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Optimal sliding distance in femoral neck system for displaced femoral neck fractures: a retrospective cohort study

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Abstract

Background Displaced femoral neck fractures frequently result in considerable patient morbidity, with complications such as postoperative femoral neck shortening occurring in up to 39.1% of cases. This shortening is associated with reduced hip function and mobility. The Femoral Neck System (FNS), which allows for controlled sliding to facilitate fracture reduction and healing, may mitigate these issues. However, the ideal sliding distance to balance fracture healing and minimize complications is not well defined.

Methods We performed a retrospective cohort study of 179 patients who underwent FNS fixation for displaced femoral neck fractures at our institution from September 2019 to September 2023. Patients were categorized into three groups based on the intraoperative sliding distance allowed by the FNS: the Minimal Slide group (≤ 5 mm), the Moderate Slide group (> 5 to ≤ 10 mm), and the Extensive Slide group (> 10 to 20 mm). Primary outcomes included postoperative femoral neck shortening, the incidence of moderate to severe shortening, time to fracture union, and hip joint function as assessed by the Harris Hip Score (HHS) and the Parker Mobility Score. Secondary outcomes included complication rates such as implant cut-out, nonunion, avascular necrosis of the femoral head, and the need for secondary surgery.

Results The Extensive Slide group of moderate to severe shortening at 32.31%, which was 1.59-fold and 8.88-fold that of the Moderate Slide (20.34%) and Minimal Slide group's (3.64%), respectively ($P < 0.01$). The sliding predominantly occurred within the first three months postoperatively and had substantially ceased by six months. At one year postoperatively, the median shortening was 2.7 mm (IQR, 0.7 to 3.5 mm) for the Minimal Slide group, a value that was notably lower compared to the 3.2 mm (IQR, 2.4 to 4.6 mm) for the Moderate Slide group and the 3.5 mm (IQR, 1.3 to 8.1 mm) for the Extensive Slide group. The average time to achieve union was similar across all groups, with no significant differences. Functional outcomes, as assessed by the Harris Hip Score (HHS) and the Parker Mobility

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Score, the Harris Hip Score (HHS) demonstrated statistical significance, the Parker Mobility Score did not reach statistical significance.

Conclusions Restricting FNS slide to ≤ 5 mm in surgery may reduce shortening, improve hip function, and not hinder fracture healing or implant stability. Considering the key 3-month sliding timeline postoperatively is advisable in clinical practice. Further research with a broader patient cohort is vital to confirm these findings and to anchor them in evidence-based practice.

Keywords Femoral Neck fractures, Femoral Neck System, Sliding Distance, Internal fixation, Postoperative shortening

Femoral neck fractures are a prevalent type of orthopedic injury, constituting approximately 3.58% of all fracture cases in China [1], with a subset occurring in young adults as a result of high-energy traumas that often lead to displacement [2–4]. The incidence of secondary surgeries following internal fixation for these fractures can reach up to 20% [5], highlighting the ongoing challenges in their treatment. Currently, there is widespread concern about postoperative complications such as fracture nonunion and avascular necrosis of the femoral head, but there is insufficient attention paid to the early occurrence of femoral neck shortening [6].

The Femoral Neck System (FNS) debuted in 2017 [7], a novel internal fixation technique for femoral neck fractures, the number of FNS implants has been steadily increasing, attracting growing attention. Additionally, complications that may arise require our attention as well. Through the sliding mechanism, it promotes healing. However, studies report a significant risk of moderate to severe femoral neck shortening postoperatively, affecting 23.3–39.1% [8, 9]. This shortening correlates with poor fracture consolidation and can lead to gait changes, increased pain, and reduced hip function [8, 9]. Therefore, minimizing postoperative shortening is vital for patient outcomes. Determining the ideal shortening threshold to balance healing and avoid excessive shortening is an ongoing research challenge.

In displaced fractures with cortical comminution, the lack of resistance to shortening necessitates internal fixation for stability. The Femoral Neck System (FNS), however, may be inadequate in preventing shortening due to the absence of an anti-shortening mechanism. Strategies such as anti-shortening screws [8] and the pre-collapse technique [9] have been proposed to address this. Despite Lin's pre-collapse technique, which reduces the risk of significant shortening, a 13% incidence persists [9], underscoring the need for research on the effects of sliding distance variations on clinical outcomes.

