosis. In a previous study, it was shown that osteoporosis and other comorbidities after PFN-A applied for patients with ITFs did not significantly change the cut-out risk.[30] In our study, similarly, osteoporosis was not significant in determining cut-out risk.

De Bruijn et al[39] found no significant relationship between fracture type and cut-out. In the current study, cut-out was observed more frequently in patients with type A2 and A3 fractures according to the Arbeitsgemeinschaft für Osteosynthesefragen classification. However, fracture type was not significant in determining cut-out risk.

A comprehensive and reliable scoring system for the early estimation of cut-out in cases of ITFs due to internal or external fixation is lacking in the current literature. Huang et al recently reported a quantitative scoring system developed to predict implant failure after single-screw cephalomedullary nailing.[24-39] However, that scoring system was created with the inclusion of the variables of the patient's bone quality or age, fracture type, reduction quality, and internal fixation location according to the authors' preference, without performing independent risk analysis.[40] Furthermore, the effect of gender, which is frequently mentioned in the literature, was ignored. We also think that it is not appropriate to attempt to produce a comprehensive scoring system based on 77 fractures of only 76 patients, as was the case in the aforementioned study. For these reasons, there is no reliable and comprehensive scoring system predicting cut-out complications in the current literature. In our study, all potential risk factors for cut-out complications defined in the literature were evaluated, and a practically usable scoring system was created that predicts cut-out risk based on a multivariate logistic regression model. Our current study also included a larger number of patients.

Katagiri et al suggested that NDSSs should be based on multivariate logistic regression models,[40] and other authors agree.[42-45] In our study, a new scoring system was defined according to a model created using multivariate logistic regression analysis.

According to the NDSS, it is important that the reduction be within at least acceptable limits for female patients (2 points). If the reduction quality is poor (3 points), the risk of cut-out increases significantly, with a risk of 28.3%.

The NDSS presented here can guide us in clinical practice. We think that routine follow-up and postoperative rehabilitation can be applied for low-risk patients (0-1-2 points), but it would be more appropriate to have closer follow-up and different rehabilitation programs for high-risk patients (3-4 points). The risk is 96.6% in patients with a score of 5, and these patients should be followed before being discharged, and revision surgery should be considered without waiting when their general conditions allow it.

The limitations of this study are that it used data obtained from retrospective scanning and that it was performed in a single center. Further prospective studies evaluating this scoring system are needed. However, the major strength of the study is that it represents the first effort to determine cut-out risk with a newly developed scale by examining all potential risk factors identified in the literature.

Female gender, TAD of >29.45, CalTAD of >31.75, and acceptable or poor reduction quality are the parameters found to be significant in determining cut-out risk in this study.

With the NDSS, risks can be calculated for all situations that may occur according to the scores calculated for the patients.

Cut-out risk increases significantly in patients with scores above 2 points.

Ethics Committee Approval: This study was approved by No. 1 Clinical Research Ethics Committee of Ankara City Hospital . (Approval No: E1-20-1226, Date:November 11,.2020).

Informed Consent: Written informed consent was obtained from the patients wh agreed to take part in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – B.K., G.Ö.; Design – B.K., O.B.; Supervision – G.Ö., O.B.; Resources – B.K., A.D.; Materials – T.K., Ö.H.K.; Data Collection and/or Processing – B.K., Ö.H.K.; Analysis and/or Interpretation – B.K., T.K.; Literature Search – B.K., O.B.; Writing – B.K., O.B.; Critical Review – G.Ö.

Declaration of Interests: The authors have no conflict of interest to declare.

Funding: The authors declared that this study has received no financial support.

References

1. Ahn J, Bernstein J. In brief: fractures in brief: intertrochanteric hip fractures. Clinical orthopaedics and related Research®. *Clin Orthop Relat Res*. 2010; 468(5):1450-1452. [CrossRef]
2. Lu Y, Uppal HS. Hip fractures: relevant anatomy, classification, and biomechanics of fracture and fixation. *Geriatr Orthop Surg Rehabil*. 2019;10: 2151459319859139. [CrossRef]
3. Çepni Ş, Subaşı İÖ, Şahin A, Bozkurt İ, Fırat A, Kılıçarslan K. Tip–neck distance ratio as a novel predictor for failure in cephalomedullary nailing of unstable trochanteric fractures (UTF). *Arch Orthop Trauma Surg*. 2022;142(10): 2619-2626.
4. Davis TR, Sher JL, Horsman A, Simpson M, Porter BB, Checketts RG. Intertrochanteric femoral fractures. Mechanical failure after internal fixation. *J Bone Joint Surg Br*. 1990;72(1):26-31. [CrossRef]

