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Individualized fluoroscopic lateral femoral neck view for fixation of hip fractures in the lateral decubitus position

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ABSTRACT

Aims: The aim of this study is to evaluate whether displaced hip fractures can be reduced and nailed properly in the lateral decubitus position without using a traction table with Proximal Femoral Nail Antirotation as a fixation device with inlet flouroscopic view.

Methods: In this retrospective study, 58 patients with hip fractures who were treated with Proximal Femoral Nail Antirotation in a single center were evaluated to determine the efficacy of the inlet fluoroscopic image. The postoperative X-rays of the patients underwent a comprehensive evaluation including the tip-apex distance, the quality of fracture reduction, and the positioning of the screw. The length of hospital stay, postoperative, and total hospital stays were evaluated. We propose personalized fluoroscopy positioning method for the reduction and internal fixation of hip fractures, eliminating the need for a traction table.

Results: The mean age of the patients was 78.43±11.67 years. By inlet viewing of the hip the most common placement of the integrated compression screws on postoperative radiographs was found to be 63.8% in Cleveland zone 5 and an increase in the femoral neck angle mean was 133,6° resulted in a significant decrease in the postoperative hospital stay of which mean was 3.95 days . The tip-apex distance was 19 mm as a mean.

Conclusion: The nailing of proximal femoral fractures using a lateral decubitus position and neutral fluoroscopy view may not achieve optimal quadrant placement of the nail. However, by repositioning the C-arm fluoroscopy with a 45-degree inlet angulation from the initial reference point, aligned with the femur and considering individual adduction, an enhanced lateral visualization of the femoral neck can be achieved, which will also help reduce potential complications during surgery.

Keywords: Flouroscopy, hip fracture, lateral decubitus position, proximal femoral nailing

INTRODUCTION

Hip fracture is widely recognized as the leading cause of hospital admission among the elderly population.[1,2] Addressing this prevalent issue is crucial to improving the quality of the patient's life, minimizing hospital stays, facilitating a prompt return to pre-fracture normalcy, and ultimately reducing the burden on healthcare systems.[2] To optimize treatment outcomes, significant advancements have been made in the development of both intramedullary and extramedullary implants within the field of surgery.[3] Among the various implant options available, cephalomedullary nails have emerged as the preferred choice for hip fracture management, encompassing fractures in the intertrochanteric, subtrochanteric, and, in specific instances, the basilar neck regions.[4-6]

Hip fractures are commonly treated through reduction and nailing in the supine position, typically with the aid of a traction table.[7,8] However, it is important to note that not all hospitals are equipped with a traction or fracture table.[9] Factors such as the patient's body structure (e.g., obesity or limited mobility) and health conditions (e.g., certain cardiovascular diseases) may necessitate alternative surgical positions as preferred by the surgeon.[10] Additionally, the use of traction tables has been associated with various complications, including pudendal nerve palsy, erectile dysfunction, and perineal sloughing.[10-12]

There have been limited reports on the use of proximal femoral nail antirotation (PFNA) for hip fractures treated in the lateral decubitus position (LDP).[9,13,14] The LDP has gained preference as the treatment position due to its advantages, such as providing easy access to the patient's hip and proximal femur and allowing for convenient visualization of both the anterior and posterior regions, particularly in obese patients. Additionally, this position offers better visibility of the trochanteric region.[14]

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Mechanical complications are the most common complications associated with implant failure and subsequent revision surgery.[1,6,15,16] Among these complications, the cutout of the neck-head by fixation device (e.g., lag screw, integrated compression screws, helical blade) has been identified as the most frequent type of mechanical failure.[17] Consequently, the positioning of the nail or proximal fixation on the femoral head plays a crucial role in addressing this issue.[1,2,6] However, when utilizing the LDP for hip fracture surgery, intraoperative imaging of the PFNA and its associated head screw can pose challenges, resulting in variations and a lack of consensus regarding the lateral imaging techniques to use.[17] It is worth noting that anatomical studies have revealed the obliquely elliptical cross-sectional morphology of the femoral neck, with a higher incidence of defects observed in the posterosuperior and anteroinferior regions.[7]

