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ORIGINAL ARTICLE

Clinical efficacy and safety of closed reduction versus *in situ* internal fixation for valgus-impacted femoral neck fractures: A meta-analysis

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ABSTRACT

Objectives: In this meta-analysis, we discuss the clinical efficacy of closed reduction with *in situ* fixation for valgus-impacted femoral neck fractures (VIFNFs) by contrasting postoperative functional recovery and complication profiles.

Materials and methods: We performed a systematic literature search in PubMed, Embase, Web of Science, the Cochrane Library, and ScienceDirect for publications up to October 2025. The search targeted original studies which directly compared the surgical outcomes of closed reduction and *in situ* internal fixation for valgus-impacted femoral neck fractures. Search terms included combinations of: valgus-impacted (or valgus impaction), femoral neck fracture, *in situ*, reduction, and internal fixation. Pooled data were analyzed using mean differences (MD) with 95% confidence intervals (CIs) for continuous outcomes and risk differences (RD) with 95% CIs for dichotomous outcomes.

Results: The final analysis included a total of 447 patients extracted from five studies that met the predetermined inclusion criteria. The meta-analysis demonstrated that the closed reduction group exhibited a statistically significant reduction in postoperative femoral neck shortening (FNS) compared with the *in situ* fixation group (MD: 4.05; 95% CI: 2.68 ~ 5.42; $p < 0.00001$). For the caput-collum-diaphysis (CCD) angle, the closed reduction group showed a borderline significant improvement relative to the *in situ* fixation group (MD: 9.79; 95% CI: 0.19 ~ 19.39; $p = 0.05$). The *in situ* fixation group was associated with a substantially lower reoperation rate (RD: –0.08; 95% CI: –0.16 ~ –0.01; $p = 0.04$). No statistically significant intergroup differences were detected for the Harris Hip Score (HHS) (MD: –4.13; 95% CI: –9.37 ~ 1.11; $p = 0.12$), incidence of femoral head necrosis (RD: –0.05; 95% CI: –0.14 ~ 0.05; $p = 0.36$), or fixation failure rate (RD: –0.05; 95% CI: –0.17 ~ 0.06; $p = 0.37$).

Conclusion: Closed reduction yields a statistically significant advantage in reducing postoperative FNS and a borderline significant benefit in maintaining the CCD. In contrast, *in situ* fixation is associated with a lower reoperation rate. The two strategies show comparable outcomes for the HHS, femoral head necrosis incidence, and fixation failure rate. Thus, surgical approach should be individualized based on patient-specific profiles.

Keywords: Femoral neck fracture, *in situ*, internal fixation, reduction, valgus-impacted.

Hip fractures represent a major global public health challenge, with cases projected to surge from 1.26 million in 1990 to 7.3 to 21.3 million by 2050, and a notable shift toward Asia in their geographical distribution.[1] The etiology of hip fractures in the elderly is primarily attributed to a synergistic effect between an elevated risk of falls, due to degenerative neuromuscular changes, and compromised bone integrity, caused by osteoporosis or trauma. These intertwined physiological declines collectively contribute to the severe clinical outcomes observed in this patient population.[2] Among these, valgus-impacted femoral neck fractures (VIFNFs) are a common subtype, accounting for 15% to 20% of all femoral neck fractures (FNFs).[3]

Clinically, FNFs are categorized according to the Garden classification system, which includes

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type I (incomplete, valgus-impacted), type II (complete, non-displaced), type III (complete, partially displaced), and type IV (complete, fully displaced) fractures.[4] The corresponding spectrum of management options ranges from *in situ* fixation for stable patterns to closed reduction and internal fixation (CRIF), open reduction and internal fixation (ORIF) or total hip arthroplasty (THA) for displaced fractures. Given the significant risk of immobilization-related complications (e.g., pressure ulcers, pneumonia) with conservative care, minimally invasive fixation has become the mainstay surgical approach. *In situ* fixation is valued for its technical simplicity, but fails to correct the underlying deformity, potentially elevating postoperative risks of nonunion or femoral head necrosis. By contrast, reduction and fixation addresses valgus and impaction deformities, reducing complication rates, although at the expense of greater technical demand.[5,6]

Valgus-impacted femoral neck fractures present a core surgical dilemma: choosing between *in situ* fixation and reduction with internal fixation. *In situ* fixation is technically straightforward, but accepts a non-anatomical position, while reduction and fixation restore anatomical alignment for better biomechanics yet is more technically demanding and may compromise initial fracture stability. Heu et al.'s[7] recent systematic review compared the two surgical strategies, but only provided descriptive analysis without quantitative synthesis, and Vidakovic et al.[8] focused on conservative versus *in situ* fixation without addressing reduction versus *in situ* fixation. In the present meta-analysis, we review these studies by quantitatively synthesizing comparative data, delivering precise effect size estimates for key outcomes and more comprehensive evidence. Given the unresolved optimal approach, this meta-analysis aims to systematically compare postoperative outcomes of closed reduction versus *in situ* internal fixation for VIFNFs, clarify differences in functional recovery and complication rates, and provide evidence-based guidance for treating older adults with FNFs.

