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Original Research Article

Comparative analysis of TAD and CalTAD in predicting lag screw cutout risk in trochanteric fractures treated with intramedullary devices: a retrospective study

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ABSTRACT

Background: Cutout is one of the common cause of mechanical failure after internal fixation of trochanteric fractures using intramedullary devices. Tip apex distance (TAD) and Calcar referenced tip apex distance (CalTAD) are the radiographic parameters to predict the cutout risk. The aim of the study is to compare CalTAD with TAD in predicting the screw cutout risk and also to assesses other parameters responsible for it.

Methods: A total of 100 patients were included in this retrospective study. For each patient the following data were recorded. Number of cutouts, AO/OTA classification, quality of the reduction, type of nail, center column diaphyseal angle, type of distal locking, post-operative weight-bearing, TAD, CalTAD values and the position of the screw in the femoral head according to the Cleveland system.

Results: The incidence of cutout across the sample was 6%. The median TAD in cutout group was 32.2±6.5 (Mean±SD) while in no cutout group it was 20.7±5.1($p<0.001$). Similarly, the median CalTAD in cutout group was 33±5.6 (Mean±SD) while in no cutout group it was 21.1±4.6 ($p<0.001$). The highest value of sensitivity and specificity showed that the best cut off values of TAD is 30.06 (95% CI: 0.823-1.000, $P<0.001$) and Cal TAD is 30.93 (95% CI: 0.835-1.000, $p<0.001$).

Conclusions: In order to reduce the incidence of cutout it is advisable to achieve positive cortical reduction, placing the lag screw in centre-centre or centre-inferior in femoral head (Preferably in Cleveland Zone-5) and avoid TAD>30.06 and Cal TAD>30.93.

Keywords: CalTAD, Cut out, Intramedullary device, TAD, Trochanteric fractures

INTRODUCTION

Trochanteric fractures constitute one of the major orthopedic trauma and it's incidence increases in elderly.[1] There is a close relationship between hip fractures and increased risk of mortality, morbidity and reduced life quality in elderly.[2] Early surgical intervention is strongly recommended by several authors as it has been shown to decrease the incidence of mortality, morbidity and complications associated with hip fractures.[3,4] Surgical treatment of trochanteric fractures varies from the use of extramedullary and intramedullary devices. The use of cephalomedullary nails (short and long) are superior for treatment of unstable trochanteric fractures with advantage of improved fracture fixation biomechanics.[5,6] Cutout is the most common cause of fixation failure with cephalomedullary nails. The prevalence of cutout is estimated between 1.85%-16.5%.[7,8] Several factors are thought to affect the fixation failure which includes bone stock quality, cephalic screw position and length, fracture reduction, Tip apex distance (TAD), calcar referenced tip -apex distance (Cal TAD).[9] Baumgaertner et al, identified higher chances of cutout when TAD>25 mm.[10] A study by Kuzy et al, who introduced Cal TAD a new parameter in predicting cutout.[11] The majority of studies have found that the risk of cutout is significantly lower when TAD less than 25 mm.[12] Contrary to expectations, research has also shown that higher TAD's do not actually elevate the risk of cutout.[13,14]

Most of the studies have been challenging the validity of both TAD and CalTAD as predictors of cutout of the head screw.[15-17] Thus, the objective of this study is to compare CalTAD with TAD in predicting the cutout risk in trochanteric fractures treated with cephalomedullary nail and also to analyse the reliability of multiple other factors as predictors of the risk of lag screw cutout.

METHODS

This was a Retrospective cross-sectional study on consecutive patients with Pertrochanteric femur fractures treated with intramedullary nail (short and long proximal femoral nail (PFN)) between 2021 and 2023.

Inclusion criteria

Isolated trochanteric femur fractures (AO 31A1, 31A2, 31A3) (Figure 1) treated with intramedullary nail (short and long PFN Nebula and Yogeshwar) with two locking bolts inserted into the head done at our Orthopedic department Athani hospital, Kerala, India between 2021 and 2023 with minimum follow up of 3 months.

