RADIOLOGIC PREDICTIVE FACTORS FOR CUT OUT FAILURE OF PROXIMAL FEMORAL NAIL ANTI-ROTATION IN TREATMENT OF INTERTROCHANTERIC FRACTURES

Yanin Plumarom, Songwut Sirivitmaitree, Arkaphat Kosiyatrakul, Puripun Jirangkul, Danai Heepthamai, Ong-art Phruetthiphat

Department of Orthopaedic Surgery, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok 10400, Thailand

Abstract

Background: Proximal femoral fractures are the most common type of fracture among elderly patients. Moreover, half of the fractures are unstable types (AO 31A2-A3). The aim of surgical treatments of these fractures is to achieve stable fracture fixation allowing early weight bearing and returning to pre-fracture functional status. Even though the Tip Apex Distance (TAD) less than 25 mm has been used to identify the appropriate position of the lag screw, little data has demonstrated the optimized TAD using a helical blade.

Objectives: The study aimed to identify radiologic factors influencing fixation failure using a newly designed Proximal Femoral Nail Anti-rotation (PFNA).

Methods: A total of 400 cases of low energy intertrochanteric fractures undergoing PFNA fixation were reviewed. Of these, 10 cases of fixation failure were further investigated determining the exact cause. Of 390 patients with successful outcomes treated using PFNA fixation, 20 cases were randomized as a control group. A comparative study was conducted between those with fixation failure group and control group.

Results: The displacement in lateral view and sum of displacement between AP and lateral view of radiographs were noted to have significant differences between the groups (p=0.002 and 0.015). No significant differences were found between the groups in terms of Neck Shaft Angle (NSA) and Tip Apex Distance (TAD) including migration of the PFNA blade in the Cleveland zone. Additionally, the cutoff point was determined as less than 0.91 using the sum of the distance of displacement of AP with specificity of 95% and sensitivity of 80%. Moreover, the lateral view of the radiographs was less than 1.42 with specificity of 80% and sensitivity of 80%.

Conclusion: This study demonstrated that the displacement in lateral hip view and sum of the displacement in both AP and lateral hip view were alternative parameters measured to decrease failure rate in PFNA. These parameters may be useful as an alternative to decrease the mechanical failure of PFNA fixation.

Keywords : Intertrochanteric fractures, Proximal Femoral Nail Anti-rotation fixation, Radiologic factors, Fixation failure

J Southeast Asian Med Res 2019; 3(2): 52-58.
http://www.jseamed.org

Correspondence to:
Plumarom Y, Department of Orthopaedic Surgery, Phramongkutklao Hospital and Phramongkutklao College of Medicine, Bangkok 10400, Thailand
E-mail: yaninyo24@gmail.com

Introduction

Proximal femoral fractures are the most common type of fracture among elderly patients. Moreover, one half of the fractures comprise unstable types (AO 31A2-A3).[1] The aim of surgical treatments of these fractures is to achieve stable fracture fixation allowing early weight bearing and returning to pre-fracture functional status.[2] Many different devices have been developed but implant failure still occurred. No extramedullary or intramedullary device has definitely been proved preferable.[3] However, cephalomedullary nail fixation may be advantageous when compared with extramedullary devices.[4]

The most common mode of fixation failure is cutting out the lag screw from the femoral head. Tip apex distance (TAD) is the most valuable factor in determining the risk of lag screw cutting out, with an established distance of less than 25 mm from the edge of femoral head.[5, 6] The proximal femoral nail anti-rotation (PFNA) has been designed by AO [4], which has been changed from a lag screw to a helical blade for better purchasing in the femoral head to decrease rate of cutting out failure.[4-5]

In addition to TAD, other factors determine fixation failure such as the screw position and achieving screw position in the center-center position.[5, 7, 8, 11] In the early studies, cutting out failure was reported, ranging from 8 to 23%, while awareness of TAD and position of screw fixation were able to help reduce this failure rate to 1.6 to 3%. [11]

Even though TAD less than 25 mm [13] has been used as a good position of the lag screw[5], little data has demonstrated the optimized TAD using a helical blade. In addition, current data has not clearly defined the factors determining implant failure using the helical blade. Therefore, the objectives of our study were to identify radiologic factors influencing fixation failure with a newly designed PFNA.

Methods

After obtaining IRB approval (IRB ID #R095q/58_Exp), a cohort of consecutive adult patients with low energy intertrochanteric fracture treated using PFNA fixation were retrospectively reviewed from radiographs and medicalcharts at a single institution between January 2012 and December 2016.