MATERIALS AND METHODS

Search strategy

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines served as the basis for this meta-analysis.[9] We searched Cochrane Library, PubMed, ScienceDirect, Web of Science, and Embase using the following terms: "femoral neck fracture", "Valgus-Impacted", "*in situ*", "reduction", and "internal fixation". Search terms are limited to titles or abstracts, without restrictions on publication year, research type, or language. The last search lasted until October 2025. Duplicate records were first removed. Titles and abstracts were, then, screened sequentially to exclude clearly irrelevant studies. Full texts of tentatively included studies, and relevant systematic reviews, were retrieved and assessed for eligibility. Additionally, reference lists of all identified articles were hand-searched to capture any missed relevant studies. This study was registered in the PROSPERO database (CRD420251275399) and the Open Science Framework (OSF; DOI: 10.17605/OSF.IO/UDSBG).

Inclusion and exclusion criteria

We screened studies for inclusion based on three core criteria: (1) enrollment of patients with VIFNFs; (2) directly contrasting *in situ* internal fixation with CRIF in terms of clinical outcomes; and (3) reporting of at least one prespecified outcome: postoperative femoral neck shortening (FNS), caput-collum-diaphysis (CCD) angle, reoperation rate, Harris Hip Score (HHS), incidence of femoral head necrosis, or fixation failure rate. Undertaken independently by two reviewers, the quality assessment and data extraction process employed a standardized form to ensure consistency. Exclusion criteria were as follows: (1) duplicate publications, non-original work (e.g., reviews, case reports, conference abstracts), meta-analyses, or basic research; (2) interventions failing to meet our inclusion criteria or absence of a control group; (3) inaccurate/incomplete raw data, or data that were challenging to extract; and (4) studies reporting outcomes irrelevant to our prespecified endpoints.

Data extraction

To ensure accuracy and consistency, two reviewers independently collected data from the included studies. Key details such as the first author, publication year, sample size, study design, and specific interventions were recorded. The prespecified primary and secondary outcomes for analysis were postoperative FNS, CCD angle, reoperation rate, HHS, and the incidence of femoral head necrosis and fixation failure.

Quality assessment

The methodological quality of all included studies was independently evaluated by two reviewers. Specifically, all non-randomized-controlled trials (non-RCTs) were assessed with the Methodological Index for Non-Randomized Studies (MINORS).[10]

Statistical analysis

Statistical analysis was performed using the RevMan version 5.4 software (R Foundation for Statistical Computing, Vienna, Austria). Continuous data were pooled as mean differences (MDs), while dichotomous outcomes were pooled as risk differences (RDs), with both measures reported alongside their 95% confidence intervals (CIs). Between-study heterogeneity was quantified by the I^2 statistic and Cochran's p value. A fixed-effects model was applied when heterogeneity was low ($I^2 < 50\%$ and $p > 0.1$); otherwise, a random-effects model was employed for the meta-analysis. A p value of <0.05 was considered statistically significant.

RESULTS

Initial searches across the specified databases identified 563 potentially relevant studies, with no additional records retrieved from supplementary sources. Duplicate records were first removed using EndNote software, which led to the exclusion of 236 articles. A two-stage screening protocol was subsequently implemented: initial title and abstract screening led to the exclusion of 317 studies that failed to satisfy the preliminary eligibility criteria, followed by a comprehensive full-text assessment of the remaining 10 articles. Ultimately, five studies fulfilled the predefined inclusion criteria and were enrolled in the final meta-analysis.[11-15] The study selection process is illustrated in Figure 1.

The methodological quality of the included non-RCTs was evaluated using the MINORS, with scores ranging from 17 to 18, indicating moderate methodological rigor. The complete breakdown of these scores is detailed in Table I. The baseline demographic and clinical characteristics of the included studies are summarized in Table II.

Four studies reported postoperative one-year HHS outcomes. Statistical heterogeneity was evident across studies ($p < 0.00001$, $I^2 = 89\%$), necessitating a random-effects model for meta-analysis. Pooled results showed no significant between-group difference in postoperative HHS scores (MD: –4.13; 95% CI: –9.37 ~ 1.11; p=0.12) (Figure 2, Table III).

