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# Early mechanical failure patterns after femoral neck fixation with the Femoral Neck System and Dynamic Hip Screw

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# Early mechanical failure patterns after femoral neck fixation with the Femoral Neck System and Dynamic Hip Screw

**Running head:** FNS vs DHS — Early Mechanical Failure Patterns


## Abstract

**Background**. The Femoral Neck System (FNS) has been introduced as a minimally invasive alternative to the Dynamic Hip Screw (DHS) for intracapsular femoral neck fracture fixation. Comparative data on early mechanical failure patterns remain limited.

**Purpose**. To compare early mechanical failure profiles after FNS and DHS fixation during a period of progressive FNS adoption.

**Methods**. We conducted a retrospective single-center cohort study including 130 consecutive patients treated by internal fixation for intracapsular femoral neck fractures between December 2020 and January 2024 (42 DHS, 88 FNS). The primary outcome was mechanical failure requiring revision surgery within one year. Tip–apex distance (TAD) was measured on immediate postoperative radiographs.

**Results**. Revision rates were comparable between groups (7.1% for DHS versus 9.1% for FNS; $p = 0.25$), although the study was underpowered (post-hoc power ≈20%). Failure patterns differed qualitatively: DHS failures were predominantly related to femoral neck shortening and medialization, whereas FNS failures additionally included peg cut-out and peri-implant fracture. Mean TAD was similar between groups (18.8 ± 4.8 mm versus 19.6 ± 5.2 mm; $p = 0.34$). Patients with cut-out had significantly higher TAD values than those without cut-out (30.5 ± 3.0 mm versus 19.1 ± 4.8 mm; $p < 0.001$), and all cut-out events occurred above the 25 mm threshold. Functional recovery was comparable between groups.

**Conclusion**. Although revision rates were similar, FNS and DHS demonstrated distinct mechanical failure patterns. Implant design may influence the mode rather than the overall likelihood of failure. Optimization of implant positioning remains essential regardless of implant type.



**Keywords:** Femoral neck fracture · Femoral Neck System · Dynamic Hip Screw · Internal fixation · Mechanical failure · Revision surgery · Tip-apex distance

# Introduction

Femoral neck fractures remain a major challenge in orthopaedic trauma, particularly in elderly patients, in whom they are associated with high morbidity, loss of independence, and increased mortality. While arthroplasty is widely accepted for displaced fractures in frail individuals, internal fixation continues to play a key role in the management of non-displaced fractures and in selected physiologically younger or active elderly patients [1][2].

The Dynamic Hip Screw (DHS) has long been considered a reliable reference implant for the fixation of intracapsular femoral neck fractures. Its mechanical stability and extensive clinical evidence have established it as a standard technique.[3] However, the surgical approach required for DHS fixation involves soft-tissue dissection and may be associated with increased operative morbidity, absence of rotational stability, excessive femoral neck impaction, which has encouraged the development of an alternative system [4].

The Femoral Neck System (FNS) was introduced as a minimally invasive, angular-stable device designed to provide reliable fixation through a shorter approach and a simplified construct [5]. Early biomechanical and clinical studies have reported encouraging results [6], but real-world clinical data remain limited, particularly regarding early mechanical complication profiles during the initial phase of clinical implementation.

Most comparative studies have focused on overall outcomes and revision rates [7]. Less attention has been paid to whether the introduction of a new fixation system may modify the pattern, rather than merely the rate, of early mechanical failure compared with established techniques in routine clinical practice [8].

The primary objective of this study was to describe and compare early mechanical failure patterns after FNS and DHS fixation in a consecutive cohort of patients with intracapsular femoral neck fractures. Our main research question was whether these two implants are associated with different failure profiles during a period of progressive adoption of the FNS, beyond a simple comparison of overall revision rates.

## Materials and Methods

*Study design and population*

We conducted a retrospective, single-center cohort study at a tertiary university hospital, including all consecutive adult patients who underwent internal fixation for an intracapsular femoral neck fracture between December 2020 and January 2024. The study protocol was approved by the institutional review board.