This retrospective study examines the impact of varying sliding distances on the prognosis of young adults with displaced femoral neck fractures, correlating optimal sliding distances with fracture healing times and complications. We hypothesize that constraining the sliding distance of the FNS rod may reduce postoperative femoral neck shortening, enhancing hip function and quality of life, while also assessing the safety and ideal reduction in sliding distance.

Study design

We conducted a retrospective cohort study to evaluate the effect of varying sliding distances in the FNS on postoperative femoral neck shortening following internal fixation in young and middle-aged adults with displaced femoral neck fractures. The study included patients aged 18 to 65 years who were treated with the FNS at the Fuzhou Second General Hospital between September 2019 and September 2023. Patients were categorized into three groups based on the intraoperative measurement of FNS sliding distance: the Minimal Slide group (≤5 mm), the Moderate Slide group (>5 to ≤10 mm), and the Extensive Slide group (>10 to 20 mm). The primary aim was to assess differences in the incidence of postoperative femoral neck shortening, time to fracture union, hip function scores, and complication rates across the groups. Ethical approval was obtained from the hospital's review board, and the study was conducted in accordance with the Helsinki Declaration [10]. Informed consent was waived due to the retrospective nature of the study. This report adheres to the STROBE guidelines for observational studies [11, 12].

Inclusion and exclusion criteria

Eligibility for the study was determined by the following criteria: age between 18 and 65 years, unilateral femoral neck fracture, treatment with the FNS, and a minimum 12-month follow-up. Patients were excluded for multiple fractures, pathological fractures, surgery delay more than 2 weeks post-injury, poor reduction quality (Garden Index : III or IV), congenital hip dysplasia, pre-existing hip dysfunction (e.g., due to polio or amputation on the ipsilateral side), and incomplete follow-up data.

Patient demographics

In this study, we evaluated a cohort of 179 individuals, with 114 males (63.7%) and 65 females (36.3%). The mean BMI was 23.57 (±0.29). The prevalence of non-smokers was 161 (90.1%), and non-drinkers was 159 (89.4%). High-energy injuries accounted for 117 (65.3%) of the cases, with right-side injuries present in 95 (53.0%). Garden IV type fractures were identified in 115 (64.2%), and Pauwels III type fractures in 65 (36.3%). Cortical comminution was observed in 123 (68.7%) of the fracture cases.

All procedures were conducted by experienced orthopedic surgeons, each with an annual caseload of over 10 femoral neck fractures and a minimum of five years of specialized surgical expertise, ensuring uniformity and standardization in the surgical techniques employed. To guarantee the precision and dependability of the data gathered, a rigorous training program was implemented for all personnel involved in data collection. This training encompassed a thorough review of the research protocol, standardized methodologies for data documentation, and consistent criteria for radiological evaluation.

To maintain objectivity, assessments were independently conducted by a team of orthopedic trauma surgeons, not the operating surgeons, to prevent potential bias. In instances of multiple evaluators, a consensus meeting resolved any discrepancies, with all reviewers examining imaging data and reaching a unified decision for documentation.

Surgical procedure

Under general anesthesia, the surgical procedure involved positioning patients supine with the healthy hip flexed and abducted to facilitate surgical access. Precision fracture reduction [13] was achieved using C-arm fluoroscopy, followed by the strategic placement of two Kirschner wires for provisional fixation along the femoral neck axis. A guide pin was meticulously inserted through a minimally invasive lateral proximal approach, aligned with the femoral neck axis, and advanced to a depth just beneath the subchondral plate of the femoral head, confirmed by fluoroscopic imaging. The hole was then reamed, and a bolt was selected, ideally 5 to 15 mm longer than the measured depth, to accommodate the pre-collapse technique(Fig. 1), which is central to the methodology of this study. This technique, involving the assembly of the bolt and plate within the Femoral Neck System (FNS), ensures optimal fit and function by reducing the bolt's travel within the plate's slot. The bolt was then implanted over the guide pin, preceded by the placement of locking and anti-rotation screws. A final fluoroscopic assessment confirmed the accurate positioning of the hardware and the quality of fracture reduction. The integrity of the fracture site and the efficacy of the sliding mechanism were evaluated. The surgical incision was meticulously closed in layers and sutured once hemostasis was secured.

