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BIOMECHANICAL COMPARISON OF PROXIMAL FEMORAL NAIL (PFN) WITH ANTI-ROTATORY LAG SCREW AND PROXIMAL FEMORAL NAIL WITH BLADE LAG SCREW IN PROXIMAL FEMUR FRACTURES

Burak Özturan[1], Tarık Sarı[2]

1 Department of Orthopaedics and Traumatology, Acıbadem Kozyatağı Hospital, İstanbul, Türkiye
2 Department of Orthopaedics and Traumatology, SB Göztepe Prof. Dr. Süleyman Yalçın City Hospital, İstanbul, Türkiye

Abstract

Aim: It was evaluated whether nail systems with different lag screws used to treat proximal femoral fractures caused a change in durability in axial loading.

Methods: 14 bone models with femoral fractures of type AO/OTA 31/A2 were randomly divided into two groups, seven bones in each group. Bone models in the first group were fixed with the proximal femur nail which has a blade lag screw, while bone models in the second group were fixed with the proximal femur nail which has an anti-rotatory lag screw. Axial cyclic force at a speed of 5 mm/min was applied to the femoral heads of all bone models in accordance with the femoral mechanical axis. The test was continued until implant failure developed or the bone model was broken.

Results: Bone models in the PFN group were broken with a minimum force of 908 N and a maximum of 1195 N, while their average was 1050 N; the bone models in the A-PFN group were broken with a minimum force of 847 N and a maximum 1219 N, while their average was 1096 N. There was no statistically significant difference between fracture-forming forces after axial loading of the bones in the two groups ($p=0.95$; $p>0.05$)

Conclusions: There were no cut-out and varus collapse complications in the proximal femoral nails applied in the correct position by providing complete reduction in unstable intertrochanteric femoral fractures. After these results, it was predicted that both models of nails could be used safely in unstable intertrochanteric femoral fractures

Keywords: *PFN, intertrochanteric femur fractures, unstable*

Corresponding Author: Burak Özturan, e-mail: ozturanb@gmail.com

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Introduction

The number of hip fractures due to osteoporosis, which occurs after the aging of the world population, is increasing day by day. While the incidence of hip fracture was 1.6 million worldwide in the early 1990s, it is predicted that this count will be approximately 6 million in 2050[1,2].

Fractures of the intertrochanteric region of the femur are frequently seen in patients over 65 years of age as a result of low-energy traumas. It is one of the most common fractures due to osteoporosis in the elderly patient group[2,3]. The incidence of these fractures is currently between 8% and 10%. The incidence of femoral intertrochanteric fractures is also accelerating with increasing life expectancy. In this context, it can be said in general manner that more than 75% of intertrochanteric fractures occur as a result of simple falls during walking or standing in the elderly, while a small percentage occur as a result of high-energy traumas such as traffic accidents and falls from high seen in younger ages[4].

While systems such as DHS and proximal hip plates or proximal femoral nails are recommended for the surgical treatment of intertrochanteric fractures, which are thought to be stable according to preoperative imaging, proximal femoral nails (PFN) are recommended for the surgical treatment of intertrochanteric fractures that are thought to be unstable due to their biomechanical advantages [5].

The condition of success in the treatment of intertrochanteric femur fractures hinge on the patient's general condition and additional diseases, pre-fracture mobilization capacity, osteoporosis level, patient-related factors such as patient expectation, as well as parameters such as fracture type, surgical timing (early-late), implant type used, reduction quality and surgeon's experience. Proximal femoral nails are preferred majorly in intertrochanteric femoral fractures[6].

In this biomechanical study, it was evaluated whether using different lag screws in the proximal femoral nails used in the treatment of proximal femur fractures to prevent rotation causes a change in the durability of the nail under axial loading.

Materials and Methods

This study was approved by the Istanbul Medeniyet University Göztepe Training and Research Hospital Ethics Committee with its decision dated 24.08.2022. In our study. 14 third generation synthetic bone models (Synbone AG indust. Switzeland®, model 2221) with a head-neck angle of 135 degrees, anteversion of 15 degrees, a height of 337 mm, a head diameter of 48 mm and a canal diameter of 10 mm were used (Figure 1).