The importance of obtaining accurate lateral imaging in the supine position has been widely acknowledged, prompting research into various fluoroscopic positions to achieve different lateral views.[7,8] While some researchers have explored techniques involving alterations in the position of the fractured hip in the LDP to obtain fluoroscopic images of the lateral femoral neck, which may result in reduction loss, others solely rely on vertrical views without direct contact with the affected hip.[12,14] Despite the recognized significance of lateral imaging as a prognostic factor impacting both radiological and functional outcomes, the existing discrepancies highlight a lack of consensus and effectiveness in this area.[18]

The objective of the present study was to evaluate the feasibility and efficacy of using PFNA as a fixation device in the LDP without the need for a traction table, by an inlet fluoroscopic view. By addressing the limitations and uncertainties surrounding lateral imaging techniques, this research aimed to enhance the reduction and proper fixation of hip fractures in the LDP, ultimately improving surgical outcomes and patient care in doing so, it also helps to reduce complications during and after surgery.

METHODS

The study was initiated with the approval of the Kastamonu University Clinical Researches Ethics Committee (Date: 19.04.2023, Decision No: 2023-KAEK-48). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

The present retrospective study was conducted at the Department of Orthopaedic and Trauma Surgery of Kastamonu Education and Research Hospital, including patients who presented between September 1, 2017, and November 1, 2020, with acute peritrochanteric hip fractures and subsequently underwent surgical intervention utilizing PFNA in the LDP. The study focused on patients who had undergone surgical procedure with individualized lateral femoral neck imaging technique. The analysis involved a comprehensive review and examination of hospital records and electronic data. Notably, other surgical techniques for hip fractures were specifically excluded from the analysis.

Before applying the technique we performed a saw bone model imaging study to explain which angle of lateral imaging is more reliable. Different images were obtained in different inlet positions of the lateral femoral neck in the neutral hip position (no adduction) as seen in **Figure 1**. The most suitable angle was found to be 45°. At other entry angles, the metal object did not show itself in the correct position situated has not correctly demonstrated outside the joint. This suggests that improper placement of the proximal fixation material due to improper positioning of the flouroscopy give rise to potential complications.

After finding 45° as the most suitable angle in sawbone models we applied this to patients with hip fractures in the LDP, just like the positions called "groin lateral view," "horizontal beam lateral view," and "cross-table lateral view" in supine positions which are used to obtain lateral hip radiographs in the supine position by directing the tube angle at a 20-45° angle toward the groin area[19,20] without touching or moving the hip, by positioning the