Perioperative management and follow-up

All patients underwent comprehensive preoperative assessment, including blood tests, electrocardiograms, to ensure surgical tolerance. Preoperative preparations included the administration of prophylactic antibiotics and implementation of deep vein thrombosis prophylaxis. Postoperative pain management was achieved through a multimodal analgesia protocol, including patient-controlled analgesia. Patients also received low molecular weight heparin for thromboprophylaxis until full mobility was restored. Early postoperative mobilization was encouraged, with bed exercises and lower limb muscle training to promote circulation and reduce complications. Partial weight-bearing was initiated at 6–8 weeks postoperatively, under the guidance of a rehabilitation physician, based on fracture healing observed on follow-up radiographs, progressing to full weight-bearing. Postoperative follow-ups were scheduled at 1 month, 3 months, 6 months, 1 year, and 2 years, with clinical assessments and imaging studies to evaluate patient recovery. All data were collected by trained researchers.

Observational indicators

Baseline data collection included patient demographics such as age, gender, body mass index (BMI), smoking and drinking history, mechanism of injury, affected side, and fracture type. Surgical indicators included preoperative waiting time, traction use, reduction methods, intraoperative blood loss, and surgical duration, providing detailed patient background information for subsequent analysis.

Primary outcome measures

Postoperative femoral neck shortening and the incidence of moderate to severe shortening were assessed using the Zlowodzki method [14]. This involved measuring the femoral head's shortening in the horizontal (X-axis) and vertical (Y-axis) directions on a bilateral hip anteroposterior radiograph. The axial shortening distance of the femoral neck (Z) was calculated using the formula: $Z = Y \times \sin(\theta) + X \times \cos(\theta)$, where θ is the angle between the Y-axis and the femoral neck axis. Shortening was categorized as mild (<5 mm), moderate (5–10 mm), or severe (>10 mm).

Secondary outcome measures

The Tip-Apex Distance (TAD) [9] was determined by measuring the distance from the bolt tip (Tip) to the apex of the intersection between the femoral head-neck junction and the joint surface (Apex) on both anteroposterior (Xap) and lateral (Xlat) views. The actual bolt width (Dtrue) and the bolt width measured on X-ray (Dap and Dlat) were measured, and a magnification factor was calculated. The TAD value was calculated using the formula: $TAD = Xap \times (Dtrue/Dap) + Xlat \times (Dtrue/Dlat)$.

Reduction quality

The Garden Index [15] was assessed using anteroposterior and lateral hip radiographs. Garden Index I with an AP angle of 160° and lateral angle of 180° for optimal alignment; Garden Index II at 155° AP and 180° lateral for good alignment; Garden Index III with an AP angle below 155° or a lateral angle above 180°, indicating the potential need for surgical intervention; and Garden Index IV at 150° AP and over 180° lateral, reflecting significant displacement. We highlight that grades III and IV are associated with an elevated risk of femoral head necrosis, advocating for more aggressive treatment strategies.

The Gotfried evaluation system [16] categorized reduction quality based on the relative position of the medial cortex of the fracture fragment and the distal medial cortex of the femoral shaft. Reductions were classified as anatomic, positive support, or negative support, with negative support being the least desirable due to its structural instability.

Functional assessment

Harris Hip Score [17]: Hip joint function was evaluated based on four aspects: range of motion, function, pain, and deformity, with a maximum of 100 points for each aspect, totaling 400 points. Hip joint function was classified as excellent (90–100 points), good (80–89 points), fair (70–79 points), and poor (70 points or below).

Parker Score [18]: The Parker activity score scale assessed hip joint function on a scale from 0 to 9, with 9 points indicating the patient's ability to independently perform all daily activities and 0 points indicating complete dependence on others.

Complications and reoperations

Postoperative complications, including deep incisional infections, implant cutout, implant loosening [19], nonunion [20], and avascular necrosis of the femoral head [21], were recorded and assessed by two attending physicians based on clinical observations and imaging study results.

