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Correlation of neck-shaft angle with functional recovery following internal fixation of intertrochanteric femur fractures: a prospective observational study

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ABSTRACT

Background: Intertrochanteric femur fractures are a common orthopaedic injury among the elderly. The postoperative neck-shaft angle (neck-shaft angle (NSA)) is a critical biomechanical parameter that may influence functional outcomes following internal fixation. This study aimed to assess the correlation between NSA and functional recovery in patients treated with proximal femoral nail (proximal femoral nail (PFN)) or proximal femoral nail (PFN)A2.
Methods: This prospective observational study included 80 patients aged >45 years with intertrochanteric femur fractures treated using PFN or proximal femoral nail anti-rotation 2 (PFNA2). NSA, femoral neck shortening and Harris Hip Score (Harris Hip Score (HHS)) were evaluated at immediate postoperative, 3 months and 6 months intervals. Statistical analysis included Pearson correlation, multivariate regression and ANOVA.
Results: At 6 months, NSA positively correlated with HHS ($r=0.296$, $p=0.0077$). Patients with NSA between 125°-135° showed statistically significantly better outcomes (63% excellent/good), while those with varus alignment (<125°) had poor outcomes in 83% of cases. Age negatively correlated with recovery ($r=-0.452$, $p<0.0001$). Closed reduction and PFNA2 implants were associated with more favourable results.
Conclusions: Restoration of NSA within the physiological range (125°-135°) is significantly associated with improved functional outcomes following intertrochanteric fracture fixation. Accurate anatomical alignment should be a surgical priority, particularly in elderly patients.

Keywords: Functional outcome, Harris hip score, Intertrochanteric fracture, Neck-shaft angle, Proximal femoral nail, PFNA2

INTRODUCTION

Intertrochanteric femur fractures constitute approximately 45% of all hip fractures and predominantly affect the elderly population, particularly postmenopausal women with osteoporosis. These injuries are typically caused by low-energy mechanisms such as falls from standing height and are projected to increase with the global aging population, representing a significant healthcare challenge.[1-3] Surgical fixation is the gold standard in the management of these fractures, with proximal femoral nailing systems such as the proximal femoral nail (PFN) and the PFNA2 commonly employed. The primary goals of surgical treatment are anatomical reduction, stable fixation, early mobilization and restoration of function.[4-7] Among the critical determinants of postoperative success is the neck-shaft angle (NSA) the angle between the femoral neck and shaft, physiologically ranging from 125° to 135°. Deviation from this range may impair load distribution, increase implant stress and result in poor abductor mechanics, leading to suboptimal functional outcomes.[8] While varus alignment (<125°) has been

associated with mechanical failure and valgus alignment (>135°) with altered gait mechanics, the specific relationship between postoperative NSA and validated functional outcome measures, such as the Harris Hip Score (HHS), remains inadequately characterized. This prospective study aims to investigate the correlation between NSA and functional recovery at 6 months following internal fixation of intertrochanteric fractures.

METHODS

This prospective observational study was conducted in the Department of Orthopaedics, Bharati Vidyapeeth (Deemed to be University) Medical College, Pune, over a duration of 20 months, from June 2023 to February 2025. Ethical approval for the study was obtained from the Institutional Ethics Committee prior to commencement and informed written consent was secured from all participants before inclusion. The study included patients aged above 45 years who presented with radiologically confirmed intertrochanteric femur fractures and underwent surgical fixation using either a Proximal Femoral Nail (PFN) or a Proximal Femoral Nail Anti-rotation II (PFNA2). Patients with pathological fractures, ipsilateral lower limb injuries, open fractures with neurovascular compromise or severe neurological deficits such as post-stroke hemiplegia were excluded from the study.

