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Does the Entry Point of Proximal Femoral Nail Antirotation Affect the Malalignment of Intertrochanteric Fracture? A Cadaveric Study

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Purpose: Proximal femoral nailing (PFN) is a reliable and common procedure for treating intertrochanteric fractures. The optimal entry point is considered a critical step in avoiding malreduction. This study investigated the effects of various entry points on fracture displacement and force reduction.

Methods: Twenty-four cadaveric femurs were randomly categorized into three groups: the greater trochanter (GT) tip, medial to the GT tip, and lateral to the GT tip. Each intact femur was provisionally stabilized using a ring external fixator. The entry point was identified and reamed to accommodate the nail insertion. After osteotomy was performed to simulate an A1-type fracture, the PFN was inserted. Digital calipers were used to measure horizontal fracture displacements. The force required to reduce displaced fractures to the anatomical position was measured using a digital force gauge. Fluoroscopic images were recorded to assess changes in the neck-shaft angle.

Results: The lateral entry group showed significantly displaced fractures in the coronal plane, whereas the medial and tip entry groups were insignificant. Displacement in the sagittal plane was not significantly different between the groups. The lateral entry group showed significantly irreducible displaced fractures compared with the other groups. After nail insertion, the changes in the neck-shaft angle were 0.77° varus, 3.66° valgus, and 3.16° varus in the tip, medial, and lateral entry groups, respectively. The degree of neck-shaft angle change demonstrated significant differences between the groups.

Conclusions: The lateral entry point of PFNA tends to displace reduced fractures, resulting in malalignment and irreducibility. Lateral entry points should be avoided to prevent surgery-related complications.

Keywords: proximal femoral nailing, intertrochanteric fracture, entry point, cadaveric femurs

Intertrochanteric fractures are the most common osteoporotic fractures, which are associated with high mortality in the aging population(1). Proximal femoral nailing (PFN) is a standard treatment that can achieve good clinical outcomes in these patients(2-5). However, some surgical complications have been reported, including screw cut-out, femoral head penetration

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from the blade, and varus displacement. These complications usually result in morbidity and should be revised after the first surgery(6,7). Surgical techniques play a crucial role in limiting the incidence of these complications. Therefore, the optimal entry point of the PFN is assumed to be one of the critical steps for satisfactory surgical outcomes to avoid malalignment and implant-related complications.

Previous studies have emphasized the importance of the PFN entry point and described the greater trochanter (GT) tip as the standard entry point for trochanteric nails(8). Some authors have suggested that the entry point should be at a point slightly medial to the tip of the GT to achieve an excellent nail and helical blade position. In contrast, the lateral entry point can lead to malalignment(9-11). In contrast, the entry point lateral to the GT tip was suggested in a 3D anatomical reconstruction study(12). According to these reports, the proper entry point for PFN is still debatable. However, to the best of knowledge, no previous experimental study has compared malalignment at different entry points in an intertrochanteric fracture model. Therefore, this study aimed to report the direction and magnitude of fracture displacement following PFN insertion from different entry points and the feasibility of reducing displacement after nail insertion.

METHODS

Twenty-four embalmed human cadaveric femurs were included in this study. All specimens were confirmed to have no history of lower-extremity trauma or disease. The protocol adhered to the guidelines and was approved by the institutional review board of Lerdsin General Hospital. All femurs were randomly categorized into the following three groups: the tip entry group represented the entry point at the GT tip, the medial entry group was 5 mm medial to the GT tip, and the lateral entry group was 5 mm lateral to the GT tip (Figure 1). The GT tip was defined as the intersection between the line connecting the center of the femoral neck in the axial view and the most proximal aspect along the greater trochanteric crest in the anteroposterior view(13).

