TRAUMA SURGERY

Tip–neck distance ratio as a novel predictor for failure in cephalomedullary nailing of unstable trochanteric fractures (UTF)

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Abstract

Objectives Intertrochanteric femur fractures (ITFF) are frequently fixed with proximal femoral nailing (PFN), and a common cause of fixation failure is cut-out of the lag screws. In the literature, many factors have been defined to determine the failure risk, including the tip–apex distance (TAD), calcar-referenced tip–apex distance (CalTAD), the Cleveland zone and Parker's ratio. In this study, a novel technique is described which favors infero-posterior placement of the lag screw and predicts failure risk for PFN. The purpose of this study was to evaluate the tip–neck distance ratio as a factor for the prediction of cut-out after PFN of ITFF.

Materials and methods A retrospective evaluation was made of the data of 125 patients applied with PFN for ITFF between October 2016 and September 2019. The occurrence of mechanical complications was analyzed in relation to age, gender, fracture side, American Society of Anaesthesiologists classification, fracture classification, reduction quality, bone quality, Cleveland zone, Parker's ratio, TAD, CalTAD and the TNDR.

Results A total of 125 patients, including 16 with mechanical complications, were suitable for full analysis. In the univariate analysis, reduction quality ($p = 0.003$), the TAD ($p = 0.048$) and the TNDR ($p = 0.030$) were statistically associated with mechanical complications ($p < 0.05$). In the multivariate analysis, good quality of reduction reduced risk of mechanical failure ($p = 0.011$) and the TNDR ($p < 0.001$) indicated that these were two independent factors affecting mechanical complications.

Conclusion The results of this study provide clinical evidence that the TNDR is a predictor for cut-out risk. Placement of the lag screw posterior and inferior reduces the risk of mechanical complications.

Level of evidence Level 3.

Keywords Intertrochanteric femur fracture · PFNA · Cut-out

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Introduction

Intertrochanteric femur fractures (ITFF), which usually occur as a result of low-energy trauma in the elderly and high-energy trauma in the young, are generally treated with extramedullary and intramedullary fixation methods [1, 2]. Implant failure in elderly patients with an ITFF has a great effect on morbidity and mortality [3]. Intertrochanteric fractures are frequently fixed with proximal femoral nailing (PFN), and a common cause of fixation failure is cut-out of the lag screws [4, 5]. Bone quality, fracture geometry, reduction, implant design and implant placement are the main factors determining success in trochanteric fractures [6, 7]. Consequently, the ability to predict and prevent the causes of cephalomedullery (CM) nail cut-out and cut-in are important.

To date, the methods used for the placement of the lag screws are the tip–apex distance (TAD), calcar-referenced tip–apex distance (CalTAD), Cleveland zone and Parker's ratio [8–10]. The tip–apex distance (TAD) has been shown to be an important predictor for cut-out in PFN [11] and favors central–central positioning of the lag screws. In the literature, it has been reported that inferior positioning of lag screws in the AP plane reduces the risk of cut-out with the view that there is better bone stock, and surgeons have tended towards this positioning of lag screws [8, 10, 12–14]. Parker's ratio and CalTAD measurements support this view as predictors. However, CalTAD is based on AP view measurements only and supports infero-central lag screws positioning. Parker's ratio evaluates measurements on both AP and lateral views separately with lag screws positioned inferiorly in the AP view and central in the lateral view [10]. However, in this technique, the measurements are made independently from lag screw type and the measurement may cause errors in cases with anatomic variations, where the lag screw axis is not parallel to the neck axis for acceptable loss of reduction. Therefore, a novel technique is described in this paper which favors infero-posterior placement of the lag screw and predicts failure risk for PFN. This is the Tip–Neck Distance Ratio (TNDR) (Fig. 1).

The purpose of this study was to evaluate the TNDR as a factor for the prediction of cut-out after PFN of ITFF [15].

Materials and methods

Local Ethics Committee approval and informed consent from all the patients were obtained. A retrospective evaluation was made of the prospectively collected data of 185 patients, treated with PFN for an intertrochanteric femur fracture between October 2016 and September 2019. All fractures were treated by a single surgeon who had more than 5 years of experience of trauma surgery.