Two studies reported postoperative FNS. Statistical heterogeneity was present across studies ($p = 0.10$, $I^2 = 63\%$), warranting a random-effects model for meta-analysis. Pooled results showed that the closed reduction group had a significantly lower postoperative FNS than the *in situ* fixation group (MD: 4.05; 95% CI: 2.68 ~ 5.42; $p < 0.00001$) (Figure 3, Table III).

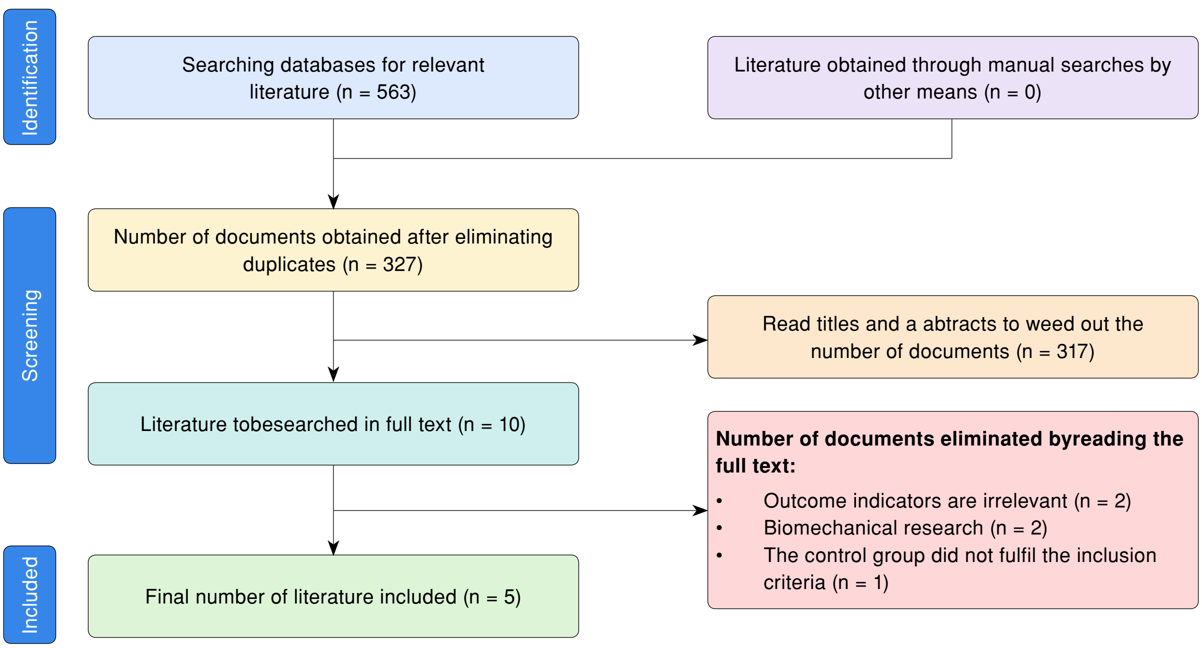

FIGURE 1. Study flowchart.

TABLE I
Quality assessment for non-randomized trials

Quality assessment for non-randomized trials	Jang et al.[11] 2025	Kweon et al.[12] 2023	Nobori et al.[13] 2025	Park et al.[14] 2021	Yu et al.[15] 2022
A clearly stated aim	2	2	2	2	2
Inclusion of consecutive patients	1	1	2	1	1
Prospective data collection	0	0	0	0	0
Endpoints appropriate to the aim of the study	2	2	2	2	2
Unbiased assessment of the study endpoint	2	2	1	2	1
A follow-up period appropriate to the aims of study	2	2	2	2	2
Less than 5% loss to follow-up	1	1	1	1	2
Prospective calculation of the sample size	0	0	0	0	0
An adequate control group	2	2	2	2	2
Contemporary groups	1	2	1	2	2
Baseline equivalence of groups	2	2	2	2	2
Adequate statistical analyses	2	2	2	2	2
Total score	17	18	17	18	18

TABLE II
Characteristics of included studies

Study	Date	Design	Group	Cases	Age year	Female	Follow-up
Jang et al.[11]	2025	RCS	*In situ*	161	69.7 ± 10.8	133	24
			reduction	45	66.3 ± 10.9	34	24
Kweon et al.[12]	2023	RCS	*In situ*	23	66.4 ± 18.5	15	18.7 ± 5.7
			reduction	23	69.7 ± 10.6	13	15.4 ± 2.6
Nobori et al.[13]	2025	RCS	*In situ*	56	80.62 ± 7.02	43	25
			reduction	36	78.94 ± 7.88	31	25
Park et al.[17]	2021	RCS	*In situ*	28	52.6 ± 10.3	22	36.3
			reduction	27	51.3 ± 9.8	22	36.2
Yu et al.[15]	2023	RCS	*In situ*	24	52.14 ± 11.23	14	31.25 ± 5.99
			reduction	24	54.36 ± 10.95	17	29.96 ± 5.36

RCS: Retrospective controlled trial; SD, standard deviation; Follow-up time in months.