Hip fracture patients were excluded when they sustained high energy trauma, polytrauma, pathologic fracture and ballistic injury. Patients followed-up less than one year were excluded from the study. A total of 400 cases of low energy intertrochanteric fractures undergoing PFNA fixation were reviewed. Failed fixation cases were selected to review in the study. Finally, ten cases of fixation failure were further investigated to determine the exact cause of those failures. The inclusion criteria for the control group were adult patients who sustained low energy fracture treated with PFNA. Therefore, 20 cases from 390 patients with successful outcomes treated with PFNA fixation were randomized as the control group using a computer program. A comparative study was conducted between the fixation failure group and control group. Demographic data and comorbidities were collected in both groups, and fracture patterns were both classified based on AO/OTA classification. All patients were identified for clinical and radiological outcomes at 3, 6, and 12 months. We investigated causes of mechanical failure with the following parameters: quality of reduction (neck-shaft angle, displacement between cortices of proximal and distal fragments in AP and lateral view), TAD and helical blade position using the Cleveland zone.

Operative procedure

Fracture fixation was performed by titanium PFNATM nail (Synthes). All patients were placed on the fracture table in the supine position. Closed reduction was fluoroscopically performed under regional or general anesthesia. After anatomical reduction was achieved, a guidewire was inserted in the tip of the greater trochanter. After that, proximal reaming was performed. Then, the diameter of the nail was measured under fluoroscopy. The proximal femoral nail was applied into the medullary canal while the guidewire was removed. Before applying a helical blade in the femoral head, a guidewire was inserted in the femoral head to measure the exact position and length of the helical blade using AP and lateral projection of the fluoroscopic view. We further applied the helical blade in the femoral head. Then tightened it as the final step.

Postoperative management

Proper pain control was performed in all patients, and they were allowed to have weight bearing as tolerated, deep vein thrombosis prophylaxis performing mechanical pumping was applied to all patients during hospital admission.

Outcome measurement

All patients were followed up in a clinic at 6 weeks, 3 months, 6 months and 1 year. Radiographic measurements were taken by two trained orthopedic surgeons and a radiologist who did not participate in the operative field and mean measurements were calculated. Antero-posterior (AP) and lateral radiographs were assessed using PACS Software. They were also used to evaluate the helical blade position including the Cleveland zone position of the helical blade (using a custom-designed template system), TAD, NSA, quality of fracture reduction, implant failure and loss of reduction. All parameters were evaluated to identify the exact cause of fixation failure.

Statistical analysis

Demographic data was recorded for each patient and analyzed using STATA. Group comparisons for continuous variables were analyzed using a two-sample independent *t* test and Chi-square analysis was used to determine differences between categorical variables. Receiver Operating Characteristic (ROC) curves (generated by logistic regression) was performed using SAS Software (Version 9.3, SAS Institute, Inc., Cary, North Carolina, USA) to determine cut off point of significant factors. Statistical significance was defined as $p < 0.05$.

Results

Ten patients with fixation failure, treated with PFNAs in the study were identified, while 20 patients were randomly selected as a control group. The average age of successful fixation and fixation failure were 78 (59 to 88) and 78.5 (61 to 87), respectively. The most common OTA/OA classification was 31A1 in both groups. No differences were observed between groups in terms of demographic data as demonstrated in **Table 1**. Significant differences were noted on distance of displacement (**Table 2**). The displacement in lateral view and sum of displacement of AP and lateral view of radiographs were noted to exhibit significant differences between groups ($p = 0.002$ and 0.015, respectively). No significant differences were found between groups in terms of NSA and TAD (**Table 2**) including the migration of the PFNA blade in the Cleveland zone. Additionally, a cutoff point was determined at 0.91 cm using the distance of displacement of the lateral view of the radiographs with specificity of 95% and sensitivity of 80%. The sum of distance of displacement in AP and lateral view of the radiographs was at 1.42 cm with specificity of 80% and sensitivity of 80%.