Inclusion criteria of the study were patients aged > 60 years, with an unstable femoral fracture (31-A2, 31-A3) according to the AO/OTA proximal femur classification [16]. Exclusion criteria were defined as a pathological, open, or concomitant lower extremity fracture, death, lack of standard radiographs, and radiological follow-up for at least 3 months postoperatively [8]. According to these criteria, a total of 125 patients were accepted in the study. Cut-out was defined as supero-medial migration of the PFNA lag screw into the femoral head and hip joint [4]. Patients were grouped according to cut-out state, as the cut-out group (n:16) and no cut-out group (n:119). All radiographic measurements were evaluated in both groups.

Patient demographic data and clinical characteristics were obtained from the medical records, including age at the time of operation, gender, side, body mass index (BMI), American Society of Anaesthesiologists (ASA) score, and the severity of osteoporosis at the time of fracture. Osteoporosis was evaluated from the contralateral radiograph according to the Singh Index [17].
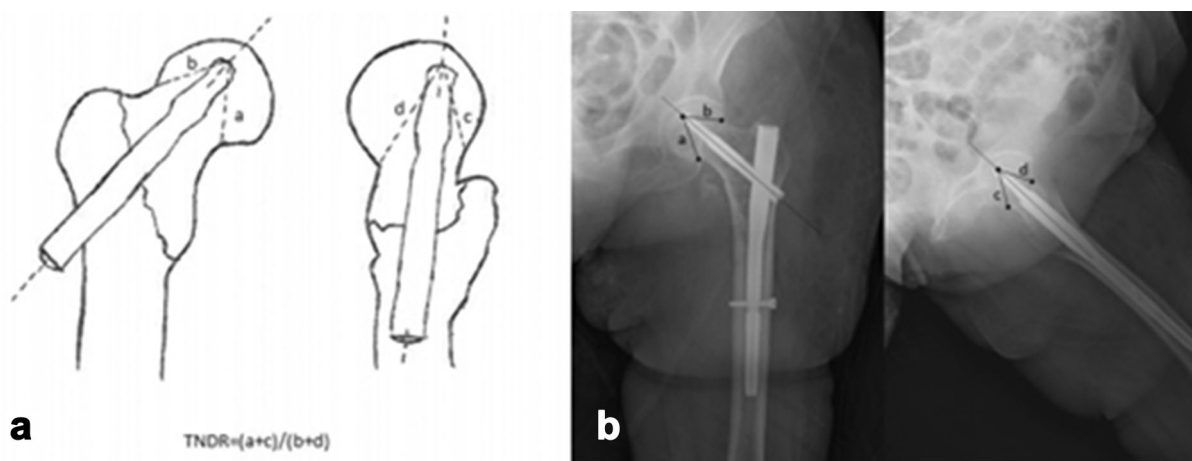

Fig. 1 **a, b** Graphical (**a**) and radiographic (**b**) presentation of the tip–neck distance ratio distance measurement. The total distance between the inferior of the femoral head–neck junction and the blade tip on the pelvic AP radiograph (**a**) and the distance between the posterior femoral head–neck junction and the blade tip on the hip lateral radiograph (**c**) was calculated as the proportion of the total distance between the blade tip and the superior of the femoral head–neck junction on the AP radiograph (**b**) and the distance between the anterior of the femoral head–neck junction and the blade tip on the lateral radiograph (**d**). TNDR was calculated as (a + c)/(b + d)

Radiographic evaluation

Standard immediate postoperative and follow-up radiographs were taken as pelvic anteroposterior (AP) and Löwenstein lateral views. The pelvic AP view was taken with the patient positioned supine, both lower extremities in 15° internal rotation to accommodate femoral anteversion, distance between the X-ray tube and the film of 1.2 m, and projection towards the middle of the line connecting the upper symphysis pubis and anterior–superior iliac spine. The Löwenstein lateral view was taken with patient turned onto the affected hip at least 45°, with the hip flexion angle of 90° and internal rotation angle of 45° in a supine position and then images of each side were taken vertically from the groin region [18].

