Original Article

Femoral Neck System Fixation in Young Adults: A Prospective Cohort Analysis of Functional and Radiological Outcomes

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Abstract

Background: Femoral neck fractures in young adults pose a significant challenge due to high shear forces and the need for head-preserving fixation. Conventional methods are associated with complications such as non-union and avascular necrosis. The Femoral Neck System (FNS) has been developed to provide improved biomechanical stability and minimally invasive fixation. **Material and Methods:** This prospective single-centre cohort study included 15 adults (20 to 60 years) with acute femoral neck fractures treated with FNS between March 2023 and March 2025. Patients underwent standardized surgical fixation and postoperative rehabilitation. Functional outcomes were assessed using the Harris Hip Score (HHS), while radiological union was evaluated through serial radiographs and CT imaging up to 18 months. Statistical analysis was performed using SPSS, with significance set at $p<0.05$. **Results:** The mean age was 37.6 ± 9.1 years, with road traffic accidents being the most common mechanism (60%). Radiological union was achieved in 86.7% of patients at a mean of 14.1 ± 6.2 weeks. Mean HHS improved significantly from 68.3 at 6 weeks to 87.7 at 18 months ($p<0.001$), with 80% achieving excellent or good outcomes. No significant associations were found between outcomes and demographic or fracture variables, though earlier surgery showed a trend toward better results. **Conclusion:** FNS provides reliable fixation with favourable functional and radiological outcomes in young adults with femoral neck fractures, including unstable patterns. It represents an effective head-preserving strategy; however, larger comparative studies with longer follow-up are needed to confirm its long-term superiority.

Keywords: Femoral Neck System (FNS); Femoral Neck Fracture; Internal Fixation; Harris Hip Score (HHS); Pauwels Classification; Young Adults.

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Introduction

Femoral neck fractures account for approximately 3.6% of all the fractures and 53% of the hip fractures, predominantly affecting the elderly following low-energy falls, but also occurring in younger adults (<60 years) due to high-energy mechanisms such as road traffic accidents (RTAs).[1] In this younger demographic, head-preserving internal fixation is favoured over arthroplasty to maintain native hip biomechanics and function. However, conventional fixation methods including cannulated cancellous screws (CCS) and dynamic hip screws (DHS) are associated with considerable complication rates, with avascular necrosis (14.3%) and non-union (9.3%) reported, particularly in vertically oriented and unstable Pauwels type II/III fracture patterns characterized by high shear forces.[2]

The Femoral Neck System (FNS), a contemporary minimally invasive implant comprising a locking plate, central neck bolt, and anti-rotation screw, has demonstrated improved biomechanical stability by enhancing resistance to torsional stress and varus collapse compared to traditional constructs.[3] This prospective study evaluates the functional and radiological outcomes of FNS fixation in 15 adults aged 20 to 60 years managed at a tertiary trauma centre between March 2023 and 2025, aiming to address the need for reliable head-preserving strategies in young active patients.

Materials and Methods

This prospective single-center cohort study included 15 adult patients (aged 20 to 60 years) presenting with acute femoral neck fractures and treated with the FNS between March 2023 and March 2025 at a tertiary trauma centre. Institutional ethical approval was obtained and the informed consent was secured from all participants. Simple random sampling was employed and the sample size was calculated as 15 based on an assumed prevalence of 1%, confidence interval of 95% and margin of error of about 5%. Inclusion criteria comprised medically fit adults with closed femoral neck fractures. Patients aged <20 or >60 years, those with open or pathological fractures and individuals with significant comorbidities (including diabetes mellitus, HIV, tuberculosis or malignancy) were excluded.

Preoperative evaluation included baseline functional assessment

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using the Harris Hip Score (HHS), detailed clinical examination (including Trendelenburg test and limb length assessment) and routine laboratory investigations (complete blood count, renal and liver function tests, random blood sugar/HbA1c and serology). Radiological assessment included anteroposterior (AP) pelvis with both hips, AP and lateral views of the affected hip along with computed tomography (CT) of the pelvis with three-dimensional reconstruction.