Statistical analysis

All statistical analyses were conducted using IBM SPSS, version 27. Prior to the analysis, data were screened for normality using the Shapiro-Wilk test. Continuous variables, such as age, BMI, and surgical time, were reported as mean ± standard deviation (SD) and were compared across the three groups using one-way ANOVA, with post-hoc pairwise comparisons performed using Tukey's HSD test. Non-parametric continuous variables, including shortening distance and bleeding, were analyzed using the Kruskal-Wallis test, followed by Dunn's test with Bonferroni correction for pairwise comparisons. Categorical variables, such as sex, smoking status, and drinking status, were compared using the Chi-square test or Fisher's exact test where appropriate. The incidence of complications was analyzed using binary logistic regression, adjusting for potential confounders. For the primary outcome of femoral neck shortening, we utilized mixed-model ANOVA to account for the repeated measures (shortening distance at different time points) and to compare the changes over time and between groups. The secondary outcomes, including the Harris Hip Score (HHS) and the Parker Mobility Score, were analyzed using a two-way ANOVA to assess the interaction effects between groups and time points. The level of statistical significance was set at $\alpha = 0.05$ for all tests. All reported p-values were two-tailed, and confidence intervals (CI) were calculated at the 95% level.

Result

Baseline characteristics

The study cohort consisted of 55 patients in the Minimal Slide group (≤5 mm), 59 in the Moderate Slide group (>5 to ≤10 mm), and 65 in the Extensive Slide group (>10 to 20 mm), all diagnosed with femoral neck fractures. A thorough analysis of baseline characteristics—such as age, gender distribution, Body Mass Index (BMI), smoking and alcohol consumption habits, mechanism of injury, side of injury, Garden and Pauwels classifications, presence of cortical comminution, surgical duration, intraoperative blood loss, Tip-Apex Distance (TAD), and time to union—revealed no significant differences among the groups. This baseline equivalence is crucial for the validity of subsequent comparative analyses. The mean age was 45.95, 49.14, and 49.28 years, with male representation at 64.55%, 57.63%, and 69.23%, and female at 35.45%, 42.37%, and 30.77%. The average BMI values were 23.95, 23.68, and 23.09, respectively (Table 1).

Primary outcome measures

The extent of postoperative femoral neck shortening was a pivotal outcome and exhibited significant variation among the three study groups, with the Minimal Slide group demonstrating the most favorable results in terms of minimal shortening. On the first postoperative day, the median shortening was 0.0 mm (IQR: 0.0, 0.7 mm) for the Minimal Slide group, 0.1 mm (IQR: 0.0, 2.0 mm) for the Moderate Slide group, and 0.4 mm (IQR: 0.0, 2.7 mm) for the Extensive Slide group, with no initial statistical significance noted ($P = 0.165$). However, by the one-year mark, the Minimal Slide group showed a significantly lower median shortening of 2.7 mm (IQR: 0.7, 3.5 mm) compared to the Moderate Slide group at 3.2 mm (IQR: 2.4, 4.6 mm) and the Extensive Slide group at 3.5 mm (IQR: 1.3, 8.1 mm), with P-values below 0.05 indicating statistical significance (Table 2). The sliding predominantly