Table 1: Demographic data of enrolled participants

	Fixation failure cases (study group) n = 10	**Successful fixation cases (control group) n = 20**	***p*-value**
Sex			
Male	4(40)	8(40)	1.000
Female	6(60)	12(60)	
Mean age	78(59-88)	78.5(61-87)	0.948
AO classification			
1	5(50)	10(50)	1.000
2	3(30)	6(30)	
3	2(20)	4(20)	
Side			
1	4(40)	9(45)	0.794
2	6(60)	11(55)	

Table 2: Radiographic analysis

	Fixation failure cases (study group) n = 10	Sucessful fixation cases (control group) n = 20	*p*-value
Cleveland zone			0.835
1	0(0)	1(5)	
2	1(10)	3(15)	
4	2(20)	3(15)	
5	3(30)	9(45)	
6	3(30)	3(15)	
8	1(10)	1(5)	
Neck Shaft Angle (NSA)	134.5(120-153)	134(122-153)	0.846
Tip Apex Distance (TAD)	3(2-4)	2.5(2-5)	0.198
Displacement in AP view (cm.)	1.08(0-3.84)	0.41(0-3)	0.143
Displacement in lateral view (cm.)	1.28(0-2.43)	0.49(0-1.57)	0.002*
Sum of displacement (cm.)	2.23(0-5.95)	0.85(0.3-3)	0.015*
Difference migration	-0.68(-3.23-1.4)	-0.09(-0.5-0.31)	0.231

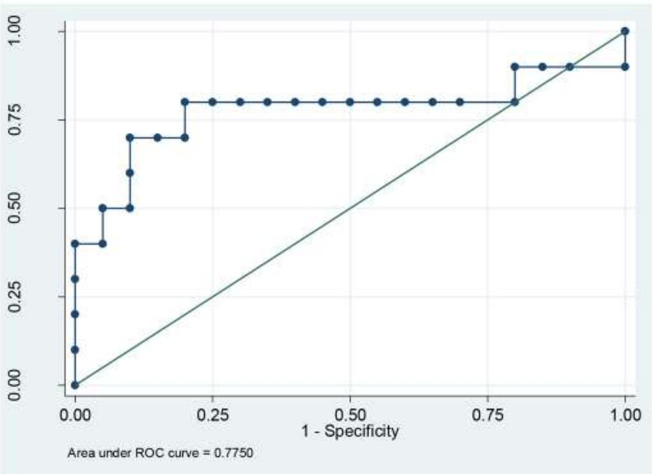


Fig 1: The ROC curve of displacement measured by affected hip in the lateral view

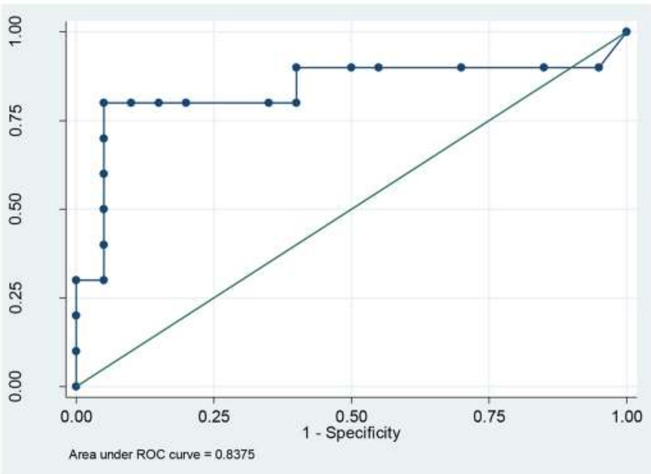


Fig 2: The ROC curve of displacement measured by summation of affected hip in the AP and lateral view

Discussion

Intertrochanteric fractures are common in elderly populations,[14] and reducing complications when performing operations hip fractures is important. The complication rate of proximal femoral nail and related necessity of revision procedure varies from 3 to 28% in the literature.[1, 2, 4, 5]

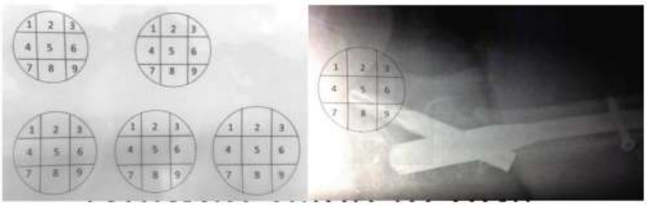
Simmermacher et al.[5] reported an overall technical failure rate of 4.6% among 191 fractures. Helical blades, forcibly impacted in the cancellous bone,[19] reduced the risk of cut out; however, they were less resistant to cut through. Appelt et al.[20] demonstrated a complication rate of 15.2% (n=27) in the study of 178 patients. Fogagnolo et al.[21] found mechanical failures up to 23.4% among patients (n=11) in case series including 47 peritrochanteric fractures. Domingo et al.[22]demonstrated that ten patients (3.3%) requiring a revision procedure were AO type 2 and type 3 fractures. Similarly, Simmermacher et al. concluded that PFN-related complications were mostly associated with AO type 2 fractures.