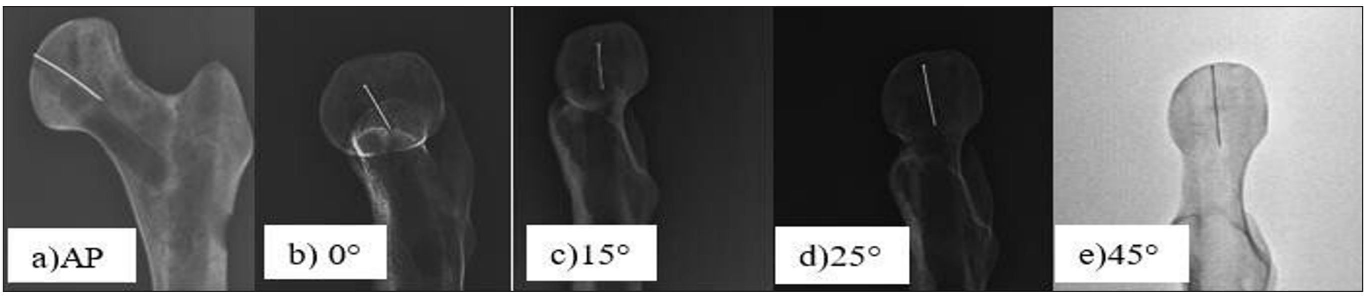

Figure 1. Lateral femoral neck fluoroscopic images of the metal located on the articular surface in the neutral hip position (corrected adduction). It is observed that the correct image is obtained at a 45-degree angle. In the images at other angles, the metal on the articular surface appears to be in a safe area as if it is not on the joint surface a: Hip AP view in internal rotation view. The metal tip is seen on the articular surface b: 0° inlet view. c: 15° inlet view. d: 25° inlet view. e: 45° inlet view.

image intensifier of the fluoroscopy device (or the X-ray tube section in obese patients) above the patient in the inlet position. This allowed us to obtain a true lateral femoral neck image in LDP.

The initial diagnosis of fractures was made via direct radiography and clinical evaluation for all enrolled patients. Pertinent patient data, including age, gender, fracture type, and length of hospital stay, were meticulously documented. Subsequently, immediate postoperative radiographs to evaluate femoral neck-shaft angle (NSA) were assessed to evaluate the quality of fracture reduction, which was categorized as good (<5° varus/valgus and/or anteversion/retroversion), acceptable (5-10° varus/valgus and/or anteversion/retroversion), or poor (>10° varus/valgus and/or anteversion/retroversion). The screw's placement was assessed using the tip-apex distance (TAD) methodology, originally defined by Baumgaertner et al.[6] which involves measuring the combined distance in millimeters from the lag screw's tip to the femoral head's apex on both anteroposterior and lateral radiographs. Furthermore, the positioning of the screw within the femoral head was documented according to the Cleveland and Bosworth classification system, which partitions the cephalic circumference into nine segments and sequentially labels them from left to right and top to bottom.[1,9]

The exclusion criteria for the present study were patients who did not undergo hip fracture surgery in the LDP because of unpositioning of the patient due to thoracic trauma or other extremity trauma, and those who opted for a different fixation method, such as cables or alternative implants. Patients with pathological fractures, open fractures, or cases requiring open surgery were also excluded.

Preoperatively, each patient underwent a comprehensive evaluation conducted by a medical consultant and an anesthesiologist. The surgical procedure was performed by the same senior orthopedic surgeon, taking into consideration the patient's comorbidities and preoperative treatment regimen, unless there was a medical condition that necessitated a delay in the surgery. Prophylactic measures for thromboembolic diseases included the administration of enoxaparin once daily for 4 weeks. Antibiotic prophylaxis was implemented using a first-generation cephalosporin at a 2 g dose administered prior to the surgical intervention and continued for 24 h, as per the standard protocols.[1]

The surgical procedures were conducted by a single surgeon on a radiolucent table. The patients were positioned in the LDP and securely immobilized. Specifically, the affected hip was maintained in an extended position, while the non-affected hip was flexed. The fixation device was meticulously inspected to ensure appropriate fluoroscopic visualization. During the surgical intervention, three scrubbed individuals, all wearing protective lead coats and neck collars underneath their sterile dressings, were present in the operating room. This team consisted of a primary surgeon, a registered nurse's first assistant, and a scrub nurse, all actively involved in the procedure, adhering to the principles of sterility and safety measures. Reduction of the fracture was accomplished through either manual longitudinal traction and internal rotation of the affected leg or utilization of a limited open approach, as shown in **Figure 2**. To validate the quality of the reduction achieved, images were obtained using an image intensifier for both anteroposterior (AP) and inlet flouroscopic position for true lateral view, as shown in **Figures 3A** and **3B**, respectively.

Figure 2. a: Fluoroscopic position for hip anteroposterior (AP) view **b:** Fluoroscopic position for hip lateral view and the corresponding image at the same moment.