Exclusion criteria

Proximal femur fractures involving diaphysis or subtrochanteric fractures. Trochanteric fractures treated with open reduction and internal fixation and extramedullary devices. Patient without minimal follow up of 3 months. Pathological fractures. Age less than 60 years. Previous operations on same hip. Neuomuscular diseases, polytrauma

Each patient the following data was recorded

Gender, American Society of Anaesthesiologists ASA classification, operation time, type of Anesthesia, AO/ OTA classification, quality of reduction (good, acceptable and poor) based on post operative radiograph in accordance with Baumgartner and Sernbo criteria.[18,19]

Two criteria were evaluated from AP and lateral radiographs. The first was the alignment and the second was the amount of displacement. In the evaluation of alignment, the CCD angle should be between 120° and 135° in the AP view and 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 if only 1 was met and poor if neither was met. Centre Column Diaphyseal angle (CCD) 125, 130, 135 degree, short/long nail used, type of distal locking (Static / Dynamic), post operative weight bearing, TAD (Tip Apex Distance), Cal TAD (Calcar referenced TAD), position of lag screw in femoral head according to the Cleveland zones (Figure 2).

For all cases, the entry point for femoral nail is medial to tip of greater trochanter in anteroposterior view and translated anteriorly in lateral view to insert the lag screw in central position. Different patterns of anteromedial cortical support were proposed by Chang et al.[20] Positive, neutral and negative support were described in both anteroposterior (for medial cortex) and lateral views (for anterior cortex).

In the anteroposterior view, positive support was defined as a 4 mm medial displacement of the proximal femoral head-neck fragment relative to the superomedial edge of the distal femoral shaft fragment. Neutral support was defined as anatomical reduction of the head–neck and shaft fragments. Negative support was defined as a 4-mm lateral displacement of the proximal femoral head-neck fragment relative to the superomedial edge of the distal femoral shaft fragment (Figure 3).

In the lateral view, the relationship between the two anterior cortices of the head–neck and shaft fragments were also classified into three categories. If the anterior cortex of the head-neck fragment was 4 mm in front of the distal femoral shaft fragment, it was considered as positive support. If the anterior cortices were anatomically contacted, they were classified as neutral support If the anterior cortex of the head-neck fragment was 4 mm behind the distal femoral shaft fragment, it was classified as negative support (Figure 4). According to this study, the positive-positive support reduction produced less cut out risk and better mechanical stability for unstable pertrochanteric fractures. This reduction should be achieved during surgery to prevent the possibility of cutout risk. The negative-negative support reduction pattern was prone to fixation failure and should be avoided during surgery. In our study positive -positive cortical reduction was achieved for majority of the cases treated with femoral nail.

Lag screw cut out is defined as perforation of screw through the superior cortex of the femoral head or neck followed by rotation and varus collapse of proximal fragment.

Radiological evaluation

TAD and CalTAD were calculated on postoperative x-rays in two projections, namely anteroposterior projection of the lower limbs rotated internally by 15° and cross-table lateral projection. Baumgaertner et al, reported that TAD is defined as the sum of the distance between tip of screw and the apex of femoral head in the AP and lateral view.[10]

To measure the TAD in AP view, we set a point in middle between the tips of the two lag screws and measured the distance to a point in femoral head intersecting a line drawn from centre of and parallel to femoral neck into the apex of the femoral head (Xap). In lateral view, TAD is measured as the distance between apex of femoral head and tip of distal lag screw (X lat) (Figure 5).

Cal TAD is measured as the sum of CalTAD in AP and TAD in lateral radiograph. Cal TAD is measured in AP view as a line drawn from a point in middle between tip of two lag screws which intersects in femoral head into a line drawn from parallel to femoral neck passing through calcar (X calap) (Figure 5).

TAD and CalTAD was measured in the present study using the formula (Figure 5).

TAD ap=(Xap X (D true /Dap)), CalTAD ap=(X calap X (D true /Dap)), TAD lat =(X lat X (D true / D lat)), TAD = TAD Ap+TAD lat, Cal TAD=Cal TAD Ap+TAD lat

Measurements were performed with the aid of picture archiving and communication system (K-PACS V 1.0.1) software. A single observer (a consultant trauma surgeon) measured the TAD, CalTAD, screw position according to Cleveland method and the fracture reduction in order to eliminate inter-observer variability. The study was approved by the institutional Ethics Committee Athani Hospital. Data collection and analysis were performed in compliance with the Declaration of Helsinki. The study was designed and written according to STROBE guidelines.[21]