All procedures were performed under spinal anaesthesia with the patient positioned supine on a traction table. Closed reduction was achieved using standard techniques (Leadbetter, Flynn or modified Flynn), with adequacy confirmed intraoperatively using fluoroscopy based on Lowell's criteria and a Garden alignment index ≤180. A lateral incision of approximately 5 cm was used for implant insertion. Guidewires were placed for both the central neck bolt and anti-rotation screw, followed by sequential reaming and insertion of the FNS assembly (neck bolt, side plate, locking screw and anti-rotation screw). A single-hole plate was used in most cases, with a two-hole plate utilized in selected patients; the mean bolt length was 89.7 mm. Prophylactic intravenous antibiotics (third-generation cephalosporin with aminoglycoside) and thromboprophylaxis (in high-risk patients) were administered. Postoperatively, patients received intravenous antibiotics and analgesics as per protocol. Early rehabilitation was initiated on postoperative day one, including knee range-of-motion exercises and quadriceps strengthening. Toe-touch weight-bearing was allowed at six weeks, progressing to full weight-bearing by three months depending on radiological and clinical progression.

Patients were followed up at 6 weeks and subsequently at 6 and 18 months. Serial radiographs (AP and lateral views) were obtained to assess fracture union, defined as bridging callus across at least three of four cortices with trabecular continuity [Figure 1]. Computed tomography was performed at 18 months for further evaluation [Figure 2]. Functional outcomes were assessed using the HHS at each follow-up visit [Figure 3]. Statistical analysis was performed using SPSS version 22. Continuous variables were expressed as mean ± standard deviation and categorical variables were analysed using Chi-square test and ANOVA. A p-value <0.05 was considered statistically significant.

Results

A total of 15 patients underwent FNS fixation, with a mean age of 37.6 ± 9.1 years (range 22 to 52 years) and a mean BMI of 22 ± 2.3 kg/m² [Table 1]. The cohort was predominantly male (73.3%, n=11), with the left hip involved in 53.3% (n=8). RTAs were the most common mechanism of injury (60%, n=9), followed by self-falls (40%, n=6). According to Pauwels classification, 40% (n=6) were Type I, 33.3% (n=5) Type II and 26.7% (n=4) Type III fractures.

The mean interval from injury to surgery was 2.3 ± 1.0 days (range 1 to 4 days). Operative time ranged between 52.5 ± 4.2 minutes (range 45 to 60 minutes), with an average intraoperative blood loss of 62 ± 8 ml (range 50 to 75 mL). The mean duration of hospital stay was 4.3 ± 1.2 days (range 3 to 6 days). The average FNS bolt length was 89.7 ± 4.4 mm (range 80 to 95 mm) and the mean incision length was 5.3 ± 0.7 cm (range 4.5 to 6.5 cm), shown in [Table 2].

Radiological union was achieved in 86.7% of cases (13/15) at a mean duration of 14.1 ± 6.2 weeks (range 12 to 20 weeks), defined by bridging callus across at least three cortices and restoration of trabecular continuity, with confirmation on CT imaging at 18 months. Functional outcomes, assessed using the HHS, showed significant improvement over time, increasing from 68.3 ± 8.3 at 6 weeks (range 55 to 80) to 84.1 ± 9.4 at 6 months and 87.7 ± 8.1 at 18 months (range 67 to 97), which was statistically significant (ANOVA, p<0.001). Based on final HHS grading, outcomes were excellent in 40% (n=6), good in 40% (n=6), fair in 13.3% (n=2) and poor in 6.7% (n=1), shown in [Table 3].

No statistically significant associations were observed between functional outcomes and variables such as age, side of involvement, mechanism of injury or Pauwels classification. However, a trend toward better functional outcomes was noted in patients who underwent surgery within two days of injury [Table 4].