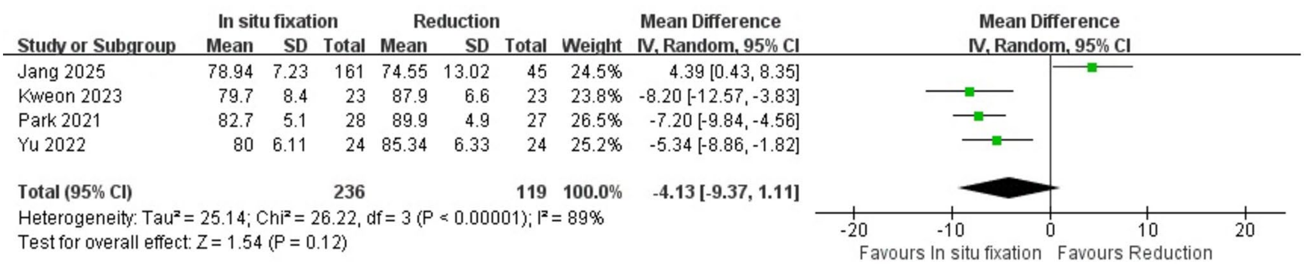

FIGURE 2. Forest plot showing postoperative HHS
SD, standard deviation; CI, confidence interval; HHS, Harris Hip Score.

Two studies reported postoperative CCD angle. Substantial statistical heterogeneity was observed across these studies ($p < 0.00001$, $I^2 = 94\%$), thus a random-effects model was employed for meta-analysis. The pooled results indicated that the closed reduction group had a borderline significant difference in postoperative CCD angle compared with the *in situ* fixation group (MD: 9.79; 95% CI: 0.19 ~ 19.39; p = 0.05) (Figure 4, Table III).

Five studies reported postoperative femoral head necrosis incidence. Statistical heterogeneity was moderate across studies (p = 0.05, I^2 = 57%), warranting a random-effects model for meta-analysis. Pooled results showed no significant between-group difference in postoperative femoral head necrosis incidence (RD: −0.05; 95% CI: −0.14 ~ 0.05; p = 0.36) (Figure 5, Table III).

Three studies reported postoperative reoperation rates. Statistical heterogeneity was minimal across studies (p = 0.17, I^2 = 43%), warranting a fixed-effects model for meta-analysis. Pooled results showed the *in situ* fixation group had a lower reoperation rate than the closed reduction group (RD: −0.08; 95% CI: −0.16 ~ −0.01; p = 0.04) (Figure 6, Table III).

Four studies reported a total of 24 cases of postoperative fixation failure. Statistical heterogeneity was substantial across studies (p = 0.0004, I^2 = 84%), necessitating a random-effects model for meta-analysis. Pooled results showed no significant between-group difference in fixation failure incidence (RD: −0.05; 95% CI: −0.17 ~ 0.06; p = 0.37) (Figure 7, Table III).

To ensure the reliability and robustness of pooled results, we conducted sensitivity analyses for studies with $I^2 > 75\%$ in heterogeneity testing. This involved iteratively removing one study at a time and re-pooling effect sizes to assess how each individual study impacted the overall results an approach to evaluate conclusion stability and inform evidence interpretation.

For outcomes with marked heterogeneity, including one-year postoperative HHS (I^2 = 89%) and fixation failure (I^2 = 84%), removing Jang et al.[11] substantially reduced heterogeneity (I^2 = 0%). We, then, re-examined the full text to identify potential sources. Baseline characteristic differences were likely the primary driver: Jang et al.[11] enrolled older patients (mean age: *in situ* group: 69.7 ± 10.8, reduction group: 66.3 ± 10.9 years) with a higher Charlson Comorbidity Index (3.3-3.8) compared to other studies (e.g., Park et al.,[14] which included 51 to 53 years old). Older adults exhibit reduced bone quality and impaired healing, making them more susceptible to reduction-related complications and higher fixation failure risk. Younger cohorts, by contrast, have higher activity levels and better prognoses; this variability in age and health status directly impacts outcome consistency.