Statistical analysis

Data was entered into Microsoft Excel and analysed using the SPSS v 29.0. The Shapiro–Wilk test was used to test the normality of distribution of the continuous variables. In symmetrical distributions, the variables are represented as mean and standard deviation (SD) and Categorical data are expressed as absolute numbers and percentages. Statistical comparisons of categorical variables were assessed using Pearson's $\chi 2$ test or Fisher's exact test, depending on the minimal expected count in each crosstab. Statistical comparisons of continuous variables were assessed using Student's t-test. Univariate analysis was used to estimate the ROC curves for TAD and CalTAD, in order to measure testing accuracy; the area under the curve (AUC) reflected test accuracy as follows: uninformative if AUC=0.5, low accuracy if $0.5<AUC\leq0.7$, moderate accuracy if $0.7<AUC\leq0.9$, very high accuracy if $0.9<AUC<1$ and perfect if AUC=1. The thresholds for TAD and CalTAD were defined as the optimal cut-off that maximized the distance to the identity (diagonal) line in the ROC curve according to Youden's J statistic a p value<0.05 was defined as statistically significant.

RESULTS

Demographic results

A total of 100 individuals who met the criteria from among 170 patients treated trochanteric fractures with short and long PFN were included in the study. Cutout rate in total sample was 6%. Among 100 patients 25% (N=25) were males and 75 % (N=75) were females with minimum age of 78 years. The average operation time was 90 min with minimum of 60 min to maximum of 120 min.

Out of 100 patients 7% in ASA-1, 32% in ASA-2, 60% in ASA-3 and 1% in ASA-4. Among these 90% patients were received subarachnoid anaesthesia along with femoral block for post operative pain management, rest 10 % patients received only spinal anaesthesia. The average duration of hospitalization was 7 days. All the patients were followed for 3 months and none of the patients died during first 3 months.

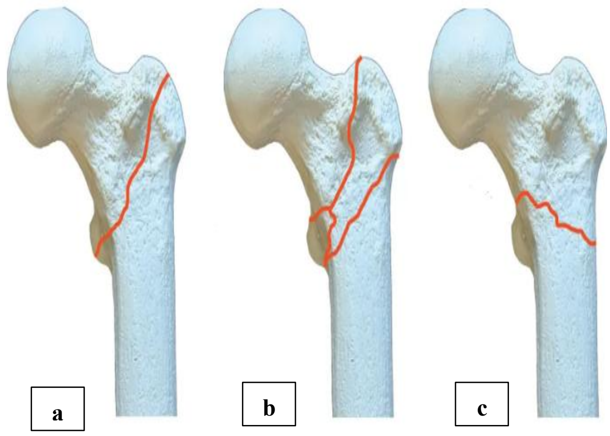


Figure 1: AO Classification of Trochanteric fracture femur. (a) Simple pertrochanteric fracture (31A1); (b) communited trochanteric fracture with incompetent lateral wall (31A2) and (c) reverse oblique trochanteric fracture (31A3).

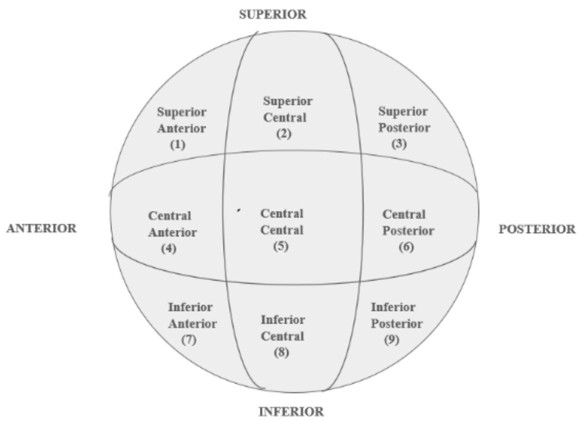


Figure 2: Cleveland system of classification.

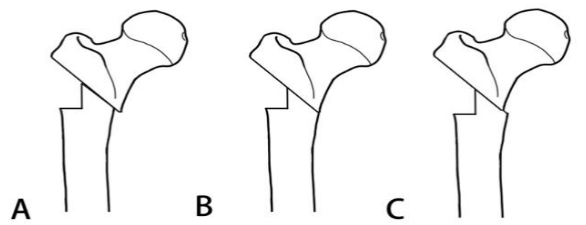


Figure 3: Medial cortical support in anteroposterior view. (A) Positive reduction; (B) neutral reduction; (C) negative reduction.