Table 1: Baseline Demographic and Injury Characteristics of the Study Cohort

Parameter	Category/mean ± SD	N (%) or range
Age (years)	37.6 ± 9.1	22-52
Gender	Male	11 (73.3)
	Female	4 (26.7)
Side of injury	Right	7 (46.7)
	Left	8 (53.3)
Mode of injury	RTA	9 (60.0)
	Self-fall	6 (40.0)
BMI (kg/m²)	22 ± 2.3	18-26
Injury to surgery (days)	2.3 ± 1.0	1-4
Pauwels type	Type I	6 (40.0)
	Type II	5 (33.3)
	Type III	4 (26.7)

Table 2: Perioperative and Surgical Parameters

PARAMETER	MEAN ± SD	RANGE
FNS bolt size (mm)	89.7 ± 4.4	80-95
Incision length (cm)	5.3 ± 0.7	4.5-6.5
Hospital stay (days)	4.3 ± 1.2	3-6

Blood loss (mL, mode)	50-75	25-100
Operative time (min)		45-60

Table 3: Functional Outcomes Based on Harris Hip Score (HHS) Over Follow-up.

Outcome measure	6 weeks	6 months	18 months
HHS (mean ± SD)	68.3 ± 8.3	84.1 ± 9.4	87.7 ± 8.1
Excellent (90-100)	'-	'-	6 (40.0)
Good (80-89)	'-	'-	6 (40.0)
Fair (70-79)	'-	'-	2 (13.3)
Poor (<70)	'-	'-	1 (6.7)
ANOVA p-value	'-	'-	<0.001

Table 4: Subgroup Analysis of Functional Outcomes (HHS) at Final Follow-up.

Subgroup	Excellent	Good	Fair	Poor	P-value
Male	5	4	1	1	0.72
Female	1	2	1	0	
Right side	3	3	1	0	0.89
Left side	3	3	1	1	
RTA	4	3	1	1	0.65
Self-fall	2	3	1	0	
Surgery <2 days	5	3	1	0	0.08

Discussion

Femoral neck fractures constitute a significant orthopaedic burden, accounting for approximately 3.6% of all fractures and over half of hip fractures worldwide, with an estimated 1.31 million new cases annually contributing substantially to morbidity, mortality and disability-adjusted life years.[1,2] Although these injuries predominantly affect the elderly population due to osteoporosis and low-energy mechanisms, high-energy trauma contributes to a considerable proportion of cases in younger adults (<60 years), accounting for up to 50% of injuries. These are commonly associated with road traffic accidents (RTAs) or falls from height, which is consistent with the present cohort demonstrating a mean age of 37.6 years and a male predominance (73.3%).[4-6] Our findings, demonstrating a mean age of 37.6 ± 9.1 years with a male predominance of 73.3%, was consistent with this evolving epidemiological pattern. This demographic shift underscores the increasing clinical relevance of femoral neck fractures in young, active patients, in whom preservation of the native femoral head is paramount. Accordingly, there is a growing emphasis on stable, head-preserving fixation strategies capable of withstanding higher biomechanical demands while minimizing the need for early arthroplasty and its associated long-term limitations.[7]

RTAs were the predominant mechanism of injury in our cohort (60%), consistent with existing literature reporting high-energy trauma in approximately 50% to 70% of femoral neck fractures among individuals younger than 60 years. Such mechanisms, particularly motor vehicle collisions, generate significant vertical shear forces and are frequently associated with unstable Pauwels type II and III fracture patterns.2,4,5,6 Self-falls accounted for 40% of cases and likely reflect injuries sustained in domestic or occupational settings among active individuals, a trend increasingly recognized in developing regions experiencing a parallel rise in both urbanization and trauma incidence.[1,8] This distribution highlights the dual challenge of addressing high-velocity trauma in a predominantly young male population, which reflected in our cohort with 73.3% males, while also underscoring the importance of preventive strategies alongside the optimization of fixation techniques for these biomechanically demanding fracture patterns.[9]