TABLE III
GRADE evidence summary

Quality assessment No. of studies	Design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	No. of patients: *In situ* fixation	No. of patients: Reduction	Effect: MD/OR (95% CI)	Quality
HHS (4 articles)	RCS	No serious risk of bias	Very serious	No serious indirectness	No serious imprecision	None	236	119	−4.13 (−9.37 ~ 1.11)	⊕⊕Low
FNS (2 articles)	RCS	No serious risk of bias	Serious	No serious indirectness	No serious imprecision	None	51	50	4.05 (2.68 ~ 5.42)	⊕⊕⊕Moderate
CCD (2 articles)	RCS	No serious risk of bias	Very serious	No serious indirectness	No serious imprecision	None	51	50	9.79 (0.19 ~ 19.39)	⊕⊕Low
Femoral head necrosis (5 articles)	RCS	No serious risk of bias	No serious	No serious indirectness	No serious imprecision	None	292	155	−0.05 (−0.14 ~ −0.05)	⊕⊕⊕Moderate
Reoperation rate (3 articles)	RCS	No serious risk of bias	No serious	No serious indirectness	No serious imprecision	None	240	104	−0.08 (−0.16 ~ −0.01)	⊕⊕⊕⊕High
Fixation failure (4 articles)	RCS	No serious risk of bias	Serious	No serious indirectness	No serious imprecision	None	236	119	−0.05 (−0.17 ~ 0.06)	⊕⊕⊕Moderate

MD, mean differences; OR, odds ratios; CI, confidence interval; HHS, Harris Hip Score; RCS, retrospective controlled study; FNS, femoral neck shortening; CCD, caput-collum-diaphysis angle; Grade certainty assessment: ⊕⊕⊕⊕, High certainty; ⊕⊕⊕, Moderate certainty; ⊕⊕, Low certainty; ⊕, Very low certainty.

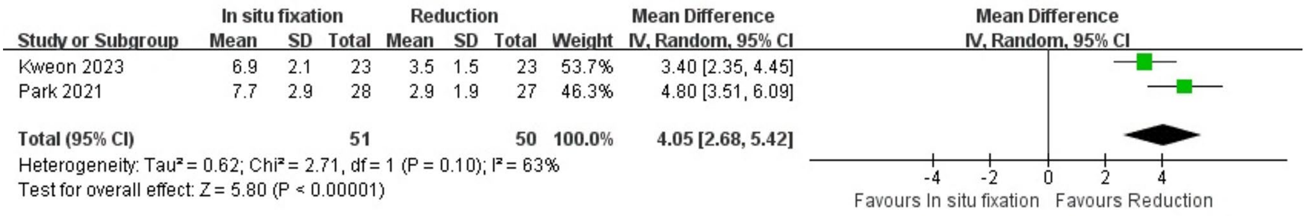

FIGURE 3. Forest plot showing postoperative FNS.
SD, standard deviation; CI, confidence interval; FNS, femoral neck shortening.

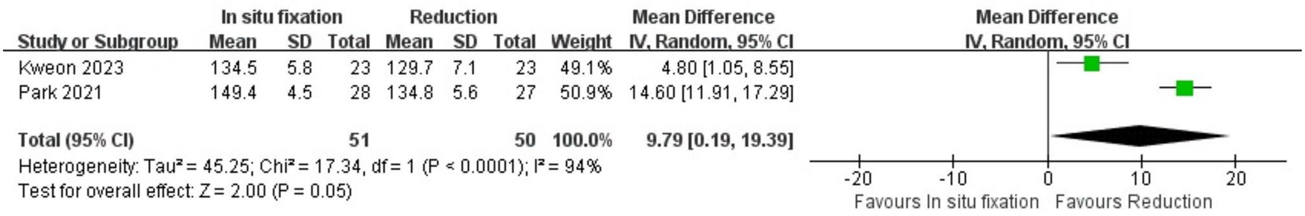

FIGURE 4. Forest plot showing postoperative CCD.
SD, standard deviation; CI, confidence interval; CCD, caput-collum-diaphysis angle.

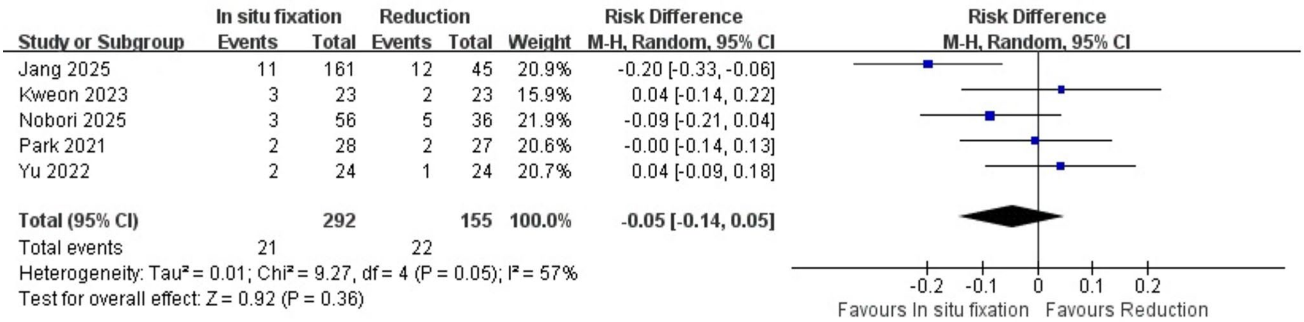

FIGURE 5. Forest plot showing postoperative Femoral head necrosis.
CI, confidence interval.