Previously, we commonly used a dynamic hip screw (DHS) for intertrochanteric fractures' fixation. TAD was a significant impact factor to predict failure fixation on that fixation. Baumgartner et al.[6] reported the ideal position of the lag screw should be in the center-center position of AP and lateral views of radiographs. Currently, PFNA is a newly designed implant used for fixation of intertrochanteric fractures. In addition, it presents more advantages than DHS for many reasons such as decreasing blood loss, reducing duration of surgery producing earlier weight bearing and mobilization, reducing hospital stay and decreasing risk of infection.[5,11,12,15,16,17,18] Andrej N et al.[7] demonstrated that TAD could be applied to use as a predictive factor for PFNAs' fixation failure. However, they suggested that TAD ranging from 20 to 30 mm should be applied as an appropriate position of the blade, which was not as close as that of Baumgartner's study. Additionally, they found that zone of distribution of the blade was not a significant factor, similar to our study. Semmi et al.[15] found that 14 of 152 patients (9.2%) undergoing osteosynthesis of intertrochanteric fractures finally underwent a revision procedure from mechanical complications, suggesting that the quality of fracture reduction was an important factor resulting in a revision procedure. Similarly, J.J. Liu et al.[16] revealed that 9 failures of 308 patients with intertrochanteric fracture using PFNA. They found that faulty operative procedures, unsatisfactory reductions, serious osteoporosis and incorrect positioning of the helical blade were important factors responsible for failed internal fixation. Ashok et al. reported that implant positioning, fracture reduction and a good learning curve were mandatory for successful outcomes.[12] Our study demonstrated that the distance between proximal and distal fragments of fractures in the lateral view and sum of displacement of AP and lateral views were important factors to predict implant failure. Surgeons usually use an intraoperative image intensifier to check the quality of reduction creating an easy method to evaluate NSA in the AP hip view.[4,7,8,10,15] However, evaluating quality of reduction in hip lateral view is quite difficult. According to J.J. Liu et al.[16], they determined the quality of reduction using NSA in AP hip view. Therefore, the quality of reduction in the AP hip view should be performed in a good position. Therefore, our hypothesis was that poor quality of reduction in the AP view should constitute a failure cause, but the statistical analysis in the study lacked significance. According to the ROC curve in our study, we found the optimal summation of displacement in AP and lateral hip views. When the sum of displacement of AP and lateral views was below 1.42 cm, we could predict to successful outcomes with a sensitivity of 80% and specificity of 80%. Similarly, when the displacement in lateral view was below than 0.91 cm with sensitivity of 80% and specificity of 95%, we could forecast a successful outcome also. The study had several limitations. One limitation was that this comprised a retrospective case control study. Thus, the final outcomes depended on what was recorded in the medical charts. In addition, important demographic data such as BMD, BMI and pre-injury status were unrecorded, which might have constituted significant factors of fixation failure. Another limitation was that the study enrolled a small sample size which could not represent all intertrochanteric fractures' of patients. Moreover, our study population was mainly categorized as AO A1 (50%) and A2 (30%) in both groups. This was why the displacement in AP view lacked significance between the groups. A larger sample size may have exposed some parameters changing the significance.

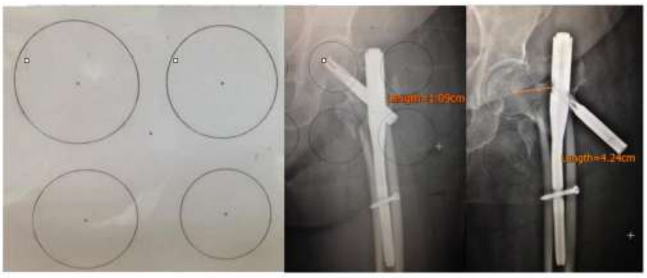
Conclusion

This study demonstrated that the displacement in lateral hip view and sum of the displacement in both AP and lateral hip views constituted alternative parameters to help decrease failure rate of intertrochanteric fracture using PFNA. Therefore, the optimal displacement of distance should not be more than 0.91 cm in the lateral view and sum of distance of displacement should not be more than 1.42 cm in both views. These parameters may be useful as optional parameters to help guide surgeons to achieve high quality reductions in the operating room so that their constructs will decrease mechanical failure from PFNA fixation.