Patients were eligible if they presented with a Garden I to IV intracapsular femoral neck fracture treated by osteosynthesis using either a one-hole FNS or a two-hole DHS. Patients treated with alternative implant configurations or pathological fractures were excluded.

During the study period, implant choice was left to the surgeon's discretion and evolved with increasing adoption of the FNS, resulting in an unequal group distribution reflecting routine clinical practice during a transition phase. Garden IV fractures were exclusively found in the DHS group, reflecting real-world decision-making at the time: during the early phase of FNS adoption in our institution, highly displaced fractures were preferentially managed with the established DHS or referred for arthroplasty, while the FNS was first introduced for non-displaced or minimally displaced fractures. This selection pattern constitutes an important source of bias that is explicitly acknowledged (see Limitations).

*Fracture classification and surgical technique*

Preoperative radiographs were independently reviewed by two experienced orthopaedic surgeons. Fractures were classified according to the Garden and Pauwels classifications.

The Femoral Neck System (DePuy Synthes, Zuchwil, Switzerland) consists of a lag peg inserted into the femoral neck combined with an anti-rotation screw and a short lateral plate secured distally with a locking screw (Figure 1). The Dynamic Hip Screw (DePuy Synthes, Zuchwil, Switzerland) was implanted using a standardized two-hole side plate configuration with a lag screw and distal non-locking screws (Figure 2).

All procedures were performed under general anesthesia with fluoroscopic guidance. Surgical approach and perioperative management followed institutional standards.

*Radiological assessment*

Immediate postoperative radiographs were obtained for all patients. Follow-up imaging was performed at 3, 6, and 9 months postoperatively.

Tip-apex distance (TAD) was measured on immediate postoperative radiographs according to the method described by Baumgaertner et al., defined as the sum of the distances from the tip of the implant to the apex of the femoral head on anteroposterior

and lateral views, after correction for radiographic magnification. Measurements were performed using calibrated digital imaging software.

*Outcomes*

The primary outcome was early mechanical failure requiring revision surgery within the first postoperative year. Mechanical failure was defined as loss of fixation leading to revision surgery, including femoral neck shortening associated with medialization (Figure 3), peg cut-out (Figure 4), or peri-implant fracture (Figure 5). Septic complications, osteonecrosis, and secondary osteoarthritis were recorded separately and were not classified as primary mechanical failures, as they are not directly related to fixation stability [9][10].

Secondary outcomes included operative time, perioperative blood management (transfusion or iron supplementation), and functional recovery assessed by the ability to walk postoperatively, with or without walking aids.

*Statistical analysis*

Categorical variables were compared using Fisher's exact test, and continuous variables using the Wilcoxon-Mann-Whitney test. Statistical significance was defined as $p < 0.05$. TAD values were compared between patients with and without cut-out using the Mann-Whitney U test.

Given the limited number of mechanical failures, no multivariate adjustment was performed. Missing data were handled using a worst-case scenario approach.

A post-hoc power calculation was performed to estimate the study's ability to detect the observed difference in overall revision rates (7.1% in the DHS group vs. 9.1% in the FNS group). Using a two-sided Fisher's exact test at $\alpha = 0.05$, the calculated post-hoc power was approximately 20%, confirming that the study was substantially underpowered to detect or exclude a moderate difference in overall revision rates between implants. This limitation is explicitly discussed and reinforces the descriptive nature of our comparative analysis.

**Funding**: No external funding was received for this study.

# Results

*Population characteristics*

Between December 2020 and January 2024, 130 consecutive patients with intracapsular femoral neck fractures treated by internal fixation were included: 42 in the DHS group and 88 in the FNS group. Baseline characteristics are summarized in Table 1.

The mean age was 70 ± 19.6 years in the DHS group and 76 ± 15.7 years in the FNS group ($p = 0.11$). Women represented 55% and 69% of patients respectively ($p = 0.18$). Fracture distribution differed slightly between groups, with no Garden IV fractures in the FNS group (see study design). No statistically significant differences in baseline characteristics were found, although the modest sample size limits the sensitivity of these comparisons.