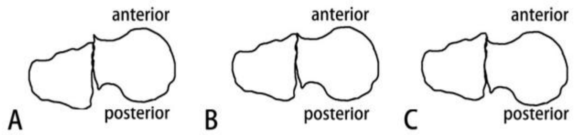


Figure 4: Anterior cortical support in lateral view. (A) Positive reduction; (B) neutral reduction; (C) negative reduction.

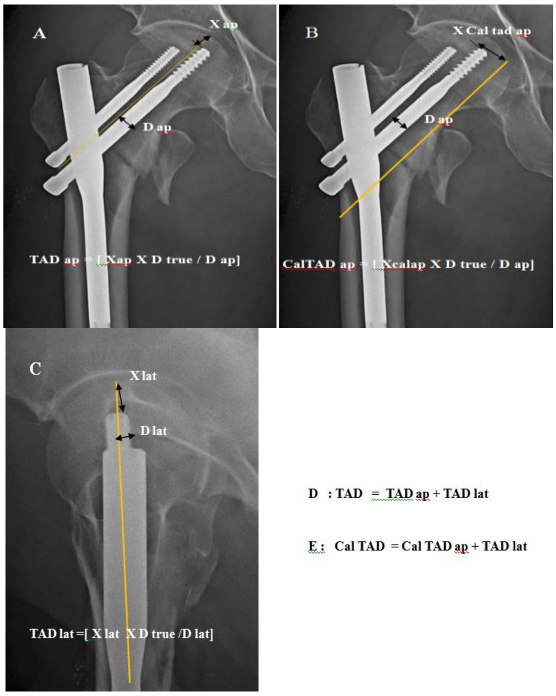
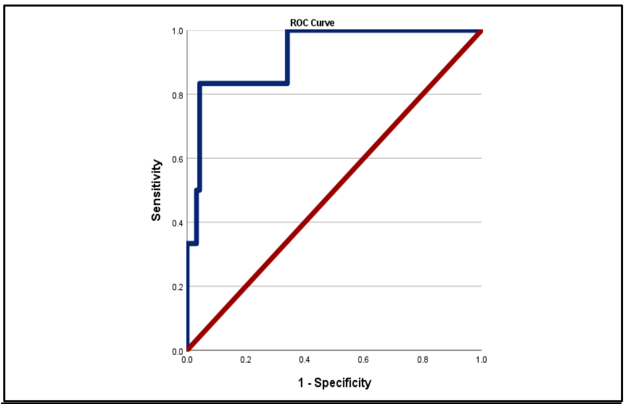


Figure 5: (A) Tip apex distance calculated on Anteroposterior radiograph (TAD ap); (B) Calcar referenced tip apex distance calculated on Anteroposterior radiograph (CalTAD ap); C) tip apex distance calculated on lateral radiograph (TAD lat); D) tip apex distance (TAD); E) Calcar referenced tip apex distance (Cal TAD).

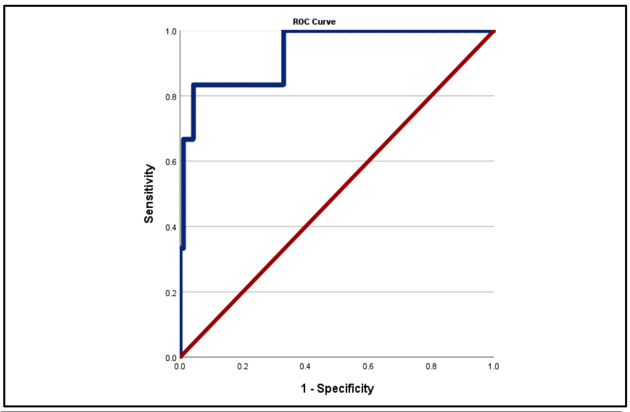
D true: Actual diameter of lag screw. (Nebula: Proximal locking bolt: 6.4 mm, Distal locking bolt: 8 mm). (Yogeshwar: Proximal locking bolt: 6.9 mm, Distal locking bolt: 8mm). D ap: Calculated diameter of lag screw in Anteroposterior radiograph. D lat: Calculated diameter of lag screw in lateral radiograph.



Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
0.924	0.051	0.001	0.823	1.000

Figure 6: ROC curve TAD. The Youden's test shows that the more sensitive and specific value of TAD for predicting the risk of the cut-out is 30.06 having Sensitivity of 83.3% and specificity of 95.7%.

ROC curve TAD, Youden J test best cutoff =30.06**.**



Area	Std. Errora	Asymptotic Sig.b	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
0.934	0.050	.000	0.835	1.000

Figure 7: ROC curve CalTAD. The Youden's test shows that the more sensitive and specific value of CalTAD for predict the risk of the cut-out is 30.93 having Sensitivity of 83.3% and specificity of 95.7%.

ROC curve CalTAD, Youden J test best cutoff = 30.93.

Comparison of general factors associated with risk of cutout

Table 1 summarizes the potential risk factors that may contribute to the likelihood of cutout. Median age, gender, fracture site, type of distal locking, AO classification, Type of nail used (short and long PFN), post op weight bearing and CCD angle were not significantly associated with risk of cutout ($p>0.05$). Poor quality of reduction was significantly associated with risk of cutout ($p<0.05$).

Position of screw in femoral head was not associated with cutout risk (p>0.05). Comparative analysis of the sample divided on the basis of presence or absence of cutout demonstrated significant difference related to both TAD and CalTAD.

Comparison between TAD and CalTAD

Median overall TAD was 21.4±5.8 the median TAD in cutout group was 32.2±6.5 (Mean±SD) while in no cutout group it was 20.7±5.1(p<0.001). Similarly median overall CalTAD was 21.8±5.5, the median CalTAD in cutout group was 33±5.6 (Mean±SD) while in no cut out group it was 21.1±4.6 (p<0.001).

The application of the Youden test to detect the highest value of sensitivity and specificity showed that the best cut off values of TAD 30.06 (95% CI: 0.823-1.000, P<0.001) (Figure 6) and Cal TAD 30.93 (95% CI: 0.835-1.000 p<0.001) (Figure 7).

Table 1: Demographic data and baseline characteristics of all patients with trochanteric fractures, AO/ OTA classification: AO foundation and orthopaedic trauma association classification system, TAD: tip apex distance, Cal TAD: calcar referenced tip apex distance.

Variables	Cut-out no (n=94)	Cut-out yes (n=6)	Total (n=100)	P value
Age, Mean±SD	77.85±7.62	81.67±7.34	78.08±7.63	0.119
Gender (n, %)				
Male	22 (23.4)	3 (50)	25 (25)	0.163
Female	72 (76.6)	3 (50)	75 (75)	
Side, (n, %)				
Right	56 (59.6)	3 (50)	59 (59)	0.687
Left	38 (40.4)	3 (50)	41 (41)	
AO/OTA classification (n, %)				
A1	45 (47.9)	1(16.7)	46 (46)	0.213
A2	07 (7.4)	0 (0)	07 (07)	0.99
A3	42 (44.7)	5 (83.3)	47 (47)	0.09
Quality of reduction (n, %)				
good	57(60.6)	0(100)	57 (57)	0.005
acceptable, poor	37(39.4)	6(100)	43 (43)	
Distal locking (n, %)				
Static	28 (29.8)	0 (0)	28 (28)	0.179
Dynamic	59 (62.8)	6 (6)	65 (65)	
Dynamic+static	07 (7.4)	0 (0)	07 (7)	
PFN (n, %)				
Long	56(59.6)	5(83.3)	61 (61)	0.400
Short	38(40.4)	1(16.7)	39 (39)	
Centre-column-diaphyseal (CCD) angles (n, %)				
120-125	15 (16)	2 (33.3)	17 (17)	0.263
126-130	46 (48.9)	2 (33.3)	48 (48)	0.679
131-135	33 (35.1)	2 (33.3)	35 (35)	0.99
Modified Cleveland system (MSC) (n, %)				
5	10 (10.6)	0 (0)	10 (10)	0.999
2-4-6-8	33 (35.1)	4 (66.7)	37 (37)	0.190
1-3-7-9	51 (54.3)	2 (33.3)	53 (530	0.415
Post-operative weight-bearing (n, %)				
Immediate	56 (59.6)	3 (50)	59 (59)	0.687
Delay	38 (40.4)	3 (50)	41 (41)	
TAD (Mean±SD) (mm)	20.7±5.1	32.2±6.5	21.4±5.8	<0.001
CalTAD (Mean±SD) (mm)	21.1±4.6	33.0±5.6	21.8±5.5	<0.001