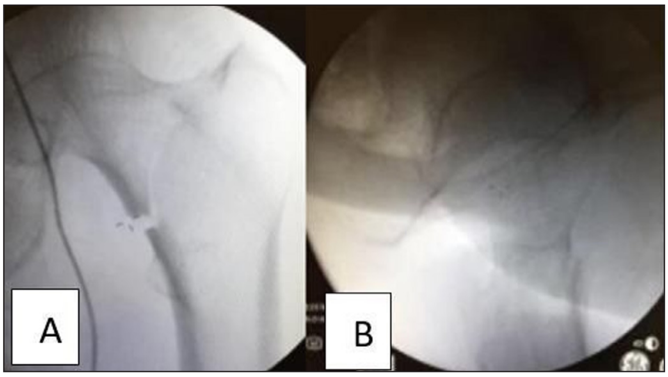

Figure 3. Preoperative fluoroscopic images of the patient in the lateral decubitus position. **a:** Hip anteroposterior (AP) view **b:** Hip inlet lateral view.

The Trigen-Intertan Intertrochanteric Antegrade Nail with integrated compression screws for the proximal fixation, a 130°, 20 cm nail specifically designed for proximal femoral nailing, was used in the present study. This brand was selected due to the radiolucency of the drill guide handle, which facilitated the attainment of improved lateral imaging during PFN application.

When we apply fluoroscopic view before or during the operation patient's lower extremity is in adduction by itself without any further positioning due to the surgical position (Figure 4, line A). To determine the appropriate inlet angle, the initial position of the corrected fluoroscopic image relative to the lateral femoral cortex in the hip should be considered. Assuming the starting 0° position of the fluoroscopy in an almost vertical position (Figure 4, B line) at the beginning in the patients' placed position for the surgery, for the correct lateral view of the femoral neck visualization, the fluoroscopy should be adjusted to a 45° inlet position according to starting 0° (Figure 4, C line). The actual inlet angle differs for each individual. The main reasons for this variability include differences in pelvic height-width, femoral length, and thigh thickness. Therefore, in the LDP patients exhibit varying degrees of adduction, necessitating personalized adjustment of the fluoroscopic angle to achieve optimal lateral visualization of the femoral neck.

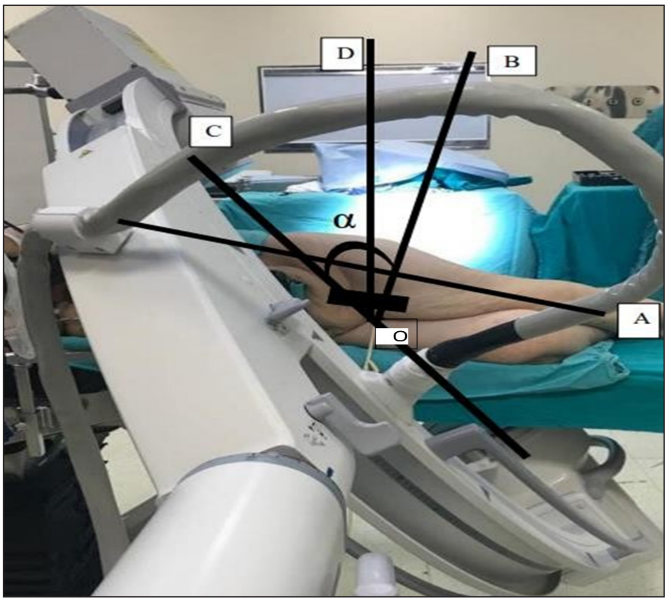

Figure 4. Position of the C-arm fluoroscope in real-time in the operating room to obtain the lateral view of the femoral neck. Line A represents the axis of the femur. Line B represents the perpendicular line to line A, indicating the corrected starting point - "0" point. Line C represents the necessary inlet position for obtaining the true lateral femoral neck view. Line D refers to the upright position of the C-arm fluoroscopy commonly used for classic femoral neck lateral imaging. The inlet angle (between B and C lines- BOC angle) has been determined as 45°

Considering that the fluoroscopy beam, which needs to be perpendicular to the femoral neck for the true hip lateral view (Figure 5), we believe that described inlet femoral neck view is the most suitable approach for lateral hip imaging in the LDP.