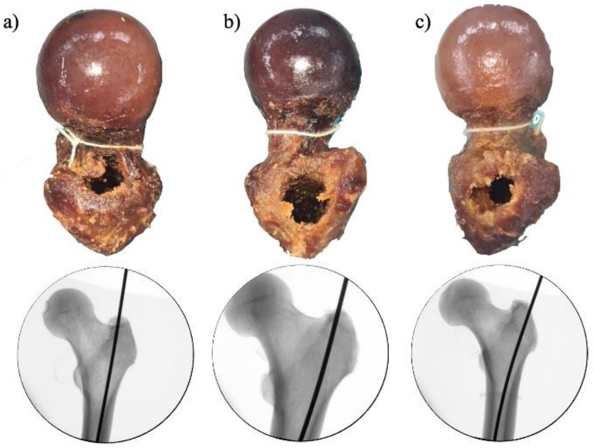

Fig. 1 The pictures show the difference in entry points in each group; a) the medial entry group, b) the tip of the GT entry group, and c) the lateral entry group.

All specimens were subjected to computed tomography of the entire femur to measure the anatomic parameters, including the neck-shaft angle, which was defined as the intersection angle between the femoral shaft and neck axes; femoral length, which was defined as the distance from the GT tip to the articular surface of the femoral condyle; anteversion of the proximal femur, which was defined as the angle between the line characterized by the posterior aspect of the distal femoral condyle and a line drawn from the center of the femoral head to the midline of the femoral neck in the axial plane(14); and canal diameter, which was described as the distance between the inner cortex of the proximal femur the 10-cm below the lesser trochanter level.

The setup was standardized by positioning the bones with two tensioned wires connected to the ring external fixator on the femoral head. Simultaneously, the distal part was stabilized using a short intramedullary rod, enabling freedom of movement when any displacement occurred after nail implantation (Figure 2). The guidewire was inserted at the designated entry point, and the proximal femur was reaming to accommodate nail insertion. A 9-mm short proximal femoral nail antirotation (PFNA-II, Synthes) was inserted, checked for a proper position by fluoroscopy, and removed. Subsequently, osteotomy was performed to simulate stable intertrochanteric fractures (AO/OTA classification type 31A1) from the mid-level of the GT to the mid-level of the lesser trochanter(15). The PFNA was reinserted into the femur at the same position. Displacement was defined as the distance of the gap at the medial cortex of the osteotomy site, which was evaluated in the anteroposterior and mediolateral directions, and subsequently measured using a digital vernier caliper. Furthermore, the force required to reduce the displacement was described as the force applied to the distal part by a digital gauge (SF-300, SHAHE) to reduce the fracture to a normal anatomical position.

Next, the neutral position of the femur was determined. The C-arm was positioned in a lateral projection with the beam parallel to the ground and perpendicular to the femoral condyles to obtain the true lateral view of the distal femur. Subsequently, the bone was manipulated until the posterior femoral condyles were completely overlapped. The C-arm was then moved proximally parallel to the bone and rotated to the anteroposterior projection of the proximal femur(13). Furthermore, images of the anteroposterior view were recorded and used to measure the neck-shaft angle following nail insertion using the ImageJ software (ImageJ v1.49, National Institutes of Health, USA) (Figure 3).

Statistical analysis

Demographic data of age, sex, side, femoral length, ante-version angle, and neck-shaft angle were described using means with standard deviations and frequencies with percentages for continuous and categorical data, respectively. The direction of displacement in the coronal (categorized into medial, neutral, or lateral) and sagittal (anterior, neutral, or posterior) planes and the ability to reduce (yes or no) following the three entry points were analyzed using Fisher's exact test. Linear regression analysis was used to determine the difference in fracture displacement in the anteroposterior and mediolateral planes, force to reduction (in the case of reduction), neck-shaft angle after nail insertion, and neck-shaft angle change according to the difference in entry points. Statistical significance was set at $p < 0.05$.