5. Baumgaertner MR, Curtin SL, Lindskog DM, Keggi JM. The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip. *J Bone Joint Surg Am*. 1995;77(7):1058-1064. [CrossRef]
6. Morvan A, Boddaert J, Cohen-Bittan J, Picard H, Pascal-Mousselard H, Khiami F. Risk factors for cut-out after internal fixation of trochanteric fractures in elderly subjects. *Orthop Traumatol Surg Res*. 2018;104(8):1183-1187. [CrossRef]
7. Lopes-Coutinho L, Dias-Carvalho A, Esteves N, Sousa R. Traditional distance "tip-apex" vs. new calcar referenced "tip-apex"-which one is the best peritrochanteric osteosynthesis failure predictor? *Injury*. 2020;51(3):674-677. [CrossRef]
8. Kashigar A, Vincent A, Gunton MJ, Backstein D, Safir O, Kuzyk PR. Predictors of failure for cephalomedullary nailing of proximal femoral fractures. *Bone Joint J*. 2014;96-B(8):1029-1034. [CrossRef]
9. Hsueh KK, Fang CK, Chen CM, Su YP, Wu HF, Chiu FY. Risk factors in cutout of sliding hip screw in intertrochanteric fractures: an evaluation of 937 patients. *Int Orthop*. 2010;34(8):1273-1276. [CrossRef]
10. Andress HJ, Forkel H, Grubwinkler M, et al. Treatment of per-and subtrochanteric femoral fractures by gamma nails and modular hip prostheses. Differential indications and results. *Unfallchirurg*. 2000;103(6):444-451. [CrossRef]
11. Tsai SW, Lin C-FJ, Tzeng YH, et al. Risk factors for cut-out failure of Gamma3 nails in treating unstable intertrochanteric fractures: an analysis of 176 patients. *J Chin Med Assoc*. 2017;80(9):587-594. [CrossRef]
12. Nguyen BN, Hoshino H, Togawa D, Matsuyama Y. Cortical thickness index of the proximal femur: A radiographic parameter for preliminary assessment of bone mineral density and osteoporosis status in the age 50 years and over population. *Clin Orthop Surg*. 2018;10(2):149-156. [CrossRef]
13. Goldhahn J, Suhm N, Goldhahn S, Blauth M, Hanson B. Influence of osteoporosis on fracture fixation-a systematic literature review. *Osteoporos Int*. 2008; 19(6):761-772. [CrossRef]
14. Kuzyk PR, Zdero R, Shah S, Olsen M, Waddell JP, Schemitsch EH. Femoral head lag screw position for cephalomedullary nails: a biomechanical analysis. *J Orthop Trauma*. 2012;26(7):414-421. [CrossRef]
15. Cleveland M, Bosworth DM, Thompson FR, Wilson HJ, Ishizuka T. A ten-year analysis of intertrochanteric fractures of the femur. *JBJS*. 1959;41(8):1399-1408. [CrossRef]
16. Turgut A, Kalenderer Ö, Karapınar L, Kumbaracı M, Akkan HA, Ağuş H. Which factor is most important for occurrence of cutout complications in patients treated with proximal femoral nail antirotation? Retrospective analysis of 298 patients. *Arch Orthop Trauma Surg*. 2016;136(5):623-630. [CrossRef]
17. Glonek GFV, McCullagh P. Multivariate logistic models. *J R Stat Soc B (Methodol)*. 1995;57(3):533-546. [CrossRef]
18. Caruso G, Bonomo M, Valpiani G, et al. A six-year retrospective analysis of cut-out risk predictors in cephalomedullary nailing for pertrochanteric fractures: can the tip-apex distance (TAD) still be considered the best parameter? *Bone Joint Res*. 2017;6(8):481-488. [CrossRef]
19. Lenich A, Vester H, Nerlich M, Mayr E, Stöckle U, Füchtmeier B. Clinical comparison of the second and third generation of intramedullary devices for trochanteric fractures of the hip—blade vs screw. *Injury*. 2010;41(12):1292-1296. [CrossRef]
20. Yu X, Wang H, Duan X, Liu M, Xiang Z. Intramedullary versus extramedullary internal fixation for unstable intertrochanteric fracture, a meta-analysis. *Acta Orthop Traumatol Turc*. 2018;52(4):299-307. [CrossRef]
21. A C U, E W, B K, C J, A P S. Treatment of trochanteric fractures with the gamma3 nail-methodology and early results of a prospective consecutive monitored clinical case series. *Open Orthop J*. 2014;8:466-473. [CrossRef]
22. Georgiannos D, Lampridis V, Bisbinas I. Complications following treatment of trochanteric fractures with the gamma3 nail: is the latest version of gamma nail superior to its predecessor? *Surg Res Pract*. 2014;2014:143598. [CrossRef]
23. Andruszkow H, Frink M, Frömke C, et al. Tip apex distance, hip screw placement, and neck shaft angle as potential risk factors for cut-out failure of hip screws after surgical treatment of intertrochanteric fractures. *Int Orthop*. 2012;36(11):2347-2354. [CrossRef]
24. Huang H, Xin J, Ma B. Analysis of complications of intertrochanteric fracture treated with gamma 3 intramedullary nail. *Int J Clin Exp Med*. 2014;7(10): 3687-3693.
25. Papaioannou I, Repantis T, Korovessis P. A unique cause of gamma 3 cut-out: A case report and literature review. *J Clin Orthop Trauma*. 2021;13:92-94. [CrossRef]