Table 1 Comparison of demographic and Perioperative Data among three groups

Groups		**Minimal Slide Group (*n* = 55)**	**Moderate Slide Group (*n* = 59)**	**Extensive Slide Group (*n* = 65)**	**Test statistic**	***P*-value**
Age	$(\bar{x}\pm s)$	45.95 ± 2.06	49.14 ± 1.65	49.28 ± 1.51	1.14	0.322
Sex	Man	35 (64.55%)	34 (57.63%)	45 (69.23%)	1.801	0.406
	Woman	20 (35.45%)	25 (42.37%)	20 (30.77%)		
BMI	$(\bar{x}\pm s)$	23.95 ± 0.32	23.68 ± 0.32	23.09 ± 0.24	2.246	0.109
Smoking	No	51 (92.73%)	52 (88.14%)	58 (89.24%)	0.721	0.697
	Yes	4 (7.27%)	7 (11.86%)	7 (10.77%)		
Drinking	No	48 (87.27%)	54 (91.53%)	57 (87.74%)	0.651	0.722
	Yes	7 (12.73%)	5 (8.47%)	8 (12.26%)		
Mechanism of injury	Low energy	23 (41.82%)	19 (32.2%)	20 (30.77%)	1.837	0.399
	High energy	32 (58.18%)	40 (67.8%)	45 (69.23%)		
Side of Injury	Left	26 (47.27%)	33 (55.93%)	25 (38.46%)	3.794	0.150
	Right	29 (52.73%)	26 (44.07%)	40 (61.54%)		
Garden Classification	Garden III	25 (45.45%)	19 (32.2%)	20 (30.77%)	3.28	0.194
	Garden IV	30 (54.55%)	40 (67.8%)	45 (69.23%)		
Pauwels Classification	Pauwels I	12 (21.82%)	20 (33.90%)	19 (29.23%)	2.277	0.685
	Pauwels II	20 (36.36%)	20 (33.90%)	23 (35.38%)		
	Pauwels III	23 (41.82%)	19 (32.2%)	23 (35.38%)		
Cortical Comminution	No	15 (27.27%)	22 (37.29%)	19 (29.23%)	1.529	0.466
	Yes	40 (72.73%)	37 (62.71%)	46 (70.77%)		
Time from injury to surgery (days)	M(Q1,Q3)	3.49 ± 0.23	3.97 ± 0.25	3.77 ± 0.19	1.118	0.329
Surgical time (min)	$(\bar{x}\pm s)$	60.33 ± 2.34	61.34 ± 2.29	61.80 ± 1.94	0.117	0.889
Bleeding (ml)	M(Q1,Q3)	42.64 ± 3.11	39.83 ± 2.65	43.00 ± 2.49	0.403	0.669
Reset Grading	Garden index I	40 (72.73%)	49 (83.1%)	57 (87.88%)	4.566	0.102
	Garden index II	15 (27.27%)	10 (16.9%)	8 (12.12%)		
Reduction Quality	Neutral **Support**	37 (67.27%)	40 (67.80%)	43 (66.15%)	2.175	0.704
	Positive Support	13 (23.64%)	17 (28.81%)	16 (24.62%)		
	Negative Support	5 (9.09%)	2 (3.39%)	6 (9.23%)		
TAD(mm)	$(\bar{x}\pm s)$	15.27 ± 7.58	16.45 ± 7.81	15.35 ± 5.45	0.527	0.591
Healing time (weeks)	M(Q1,Q3)	8.51 ± 0.43	8.22 ± 0.41	8.74 ± 0.36	2.277	0.085
Harris score	M(Q1,Q3)	91.95 ± 5.53	89.44 ± 6.74	88.74 ± 6.84	4.002	0.02
Parker score	M(Q1,Q3)	8.60 ± 0.564	8.44 ± 0.73	8.36 ± 0.65	1.748	0.131

Table 2 Comparison of femoral Neck Shortening among three groups

Groups		**Minimal Slide Group (*n* = 55)**	**Moderate Slide Group (*n* = 59)**	**Extensive Slide Group (*n* = 65)**	**Test statistic**	***P*-value**
Shortening distance(1 day, mm)	M(Q1,Q3)	0.0 (0.0, 0.7)	0.1 (0.0, 2.0)	0.4 (0.0, 2.7)	3.608	0.165
Shortening distance(3 month, mm)	M(Q1,Q3)	2.5 (0.7, 3.5)	3.1 (2.2, 4.6)	3.3 (1.3, 7.9)	8.274	0.016
Shortening distance(6 months, mm)	M(Q1,Q3)	2.6 (0.7, 3.5)	3.2 (2.4, 4.6)	3.4 (1.3, 8.1)	6.757	0.034
Shortening distance(1 year, mm)	M(Q1,Q3)	2.7 (0.7, 3.5)	3.2 (2.4, 4.6)	3.5 (1.3, 8.1)	6.76	0.034
Shortening grading(1 year)	Mild(>0,≤5 mm)	53 (96.36%)	47 (79.66%)	44 (67.69%)	17.998	<0.01
	Moderate(>5-≤10 mm)	2 (3.64%)	7 (11.86%)	8 (12.31%)		
	Severe(>10 mm)	0 (0%)	5 (8.47%)	13 (20.00%)		

occurred within the first three months postoperatively and had substantially ceased by six months.

