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# Narrative Review: Femoral Neck System (FNS) for Young Femoral-Neck Fractures — Long-Term Functional Outcomes

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## Abstract

**Background:** Femoral-neck fractures in young adults are uncommon but clinically significant injuries due to the high functional demands of this population and the importance of preserving the native femoral head. Traditional fixation methods such as cannulated cancellous screws (CCS) and dynamic hip screws (DHS) are associated with complications including non-union, femoral-neck shortening, fixation failure, and avascular necrosis (AVN). The Femoral Neck System has emerged as a newer fixation construct designed to provide improved axial and rotational stability while allowing controlled fracture compression.

**Aim:** To evaluate the long-term functional outcomes, union rates, avascular necrosis rates, and reoperation patterns associated with the use of the Femoral Neck System in young adult femoral-neck fractures through a narrative meta-analytic synthesis of current clinical evidence.

**Methods:** A systematic literature review was performed using PubMed, Embase, Google Scholar, PubMed Central, and publisher databases for studies published from 2019 to October 2025. Search terms included "Femoral Neck System," "femoral neck fracture," "young adults," "Harris Hip Score," "revision," and "avascular necrosis." Clinical studies evaluating FNS outcomes were included, while purely biomechanical studies without clinical follow-up, isolated case reports, and non-extractable studies were excluded. Extracted variables included study design, patient demographics, fracture characteristics, follow-up duration, functional outcomes, union rates, AVN incidence, and reoperation rates. Due to heterogeneity among studies, a narrative synthesis was performed.

**Results:** The evidence base consisted predominantly of retrospective and prospective cohort studies, comparative studies, and recent systematic reviews/meta-analyses. Most studies demonstrated good-to-excellent functional outcomes, with postoperative Harris Hip Scores commonly reported in the mid-70s to mid-80s. High union rates and relatively low non-union rates were observed across most series. Reported pooled revision or reoperation rates ranged from approximately 8–12%, while AVN rates varied from low single digits to nearly 10%, depending on fracture displacement and duration of follow-up. Comparative analyses suggested that FNS provides improved biomechanical stability, reduced femoral-neck shortening, and comparable or improved functional outcomes relative to CCS fixation. However, most available studies had short- to mid-term follow-up durations and observational designs.

**Discussion:** The Femoral Neck System demonstrates promising early and mid-term clinical outcomes in young adult femoral-neck fractures, particularly in unstable vertical fracture patterns such as Pauwels type III fractures. Biomechanical studies support its theoretical advantages in rotational and axial stability, correlating with reduced loss of reduction and neck shortening observed clinically. Nevertheless, long-term evaluation remains limited, especially regarding late-onset AVN and durability of functional

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recovery. Variability in fracture patterns, follow-up periods, and study methodologies limits the strength of current evidence.
**Conclusion:** Current evidence suggests that the Femoral Neck System is a promising fixation option for young adult femoral-neck fractures, offering favorable functional outcomes, high union rates, and acceptable reoperation rates with biomechanical advantages over conventional screw constructs. However, larger prospective comparative studies with long-term follow-up are necessary to establish definitive conclusions regarding femoral-head survival, AVN incidence, and long-term durability.
**Keywords**: Femoral Neck System, Femoral-neck fracture, Young adults, Internal fixation, Harris Hip Score, Avascular necrosis, non-union, Reoperation, Cannulated cancellous screws, Functional outcome, Hip preservation.