The radiological measurements of TNDR, TAD [4], CalTAD [8], Cleveland zone [9], Parker's ratio (PR) [10], femoral neck-shaft angle difference [8] and reduction quality were evaluated by two independent, experienced orthopaedic surgeons using the hospital picture archiving and communication system (PACS) tool (Fig. 2). Inter-observer reliability for all the measurements was satisfactory with a median value of 0.83 (range 0.78–0.89). The median value of the measurements was calculated as the average of the values measured by the two surgeons. Discrepancies in the classification of the fractures and TNDR measurements were resolved with the observation of the senior author.

TNDR was measured as the proportion of the total distance between the inferior of the femoral head–neck junction and the lag screw tip on AP view (a) and the distance between the posterior femoral head–neck junction and the lag screw tip on lateral view (c) and the total distance between the lag screw tip and the superior of the femoral head–neck junction on the AP view (b) and the distance between the anterior of the femoral head–neck junction and the lag screw tip on lateral view (d) (Fig. 1). The head–neck junction was accepted as the point, where the convexity of the femoral head turns into the concavity of the femoral neck, on both views. The other radiological measurements as mentioned before were evaluated as defined in the literature [4, 8–10]. The reduction quality was determined using the Baumgaertner et al. classification, and was evaluated as good, acceptable, or poor [4].

In all the patients, the Hip Fracture Nail System (Trauson Stryker, Changzhou, China) was used as the cephalomedullary nail. The diameter of the lag screws for this device was 10.5 mm. All the operations were performed with closed reduction on a traction table. On the first postoperative day, patients were allowed mobilization as tolerated according to pain. The hip range of motion (ROM) and strengthening exercises protocol was started immediately postoperatively. After the 15th and 30th day controls, we followed the patients up in monthly periods until the 3rd month. After the 3rd month, we continued for 3-month periods. Union and complications were evaluated clinical and radiological in postoperative evaluations. Complications such as varus collapse or implant cut-out were recorded.

Statistical analysis

Statistical analyses and calculations were performed using IBM SPSS Statistics vn. 22.0 software (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY, USA) and MS-Excel 2016 program.

To determine the difference between variables in complication groups, continuous variables were evaluated with the Mann–Whitney U test, and categorical variables with the Chi-square test (Chi-square test—χ^2). The Chi-square test results were reported from continuity correction and likelihood ratio test statistics.

In addition to age and gender, the status of no complication and TAD, TNDR, and reduction quality variables which showed significance in the univariate analysis were included in the logistic regression analysis as independent variables. For explanation of the model, -2 log likelihood and Nagelkerke R2 values were reported, goodness of fit for the model was examined with Hosmer–Lameshow statistics and the odds ratios were given in a 95% confidence interval (95% CI). A value of $p < 0.05$ was accepted as statistically significant.

Results

Evaluation was made of a total of 125 patients, comprising 85 females and 40 males with a mean age of 78.3 years (range, 65–95 years). Mechanical failure of PFNA was determined in 16 (12.8%) patients. The demographic data of the patients are shown in Table 1. The mean radiological follow-up time for the fractures was 14.6 months (range, 5–40 months). No statistically significant difference was determined between the groups in respect of age, gender, side and BMI ($p > 0.05$) (Table 1).

In the univariate analysis, ASA, follow-up, and AO classification were not statistically different between the two groups ($p > 0.05$) (Table 1). No significant difference was determined between the groups in respect of the Singh Osteoporosis Index ($p = 0.847$) (Table 1). CalTAD, cervical angle difference, Parker's ratio AP and L were not statistically different between the two groups ($p > 0.05$) (Table 1). In the TAD, TNDR and good reduction quality measurements, a significant difference was determined between the groups ($p < 0.05$) (Table 1).