*Perioperative data*

Mean operative time was 51 minutes in the DHS group and 47 minutes in the FNS group, with no statistically significant difference ($p = 0.23$). No patients in the DHS group required blood transfusion; two received iron supplementation. In the FNS group, four patients required transfusion and nine received iron supplementation. These differences were not statistically significant (Table 2).

*Mechanical failures and revision surgery*

In the DHS group, three patients (7.1%) required revision surgery for mechanical failure, including two cases of femoral neck shortening associated with medialization and one peg cut-out.

In the FNS group, eight patients (9.1%) underwent revision surgery for mechanical complications: shortening with medialization in three cases, peg cut-out in three cases, and peri-implant fracture in two cases.

The overall difference in revision rates between groups did not reach statistical significance ($p = 0.25$). However, as detailed in Table 3, the mechanisms of failure differed qualitatively: DHS failures were predominantly related to shortening/medialization, whereas FNS failures encompassed three distinct mechanisms including cut-out and peri-implant fracture. Given the post-hoc power of approximately 20%, the absence of statistical significance should not be interpreted as evidence of equivalence.

Additional procedures not classified as mechanical failures were recorded separately. In the DHS group, two patients underwent implant removal for persistent peri-implant pain, and one required conversion to total hip arthroplasty for osteonecrosis. In the FNS group, five patients underwent secondary total hip arthroplasty (two for osteoarthritis, three for osteonecrosis), and one patient developed septic non-union.

*Radiological assessment — Tip-Apex Distance*

TAD was measured on immediate postoperative radiographs for all patients. The mean TAD was 19.3 ± 5.1 mm (range 8–34) across the entire cohort, with no significant difference between groups (18.8 ± 4.8 mm for DHS vs. 19.6 ± 5.2 mm for FNS; $p = 0.34$). Most patients presented a TAD below the commonly accepted threshold of 25 mm, reflecting overall satisfactory implant positioning in both groups.

A total of four cut-out events were recorded: one in the DHS group (2.4%) and three in the FNS group (3.4%). Patients who developed cut-out had markedly higher TAD values (mean 30.5 ± 3.0 mm, range 27–34) compared with patients without cut-out (mean 19.1 ± 4.8 mm, range 8–29). This difference was highly statistically significant (Mann-Whitney U test, $p < 0.001$), and all cut-out cases occurred in patients with TAD exceeding the 25 mm threshold. These findings are consistent with the established role of inadequate implant positioning as a major contributor to secondary cephalic migration and cut-out, regardless of implant type.

*Functional outcomes*

Functional recovery was assessed based on the ability to walk postoperatively. In the DHS group, 41 of 42 patients were evaluable (one lost to follow-up); 38 (92.7%) regained walking ability, including 14 requiring walking aids.

In the FNS group, 72 of 88 patients were evaluable postoperatively. The 16 non-evaluable patients included 7 deaths, 5 institutionalizations, and 4 patients lost to follow-up. Among evaluable patients, all 72 regained walking ability, with 31 (43.1%) requiring walking aids.

There was no statistically significant difference between groups in postoperative ambulatory recovery ($p = 0.55$, Table 2).

## Discussion

In this retrospective comparative study, we evaluated early outcomes of two angular-stable fixation devices for intracapsular femoral neck fractures during a period of progressive FNS adoption. Although overall revision rates for mechanical failure were comparable (7.1% DHS vs. 9.1% FNS; $p = 0.25$), our results suggest that the profile and mechanisms of early mechanical failure differ between the two implants in routine clinical practice — and that this qualitative difference may carry independent clinical relevance beyond a simple rate comparison.

Mechanical failures observed after DHS fixation were predominantly characterized by progressive femoral neck shortening associated with medialization, although one case of peg cut-out was also observed. Progressive shortening after femoral neck fixation has previously been identified as a major mechanism of failure [11,12]. In contrast, FNS failures additionally included peg cut-out and peri-implant fractures. These observations support the hypothesis that implant design may influence the mode of failure rather than its overall likelihood. The more rigid, angular-stable construct of the FNS may modify the mechanical environment at the fracture site, potentially leading to qualitatively different failure patterns when reduction quality or implant positioning is suboptimal. One possible explanation for the higher rate of cut-out observed with the FNS compared with the DHS may relate to the limited sliding capacity of the device. The FNS allows approximately 10 mm of controlled impaction before the mechanism reaches its maximal compression limit, whereas the DHS provides a greater capacity for continued collapse and dynamic compression. Once this impaction reserve is exhausted, the construct may behave as a fixed-angle device, potentially increasing stress transfer to the femoral head and thereby favoring cut-out in cases of persistent secondary collapse.