Notably, the Extensive Slide group had the highest incidence of moderate to severe shortening at 32.31%, which was 1.59 times higher than the Moderate Slide group's rate of 20.34% and markedly higher at 8.88 times compared to the Minimal Slide group's rate of 3.64% ($P<0.01$).

Secondary outcome measures

In the assessment of secondary outcomes, no significant inter-group differences were noted in Tip-Apex Distance (TAD) values, Garden index, or the Gotfried assessment system for reduction quality. However, the Harris hip score, which evaluates hip joint functionality, showed statistically significant differences ($P<0.05$). The Minimal Slide group achieved the highest mean Harris score at 91.95 (±5.53), outperforming the Moderate Slide group with a score of 89.44 (±6.74) and the Extensive Slide group with 88.74 (±6.84). This suggests a superior recovery profile for hip joint function in the Minimal Slide group. Although the Parker mobility score, which measures the ability to perform daily activities, did not significantly differ among the groups, a slightly higher average score in the Minimal Slide group hints at a possible advantage of an optimized sliding distance in enhancing postoperative hip joint functionality (Table 1). Limiting the sliding distance of the Femoral Neck System (FNS) to no more than 5 mm during surgery may reduce postoperative shortening, improve hip function, and does not negatively impact fracture healing or implant stability. Recognizing that the majority of sliding occurs within the first three months postoperatively, and largely stops by six months, is crucial for guiding clinical decisions.

Detailed examination of complications

Upon analyzing the incidence of complications, the Minimal Slide group had a 1.8% rate of implant cut-out, in contrast to the Moderate Slide group with 0% and the Extensive Slide group with 3.1%. However, these differences were not statistically significant ($P=0.409$). The rate of nonunion was 1.8% for the Minimal Slide group, 3.4% for the Moderate Slide group, and 1.5% for the Extensive Slide group, with no significant variability observed ($P=0.76$). Avascular necrosis of the femoral head was observed at rates of 3.6%, 3.4%, and 4.6% across the respective groups, without reaching statistical significance ($P=0.933$). The need for secondary total hip arthroplasty was reported at 1.8%, 3.4%, and 1.5% for the Minimal Slide, Moderate Slide, and Extensive Slide groups, respectively, again without significant differences ($P=0.76$). These collective findings suggest that the variation in pre-collapse distance did not substantially affect the complication rates during the study period, supporting the safety and efficacy of employing a minimal pre-collapse strategy (Table 3).

Discussion

This study provides a comprehensive examination of the pre-collapse technique's role in mitigating postoperative shortening following the internal fixation of displaced femoral neck fractures with the Femoral Neck System (FNS). Our findings suggest that femoral neck shortening negatively impacts postoperative hip joint function, as reflected by the Harris score. By constraining the pre-collapse distance of the FNS, we were able to significantly reduce the incidence of moderate to severe shortening, with optimal results occurring when the pre-collapse distance was kept within 5 mm. This technique did not compromise the time to fracture healing or the stability of the internal fixation, aligning with literature that supports the pre-collapse technique's efficacy in curtailing postoperative shortening [9, 22, 23].

The impact of femoral Neck Shortening on fracture healing post-FNS fixation

Throughout the fracture healing process, it is observed that shortening distances typically worsen within the first three postoperative months and stabilize by six months [6, 9, 24], with minimal progressive shortening beyond this period. While some shortening can enhance fracture site stress and facilitate healing, moderate to

Table 3 Comparison of postoperative complication rates among three groups

Groups		Minimal Slide Group ($n=55$)	Moderate Slide Group ($n=59$)	Extensive Slide Group ($n=65$)	Test statistic	P-value
Cut-out	N (%)	54 (98.2%) 1 (1.8%)	59 (100%) 0 (0%)	63 (96.9%) 2 (3.1%)	1.787	0.409
Nonunion	N (%)	54 (98.2%) 1 (1.8%)	57 (96.6%) 2 (3.4%)	64 (98.5%) 1 (1.5%)	0.548	0.76
Avascular necrosis of the femoral head	N (%)	53 (96.4%) 2 (3.6%)	57 (96.6%) 2 (3.4%)	62 (95.4%) 3 (4.6%)	0.140	0.933
Secondary Surgery (arthroplasty)	N (%)	54 (98.2%) 1 (1.8%)	57 (96.6%) 2 (3.4%)	64 (98.5%) 1 (1.5%)	0.548	0.76