Figure 1. Synbone synthetic bone model, model 2221

All bone models are 31A2 type fracture models according to AO/OTA classification. This type of fracture is a comminuted pertrochanteric femur fracture, describing a fracture with a loss of lateral wall continuity (≤20.5 mm), with several fragments extending more than 1 cm distal to the trochanter minor, and is included in the group of unstable fractures.

14 bone models with femoral fractures of type AO/OTA 31/A2 were randomly di-

vided into two groups, seven bones in each group. Bone models in the first group were fixed with the proximal femur nail which has a blade lag screw (PFN, Zimed®), while bone models in the second group were fixed with the proximal femur nail which has an anti-rotatuary lag screw (A-PFN, Zimed®). During this fixation, in order to send the lag screw from the center, firstly a Kirschner wire guide was sent until it came out from the middle of the head and then a lag screw was sent over it. Thus, tip-apex distance (TAD) of the lag screw, whose length was planned in advance according to the size of the model, was precisely adjusted and sent in the appropriate position (Figure 2).

Figure 2. Lag screw differences of proximal femoral nails used in bone models
A: lag screw with blade
B: anti-rotatory lag screw

All fracture models were tested under vertical compression forces on the Shimadzu Autograph AGS Tester. First of all, two bone models without any procedure were placed in the test device at 15° valgus in accordance with the vertical loading axis and pilot study was made. Assistance was received from metallurgical and material engineers during all the applications. After the pilot study was found to be successful, axial cyclic force at a speed of 5 mm/min was applied to the femoral heads of all bone models in accordance with the femoral mechanical axis. The test was continued until implant failure developed or the bone model was broken (Figure 3).

Figure 3. Bone model during axial loading

This experiment was repeated for each model and all data were recorded via the computer program attached to the machine for later analysis. The location where the models were broken, and the form of the fracture were noted.

Statistical Analysis

Categorical variables were presented as numbers and percentages, and continuous

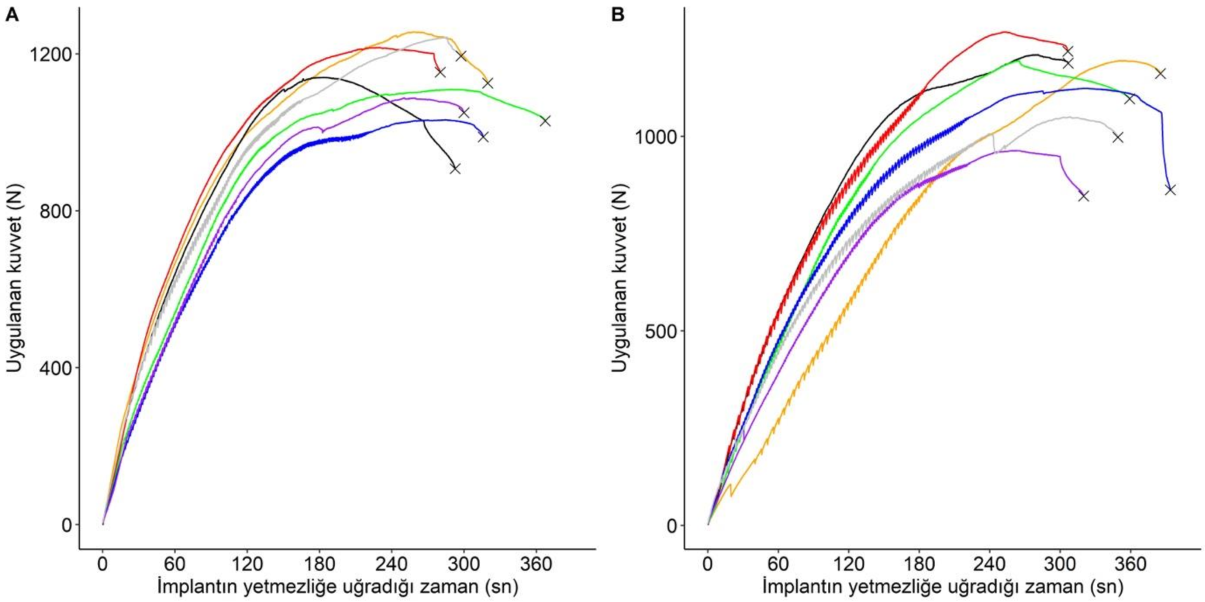

Figure 4. Force timeline at which bone models are broken
A: Bone models fixed with PFNA B: Bone models fixed with PFN with bladed lag screw