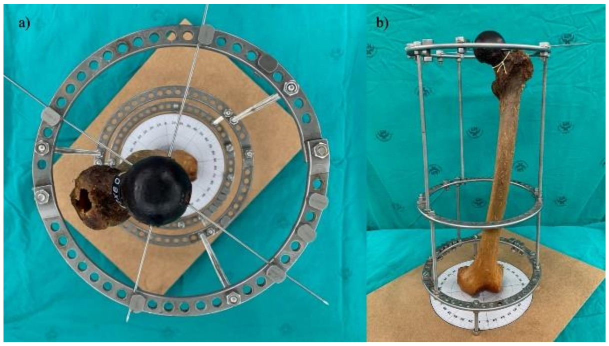

Fig. 2 The pictures show the setup of the pre-ream femur with the ring external fixator, proximal fixed with wires, and distally fixed with a small intramedullary rod.

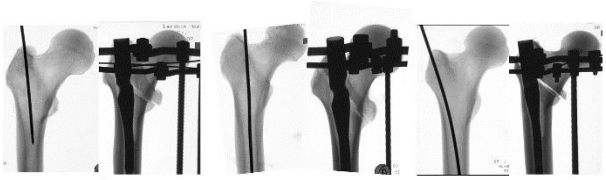

Fig. 3 The pictures demonstrate the displacement in the coronal plane after nail insertion; a) the tip entry group, b) the medial entry group, c) the lateral entry group

RESULTS

Table 1 shows the demographic data of the femoral bones in each group. The average age of the cadaver was 72.7 years (SD 11.6), and the predominant sex was male (83.3%) and left-sided (54.2%).

The direction of the displacement is presented in Table 2. In the coronal view, the tip entry group and 6/8 (75%) specimens showed lateral displacement of the distal part relative to the proximal part, whereas 2/8 (25%) indicated medial displacement. In the medial entry group, there were 1/8 (12.5%) lateral, 2/8 (25%) neutral, and 5/8 (62.5%) medial displacements. In addition, the lateral entry group demonstrated lateral displacement of 8/8 (100 %). The displacement between the entry points was significantly different ($p < 0.01$). The average displacement was 3.49 mm, 2.55 mm, and 6 mm in the tip, medial, and lateral entry groups, respectively.

In the sagittal view, the tip entry group showed 5/8 (62.5%) and 3/8 (37.5%) anterior and neutral displacements, respectively. The medial entry group showed anterior, neutral, and posterior displacements in 2/8 (25 %), 5/8 (62.5%), and 1/8 (12.5 %) patients, respectively. Furthermore, the lateral entry group demonstrated anterior, neutral, and posterior displacements in 3/8 (37.5%), 3/8 (37.5%), and 2/8 (25%), respectively. The average displacement distance was 1.84 mm, 1.26 mm, and 0.93 mm in the tip, medial, and lateral entry groups, respectively.

The ability to reduce displacement to the anatomical position was statistically different between the entry groups ($p < 0.01$). All specimens in the tip entry group were reduced, whereas 7/8 (87.5%) in the lateral entry group could not be reduced. Table 3 shows the force required to be reduced in the reducible specimens.

After nail insertion, the neck-shaft angle changed to 130.48° (SD 3.5), 134.8° (SD 4.01), and 128.22° (SD 4.03) in the tip, medial, and lateral entry groups, respectively. The changes in the tip, medial, and lateral entry groups were 0.77° varus, 3.66° valgus, and 3.16° varus, respectively. The degree of neck-shaft angle change was statistically significant between the groups (Tables 3 and 4), respectively.

Table 1 Baseline characteristics.

	All	Tip entry	Medial entry	Lateral entry
Age (years): mean (SD)	72.7 (11.6)	71.9 (14.6)	71.5 (9.6)	74.6 (11.5)
Sex (male): n (%)	20 (83.3%)	7 (87.5%)	6 (75%)	7 (87.5%)
Side (right): n (%)	11 (45.8%)	4 (50%)	3 (37.5%)	4 (50%)
Femoral length (mm): mean (SD)	432.9 (20)	443.4 (15.4)	421.2 (17.2)	434.1 (22.1)
Anteversion (degree): mean (SD)	5.5 (6.2)	7.1 (4.3)	5.4 (7.7)	3.8 (6.4)
Neck-shaft angle (degree): mean (SD)	131.3 (3.2)	131.1 (3.9)	131.1 (3.1)	131.4 (2.9)
Canal diameter (mm): mean (SD)	10.4 (1.6)	10.1 (1.9)	10.3 (1.7)	10.2 (1.4)

mm, millimeter; SD, standard deviation

Table 2 The direction of displacement and reducibility.