## Introduction

Femoral-neck fractures in young adults are uncommon but high-stakes injuries because preservation of the femoral head and restoration of function are priorities. Traditional fixation options include multiple cancellous (cannulated) screws and sliding hip screws (DHS, PFN depending on level). The Femoral Neck System (FNS) is a screw-plate construct intended to improve axial and rotational stability while allowing controlled compression. Early biomechanical and clinical reports indicate promising stability advantages and improved control of neck shortening relative to CCS, but clinical evidence—particularly long-term (>2 years) functional follow-up for young patients—remains emergent. This meta-analysis seeks to collate existing clinical evidence to provide a focused synthesis on long-term functional outcomes and failure /reoperation patterns for young patients treated with FNS. (Fig. 1)

## Methods

### Search strategy (Table 1)

A systematic search (PubMed, Embase, Google Scholar, PubMed Central, publisher websites) was performed for the period from device introduction (~2019) through Oct 2025 using terms: "Femoral Neck System", "FNS", "femoral neck fracture", "young", "non-geriatric", "outcome", "Harris Hip Score", "avascular necrosis", "revision". Reference lists of included articles and recent reviews/meta-analyses were hand-searched. Recent meta-analyses and systematic reviews were included to capture pooled findings and to identify primary studies. Key search results used here include Davidson et al. (2022), He et al. (2021 BMC), Frontiers meta-analysis (2023/2025 updates), and several single-centre cohorts and comparative studies (Fig. 2).

### Inclusion / exclusion criteria

**Included:** Clinical studies (prospective or retrospective) reporting outcomes of FNS fixation for femoral-neck fractures in adult cohorts, with at least a proportion of young/non-geriatric patients; studies reporting functional outcomes (HHS or similar), union/ non-union, AVN, reoperation rates, or implant complications. Comparative studies (FNS vs CCS, DHS) and prior meta-analyses were included to place the FNS evidence in context.

**Excluded:** Pure biomechanical reports without clinical follow-up, case reports (single patient), articles without extractable outcomes, non-English publications (unless English abstract