In the multivariate analysis, the multivariate model included age, gender, and all parameters with a value of $p < 0.05$ in the univariate analysis. Reduction quality

Fig. 2 Measurement methods of TAD [X ap+X lat] (**a**), CalTAD [X ap+X lat] (**b**), Parker ratio [AC/AB×100 AP & Lat] (**c**)
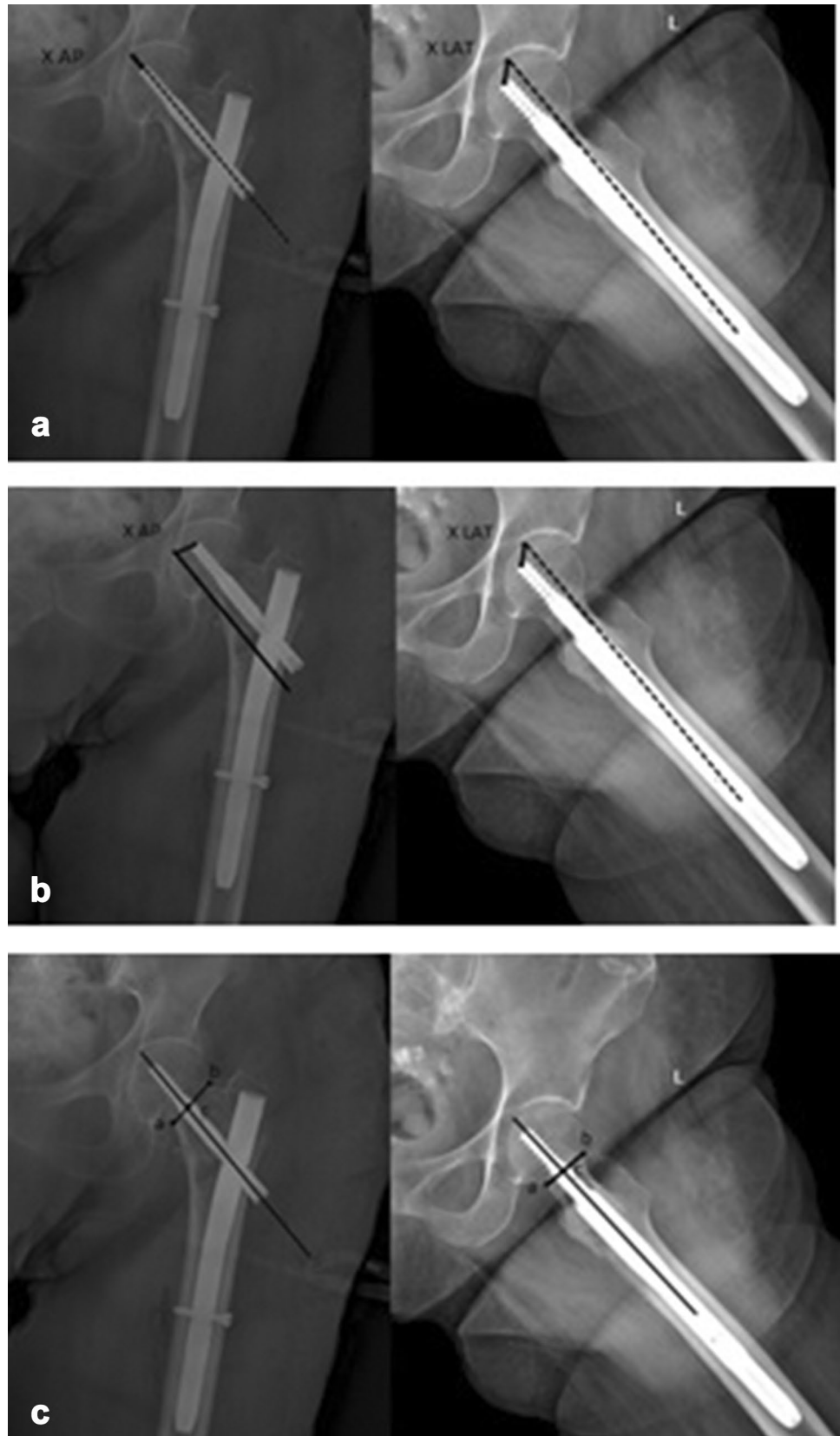
Table 1 Univariate analysis