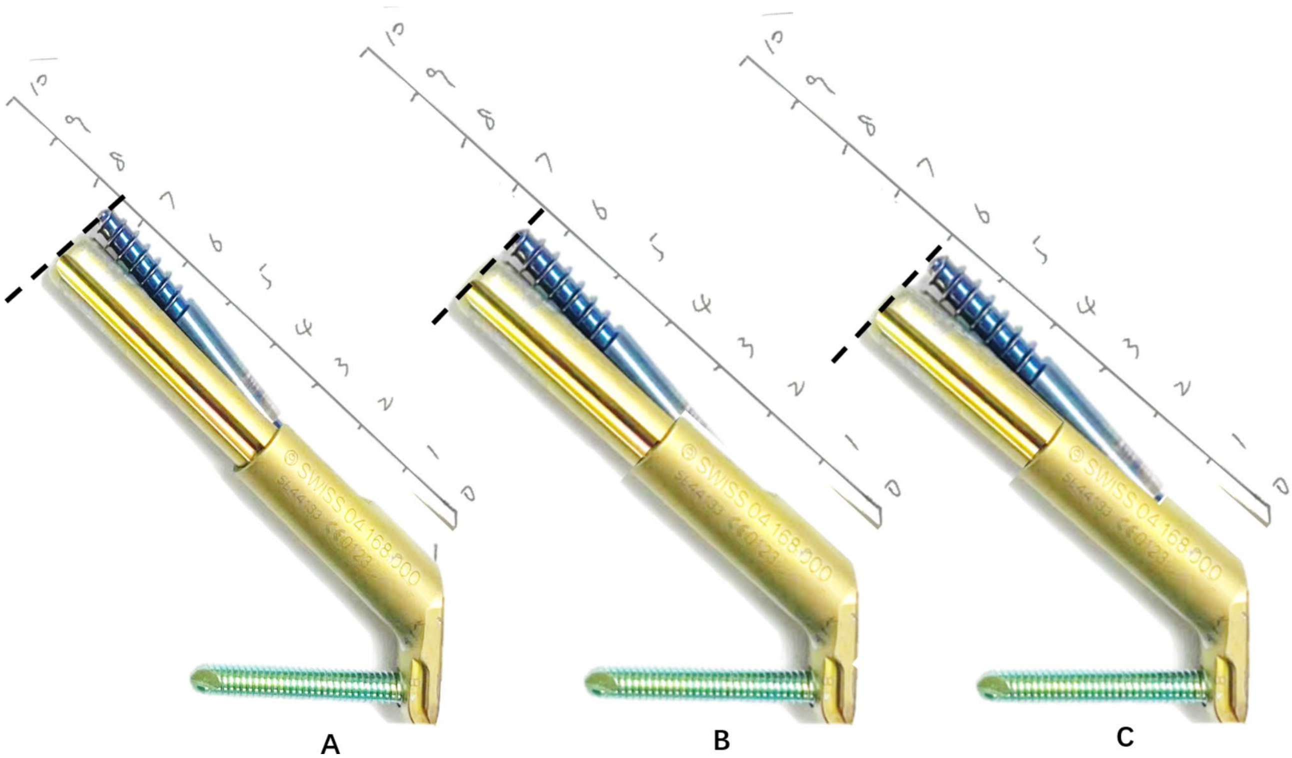

Fig. 1 **A** Extensive Slide : The FNS begins with an initial length of 75 mm, without any pre-sliding. The maximum residual sliding capacity is 20 mm. **B** Moderate Slide: After a 10 mm slide, the FNS length is reduced to 65 mm, with a maximum residual sliding capacity of 10 mm. **C** Minimal Slide: Following a 15 mm slide, the FNS length is diminished to 60 mm, with a maximum residual sliding capacity of 5 mm