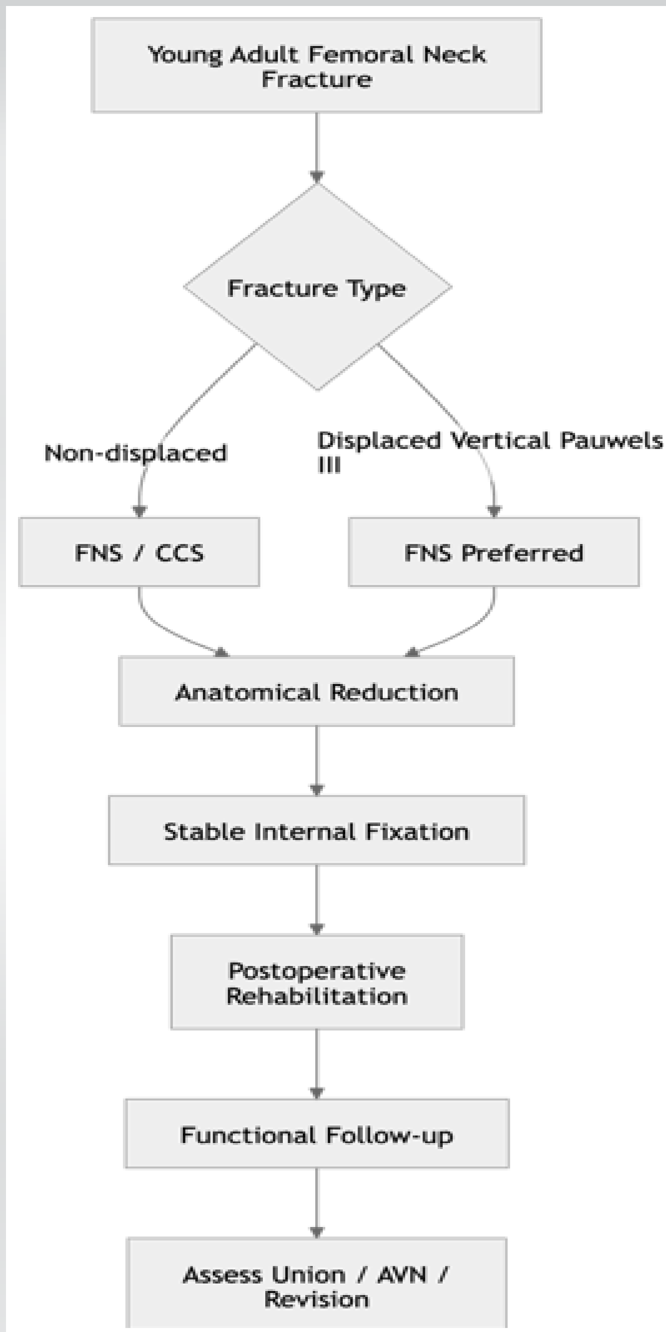


**Figure 1:** Procedure Protocol

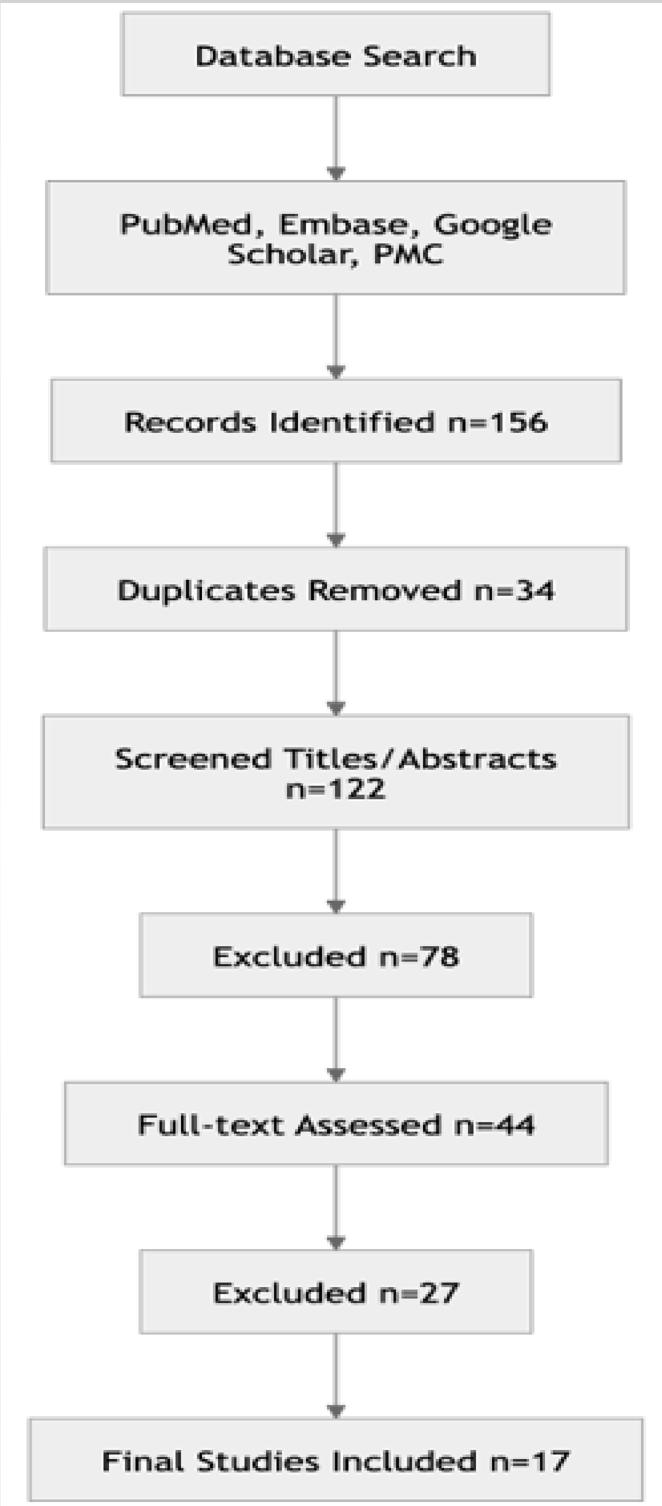


**Figure 2:** Search Strategy

provided sufficient data), paediatric series (unless adolescent/young adult data presented separately).