DISCUSSION

Trochanteric hip fractures constitute approximately half of all hip fractures in elderly. The Goal of treatment is early surgical intervention, achieve faster ambulation to reduce hospitalization, mortality and morbidity associated with hip fracture. The treatment options for trochanteric fractures includes sliding hip screw and intramedullary devices. Cephalomedullary nails are superior to sliding hip screw in terms of short operating time, reduced intraoperative visible blood loss, improved walking ability in unstable hip.[22] Kaufer proposed that the stability of fracture reduction post-surgery is determined by bone quality, fragment geometry, reduction, implant and implant placement.[23]

Cutout is one of the most common complications of trochanteric fractures treated with cephalomedullary nail. It had great impact on functional recovery and life expectancy. Baumgaertner et al, introduced the concept of TAD, an important predictor of lag screw cutout in trochanteric fractures treated with proximal femoral nailing and sliding hip screw.[18] According to this, value of TAD>25 mm increases the cutout risk significantly. Higher rates of cutout noticed if lag screw was placed in postero inferior and anterosuperior zones of femoral head, defining a central position of screw. De brujin et al, recommend centre-centre or low centre screw placement with minimal TAD to avoid cutout risk.[9] Studies have found that cutout complication is low even in patients with high TAD if lag screw was positioned inferior in head and neck.[13,14] This contradict the statement against Baumgaertner.

In a finite element analysis by Goffin et al, state that position of lag screw in inferior centre and inferior posterior produces less screw cutout as the crossing of tension and compression trabeculae in that area of the femoral head probably provides the best bone for screw placement. This argues the statement that higher TAD>25 mm produced cut out, as TAD in inferior position screw was higher and cutout risk is less. This theory was supported by Kane et al and Zhang et al.[14,24] In their study, demonstrated that TAD did not play a role in determining the cutout risk. A study by Kuzy et al, states that a new parameter Cal TAD in predicting screw cut out.[11] Positioning lag screw inferior in anteroposterior radiograph and central in lateral radiograph produced highest torsional and axial stiffness there by cutout complication is less as compared to anterior and posterior lag screw position. The cut off values of Cal TAD vary.[25,26] Cai et al and Puthezhath et al, emphasized that CalTAD values were more significant than TAD in predicting screw cutout.[27,28] As far our knowledge, no definitive CalTAD cut off value has yet been established. The aim of the study was that the best predictor of screw cut out among TAD and CalTAD in hip fractures treated with dual lag screws and also to define the best predictive cutoff value of CalTAD.

In our analysis, the mean value of TAD and Cal TAD for cutout risk found to be 32.2 and 33 respectively. Other variables theatrically influencing the risk of failure should always be considered and analysed.[29,30] In our study, we analysed age, gender, type of nail used, post operative weight bearing, type of distal locking and type of fracture (AO/OTA). None of these variables proved to be independent predictor of failure.

Studies have shown that non anatomic reduction increases the cutout risk.[31-33] Our study showed that there was a statistically significant association with quality of reduction. Good quality of reduction was associated with less cutout risk ($p<0.001$) and poor quality of reduction increases the risk of complications. Position of screw in femoral head according to Cleveland system diagram predicts the risk of cut out. In our analysis, position of screw didn't demonstrate statistically significant correlation. However, literature suggest that best screw placement is centre-centre or inferior-centre to prevent screw cutout risk.[9]

In addition, our analysis demonstrated that CalTAD has a higher efficacy in reducing cutout risk compared to TAD as indicated by the ROC analysis results, which showed a significant difference between Cal TAD (30.93) and TAD (30.06). This is a retrospective analysis involving small number of subjects. The incidence of cutout was found to be low among these. Furthermore, human error in performing the TAD and Cal TAD radiographic measurements represents the source of bias.

CONCLUSION

In order to reduce the incidence of cutouts in trochanteric fractures treated with PFN (short and long), it is advisable to achieve positive-positive cortical reduction, medialize entry point, placing the lag screw in centre-centre or centre-inferior in femoral head (Preferably in Cleveland Zone-5), avoid TAD>30.06 and Cal TAD>30.93. Limited to our study that the value of Cal TAD seems to be more effective in predicting the cutout risk compared to TAD.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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