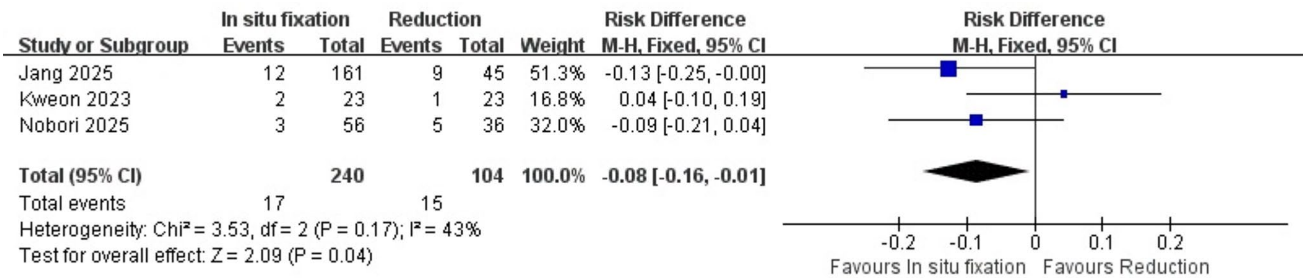

FIGURE 6. Forest plot showing reoperation.
CI, confidence interval.

Inconsistent fracture definition and classification also contributed. Jang et al.[11] failed to define severity thresholds for VIFNFs (e.g., valgus angle > 15°), whereas studies such as Park et al.[14] and Nobori et al.[13] explicitly used the Garden Alignment Index (GAI) or posterior tilt. Additionally, Jang et al.[11] employed traditional closed reduction with limited detail on traction/rotation, while others

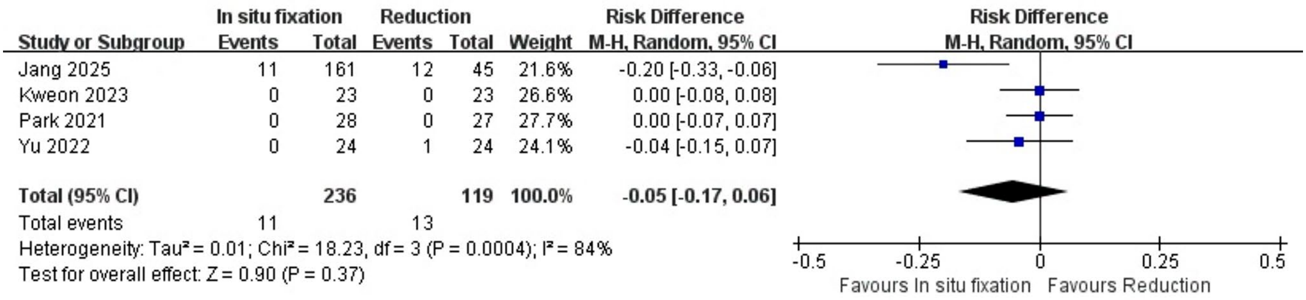

FIGURE 7. Forest plot showing postoperative fixation failure.
CI, confidence interval.

used standardized minimally invasive techniques (e.g., Park et al.[14] with Schanz pin lateral traction, Yu et al.[15] with Steinmann pin "in-out-in" percutaneous reduction). Variability in technical standardization likely affected reduction quality and outcomes.

For the substantial CCD angle heterogeneity (I^2 = 94%), we again re-examined the full text. Fracture management differences played a key role: Park et al.[14] clearly defined "severe valgus-impacted fractures" (valgus angle > 15°, AO/OTA 31-B1.1), but Kweon et al.[12] did not specify a threshold and included more fractures with combined anterior/posterior tilt this discrepancy may have led to differing CCD angle correction. Furthermore, Park et al.[14] measured CCD angle via plain radiographs, spanned 12 years of enrollment, and relied on a single radiographic observer factor introducing learning curves and measurement bias. These gaps in methodology and design standardization exacerbated heterogeneity.