	All	Tip entry	Medial entry	Lateral entry	*P*-value
Direction of displacement					
Sagittal plane (n)					
Anterior	10	5	2	3	0.440
Neutral	11	3	5	3	
Posterior	3	0	1	2	
Coronal plane (n)					
Medial	7	2	5	0	< 0.01*
Neutral	2	0	2	0	
Lateral	15	6	1	8	
Ability to reduce (n)					
Irreducible	10	0	3	7	< 0.01*
Reducible	14	8	5	1	

* Statistically significant.

Table 3 Fracture displacement, force to reduction, neck-shaft angle after nail insertion, neck-shaft angle change.

Factor	B coefficient	95% CI	*P*-value
Fracture displacement (mm)			
Coronal plane			
Tip entry	Reference		
Medial entry	-0.94	-3.42–1.55	0.44
Lateral entry	2.5	0.02–5	0.048*
Sagittal plane			
Tip entry	Reference		
Medial entry	-0.58	-2.1–0.98	0.45
Lateral entry	-0.91	-2.47–0.64	0.24
Force to reduction (Newton) (n = 14)			
Tip entry	Reference		
Medial entry	-19.49	-43.19–4.21	0.1
Lateral entry	-7.81	-51.9 – 36.28	0.7
Neck-shaft angle after nail insertion (degree)			
Tip entry	Reference		
Medial entry	4.31	0.31–8.32	0.04*
Lateral entry	-2.2	-6.27–1.74	0.25
Neck-shaft angle change (degree)			
Tip entry	Reference		
Medial entry	4.43	2.3–6.57	< 0.01*
Lateral entry	-2.39	-4.52–0.25	0.03*

* Statistically significant.
CI, confidence interval

Table 4 Neck-shaft angle direction change.

Group	Odds ratio	95% CI	*P*-value
Tip entry	Reference		
Medial entry	0.05	0–0.66	0.02*
Lateral entry	2.33	0.17–32.58	0.53

* Statistically significant.
CI, confidence interval

DISCUSSION

PFN is gaining popularity for treating intertrochanteric fractures and has been shown to be effective(4,5). It can be operated minimally invasive and has better biomechanical advantages than a dynamic hip screw(16). However, complications still occur in up to 20% of cases despite proper implant selection(6,7). Mechanical failure risk factors include improper tip-apex distance, poor quality of reduction, improper postoperative neck-shaft axis, and position of the screw blade within the femoral head(7,17). The entry point of the nail also appears to play a crucial role in preventing these complications(8,9,13).

Previous studies have reported the ideal entry point of the trochanteric nail in the subtrochanteric fracture model. Struebel et al.(18) used contralateral templating to determine the starting point of nails on the GT. The ideal entry point ranged from 16 mm medial to 8 mm lateral to the trochanter tip. The author proposed using a piriformis entry point to avoid portal-related fractures and malreduction, and encouraged the use of preoperative contralateral side templating. Grechenig et al.(19) and Farhang et al.(20) reported GT anatomical variations profile. In an anatomical study, the authors demonstrated that the entry point of the trochanteric tip entry should be 5 mm posterior to the apparent apex of the GT and adjusted based on intraoperative fluoroscopy(20). Jeong et al.(11), using the proximal femur and PFNA-II imaging process to study the optimal entry point, revealed an average distance of 9.1 mm medial from the tip of GT on anteroposterior images as a proper entry point. These studies showed high variability in the optimum entry point.