	No cut-out [$n = 109$]	Cut-out [$n = 16$]	Statistics	
	Median (min; max)	Median (min; max)	Z	p
Age	78 (65;95)	79 (70;95)	0.355	0.722
BMI	25 (14;35)	24.5 (15;36)	1.106	0.269
Follow-up time [months]	14 (5;40)	15.5 (7;34)	0.297	0.767
CalTAD[mm]	16.82 (8.03;24.8)	24.65 (18.02;32.75)	1.173	0.241
TAD [mm]	24.38 (14.75;35.23)	27.02 (18.02;42.68)	1.975	**0.048**
TNDR	0.86 (0.65;1.19)	1.19 (0.79;1.42)	2.168	**0.030**
Cervical angle difference	7 (−10;13)	12.5 (1;23)	0.531	0.595
Sign İndex	2 (1;4)	2 (1;4)	0.193	0.847
Parker's ratio AP	45 (31;63)	47.5 (38;59)	0.175	0.861
Parker's ratio L	48 (36;65)	55 (38;62)	1.029	0.303
	n (%)	n (%)	χ^2	p
Sex			0.127	7.222[+]
Female	73 (67.0)	12 (75.0)		
Male	36 (33.0)	4 (25.0)		
Side			0.318	0.573[+]
Right	56 (51.4)	10 (62.5)		
Left	53 (48.6)	6 (37.5)		
ASA			3.921	0.270[%]
1	3 (2.8)	1 (6.3)		
2	11 (10.1)	0 (0.0)		
3	65 (59.6)	9 (56.3)		
4	30 (27.5)	6 (37.5)		
AO			0.000	1.000[+]
A2	66 (60.6)	10 (62.5)		
A3	43 (39.4)	6 (37.5)		
Reduction quality			11.368	**0.003**[%]
Good	79 (72.5)	6 (37.5)		
Acceptable	25 (22.9)	5 (31.3)		
Poor	5 (4.6)	5 (31.3)		
Cleveland zone			N/A	N/A
Central–posterior	15 (13.8)	0 (0.0)		
Central–anterior	3 (2.8)	4 (25.0)		
Inferior–central	29 (26.6)	2 (12.5)		
Inferior–posterior	19 (17.4)	1 (6.3)		
Inferior–anterior	13 (11.9)	3 (18.8)		
Superior–central	6 (5.5)	3 (18.8)		
Superior–posterior	2 (1.8)	1 (6.3)		
Central–central	22 (20.2)	2 (12.5)		

Bold values are statistically significant

+ Continuity correction, % Likelihood ratio Chi-square test result

BMI body mass index, *CalTAD* calcarreference tip–apex distance, *TAD* tip–apex distance, *TNDR* tip–neck distance ratio, *A* anteroposterior view, *L* lateral view, *ASA* American society of anesthesiologists, *AO/OTA* AO foundation and orthopaedic trauma association

($p = 0.011$) and the TNDR ($p < 0.001$) showed significant results, which indicated that reduction quality and the

Table 2 Multivariate analysis

	B ± Std. Err	p	Odds Ratio	%95 CI	
				min	max
Sex	−0.674 ± 0.889	0.448	0.510	0.089	2.911
Age	0.193 ± 0.047	0,472	0.213	0.096	1.129
Reduction quality	−2.024 ± 0.794	**0.011**	0.132	0.028	0.626
TAD	0.065 ± 0.082	0.429	1.067	0.908	1.254
TNDR	−13.863 ± 3.739	**<0.001**	0.000	0.000	0.001

Bold values are statistically significant

$n = 125$; −2Likelihood = 56.324; Nagelkerke R^2: 0.810, Hosmer–Lameshow: χ^2:6.489; $p = 0.593$

The poor eduction is the reference category

TAD tip–apex distance, *TNDR* tip–neck distance ratio

TNDR were two independent factors affecting mechanical complications (Table 2).

Discussion

The place of cephalomedullary nails, particularly in the treatment of unstable ITFF, has been previously proven. The most common cause of fixation failure after CM nailing is cut-out of the lag screw [4, 5, 19]. Lag screw positioning is known to have a strong influence on the incidence of mechanical complications. In this study, a new measurement method of cut-out was proposed, and from the effect and comparisons with other measurement methods, the TNDR value was determined to be high risk in terms of mechanical complications, Table 3.

As the measurement method proposed is a proportional value, it is independent of the patient anatomy and dimensions, providing a combined value in the AP and lateral planes. Current lag-screw placement techniques tend to be inferior–central and inferior–posterior. In the measurement technique described in this study, placement of the lag screw in quadrants, such as superior–anterior, superior–central, and central–anterior, which are risk factors

for cut out, is a predictor factor and supports the current literature [14, 20].