variables as mean±standard deviation. The measurements between the two groups were compared with the Mann-Whitney U test. Situations with a two-way p value of <0.05 were considered statistically significant. Analyzes were performed with R version 4.2.1 (https://www.r-project.org/).

Results

Axial loading was applied to both groups of bones until fracture occurred. The bones in the PFN group were fractured with a minimum force of 908 N and a maximum of 1195 N, with a mean of 1050 N. The bones in the A-PFN group were fractured with a minimum force of 847 N and a maximum of 1219 N, with a mean of 1096 N (Figure 4). There was no statistically significant difference between the forces that caused fractures after axial loading on the bones in the two groups (p=0.95; p>0.05) (Table 1). All bones were fractured in a transverse manner from the distal of the existing implant after the application of axial force (Figure 5). No new fractures occurred in any bone during nailing. While axial loading was applied to the fixed fractured bones, no cut-out was observed in any of the bones in both groups. There was no varus deformity in the bones as well.

Figure 5. Transverse fractured bone model from the just distal of implant after axial loading

Table 1. Comparison of the axial forces applied between the groups at the moment of fracture. No significant difference in force applied for implant failure between Type 1 and Type 2 (p=0.95)

	Total, n=14	Group 1, n=7	Group 2, n=7	p
Force, median (min-max)	1073 [847;1219]	1050 [908;1195]	1096 [847;1219]	0.95
Force (mean±SD)	1073 [991;1159]	1050 [1009;1140]	1096 [930;1175]	0.95
Force, median (%25-%75)	1059 (125)	1064 (100)	1053 (153)	0.95

Discussion

Treatment of intertrochanteric femur fractures has become an increasingly important issue due to the increasing number of patients. There are mechanical studies showing that intramedullary treatments are superior to extramedullary treatments in unstable intertrochanteric femur fractures. It has been demonstrated biomechanically that the proximal femoral nailing system, which is an intramedullary treatment option, can withstand higher axial loads than the extramedullary treatment options due to its short lever arm feature[7]. It has been shown that the risk of mortality is higher in surgeries performed with dynamic hip screws. Due to such reasons, it is seen that intramedullary nailing technique is increasingly preferred over dynamic hip screw in the surgical treatment of intertrochanteric femur fractures every year[8].
Implant-related complications after surgery in the treatment of intertrochanteric femur fractures cause reoperation in patients and increase the risk of mortality in these patients. While the fixation-related complication rate of pertrochanteric fractures is approximately 5%, the reoperation rate is approximately 4.9%.[9] Implant-related complication rates are seen more in unstable intertrochanteric femur fractures than in stable intertrochanteric fracture patterns[10]. The most common complications are cut-out, varus deformity and perimplant fracture formation[11–13].

Cut-out is one of the most common complications in intertrochanteric femur fractures. The average incidence is around 2-3%.[10,12] Inappropriate reduction of the fracture in intertrochanteric femur fractures is one of the biggest reasons that increase the risk of cut ou[14]. As well as reduction of the fracture, central insertion of the blade is very important too in reducing the risk of cut out and implant failure[10,15]. Placing the lag screw anteriorly should be particularly avoide[12]. Another important failure criterion is the tip-apex distance (TAD). It has been shown that the tip-apex distance calculated according to the position of the lag screw on the postoperative radiograph is less than 25mm, which significantly reduces the risk of implant failure[12,16]. It has been observed that the irregularity of the entrance hole of the nail in the anteroposterior axis and the fixation of the proximal part in a posteriorly displaced manner increase the risk of cut-out[17]. In our study, no cut-out was observed in any model in which we applied axial loading. We attribute this to the appropriate fracture reduction, full compliance with the tip-apex distance rule, and the central placement of lag screw.
Varus deformity is one of the other common complications in intertrochanteric femur fractures. Non-union or implant failure may occur as a result of varus deformity[11]. Implant failure mostly develops in patients with osteoporosis or in the patients who have wide canal and thin cortex, when fracture reduction is not fully achieved. After intramedullary nailing of achieved appro-