Following the selection of an appropriate-diameter nail based on preoperative planning, the nail was inserted through a classical 4 cm entry incision located 4-5 cm proximal to the trochanteric tip. To obtain the AP view, the guide pin was driven into the neck-head region, and the C-arm was rotated in the opposite direction, either under or above the table, as shown in Figure 2A. The lateral view, as shown in Figure 2B, was obtained without rotating or physically manipulating the hip joint. Instead, fluoroscopy was achieved with a corrected adduction angle of 45° inlet, considering that the affected leg was in adduction due to the lateral decubitus position, as shown in the figure. The position and TAD of the guide wire were assessed in both the AP and lateral projections, as shown in Figure 6A. Once the optimal position of the guide wire was confirmed, the appropriate length was determined and applied, as shown in Figure 6B. Subsequently, the near cortex was predrilled, and integrated compression screws were inserted, as shown in Figure 7A AP view and in Figure 7B lateral view. Finally, a single static distal locking screw was introduced through the drill guide handle of the nail to complete the fixation process.

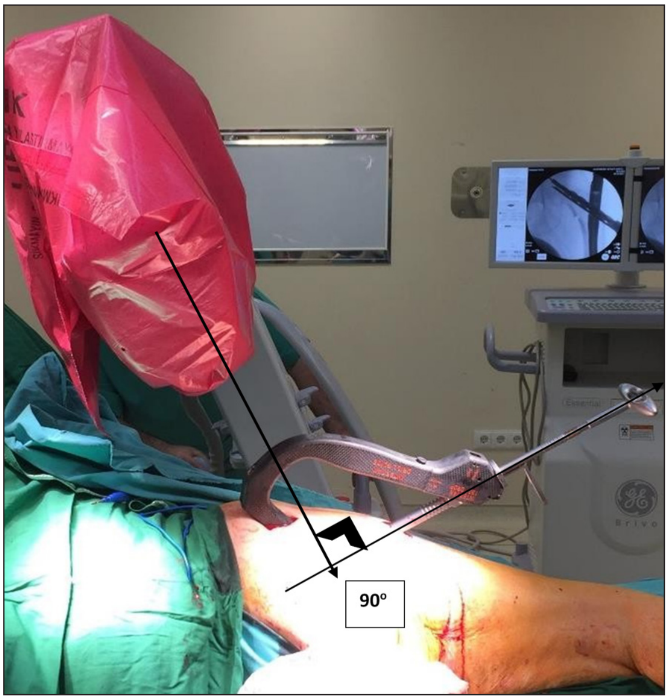

Figure 5. The angle between the K-wire/screw-blade going to the hip and the axis of the scope is 90°

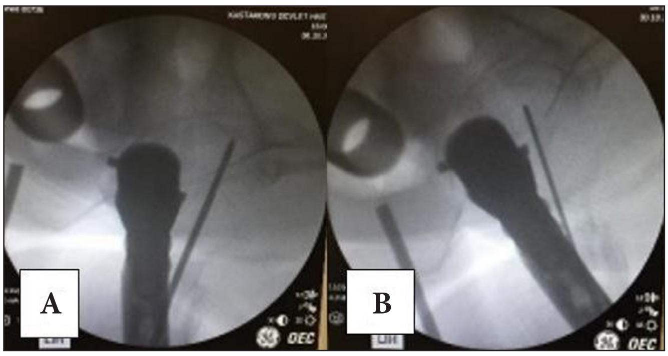

Figure 6. Intraoperative fluoroscopic images of the patient in the lateral decubitus position **a:** Excessive anterior deviation observed in the lateral view after insertion of the guide wire **b:** Re-alignment of the guide wire direction after correction.