26. Hohendorff B, Meyer P, Menezes D, Meier L, Elke R. Treatment results and complications after PFN osteosynthesis. *Unfallchirurg*. 2005;108(938), 40:41-46. [CrossRef] passim.
27. Yam M, Chawla A, Kwek E. Rewriting the tip apex distance for the proximal femoral nail anti-rotation. *Injury*. 2017;48(8):1843-1847. [CrossRef]
28. Turgut A, Kalenderer Ö, Günaydın B, Önvural B, Karapınar L, Ağuş H. Fixation of intertrochanteric femur fractures using proximal femoral nail antirotation (PFNA) in the lateral decubitus position without a traction table. *Acta Orthop Traumatol Turc*. 2014;48(5):513-520. [CrossRef]
29. Fujii T, Nakayama S, Hara M, Koizumi W, Itabashi T, Saito M. Tip-apex distance is most important of six predictors of screw cutout after internal fixation of intertrochanteric fractures in women. *JB JS Open Access*. 2017;2(4):e0022. [CrossRef]
30. Zhang W, Antony Xavier RPA, Decruz J, Chen YD, Park DH. Risk factors for mechanical failure of intertrochanteric fractures after fixation with proximal femoral nail antirotation (PFNA II): a study in a Southeast Asian population. *Arch Orthop Trauma Surg*. 2021;141(4):569-575. [CrossRef]
31. Caruso G, Corradi N, Caldaria A, Bottin D, Re DL, Lorusso V, et al. New tip-apex distance and calcar-referenced tip-apex distance cut-offs may be the best predictors for cut-out risk after intramedullary fixation of proximal femur fractures. *Sci Rep*.2022;12(1):357. [CrossRef]
32. Qiao W, Lü X, Liu J, Zhang J, Li Y, Kong L. Effect of tip-apex distance and calcar referenced tip-apex distance on the stability of intertrochanteric fractures treated with cephalomedullary nailing assessed by the finite element method. *Chin J Tissue Eng Res*. 2020;24:5755.
33. Aicale R, Maffulli N. Greater rate of cephalic screw mobilisation following proximal femoral nailing in hip fractures with a tip–apex distance (TAD) and a calcar referenced TAD greater than 25 mm. *J Orthop Surg Res*. 2018;13(1):106. [CrossRef]
34. Cai Y, Feng J, Chen Y, et al. Comparison of the predictive value of tip-apex distance and calcar referenced tip-apex distance in treatment of femoral intertrochanteric fractures with Asian type proximal femoral nail fixation. *Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi*. 2020;34(11):1359-1363. [CrossRef]
35. Puthezhath K, Jayaprakash C. Is calcar referenced tip-apex distance a better predicting factor for cutting out in biaxial cephalomedullary nails than tip-apex distance? *J Orthop Surg (Hong Kong)*. 2017;25(3):2309499017727920. [CrossRef]
36. Pervez H, Parker MJ, Vowler S. Prediction of fixation failure after sliding hip screw fixation. *Injury*. 2004;35(10):994-998. [CrossRef]
37. Sahin S, Ertürer E, Oztürk I, Toker S, Seçkin F, Akman S. Radiographic and functional results of osteosynthesis using the proximal femoral nail antirotation (PFNA) in the treatment of unstable intertrochanteric femoral fractures. *Acta Orthop Traumatol Turc*. 2010;44(2):127-134. [CrossRef]
38. Soontrapa S, Soontrapa S, Srinakarin J, Chowchuen P. Singh index screening for femoral neck osteoporosis. *J Med Assoc Thai*. 2005;88(suppl 5):S13-S16.
39. De Bruijn K, den Hartog D, Tuinebreijer W, Roukema G. Reliability of predictors for screw cutout in intertrochanteric hip fractures. *J Bone Joint Surg Am*. 2012;94(14):1266-1272. [CrossRef]
40. Huang JW, Gao XS, Yang YF. Early Prediction of Implant Failures in Geriatric intertrochanteric Fractures with single-screw Cephalomedullary Nailing Fixation. *Injury*. 2022;53(2):576-583. [CrossRef]
41. Katagiri H, Takahashi M, Wakai K, Sugiura H, Kataoka T, Nakanishi K. Prognostic factors and a scoring system for patients with skeletal metastasis. *J Bone Joint Surg Br*. 2005;87(5):698-703. [CrossRef]
42. Turner NS, Shaughnessy WJ, Berg EJ, Larson DR, Hanssen AD. A quantitative composite scoring tool for orthopaedic residency screening and selection. Clinical orthopaedics and related Research®. 2006;449:50-55.
43. Wada T, Yasunaga H, Yamana H, et al. Development and validation of a new ICD-10-based trauma mortality prediction scoring system using a Japanese national inpatient database. *Inj Prev*. 2017;23(4):263-267. [CrossRef]
44. Bliemel C, Sielski R, Doering B, et al. Pre-fracture quality of life predicts 1-year survival in elderly patients with hip fracture—development of a new scoring system. *Osteoporos Int*. 2016;27(6):1979-1987. [CrossRef]
45. Jeong JH, Park YJ, Kim DH, et al. The new trauma score (NTS): a modification of the revised trauma score for better trauma mortality prediction. *BMC Surg*. 2017;17(1):77. [CrossRef]