Delayed surgical intervention in femoral neck fractures is a well-recognized risk factor for adverse outcomes, particularly avascular necrosis (AVN) and non-union, largely due to disruption of femoral head vascularity, thrombosis of retinacular vessels and impaired revascularization. Meta-analyses have demonstrated a 2 to 3-fold increase in reoperation rates, exceeding 30%, when fixation is delayed beyond 7 days compared to early intervention.[10,11] Early surgery, ideally within 24 to 36 hours has been advocated, especially in younger patients with displaced fractures, to preserve femoral head perfusion and minimize ischemic complications.[12,13] However, emerging evidence from cohort studies in resource-constrained settings suggests that acceptable outcomes can still be achieved when surgery is performed within a broader window (<7 days), provided that anatomical reduction and stable fixation are attained, thereby emphasizing the relative importance of reduction quality over strict adherence to timing alone. In our study, the mean injury-to-surgery interval was 2.3 ± 1.0 days. Patients operated within 2 days demonstrated a trend toward superior functional outcomes, reflected by higher HHS, although this did not reach statistical significance (p=0.08). These findings are consistent with reports from similar settings and support the clinical feasibility and effectiveness of FNS fixation even in the presence of modest, system-related delays.

The Pauwels classification stratifies femoral neck fractures based on the inclination angle of the fracture line and the corresponding magnitude of shear forces, with Type I (<300) considered relatively stable, Type II (300 to 500) exhibiting intermediate instability and Type III (>500) representing highly unstable, vertically oriented fractures prone to fixation failure.[2,14] Compared to the Garden classification, Pauwels classification provides superior prognostic value in assessing biomechanical stability and guiding implant selection, particularly in younger patients with high-energy injuries. Angular-stable constructs such as the FNS have demonstrated

improved outcomes in unstable patterns, with reported union rates of 80% to 90% in Pauwels Type III fractures compared to approximately 70% with conventional cannulated cancellous screws (CCS).[15,16] Furthermore, recent finite element analyses have shown that Pauwels Type III fractures are subjected to nearly twice the mechanical stress of lower-grade fractures, reinforcing the importance of classification-based fixation strategies. In the present study, the distribution of fracture types; Type I (40%), Type II (33.3%) and Type III (26.7%) is consistent with patterns observed in young, high-energy trauma cohorts. The overall union rate of 86.7% across all fracture types highlights the effectiveness of FNS fixation, particularly in managing unstable fracture configurations.

The FNS has demonstrated favourable peri-operative characteristics, including shorter operative times, minimal blood loss and limited surgical exposure, attributable to its minimally invasive design and streamlined instrumentation. Reported operative durations typically range from 45 to 60 minutes, with intraoperative blood loss often <100 mL and incision lengths averaging approximately 5 cm. These parameters compare favourably with conventional devices such as the dynamic hip screw (DHS), which generally require longer operative times (60 to 90 minutes) and are associated with higher blood loss (100 to 150 mL).[7,17] Additionally, shorter hospital stays (approximately 4 to 5 days) reflect the benefits of early mobilization and reduced surgical morbidity. The relatively lower fluoroscopy requirements and technical simplicity of FNS further enhance its applicability, particularly in resource-constrained settings. Collectively, these factors contribute to reduced infection risk, improved peri-operative efficiency and overall cost-effectiveness, as supported by recent comparative studies and meta-analyses.3,8 In the present study, the mean operative time (52.5 ± 4.2 minutes), average blood loss (62 ± 8 mL) and mean hospital stay (4.3 ± 1.2 days) are consistent with, and in some instances comparable or superior to, previously reported benchmarks. These findings support the reproducibility and feasibility of FNS fixation within the context of a high-volume trauma setting.