Ostrum et al.(8) demonstrated analysis of five and three different trochanteric femoral nails and insertion sites in the subtrochanteric femur fracture model, respectively. Each of the designs varied in the proximal bend. They concluded that the GT tip could be used as a "universal" starting point, resulting in the most neutral alignment, regardless of the nail used. However, the lateral starting point led to varus in all nail designs and should be avoided. The trochanteric antegrade nail (Smith and Nephew), which had a proximal bend of 5°, similar to PFNA-II, resulted in the same direction of displacement. However, it demonstrated 4.4° varus, 3.2° valgus, and 1.25° with a lateral starting point, medial starting point, and tip entry point. This study supports this finding using a different intertrochanteric fracture model. Following nail insertion, an additional concern was the ability to reduce misalignment. Furthermore, the lateral entry group displaced the fracture and increased the difficulty of reducing it. However, we believe that this was a result of an anatomical mismatch between the nail and bone geometry.

Therefore, to improve outcomes in clinical situations, identifying the tip of the GT is another crucial point that surgeons should consider intraoperatively. Link et al.(13) suggested the "Cortical Overlap View," which was defined as a radiological overlap of the density line of the piriformis fossa and the intertrochanteric crest since the accurate identification of the GT tip. This understanding of the anatomy and reliable fluoroscopic landmarks can assist in verifying the proper entry point of the intramedullary nail.

"Nail-shaft axis," which was defined by the deviation of the nail axis related to the femur in the anteroposterior radiograph, was considered the crucial prognostic factor in treating the intertrochanteric fracture with the PFNA. Jiamton et al.(7) found that a too-lateral or too-medial nail position on AP radiography increases the rate of varus displacement. Pan et al.(9) studied the outcome of intertrochanteric fractures associated with different entry points categorized into the lateral-anterior and medial-posterior entry point groups. The authors concluded that the latter group resulted in early hip function recovery and better nail position with fewer surgical complications than the former group. This study confirmed the importance of the starting point, which is directly related to the final implant position. However, an incorrect or correct entry point with eccentric reaming can lead to an improper final position of the nail, particularly when the fracture exits near the correct entry point. Medialized force to prevent lateralization of the guidewire or reamer can prevent this error(21). Therefore, this step should be considered during surgery.

This study has some limitations. First, the study was conducted with intact cadaveric bone without any soft tissue attachment, implying no muscle force. Therefore, the displacement's magnitude and direction may differ from the patients' actual fracture situation. This study emphasized that even when the stable fracture was reduced anatomically, the anatomical mismatch between PFNA-II and the proximal femoral canal geometry at different entry points can lead to malalignment. Moreover, for different fracture patterns, the result might demonstrate a more obvious displacement regarding the inherent instability of the fracture patterns. Second, the implants used in this study had only one design. Therefore, the result can differ depending on the design or manufacturer of the proximal femoral nail, which has a varied nail geometry(8). Finally, the entry point was focused on the coronal plane, which mainly resulted in only varus-valgus displacement. Therefore, the difference in the sagittal plane of the entry point can affect malalignment in flexion-extension deformities and should be suggested in future studies.

CONCLUSIONS

In conclusion, this study demonstrated that the lateral entry point of PFNA-II in a simulated stable intertrochanteric fracture model leads to significant fracture displacement in the coronal plane and irreducibility of the fracture. The lateral entry point of PFNA tends to displace reduced fractures, resulting in malalignment and irreducibility. Therefore, this should be avoided to prevent complications. We recommend that the tip or medial to the GT tip be the entry point for the PFN. This surgical step should be meticulously performed to prevent implant-related complications.