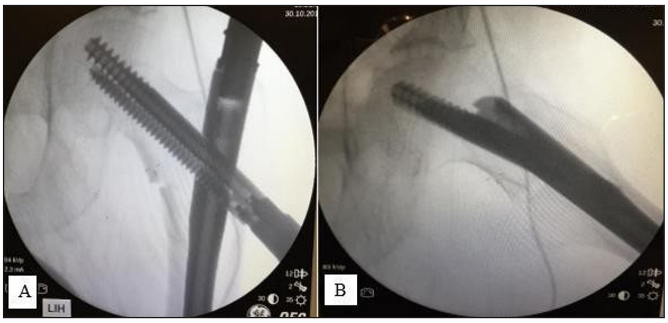

Figure 7. Final evaluations after PFNA (Proximal Femoral Nail Antirotation) procedure a: Hip anteroposterior (AP) view b: Hip lateral view

Statistical Analysis

The distribution of the data was examined using the Shapiro-Wilk test. The statistical relationships between the variables were analyzed using Spearman's correlation analysis. The impacts of the independent variables on the dependent variables were evaluated using linear regression analysis with the enter method. The descriptive statistics of the data were presented as mean±standard deviation or frequency (percentage). All statistical analyses were performed using IBM SPSS Statistics 26.0 software and analyzed and reported at a significance level α=0.05.

RESULTS

The present study included 58 patients. Subtrochanteric fracture was observed in 13 (22.4%) of these patients, while intertrochanteric fracture was present in 41(70.7%) and basicervical fracture 4 (6.9%) of them. Among the patients, 36 (62.1%) were female and 22 (37.9%) were male. The mean age of the patients was 78.43±11.67 years, the TAD score was 19±4.25, NSA 133.64±5.48°. The average value of the angle between the vertical position of fluoroscopy and the target inlet position when reached in patients was 23.5±2.9. The average length of stay in the hospital is 5.55 days while after surgery this average is 3,95 days.

The descriptive statistics for the demographic data of the patients are presented in Table 1.

The most frequent placement of the tip of the integrated compression screws on postoperative radiographs was in Cleveland zone 5 (center-center), observed in 37 cases (63.8%). The second most common location was in zone 8 (central-inferior), accounting for seven cases (12.1%). The third most common location is zone 2 central-superior region, with four cases (6.9%). In the other zones, one or two cases were observed.

The postoperative quality of fracture reduction was described as good for all the patients. It can be observed that there are no statistically significant relationships ($p>0.05$) between TAD and NSA and hospital stay duration. However, there is a statistically significant, negative, and weak relationship between NSA and postoperative total time ($r=-0.327$; $p=0.012$), indicating that as the femoral neck angle increases, the postoperative total time decreases. There are no significant correlations between femoral neck angle and other variables ($p>0.05$). However, there is a significant, moderate, positive relationship between hospital stay duration and time between admission and surgery ($r=0.670$; $p<0.001$), as well as a significant, moderate, positive relationship between postoperative total time and hospital stay duration ($r=0.532$; $p<0.001$). In the linear regression analysis, TAD and gender had no statistically significant effects on postoperative hospital stay duration ($p=0.508$).

Table I. Data of the patients and measurements on X-rays

n=58	
Gender	
Female	36 (62.1%)
Male	22 (37.9%)
Age	78.43±11.67
Fracture type	
Subtrochanteric	13 (22.45)
Intertrochanteric	41 (70.7%)
Basicervical fracture	4 (6.9%)
Tip apex distance	19±4.25
Femoral neck-shaft angle Postoperative hospital stay	133.64±5.48 3.95±1.49
Hospital stay duration	5.55±2.13
Fluoroscopy from perpendicular to the ground inlet angle[1]	23.5±2.9

[1]The angle between the vertical position of fluoroscopy and the target inlet position when reached, line D-C / DOC angle in Figure 4