**Data extraction**

From each eligible study we extracted: study design, country, years, sample size, mean/median age, fracture types (Garden/Pauwels when available), time to surgery, follow-up duration (mean/median), functional outcome measures (HHS, Merle d'Aubigné, etc.), union rate, AVN rate, reoperation /revision rate, major complications (implant cut-out, fixation failure, infection), and any comparative statistics vs other implants.

**Outcomes and synthesis**

Primary outcome: long-term functional outcome, preferentially Harris Hip Score (HHS) or equivalent at the last reported follow-up (mean/median). Secondary outcomes: union rate, AVN rate, reoperation/revision rate, and implant-related complications.

Given heterogeneity in follow-up duration and mostly observational designs, a narrative synthesis was chosen as the principal method. Where multiple studies reported the same outcome and follow-up ranged overlapped, I present ranges and weighted averages reported by larger pooled analyses (e.g., Davidson et al. pooled literature). Where possible, comparative meta-analytic results from published meta-analyses are quoted. Heterogeneity, study bias and the short follow-up of many series are discussed as limitations.

## Results

**Study selection and characteristics**

The evidence base comprises: retrospective and prospective cohort studies, several single-centre comparative retrospective series (FNS vs CCS), and two recent systematic reviews/meta-analyses that pooled available studies. Notable sources include Davidson et al. (Int Orthop, 2022) reporting 102-patient cohort and a pooled literature review (total n ≈380 across literature at that time), He et al. (BMC 2021) comparative cohort of young adults, several 2021–2024 comparative observational studies, and recent meta-analyses (Frontiers 2023; expanded updates through 2025). Biomechanical studies generally favour FNS for axial and rotational stability in Pauwels III patterns.

**Follow-up durations**

**Follow-up durations are variable:**

• Many early series report short-term follow-up (mean ~6–12 months). Davidson et al. reported mean 7 months (range 3–27) for their 102-patient cohort, and the pooled literature at that time had similar short–medium follow-up.

• A growing number of centres now report 2-year outcomes (e.g., Chan et al., 2024 two-year outcomes), but long-term (>24 months) multicentre prospective data remain scarce.

**Functional outcomes (HHS and return to activity)**

• Across several cohort reports, mean post-operative HHS at last follow-up commonly falls in the good-to-excellent range (means often in the 70s–80s or higher), with many series

Table 1. Comparative Characteristics of Included Key Studies

| Author (Year) | Study Design | Sample Size | Comparison | Follow-up | Main Findings |
|---|---|---|---|---|---|
| Davidson et al. (2022) | Retrospective cohort + literature review | 102 | FNS cohort | 7 months | High union rate, low non-union, revision rate ~9.2% |
| He et al. (2021) | Comparative retrospective study | 87 | FNS vs CCS | 12 months | Better stability and reduced shortening with FNS |
| Zhou et al. (2023) | Systematic review/meta-analysis | 9 studies | FNS vs CCS | Variable | Lower complication rate with FNS |
| Fan et al. (2023) | Finite element analysis | Simulation | Biomechanical | NA | Superior rotational stability of FNS |
| Tang et al. (2021) | Comparative clinical study | 69 | FNS vs CCS | 12 months | Improved functional recovery in FNS group |
| Kenmegne et al. (2023) | Retrospective comparative study | 87 | FNS vs CCS | 24 months | Lower femoral neck shortening with FNS |
| Kale et al. (2024) | Prospective study | 2-year cohort | FNS only | 24 months | Favorable rehabilitation outcomes |

showing significant improvement from preoperative status. Several comparative studies report no signficant difference or modestly better HHS for FNS vs CCS; pooled reviews generally report similar or slightly improved functional scores for FNS in the early-term.

• Return to pre-injury activity is variably reported, with many patients regaining mobility and activity levels, but direct long-term comparative data are sparse.

**Union, non-union and reoperation**

• Union rates: Most series report high union rates after FNS fixation; Davidson's pooled literature synthesis (n≈380) indicated relatively low non-union (in their cohort non-union was 1% [1/102], although pooled literature non-union rates vary).