Serial radiographic assessment, supplemented by CT, has demonstrated union rates of approximately 85% to 95% with FNS fixation, typically achieved within 12 to 16 weeks. Radiological union is defined by the presence of bridging callus across cortices and restoration of trabecular continuity, which remain the gold standard indicators of healing. These outcomes are particularly favourable in vertically oriented, shear-prone fractures, where the angular stability of FNS provides a biomechanical advantage over conventional constructs such as CCS.[3,18] The quality of reduction remains a critical determinant of success, with a postoperative Garden alignment index ≤180° associated with lower failure rates (<10%). Furthermore, the adjunctive use of CT imaging at extended follow-up (e.g., 1.5 years) enhances the detection of subtle complications such as delayed union, non-union or early avascular necrosis, which may not be apparent on plain radiographs alone.[13,19] Recent multi-center studies have reported union rates of 90% to 98% at one year following FNS fixation, further supporting its reliability across diverse clinical settings. In the present study, a union rate of 86.7% was achieved at a mean duration of 14.1 ± 6.2 weeks, with confirmation on CT imaging at 18 months. These findings are comparable to high-performing series (e.g., Stoffel et al. reporting union rates approaching 98%) and reinforce the effectiveness of FNS in achieving consistent fracture healing across varying Pauwels fracture patterns in a young adult population.[3]

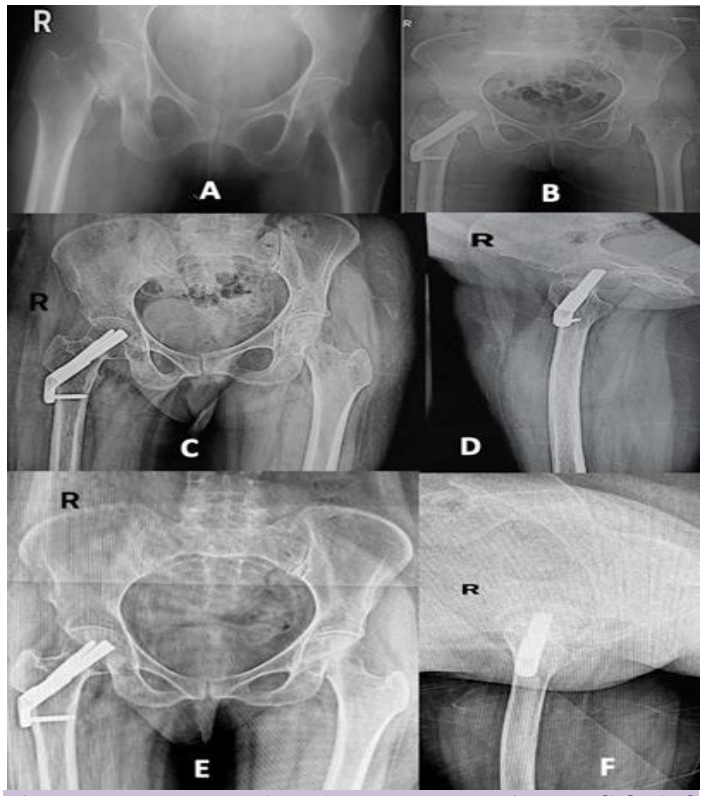

Figure 1: Representative Case Demonstrating Radiological Progression Following FNS Fixation: Preoperative radiograph (A) demonstrating a Pauwels Type III femoral neck fracture. Immediate postoperative radiograph at 6 weeks (B) following fixation with the Femoral Neck System (FNS). Follow-up radiographs at 6 months (C, D) and 18 months (E, F) illustrate progressive fracture healing with maintained alignment and implant position.