severe shortening should be avoided as it may diminish hip joint function and is considered a complication. Our results, indicating a decrease in hip joint function as measured by the Harris score, are consistent with previous research. Karanicolaset al. [25]. in 2009 identified a correlation between shortening exceeding 5 mm post-op and an increased risk of nonunion, highlighting the critical relationship between shortening and healing success. Lin et al. [8]. in 2024 emphasized the importance of fracture site contact area for healing, suggesting that postoperative shortening could reduce this area and potentially hinder the healing process. Moderate to severe shortening not only affects gait and function but may also lead to chronic pain and a decline in hip joint function [26]. Moreover, shortening is associated with an increased risk of femoral head necrosis, impacting long-term patient prognosis [14, 27]. Our analysis revealed no improvement in healing time despite an increase in the incidence of moderate to severe shortening. The occurrence of such shortening after FNS fixation is linked to various factors, including displaced fractures, cortical comminution, and inadequate reduction, which are known risk factors for significant shortening [6, 8, 27]. Therefore, preventing moderate to severe shortening is essential for enhancing postoperative quality of life and reducing the risk of long-term complications in patients undergoing FNS fixation for displaced femoral neck fractures, particularly for those with risk factors such as displaced fractures and comminuted fracture ends.

Optimal shortening distance and prevention post-FNS fixation for femoral neck fractures

During the internal fixation of femoral neck fractures, various techniques have been established to enhance stability and minimize postoperative shortening. Techniques such as the application of biplane fixation techniques for cannulated screws [28], the utilization of the FNS equipped with anti-shortening screws [8], and the enhancement of the Dynamic Hip Screw (DHS) through an additional screw [29] have each proven to be effective strategies for improving stability and reducing postoperative shortening in the treatment of femoral neck fractures. A study focusing on cannulated screws, the average of postoperative shortening was 3.2 millimeters [30]. Specifically, for displaced femoral neck fractures treated with the FNS system, the average shortening was recorded at 4.2 millimeters [22]. Our analysis of postoperative shortening following femoral neck fracture surgery revealed that the Moderate Slide group had 5.59 times the incidence of the Short Distance group, and the Extensive Slide group had 8.88 times the incidence. There was no difference in fracture healing time or the incidence of complications such as nonunion and implant cut-out between the Minimal Slide groups and the other groups. These findings underscore the importance of employing sophisticated fixation methods to optimize clinical outcomes in the treatment of femoral neck fractures. Based on these findings, we propose that maintaining a sliding space of within 5 mm may be appropriate when using FNS for the fixation of displaced femoral neck fractures. Such a sliding distance helps reduce moderate to severe postoperative shortening without affecting the fracture healing process. Future studies should further explore the specific impact of different pre-collapse distances on fracture healing and adjust the pre-collapse distance according to the patient's condition to achieve optimal treatment outcomes, thereby improving long-term prognosis.

Recommendations for improving FNS sliding space

The FNS design, which allows for a 20 mm sliding distance, aids in compressing the fracture ends and promoting healing. However, the results of this study suggest that this sliding space may need to be tailored to the patient's specific condition. Future research should consider developing an FNS with an adjustable sliding space to better accommodate the needs of different patients.

Limitations

The limitations of this study include its retrospective design and single-center data collection, which may limit the generalizability of the results. Additionally, this study did not analyze all potential factors affecting postoperative shortening, such as patient bone density and fracture types. Future studies should adopt a prospective design and consider more influencing factors to provide a more comprehensive understanding.

Conclusion

Despite these limitations, the results of this study emphasize the potential value of the pre-collapse technique in preventing postoperative shortening and provide beneficial guidance for the clinical application of FNS. This study contributes to the understanding of the role of pre-collapse techniques in orthopedic surgery and suggests that further research with a broader scope and more diverse patient populations is warranted to solidify these findings.

Author contributions

Shenjian Weng, Dongze Lin, and Jikai Zeng contributed equally to this work. Weng and Lin were involved in the study design, data collection, analysis, and manuscript drafting. Zeng was responsible for data acquisition and provided critical insights during manuscript revision. Jiajie Liu participated in data analysis and study design. Ke Zheng assisted with result interpretation and manuscript drafting. Peisheng Chen and Chaohui Lin managed data collection and offered valuable feedback. Fengfei Lin supervised the research, ensured the integrity of the study, and provided critical revisions to the manuscript. All authors have read and approved the final version of the manuscript.

Data availability

No datasets were generated or analysed during the current study.

Declarations

Competing interests

The authors declare no competing interests.

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