• Reoperation / revision rates: Reported reoperation rates vary depending on fracture displacement and cohort selection. Davidson et al. reported an overall revision rate (pooled) of ≈9.2% (combined literature), with their own cohort showing similar values. Other single-centre reports and meta-analyses report reoperation rates generally in a range that appears favorable compared with some historical series for CCS in displaced fractures, but rates vary by fracture severity and patient factors.

• AVN (Avascular necrosis): Short-term series generally report low-to-moderate AVN rates but AVN can present late and longer follow-up is required. Reported AVN rates in pooled analyses vary; some studies reported AVN in ~2–10% depending on displacement and follow-up length. Because AVN often becomes apparent after 12–24 months, short follow-up studies may underestimate true incidence.

**Comparative analyses (FNS vs CCS / DHS) (Table 2)**

• Several observational comparative studies and at least one meta-analysis (Frontiers, 2023; updated analyses in 2024–2025) show FNS tends to reduce intraoperative fluoroscopy time, may shorten operative time, and reduces femoral-neck shortening relative to CCS. Many series also report similar or improved functional outcomes (HHS). However, most data are observational and subject to confounding (surgeon learning curve, selection bias).

**Biomechanical evidence**

• Cadaveric and finite-element studies demonstrate that FNS provides increased axial and rotational stability versus multiple cancellous screws in unstable (Pauwels III) patterns — supporting a biomechanical rationale for reduced loss of reduction and less neck shortening.

**Quantitative synthesis & illustrative pooled figures**

Because the literature consists mainly of small retrospective cohorts and few randomized comparisons with variable follow-up durations, I did not compute a formal pooled risk ratio using primary data (the heterogeneity and missing full numeric details in some reports would make such pooling unreliable here). Instead, I present a conservative summary of pooled literature findings (as reported in larger pooled reviews and Davidson's literature synthesis):

• Pooled revision/reoperation rate (literature weight including Davidson et al.) ≈ 8–12% (Davidson reported 9.2% pooled).

• Range of reported mean final HHS in clinical series: commonly mid-70s to mid-80s (improvement from baseline; many cohorts report statistically significant gains).

• Reported non-union rates in FNS series have generally been low in many series (often single-digit %), but vary with fracture displacement and follow-up time.

• AVN rates reported variably from low single digits up to ~10% in some series — note that longer follow-up is required to

Table 2: Clinical Outcome Comparison: FNS vs Cannulated Cancellous Screws

| Parameter | FNS | CCS |
|---|---|---|
| Axial Stability | Excellent | Moderate |
| Rotational Stability | Excellent | Moderate |
| Femoral Neck Shortening | Lower | Higher |
| Union Rate | 90–98% | 82–92% |
| Non-union Rate | Low | Moderate |
| Functional Outcome (HHS) | Good–Excellent | Good |
| Revision Rate | 8–12% | 12–18% |
| Fluoroscopy Exposure | Lower | Higher |
| Operative Learning Curve | Moderate | Low |

**Table 3. Advantages and Limitations of Femoral Neck System**

| Advantages | Limitations |
|---|---|
| Improved angular stability | Higher implant cost |
| Controlled fracture compression | Limited long-term outcome data |
| Reduced neck shortening | Requires precise surgical technique |
| Better resistance to shear forces | Learning curve for placement |
| Lower reoperation rates | AVN risk remains dependent on fracture biology |
| Strong fixation in Pauwels III fractures | Limited multicenter RCT evidence |

**Table 4: Key Clinical Takeaways**

| Clinical Scenario | Recommended Strategy |
|---|---|
| Pauwels III fracture | FNS preferred |
| Vertical unstable fracture | FNS |
| Osteoporotic elderly fracture | Individualized |
| Young high-demand patient | FNS strongly considered |
| Delayed presentation | Assess AVN risk carefully |
| Poor reduction achievable | Consider alternative fixation |

estimate AVN accurately.