A total of 80 patients were enrolled, with the sample size determined based on feasibility and findings from previous studies indicating a significant correlation between NSA and postoperative functional outcomes. All patients underwent surgical fixation using either PFN or PFNA2 and the choice of implant was guided by the fracture configuration and the operating surgeon's discretion. Closed reduction and internal fixation (CRIF) were performed whenever feasible, while open reduction and internal fixation (ORIF) was reserved for complex fracture patterns that could not be satisfactorily reduced by closed methods. Postoperatively, all patients were followed up and evaluated at discharge, at three months and again at six months. Outcome parameters included radiographic and functional measures. The NSA was measured on standardized anteroposterior pelvic radiographs as the angle formed between the axes of the femoral neck and shaft. Femoral neck shortening (FNS) was determined by comparing the linear shortening observed on radiographs between the immediate postoperative and six-month follow-up images. Limb length discrepancy was measured clinically from the anterior superior iliac spine to the medial malleolus on the affected and unaffected sides. Functional outcomes were assessed using the HHS, categorized as excellent (90-100), good (80-89), fair (70-79) or poor (<70). All radiological measurements were carried out by an experienced orthopedic surgeon and independently verified by a second observer to minimize interobserver variability.

Data analysis was performed using SPSS software (version XX). Continuous variables were expressed as mean±standard deviation and categorical variables were presented as frequencies and percentages. Associations between neck-shaft angle and HHS were assessed using Pearson correlation analysis. Changes in parameters over time were evaluated using repeated measures ANOVA. Subgroup comparisons, such as between CRIF and ORIF or between PFN and PFNA2, were conducted using independent t-tests and Chi-square tests. Multivariate regression analysis was applied to identify independent predictors of functional outcome. In addition, a three-dimensional regression model was constructed to illustrate the combined influence of age and NSA on HHS. A p-value of less than 0.05 was considered statistically significant for all tests.

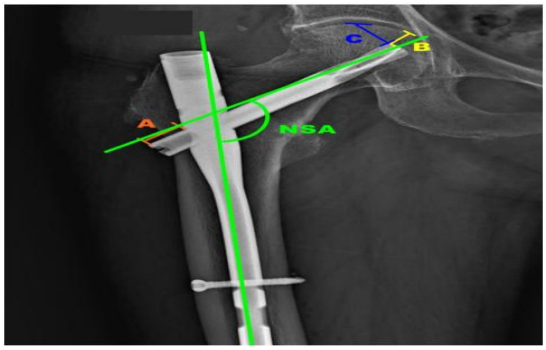

Figure 1: The NSA is measured as the angle between the axis of the femoral shaft and the femoral neck (green lines).

The length between the distal end of the helical blade and lateral side of the nail is defined in Line A. The difference of the length of Line A between immediate postoperative and 1-year after stands for the backout of the helical blade. The cut-through is measured from the upper tip of the blade to the intersection of the extended line of the upper margin of the blade with the medial cortex of the femoral head (Line B). The FNS is calculated as the value of the backout plus the value of the cut-through (Line C).

RESULTS

Demographic profile

The study included 80 patients with intertrochanteric femur fractures treated with internal fixation. The mean age was higher among females (75.4±9.61 years) than males (68.5±13.9 years). The majority were unemployed or retired, reflecting a predominantly elderly cohort.

Surgical technique and implants

CRIF was performed in 75% (n=64) and ORIF in 25% (n=16) of patients. PFN was used in 68 cases and PFNA2 in 12.[8]

Temporal changes in femoral neck length

The mean femoral neck length measured immediately postoperatively was 2.42±0.30 cm. This increased slightly to 2.49±0.33 cm at 3 months and 2.53±0.44 cm at 6

months. These changes were not statistically significant (p=0.1709), indicating minimal post-operative collapse and stable implant fixation throughout the follow-up period.

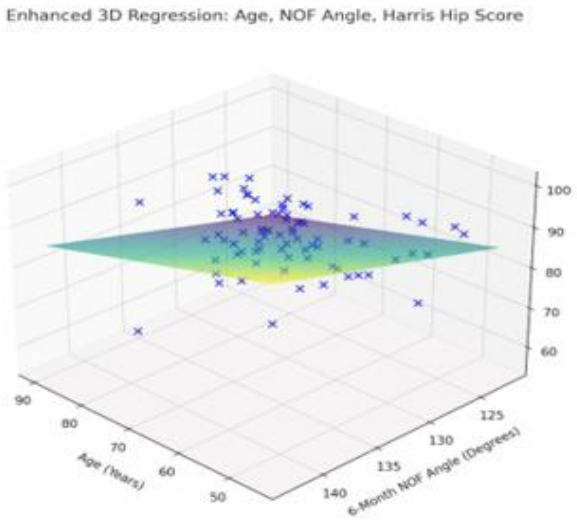

Figure 2: Three-dimensional regression surface illustrating the relationship between age, 6 months postoperative neck of femur angle and HHS.