The HHS remains a validated and widely used tool for assessing functional recovery following femoral neck fracture fixation. Contemporary literature reports excellent to good outcomes (HHS >80) in approximately 70% to 90% of patients at 1 to 2 years with modern implants such as the FNS, often surpassing results achieved with conventional constructs like CCS, likely due to improved biomechanical stability and preservation of native hip kinematics.[7,17,20,21] Progressive improvement in HHS, from early postoperative values around 60 to final scores approaching 85 to 90 reflects effective pain relief, restoration of gait and recovery of range of motion, closely correlating with union rates exceeding 85%.[18,22] Moreover, sustained HHS values above 85 have been associated with lower revision rates (<10%) in long-term follow-up. In the present study, a steady improvement in functional outcomes was observed, with mean

HHS increasing from 68.3 at 6 weeks to 87.7 at 18 months and 80% of patients achieving excellent or good results. These findings are comparable to high-quality series reported in the literature, reinforcing the ability of FNS fixation to deliver consistent and favourable functional outcomes, even in a relatively young, high-energy trauma population.

This study has several limitations that merit consideration. Firstly, the relatively small sample size, derived from a single tertiary care centre limits external validity and reduces the statistical power to detect meaningful subgroup differences. Secondly, the absence of a comparator cohort treated with alternative fixation modalities, such as CCS or a DHA precludes direct assessment of the relative efficacy and biomechanical advantages of the FNS. Third, although the follow-up duration was sufficient to evaluate early fracture union and functional recovery, it may be inadequate to capture late complications, including avascular necrosis, femoral neck shortening and implant failure, which may manifest beyond 18 months. Finally, inherent to observational study designs, the possibility of residual confounding cannot be excluded; variables such as fracture morphology, quality of reduction and surgeon expertise may have influenced the observed outcomes.

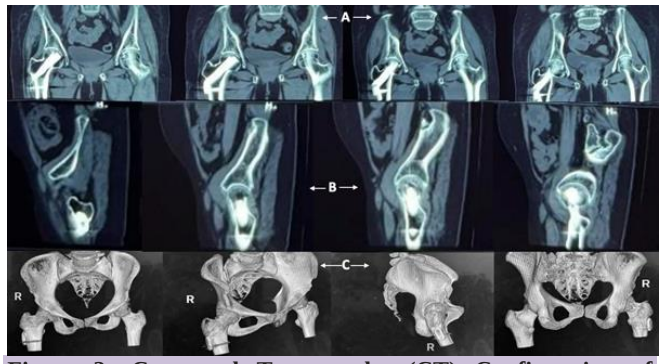

Figure 2: Computed Tomography (CT) Confirmation of Fracture Union: CT images at final follow-up demonstrating radiological union, with evidence of trabecular continuity and cortical bridging across the fracture site. Coronal view (A), sagittal view (B) and three-dimensional reconstructed image (C) confirm consolidation of the femoral neck fracture following FNS fixation.

Figure 3: Functional Outcome Assessment at Final Follow-up (18 Months): Clinical photographs demonstrating range of motion and functional recovery at 18 months postoperatively. Hip flexion (A), abduction and adduction (B, C), and external and internal rotation (D, E) are shown, reflecting satisfactory restoration of hip mobility following FNS fixation.

Conclusion

In this prospective single-centre study, fixation of femoral neck fractures using the FNS in young and middle-aged adults demonstrated favourable radiological and functional outcomes, with a high union rate (86.7%) and significant improvement in HHS over time. The implant showed reliable performance across varying fracture patterns, including biomechanically challenging Pauwels type II and III configurations, while maintaining the advantages of a minimally invasive approach with low blood loss, shorter operative time and early mobilisation. These findings support the FNS as an effective head-preserving fixation strategy in young and active patients, offering stable construct biomechanics and consistent clinical recovery. The observed trend toward improved outcomes with earlier surgical intervention further reinforces the importance of timely management alongside optimal reduction and fixation. However, given the study's limitations, including small sample size, lack of a comparative cohort and relatively short follow-up, these results should be interpreted with caution. Larger, multi-centre randomized studies with longer follow-up are warranted to validate these findings, compare FNS with established fixation methods and better define its role in preventing long-term complications such as avascular necrosis and fixation failure.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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