priate fracture reduction in unstable intertrochanteric femur fractures, varus collapse was observed less often in cases with distal screw locking than in cases without distal screw locking[11]. Although the fractures were not stable in our model, we did not have any bone models with varus collapse after axial loading due to both complete reduction and distal locking.

Periprosthetic femur fracture is one of the other mechanical complications frequently seen in in intertrochanteric femur fractures.[13,18] Peri-implantic fracture rates are seen at variable rates in the literature (1.4% -4.2%)[13,19]. The most common type of implant fracture is seen in the post-operative period.[19] Locking the distal of the femoral nail with a screw reduces the risk of refracture. It was observed that implanted femurs with distal locking screws were fractured more distally than the proximal region of the implan[18]. In all of the bone fracture models that we used, distal screwing was performed, and all fractures after axial loading consisted of distal to the tip of the implant. In this case, our study seems to be compatible with other studies in the literature.

Implant associated bone fracture during the operation is one of the other complications. While some do not require revision surgery, the patient may need to be operated again after some fractures. The insertion position of the nail and the reduction of the fracture are effective in the formation of fractures during surgery[20]. In our study, no new fractures occurred during implant placement. We attribute this to the facts that the nails are suitable for bone anatomy, the appropriate fracture reduction and we can see the entry point of the nail from the most correct point.

In our study, it is important that we use synthetic femoral bone models instead of human femur bone taken from cadavers in terms of giving inaccurate results during biomechanical study. Another important limitation of this study is that only axial loading is applied instead of simulating all the forces applied to the hip in daily life. More multicentral, randomized controlled advanced clinical studies are needed to obtain more accurate results.

Conclusion

Both models of nails can be used safely in unstable intertrochanteric femur fractures. In our study, we did not encounter cut-out and varus collapse complications with correct positioning and complete reduction in proximal femoral nails with lag screws in both models. We think that our biomechanical study is a guide for the application of intramedullary nailing in the treatment of unstable intertrochanteric femur fractures.

Author contributions
All authors contributed to the study conception and design. All authors read and approved the final manuscript.

Conflict of interest
The authors declare that they have no conflict of interest.

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Ethical approval
The study's ethical approval was given by the Istanbul Medeniyet University Göztepe Training and Research Hospital Ethics Committee with its decision dated 24.08.2022

References

1. Dhanwal DK, Dennison EM, Harvey NC, et al. Epidemiology of hip fracture: Worldwide geographic variation. Indian J Orthop. 2011;45(1):15-22. https://doi.org/10.4103/0019-5413.73656
2. Cooper C, Campion G, Melton LJ. Hip fractures in the elderly: a world-wide projection. Osteoporos Int. 1992;2(6):285-9. https://doi.org/10.1007/BF01623184
3. Khan AZ, Rames RD, Miller AN. Clinical Management of Osteoporotic Fractures. Curr Osteoporos Rep. 2018;16(3):299-311. https://doi.org/10.1007/s11914-018-0443-y