Each blue point represents an individual patient's data. The regression plane indicates a clear trend: patients with lower age and higher neck of femur (NOF) angles tend to achieve higher Harris Hip Scores. The model highlights the combined predictive influence of patient age and anatomical alignment on functional recovery following internal fixation for intertrochanteric fractures.

Neck-shaft angle

NSA decreased marginally from 129.7°±2.6° to 128.9°±3.2° over 6 months (p=0.2982), indicating stable alignment.

NSA vs. functional outcome

At 6 months, NSA showed a significant positive correlation with HHS (r=0.296, p=0.0077). Patients with NSA within 125°–135° had better outcomes (63% excellent/good) compared to those outside this range (17%).

Figure 3: Patient's PBH-AP x rays of preop, immediate postop, 3 and 6 month follow up x ray.

Influence of age

Younger patients (≤50 years) had the best outcomes (100% excellent/good), while patients >70 years showed higher fair and poor scores (p=0.0133).

Table 1: Demographic profile.

Gender (total–80)	Mean (age)	Median (age)	SD
Female (43)	75.4	75	9.61
Male (37)	68.54	70	13.89

Table 2: Harris hip score outcomes by NOF angle range at 6 months post-operation.

Harris hip score category					
6 Month NOF	**Excellent**	**Fair**	**Good**	**Poor**	**Total**
125º–135º	9 (12%)	22 (31%)	37 (51%)	4 (6%)	72
<125º	0 (0%)	0 (0%)	1 (17%)	5 (83%)	6
>135º	1 (50%)	0 (0%)	0 (0%)	1 (50%)	2

Table 3: Multivariate analysis of age, NOF angle and HHS.

Comparison	Correlation coefficient (r)	P value
Age vs Harris Score	-0.452	<0.0001
6M NOF Angle vs Harris Score	0.296	0.0077
Age vs 6M NOF Angle	-0.076	0.5038

DISCUSSION

This study demonstrates a significant positive correlation between postoperative NSA and functional outcomes, as measured by the HHS, at 6 months postoperatively in patients undergoing internal fixation for intertrochanteric fractures. Patients whose NSA remained within the physiological range of 125°–135° achieved superior

functional outcomes. In contrast, those with varus alignment (<125°) exhibited poorer HHS, consistent with previous studies indicating compromised load transfer and abductor inefficiency in such cases. Importantly, NSA emerged as an independent predictor, unaffected by patient age.[12]

Younger patients (≤50 years) displayed uniformly excellent/good outcomes, likely due to better bone quality, fewer comorbidities and greater rehabilitation potential. Nonetheless, even in older patients, maintaining NSA within physiological limits was associated with improved recovery. Patients who underwent CRIF had better functional outcomes compared to ORIF, possibly due to soft tissue preservation and better biological healing. PFNA2 provided more consistent outcomes, likely attributable to the helical blade's enhanced rotational stability. However, PFN was associated with a broader distribution of outcomes, including more excellent recoveries in some cases.[8] Postoperative NSA and femoral neck length remained relatively stable over the 6 months period, indicating good implant performance and reduction maintenance. This contrasts with previous reports of collapse and shortening, particularly in extramedullary devices.[6,11] Surgical efforts should prioritize the restoration of NSA within 125°–135°, regardless of patient age. This target appears universally relevant and strongly predictive of better functional recovery. Accurate intraoperative reduction, appropriate implant selection and adherence to surgical principles are essential for optimal outcomes.[9,12,15]

CONCLUSION

This prospective observational study establishes that maintaining the postoperative NSA within the physiological range of 125°–135° significantly correlates with improved functional outcomes, as measured by the Harris Hip Score, following internal fixation of intertrochanteric femur fractures. NSA is an independent predictor of recovery, highlighting the importance of achieving accurate anatomical alignment intraoperatively. CRIF and PFNA2 were associated with more consistent outcomes. Restoration of appropriate NSA should be prioritized to enhance recovery, particularly in elderly patients. Further multicenter studies with long-term follow-up and objective bone quality assessments are warranted to validate these findings and refine surgical protocols.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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