DISCUSSION

The current investigation pertains to the implementation of an intraoperative fluoroscopic lateral projection of the femoral neck, which augments the meticulous evaluation of the placement of fixation materials and their relative proximity to the joint. The precise localization of the metallic fragment exterior to the joint was successfully attained by employing a 45° inlet view without adduction during the fluoroscopic assessment of the sawbone model. Consequently, two crucial factors were emphasized in the intraoperative visualization of this true hip lateral angle: (1) the consideration of adduction caused by the patient's LDP for fluoroscopy, which necessitates the calculation of the appropriate starting point; and (2) the acquisition of the 45° inlet view, as demonstrated in the sawbone model. Given the variation in adduction angles among LDP patients, we believe that the individualized assessment of this imaging technique is essential for each patient as it facilitates the prevention of complications and ensures the accurate placement of blades/screws, ultimately leading to effective treatment outcomes. When nailing proximal femoral fractures, three critical criteria should be met: avoiding varus reduction, achieving an appropriate TAD, and inserting the helical blade/screw in the correct quadrant.[1,21,22]

In the the present study, based on the information we were able to visualize and obtain through intraoperative C-arm fluoroscopy, we demonstrated that the fluoroscopic lateral view of the femoral neck helps in achieving the desired values in the three crucial criteria for proximal fixation in PFN applications. In the surgical treatment of femoral fractures, although PFN is an effective method, the choice between supine decubitus positions and LDPs remains a controversial issue.[9,13,14] It is known that incorrect positioning of the proximal fixation material can lead to inadequate fracture reduction stability and negatively affect the patient's functional outcomes.8 Therefore, obtaining adequate true AP and lateral fluoroscopic images during the intraoperative period is crucial.[21-24] Better visualization of the implant placement during surgery, makes fracture fixation easier by closed reduction and preventing the need for transitioning to an open reduction with additional incisions.

Numerous studies have described different imaging techniques in this regard.[7,8,23,24] Aibinder et al.[23] proposed the use of sequential fluoroscopic rollover images to reliably identify the absence of posterosuperior screw in-out-in application in cases of femoral neck fractures. However, due to a significant increase in the number of fluoroscopic shots, this approach is considered impractical.[7] Schep et al.[24] in their 2002 study on hip region validation of fluoroscopy, emphasized the importance and difficulty of obtaining true AP and lateral images and highlighted the potential complications associated with virtual images. They reported that obtaining a lateral image could be achieved only by taking perpendicular shots in the lateral view during the sawbone study. In our study we ensured that the fluoroscopy position for the femoral neck lateral image was appropriately set at a 90° perpendicular angle. In the supine position, 150° oblique tangential and 30° oblique tangential fluoroscopic images have been described as enhancing the visibility of the lateral view of the hip.[7,8] Apart from the study by Bishop et al.[25] where better hip lateral images were obtained by directing the imaging perpendicular to the ground and tilting posteriorly by 20-30° due to femoral neck anteversion, no studies have been conducted for the LDP.

Studies have shown that a TAD of less than 25 mm is an effective indicator, especially for cutout complications.[18,26,27] Nikoloski et al.[26] reported that only 54% of the cases had a TAD of 25 mm or less, with an 18.6% implant-related complication rate and a 6.2% cutout rate. They found a significantly higher incidence of cutout complications when the TAD was above 30 mm. Herman et al.[21] applied the standard surgical technique for PFN and found an average TAD of 20.3 in the complication-free group, while the group with cutout complications had an average TAD of 24.0. Sadic et al.[27] reported an average TAD of 25.6, with only 53% of the cases having a TAD below 25 mm.