4. Mattisson L, Bojan A, Enocson A. Epidemiology, treatment and mortality of trochanteric and subtrochanteric hip fractures: data from the Swedish fracture register. BMC Musculoskelet Disord. 2018;19(1):369. https://doi.org/10.1186/s12891-018-2276-3
5. Sambandam SN, Chandrasekharan J, Mounasamy V, et al. Intertrochanteric fractures: a review of fixation methods. Eur J Orthop Surg Traumatol. 2016;26(4):339-53. https://doi.org/10.1007/s00590-016-1757-z
6. Niu E, Yang A, Harris AHS, et al. Which Fixation Device is Preferred for Surgical Treatment of Intertrochanteric Hip Fractures in the United States? A Survey of Orthopaedic Surgeons. Clinical Orthopaedics & Related Research. 2015;473(11):3647-55. https://doi.org/10.1007/s11999-015-4469-5
7. Ozturan B, Erinc S, Oz TT, et al. New Generation Nail Vs. Plate In The Treatment Of Unstable Intertrochanteric Femoral Fracture. Acta ortop bras. 2020;28:311-5. https://doi.org/10.1590/1413-785220202806234631
8. Werner BC, Fashandi AH, Gwathmey FW, et al. Trends in the Management of Intertrochanteric Femur Fractures in the United States 2005-2011. HIP International. 2015;25(3):270-6. https://doi.org/10.5301/hipint.5000216
9. Broderick JM, Bruce-Brand R, Stanley E, et al. Osteoporotic Hip Fractures: The Burden of Fixation Failure. The Scientific World Journal. 2013;2013:1-7. https://doi.org/10.1155/2013/515197
10. Bojan AJ, Beimel C, Taglang G, et al. Critical factors in cut-out complication after gamma nail treatment of proximal femoral fractures. BMC Musculoskelet Disord. 2013;14(1):1. https://doi.org/10.1186/1471-2474-14-1
11. Tisherman RT, Hankins ML, Moloney GB, et al. Distal locking of short cephalomedullary nails decreases varus collapse in unstable intertrochanteric fractures – a biomechanical analysis. Injury. 2021;52(3):414-8. https://doi.org/10.1016/j.injury.2021.02.007
12. 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. International Orthopaedics (SICOT). 2012;36(11):2347-54. https://doi.org/10.1007/s00264-012-1636-0
13. Horner NS, Samuelsson K, Solyom J, et al. Implant-Related Complications and Mortality After Use of Short or Long Gamma Nail for Intertrochanteric and Subtrochanteric Fractures: A Prospective Study with Minimum 13-Year Follow-up. JBJS OA. 2017;2(3):e0026. https://doi.org/10.2106/JBJS.OA.17.00026
14. Raghuraman R, Kam J, Chua D. Predictors of failure following fixation of intertrochanteric fractures with proximal femoral nail antirotation. smedj. 2019;60(9):463-7. https://doi.org/10.11622/smedj.2019114
15. Zhang W, Antony Xavier RP, Decruz J, et al. 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):569-75. https://doi.org/10.1007/s00402-020-03399-2
16. De Bruijn K, den Hartog D, Tuinebreijer W, et al. Reliability of Predictors for Screw Cutout in Intertrochanteric Hip Fractures. Journal of Bone and Joint Surgery. 2012;94(14):1266-72. https://doi.org/10.2106/JBJS.K.00357
17. Tsai SW, Lin CFJ, Tzeng YH, et al. Risk factors for cut-out failure of Gamma3 nails in treating unstable intertrochanteric fractures: An analysis of 176 patients. Journal of the Chinese Medical Association. 2017;80(9):587-94. https://doi.org/10.1016/j.jcma.2017.04.007
18. Lindvall E, Ghaffar S, Martirosian A, et al. Short Versus Long Intramedullary Nails in the Treatment of Pertrochanteric Hip Fractures: Incidence of Ipsilateral Fractures and Costs Associated With Each Implant. J Orthop Trauma. 2016;30(3):6.
19. Halonen LM, Stenroos A, Vasara H, et al. Peri-implant fracture: a rare complication after intramedullary fixation of trochanteric femoral fracture. Arch Orthop Trauma Surg. 2021;142(12):3715-20. https://doi.org/10.1007/s00402-021-04193-4
20. Yamamoto N, Yamakawa Y, Tomita Y, et al. Intraoperative fractures in cephalomedullary nailing for trochanteric fractures. Injury. 2022;53(2):561-8. https://doi.org/10.1016/j.injury.2021.10.017