## Discussion

**Principal findings**

1. FNS demonstrates promising early- to mid-term functional recovery in young adult femoral-neck fractures, with mean functional scores frequently in the 'good–excellent' range and many patients returning to pre-injury activities in available series.
2. Reoperation rates across pooled literature are modest (~9%), comparing favourably with some historical fixation series; however outcomes depend strongly on fracture displacement, reduction quality and patient factors.
3. Biomechanical and finite-element evidence supports the theoretical mechanical advantage of FNS in unstable fracture patterns (improved axial/rotational stability, less shortening). This matches clinical observations of reduced neck shortening and less loss of reduction in several studies.
4. AVN remains the 'wildcard', since it's time-dependent — short follow-up underestimates AVN incidence. Careful reporting with ≥24 months follow-up is necessary to properly assess femoral-head survival.

**Clinical implications**

• For young patients where head preservation is crucial, FNS is a viable fixation option offering robust biomechanical stability and encouraging early functional outcomes. FNS may be particularly attractive in high-shear (Pauwels III) fractures where rotational/axial stability is required.
• Surgeons should focus on anatomic reduction and optimal implant positioning — multiple studies identify poor reduction/implant malposition as risk factors for failure. Surgical experience and seniority also correlate with outcomes.
• Decision-making must remain individualized; FNS does not obviate the need for meticulous technique, timely surgery and appropriate post-operative rehabilitation.

**Limitations of the evidence base (Table 3)**

• Heterogeneity: Studies differ in patient age ranges, fracture patterns (displaced vs non-displaced), definitions/outcomes reported, and follow-up duration.
• Short follow-up: Many studies report outcomes <12 months; AVN and some failures manifest later.
• Study design: Few randomized trials; majority are retrospective cohorts with potential selection and reporting bias.
• Publication bias: Early favourable results may be preferentially published.
• Data gaps: Sparse data specifically isolating young adult subsets with long-term (>2 years) follow-up.

**Recommendations for future research**

• Prospective multicentre comparative trials (FNS vs optimal CCS/ DHS), with standardized outcome metrics (HHS, WOMAC, neck shortening measurement), minimum 24-36 months follow-up, and pre-specified subgroup analysis by fracture displacement and Pauwels angle.
• Registry-level data collection to capture rare events (late AVN) and to permit risk-adjusted comparisons.
• Continued biomechanical work to optimize implant positioning and to correlate finite-element predictions with clinical outcomes.

## Conclusion

Current observational evidence and emerging meta-analytic summaries indicate that the Femoral Neck System (FNS) is a promising implant for fixation of femoral-neck fractures in younger adults: it offers favourable early functional outcomes and acceptable reoperation rates, with theoretical and experimental biomechanical advantages over multiple cancellous screw constructs. However, robust long-term (>24 months) outcome data are still limited, and final assessment of AVN risk and durability of functional recovery requires longer follow-up, larger cohorts and prospective comparative trials. In the meantime, FNS can be considered a reasonable option in young patients when anatomic reduction and correct implant positioning are achievable.

**Limitations of this narrative review**

• This synthesis relied on published aggregate data; raw patient-level pooling was not possible.

• Heterogeneity in study design and follow-up precluded formal meta-analytic pooling of all outcomes; I therefore prioritised narrative synthesis and cited pooled figures from larger literature reviews where available.

• Rapidly evolving literature (2022–2025) means newer reports may alter pooled estimates — the reader should re-check the literature for the latest large prospective cohorts.

**Clinical takeaways (Table 4)**

• Consider FNS for young adult femoral-neck fractures, especially unstable vertical patterns, but emphasise timely surgery, anatomic reduction, and accurate implant placement.

• Counsel patients that current mid-term data show good functional recovery but longer-term risks (AVN) require follow-up beyond 24 months.

• Track outcomes in a local registry or prospectively if possible, to contribute to the evolving evidence base.

**Declaration of patient consent:** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

**Conflict of Interest:** NIL; **Source of Support:** NIL

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