Sonmez et al.[9] determined the average TAD to be 25.04 mm and Turgut et al.[14] reported an average TAD of 29.2 mm by positioning the hip at 90° flexion and 30-40° abduction in lateral- mode fluoroscopy in the LDP. In the present study, the average TAD was found to be 19 mm, by using inlet fluoroscopic position and only four cases (6.9%) had a TAD of 25 mm or above. Although Nikoloski et al.[26] mentioned the possibility of encountering cutout complications despite an appropriate TAD, the present study demonstrated that inappropriate intraoperative or postoperative hip lateral radiographs obtained with pain could yield a misleading TAD, as observed in angular imaging models performed with sawbones (**Figure 1**). According to Turgut et al.[17] to avoid complications in PFN, the NSA should be greater than 130°, and avoiding varus reduction is among the most crucial factors preventing cutout complications. In the present study, the average NSA was 133.64±5.48. A statistically significant correlation was found between the NSA and the patients' postoperative length of stay. Based on this information, it is suggested that NSA not only plays a significant role in the risk of cutout but also affects the patient's functional outcome.

Cleveland and Bosworth divided the femoral head and neck into nine quadrants.[1,9,28] For mechanical strength, insertion of the proximal fixation device into the central- central or inferior-central quadrant is recommended.[1,16,17,29] The superior-posterior quadrant is considered the most unsuitable position.[29] The importance and correlation of TAD and quadrant position are evident, highlighting the increasing significance of obtaining a true lateral projection during the operation. By determining the individual's optimal fluoroscopy angle and inlet view, a clearer and more accurate image than the conventional position will be achieved. According to the Cleveland zone, among our patients, 63.8% had a central-central quadrant placement, and 12.1% had a central-inferior quadrant placement. Thus, 75.6% of our patients achieved the most suitable position. Aguado-Maestro et al.[1] reported a total rate of 77.3%, Nikoloski et al.[26] reported 72.5%. and Sacid et al.[27] found 50% of the cases in the recommended quadrants. The present study demonstrated similar or better results in this regard.

Hengg et al.[31] highlighted that the graph obtained from the patient's position in the upper extremity can lead to incorrect treatment and surgical outcomes. It would be inappropriate to assume that the same applies to the lower extremity. Specifically, during hip surgery, obtaining a high-quality lateral image necessitates adjusting the fluoroscope angle to make it perpendicular to the femoral neck.[24] However, due to the wide range of tube angles in standard imaging practices for the hip, it is believed that accurate data may not be obtained.[19,20] Consequently, the importance of individualized X-ray tube angles in the diagnosis and treatment of patients is increasing.[32,33]

In this paper, we emphasize the need to use individualized X-ray tube angles instead of standard angles in the assessment of functional and clinical outcomes related to the accurate placement of the femoral neck implant in conditions such as hip fractures. Such an individualization not only has the potential to shorten the surgical duration, which is particularly crucial in the elderly patient group but also holds clinical significance by reducing radiation exposure time for healthcare workers, prioritizing their health.

The present study had some limitations. First, it was a retrospective study, which could have introduced bias and limitations in the data collection and analysis. Second, the sample size was relatively small, and while our findings hold promise, their generalizability to a larger and more diverse patient population may be somewhat constrained. Third, the use of only the sawbone model for evaluating the central position may not fully represent the clinical scenario and the variability that can occur in actual patients. These constraints should be kept in mind while interpreting the results of the current study, emphasizing the need for future research endeavors with expanded sample sizes and prospective designs to substantiate the findings presented in this study.

CONCLUSION

The conventional nailing technique of proximal femoral fractures using an LDP and neutral fluoroscopy view may not achieve optimal quadrant placement. However repositioning of fluoroscopy with a 45° inlet angulation from the initial reference point aligned with the femur, considering individual adduction, provides improved lateral visualization of the femoral neck. We also emphasize the importance of capturing lateral images with the same position in the postoperative X-rays. This ensures that the graph is taken with the correct positioning, thus providing valuable information for post-surgical evaluation.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was initiated with the approval of the Kastamonu University Clinical Researches Ethics Committee (Date: 19.04.2023, Decision No: 2023-KAEK-48).

Informed consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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