Previous studies have stated that TAD > 25 [4, 21, 22], CalTAD [8], Parker's ratio [10], positioning of lag screw outside the centre–centre or centre–inferior position according to the Cleveland zone [9, 23], varus neck-shaft angle [23, 24] and reduction quality [4] are risk factors for cut-out.

TAD has been reported by many researchers as an important predictor for cut-out [4, 22]. However, lag screw in superior position and inferior position in AP view, and anterior and posterior position in LAT view may have similar results. In a biomechanical study by Kuzyk et al., it was reported that an inferior lag screw provides higher resistance against axial and torsional stresses [13]. Although Goffin et al. suggested lag screw positioning in inferior–central and inferior–posterior, it was stated that TAD > 25 is not a more reliable predictor for cut-out [14]. Kane et al. [25], Mingo-Robinet et al. [26] and Herman et al. [27] stated that TAD was not the main factor in preventing cut-out. In the current study, the average TAD value was 24.71 and in the group with complications, it was 27.02. Although positioning the lag screw inferior increased TAD, it was not found to be more predictive for cut-out.

In a study by Kashigar et al. it was stated that the multivariate analysis result was only a predictor for CalTAD cut-out, and that this was a better predictor compared to traditional TAD [8]. However, CalTAD was different from TAD only in the AP view. It was suggested to position the lag screw more inferior in the AP plane and no measurement for lag screw positioning in the lateral plane was specified. The advantage of CalTAD over TAD is that it detects the difference between inferior and superior positioning in the AP plane but a shortcoming is that it does not evaluate the anterior or posterior position in the lateral plane. In the current study, in the TNDR measurement, a more concrete method of measurement was proposed by evaluating the differences in both the AP and lateral planes.

In the study by Parker et al. the positioning of the lag screw in the superior and posterior planes was reported to increase the cut-out risk [10]. In addition, which points would be used for the measurement were not exactly stated.

Table 3 Factors affecting the complication status

Variable	Mean ± SD	p	Odds ratio	95% CI	
				Lower limit	Upper limit
Constant	−28.567 ± 6.925	**<0.001**	0.000		
TAD	0.503 ± 0.140	0,312	1.653	1.256	2.177
TNDR	10.876 ± 3.615	**<0.001**	52,869.973	44.227	63,201,283.64
Parker's ratio AP	−0.029 ± 0.065	0.652	0.971	0.855	1.103
Parker's ratio L	0.114 ± 0.052	0.129	1.121	1.012	1.243
Reduction quality	1.249 ± 1.035	**0.003**	3.486	0.458	26.525

Through a ratio of 0 to 100 for each view, the Parker's ratio only describes blade direction in an indirect and cumbersome way [10, 28].

Kyle et al. reported that of the lag screws placed in all nine zones described by Clevand et al. [9], the anterior–superior zone and posterior–inferior zone were the ones with the most frequent cut-out [10, 29]. There is no single opinion regarding the best position of the blade in the femoral head, although studies have generally demonstrated that a centre–centre or an inferior–centre position of the blade protects against mechanical failure of inferior–central positioning of the blade and may provide better support for fractures with comminuted posteromedial cortex and allow fracture surface compaction as well as a shorter lever arm, thereby reducing the risk of mechanical failure [30]. In a study by Turgut A. et al., positioning the lag screw in the inferior–posterior position was suggested [20]. In the current study, placing the lag screw in the inferior–posterior position was found to reduce the risk of cut-out.

An important limitation of this study can be considered to be the retrospective design, despite the sufficient size of the patient groups and length of follow-up.

Conclusion

In the literature, there is a general consensus that superior positioning of the lag screw in the femoral head increases the risk of cut-out. However, discussions on whether positioning of the lag should be deep central or inferior still continue. The results of the current study showed that TNDR is a significant measurement method for the prediction of cut-out risk in ITFF treated with cephalomedullary nailing, and it was, therefore, concluded that positioning the lag screw in posterior–inferior reduces the risk of cut-out.

Declarations

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