DISCUSSION

For impacted fractures with inherent stability, *in situ* fixation is commonly employed in clinical practice. This preference stems from the concern that manipulative reduction may disrupt the naturally stable configuration by displacing the impacted fracture ends, potentially inducing bone defects and compromising stability thereafter.[16,17] Gjertsen et al.[18] reported an 89% implant survival rate at one year following *in situ* internal fixation for patients with non-displaced femoral neck fractures. However, *in situ* internal fixation is not devoid of risks even for non-displaced fractures. Kain et al.[19] noted that among patients aged ≥ 65 years with Garden I or II femoral neck fractures treated with percutaneous inverted triangular cannulated screw fixation, the revision rate due to avascular necrosis (AVN), nonunion, or internal fixation failure reached as high as 10%. Additionally, repetitive forceful reduction maneuvers during fixation can increase the risk of femoral head AVN. Even ORIF under direct visualization may lead to iatrogenic neurovascular injury and hematoma formation.[20,21]

This meta-analysis included five studies aiming to compare the postoperative outcomes of patients who underwent closed reduction versus *in situ* internal fixation for VIFNFs. The primary objective was to clarify differences in functional recovery and complication profiles between the two fixation strategies. Pooled results demonstrated that the closed reduction group achieved a statistically significant advantage in reducing postoperative FNS, along with a borderline significant benefit in maintaining CCD angle, compared with the *in situ* fixation group. In contrast, the *in situ* fixation group exhibited a lower reoperation rate. No statistically significant between-group differences were detected in HHS levels, the incidence of AVN, or the rate of fixation failure. Taken together, these findings suggest that closed reduction internal fixation is preferable for lowering the risk of postoperative FNS and preserving the CCD angle for patients with VIFNFs, whereas *in situ* internal fixation is a more favorable option to reduce reoperation risk; both techniques yield comparable functional recovery, AVN incidence and fixation failure rates in clinical practice.

The superior restoration of FNS and CCD angle in the reduction and fixation group underscores the critical role of anatomical reduction in re-establishing femoral geometry. This finding is consistent with previous reports by Park et al.[14] and Kweon et al.,[12] which demonstrated that reduction and fixation effectively minimized postoperative FNS and achieved superior CCD angle restoration. Furthermore, the work of Yu et al.[15] also supports the advantage of this approach in optimizing

CCD angle alignment and reducing FNS. These anatomical improvements provide a robust foundation for enhanced functional outcomes, particularly in younger, more active patients. Notably, however, the anatomical advantage did not correlate with a lower reoperation rate in our series. Conversely, our analysis indicated a reduced reoperation rate in the *in situ* fixation group. Although no statistically significant difference in fixation failure rates was observed between the two groups, a numerical trend toward higher reoperations, primarily due to screw loosening or fracture collapse[22] was noted in the reduction and fixation cohort. One plausible explanation for this discrepancy may be related to the inherent stability of the fracture site. As suggested by Park et al.,[14] while anatomical reduction restores alignment, it may also disrupt the initial stability provided by fracture impaction. Suboptimal fracture surface contact or residual gaps following reduction could potentially compromise the mechanical stability of the implant, predisposing to subsequent loss of fixation. While closed reduction significantly reduced FNS, its clinical impact must be weighed against patient-specific factors. Zlowodzki et al.[23] associated shortening > 5 mm with poorer function. Thus, a 4-mm reduction may lower the risk of crossing this threshold, potentially benefiting younger, active patients. In low-demand elderly patients; however, the lower reoperation rate of *in situ* fixation may hold greater clinical importance than modest radiographic improvement. The finding that closed reduction yields better radiographic outcomes yet a higher reoperation rate presents a “reoperation paradox.” This may be explained biomechanically by the “disimpaction hypothesis.” Valgus-impacted fractures possess inherent stability due to interlocked trabeculae at the impacted site. Closed reduction reverses this impaction to restore anatomical alignment; however, this process may compromise intrinsic stability by creating micro-gaps and reducing the cortical contact area. The fixation construct must, then, bear the full load in a less congruent environment, potentially increasing the risk of screw loosening or cut-out common reasons for reoperation. This paradox appears to be primarily driven by the findings of Jang et al.,[11] whose study population was notably older (mean age: *In situ* group: 69.7 ± 10.8, reduction group: 66.3 ± 10.9 years) and which reported a significantly higher reoperation rate in the reduction group. It is plausible that the "traditional" closed reduction technique (e.g., using a traction table) described by Jang et al.[11] may impart greater disruptive forces to the fracture site compared to the more refined, percutaneous techniques (e.g., Schanz pin lateral traction or "in-out-in" percutaneous reduction) employed in other studies. In an older cohort with potentially poorer bone quality, a more forceful reduction could compromise the initial stability provided by the impacted fragments to a greater extent, thereby elevating the risk of subsequent mechanical failure and reoperation. Although the absolute increase in reoperation risk was modest (8%), this trade-off underscores that anatomical reduction does not guarantee mechanical durability. Therefore, the decision to reduce should weigh the biomechanical cost of destabilization against the radiographic benefit, particularly in patients with poor bone quality or lower functional demands.[24,25]