TAD analysis provided the most robust finding of the present study. Mean TAD values were comparable between implant groups, indicating similar overall positioning quality. However, patients who developed cut-out presented markedly higher TAD values ($30.5 \pm 3.0$ mm vs. $19.1 \pm 4.8$ mm; $p < 0.001$), all above the 25 mm threshold. TAD has been extensively described as one of the most reliable radiological predictors of cut-out in sliding hip screw fixation, and its predictive value appears to extend to angular-stable fixation systems [13]. Although the number of cut-out events remains limited ($n = 4$), the statistical significance and magnitude of the TAD difference are compelling and consistent with the established biomechanical literature. The respective role of the lag peg and anti-rotation screw in cut-out mechanisms remains unclear and warrants dedicated biomechanical investigation.

The higher number and variety of FNS mechanical complications may partly reflect a learning curve effect, as the FNS was progressively adopted throughout the study period and surgical familiarity varied among operators. A temporal subgroup analysis comparing

early versus late FNS cases was precluded by sample size and warrants investigation in future cohorts.

An important limitation lies in the non-comparability of the two groups. Patients treated with FNS were on average older and included more women, suggesting a potentially higher prevalence of osteoporosis [14]. More critically, all Garden IV fractures were treated with DHS, reflecting the institution's indication patterns during the early adoption phase, as described in the Methods section. This selection bias limits direct comparison between implants and is inherent to retrospective observational studies conducted during a technological transition.

Despite these differences, early revision rates remained comparable between groups. However, given the limited number of mechanical failures (n = 10 total) and the post-hoc power of approximately 20%, the study was substantially underpowered to detect or exclude a moderate difference in overall revision rates. The absence of statistical significance should therefore be interpreted as a reflection of sample size rather than as evidence of equivalence between the two fixation methods.

Bone quality was not objectively assessed (no DXA or cortical index), representing an uncontrolled confounding factor given the age differences between groups and the known influence of osteoporosis on fixation stability.

Functional recovery assessed through ambulatory ability was comparable between groups. However, walking ability is a crude measure that does not capture differences in hip function or quality of life, and validated patient-reported outcomes were lacking. Missing functional data in the FNS group (18% non-evaluable) reflects the inherent challenges of follow-up in an elderly, fragile population [15].

Both DHS and FNS can provide satisfactory early fixation in selected intracapsular femoral neck fractures, but mechanisms of failure differ. Future prospective studies with larger cohorts, standardized functional assessment, objective bone quality evaluation, and learning curve analysis are needed to define the respective indications and technical requirements of each fixation method.

## Conclusion

In this retrospective single-center study, FNS and DHS showed comparable early revision rates for mechanical failure after intracapsular femoral neck fractures. However, failure patterns differed between implants, with the FNS associated with more diverse complications, including cut-out and peri-implant fracture. A tip-apex distance >25 mm was consistently associated with cut-out regardless of implant type. These findings suggest that implant design may influence the mode of failure rather than its overall incidence, emphasizing the importance of precise implant positioning and careful surgical technique when using newer fixation systems.

Given the retrospective design, limited number of mechanical failures, substantial baseline differences between groups, and the study's low post-hoc power, these results should be interpreted as hypothesis-generating rather than conclusive. Prospective studies with larger cohorts, standardized methodology, and longer follow-up are needed to define the optimal indications and technical requirements of the FNS relative to the DHS in intracapsular femoral neck fracture management.

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Fig1



Fig 2



Fig 3




Fig 4



Fig 5



## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table2PeriopFunctional.docx
- Table1Population.docx
- Table3MechanicalFailuresVF.docx