Picture 1. Applied Cleveland zone in the study, customized template for evaluating the tip of blade placement



Picture 2. Different blade migrations, the correct size template and measured distance between center of circle to tip of blade at postoperative film and follow-up or failure film



References

1. Geller JA, Saifi C, Morrison TA. Macaulay W. Tip-apex distance of intramedullary devices as a predictor of cut-out failure in the treatment of peritrochanteric elderly hip fractures. Int Orthop 2010; 34: 719-22.
2. Frei HC1, Hotz T, Cadosch D, Rudin M, Käch K. Central head perforation, or "cut through," caused by the helical blade of the proximal femoral nail antirotation. J Orthop Trauma 2012; 26: e102-7.
3. Parker MJ, Handoll HH. Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures. Cochrane Library Database System Rev 2010; 9: CD000093.
4. Simmermacher RKJ, Ljungqvist J, Bail H, Hockertz T, Vochteloo AJ, Ochs U. et. al. AO- PFNA studygroup: The new proximal femoral nail antirotation (PFNA) in daily practice: results of a multicentre clinical study. Injury 2008; 39: 932-39.
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: 1058-64.
6. Andrej NN, Anthony LO, Piers JY. Should the tip-apex distance (TAD) rule be modified for the proximal femoral nail antirotation (PFNA). J Orthop Surg Res 2013; 8: 35.
7. Dieter ML, Michael R. Baumgaertner MR. Unstable intertrochanteric hip fractures in the elderly. J Am Acad Orthop Surg 2004; 12: 179-90.
8. Evans EM. The treatment of trochanteric fractures of the femur. J Bone Joint Surg Br 1949; 31: 190-203.
9. Haidukewych GJ, Israel TA, Berry DJ. Reverse obliquity fractures of the intertrochanteric region of the femur. J Bone Joint Surg Am 2001; 83: 643-50.
10. Sommers MB, Roth C, Hall H, Kam BC, Ehmke LW, Krieg JC, et al. Laboratory model to evaluate cutout resistance of implants for pertrochanteric fracture fixation. J Orthop Trauma 2004; 18: 361-68.
11. Cleveland M, Thompson F, Wilson H, Ishizuka T. A ten-year analysis of intertrochanteric fractures of the femur. J Bone Joint Surg Br 1959; 41-A: 1399–408.
12. Gardner MJ, Stephen M, Briggs A, Helfet DL, Lorich DG. Radiographic outcomes of intertrochanteric hip fractures treated with the trochanteric fixation nail. Injury 2007; 38: 1189–96.
13. Zhou JQ, Chang SM. Failure of PFNA: helical blade

perforation and tip apex distance. Injury 2012, 43: 1227–28.

14. Ashok SG, Muthukumar S, Naveen CT. Results of proximal femur nail antirotation for low velocity trochanteric fractures in elderly. Indian J Orthopv 2012; 46: 556–60.
15. Koyuncu S, Altay T, Kayalı C, Ozan F, Yamak K. Mechanical failures after fixation with proximal femoral nail and risk factors. Clinical Interv Aging 2015; 10: 1959–65.
16. Liu JJ, Shan LC, Deng BY, Reason and treatment of failure of proximal femoral nail antirotation internal fixation for femoral intertrochanteric fractures of senile patients. Genet Mol Res 2014; 13: 5949-56.
17. Cyril J, Shishir S. Type II intertrochanteric fracture : proximal femoral nailing (PFN) versus dynamic hip screw (DHS). Arch Bone Joint Surg 2016; 4: 23-8.
18. Ajay PS, Vivek K. Intramedullary nail versus dynamic hip screw; intramedullary nail (advantages and disadvantages). Trauma International 2015; 1; 17-20.
19. Green JR, Nemzek JA, Arnoczky SP, Johnson LL, Balas MS. The effect of bone compaction on early fixation of porous-coated implants. J Arthroplasty 1999; 14: 91–7.
20. Appelt A, Suhm N, Baier M, Meeder PJ. Complications after intramedullary stabilization of proximal femur fractures. a retrospective analysis of 178 patients. Eur J Trauma Emerg Surg 2007; 33: 262–67.
21. Fogagnolo F, Kfuri M Jr, Paccola CA. Intramedullary fixation of pertrochanteric hip fractures with the short AOASIF proximal femoral nail. Arch Orthop Trauma Surg 2004; 124: 31–7.
22. Domingo LJ, Cecilia D, Herrera A, Resines C. Trochanteric fractures treated with a proximal femoral nail. Int Orthop 2001; 25: 298–301.