REFERENCES

1. Endo Y, Aharonoff GB, Zuckerman JD, et al. Gender differences in patients with hip fracture: a greater risk of morbidity and mortality in men. J Orthop Trauma 2005;19:29-35.
2. Arirachakaran A, Amphansap T, Thanindratarn P, et al. Comparative outcome of PFNA, Gamma nails, PCCP, Medoff plate, LISS and dynamic hip screws for fixation in elderly trochanteric fractures: a systematic review and network meta-analysis of randomized controlled trials. Eur J Orthop Surg Traumatol 2017;27:937-52.
3. Müller F, Doblinger M, Kottmann T, et al. PFNA and DHS for AO/OTA 31-A2 fractures: radiographic measurements, morbidity and mortality. Eur J Trauma Emerg Surg 2020;46:947-53.
4. Ponce SJ, Laird MP, Waddell JP. Intramedullary nailing in pertrochanteric fractures of the proximal femur. Eur J Trauma Emerg Surg 2014;40:241-7.
5. Ma K-L, Wang X, Luan F-J, et al. Proximal femoral nails antirotation, Gamma nails, and dynamic hip screws for fixation of intertrochanteric fractures of femur: A meta-analysis. Orthop Traumatol Surg Res 2014;100:859-66.
6. Liu Y, Tao R, Liu F, et al. Mid-term outcomes after intramedullary fixation of peritrochanteric femoral fractures using the new proximal femoral nail antirotation (PFNA). Injury 2010;41:810-7.
7. Jiamton C, Boernert K, Babst R, et al. The nail-shaft-axis of the of proximal femoral nail antirotation (PFNA) is an important prognostic factor in the operative treatment of intertrochanteric fractures. Arch Orthop Trauma Surg 2018;138:339-49.
8. Ostrum RF, Marcantonio A, Marburger R. A critical analysis of the eccentric starting point for trochanteric intramedullary femoral nailing. J Orthop Trauma 2005;19:681-6.
9. Pan S, Liu X-H, Feng T, et al. Influence of different great trochanteric entry points on the outcome of intertrochanteric fractures: a retrospective cohort study. BMC Musculoskelet Disord 2017;18:107.
10. Chon C-S, Kang B, Kim HS, et al. Implications of three-dimensional modeling of the proximal femur for cephalomedullary nailing: An Asian cadaver study. Injury 2017;48:2060-7.
11. Jeong J-H, Jung G-H. The determination of optimal entry point for proximal femoral nail antirotation-II by fluoroscopic simulation: A cadaveric study. J Korean Fract Soc 2017;30:173-9.
12. Zhao J-X, Su X-Y, Zhao Z, et al. Predicting the optimal entry point for femoral antegrade nailing using a new measurement approach. Int J Comput Assist Radiol Surg 2015;10:1557-65.
13. Link B-C, van Veelen NM, Boernert K, et al. The radiographic relationship between the cortical overlap view (COV) and the tip of the greater trochanter. Sci Rep 2021;11:18404.
14. Park PJ, Weinberg DS, Petro KF, et al. An anatomic study of the greater trochanter starting point for intramedullary nailing in the skeletally immature. J Pediatr Orthop 2017;37:67-73.

15. Olsen M, Goshulak P, Crookshank MC, et al. Biomechanical testing of a 3-hole versus a 4-hole sliding hip screw in the presence of a retrograde intramedullary nail for ipsilateral intertrochanteric and femur shaft fractures. J Orthop Trauma 2018;32:419-24.
16. Seral B, Garca JM, Cegoino J, et al. 3D finite element analysis of the gamma nail and dhs plate in trochanteric hip fractures. Hip Int 2004; 14:18-23.
17. Kashigar A, Vincent A, Gunton MJ, et al. Predictors of failure for cephalomedullary nailing of proximal femoral fractures. Bone Joint J 2014;96-B:1029-34.
18. Streubel PN, W Wong AH, Ricci WM, et al. Is there a standard trochanteric entry site for nailing of subtrochanteric femur fractures? J Orthop Trauma 2011;25:202-7.
19. Grechenig W, Pichler W, Clement H, et al. Anatomy of the greater femoral trochanter: clinical importance for intramedullary femoral nailing. Anatomic study of 100 cadaver specimens. Acta Orthop 2006;77:899-901.
20. Farhang K, Desai R, Wilber JH, et al. An anatomical study of the entry point in the greater trochanter for intramedullary nailing. Bone Joint J 2014;96-B:1274-81.
21. Ziran BH, Morganstein A. Preventing eccentric reaming of the trochanter during trochanteric nailing. J Orthop Trauma 2014;28:e88-90.