There was no statistically significant difference between the two groups in terms of functional outcomes and the incidence of AVN. Specifically, the lack of a significant difference in HHS despite the observed reduction in FNS with closed reduction warrants careful interpretation. The mean HHS in both groups was consistently high (> 80), suggesting a possible “ceiling effect” wherein the HHS may not be sensitive enough to detect the subtle functional decrement associated with a modest difference in shortening within this patient population. Studies by Nobori et al.[13] and Jang et al.[11] both reported comparable AVN rates regardless of reduction, indicating that reduction itself does not significantly increase the risk of femoral head vascular compromise. Notably, a severe initial posterior tilt (> 20°) is widely recognized as an independent risk factor for internal fixation failure and AVN. Okike et al.[26] found that Garden I and II femoral neck fractures with a posterior tilt > 20° were associated with a significantly higher risk of subsequent conversion to arthroplasty. Moreover, THA performed after internal fixation failure carries an increased risk of periprosthetic fracture and deep infection.[27] Therefore, even with reduction, the long-term failure risk remains non-negligible for fractures with significant posterior tilt. In such cases, direct THA may represent a more proactive treatment strategy.

The management of VIFNFs requires individualized decision-making. For younger, active patients, anatomical reduction and internal fixation are supported to achieve superior radiographic outcomes (FNS and CCD angle), despite a potential, non-significant trend toward higher reoperation risk, possibly from disrupting the impacted fracture site. For elderly patients with lower demands, *in situ* fixation offers a viable option with a lower reoperation rate, prioritizing early stability.[28,29] Severe posterior tilt (> 20°) is a critical prognostic factor that may indicate primary arthroplasty.[30] The generalizability of these findings warrants consideration. The evidence primarily derives from Asian cohorts, where population-specific factors (e.g., bone density, hip morphology) and distinct healthcare pathways (e.g., timing to surgery, rehabilitation protocols) may influence outcomes. Therefore, applying these conclusions to Western populations or different healthcare systems requires caution and external validation. Future research should refine patient selection, evaluate modern implants (e.g., femoral neck systems), and standardize rehabilitation protocols.

Furthermore, our findings should be interpreted in the context of recently published systematic reviews on similar topics. Heu et al.[7] systematically reviewed outcomes of reduction versus *in situ* fixation for VIFNFs; however, their work remained descriptive and did not provide quantitative pooled estimates. In contrast, the present meta-analysis synthesizes comparative data statistically, offering precise effect sizes (MDs and RDs) for key radiographic and clinical outcomes, along with an exploration of heterogeneity sources thereby delivering a higher level of evidence for clinical decision-making. Another relevant meta-analysis by Vidakovic et al.[8] compared *in situ* fixation with non-operative management, confirming the advantage of surgical fixation over conservative care. While their study addressed a different question (operative *vs.* non-operative), ours extends the evidence by directly comparing two surgical strategies closed reduction and *in situ* fixation thereby addressing the specific intraoperative dilemma faced by surgeons. Taken together, these reviews highlight that surgery is usually superior to non-operative management, while our analysis provides quantitative guidance on which surgical approach may better balance anatomical restoration against reoperation risk.

Nonetheless, this study has several limitations. First, all included studies were non-RCTs of moderate methodological quality, introducing potential selection bias and confounding. Second, variations in follow-up duration may affect endpoint comparability. Third, the analysis did not adjust for preoperative posterior tilt-a key prognostic factor. In practice, surgeons likely select reduction for fractures with greater posterior tilt and *in situ* fixation for more stable patterns. This “confounding by indication” means the comparison groups may differ in baseline fracture severity, potentially influencing the estimated treatment effects. Fourth, the statistical conclusions for certain outcomes should be interpreted with caution. The observed benefit of reduction on CCD angle was of borderline significance, derived from data showing substantial heterogeneity and a wide confidence interval, indicating variability in this effect across studies. Similarly, the significant reduction in reoperation rate with *in situ* fixation was based on a modest effect size with a confidence interval approaching the threshold of non-significance, suggesting limited robustness. Considerable heterogeneity was also noted for other outcomes (e.g., HHS, FNS). Finally, as only five studies were included, funnel plots and Egger’s test were not performed to assess publication bias; however, a Grading of Recommendations Assessment, Development and Evaluation (GRADE) evidence profile was provided to enhance transparency. Future well-designed, large-sample, multicenter clinical studies are needed to further validate the long-term efficacy and safety of the different fixation strategies.

In conclusion, while reduction and fixation provide statistically significant anatomical advantages in restoring FNS and CCD angle, these radiographic improvements may not translate into directly perceptible clinical benefits for all patients, particularly those with lower functional demands. In contrast, the lower reoperation rate associated with *in situ* fixation represents a more tangible and clinically impactful outcome. There are no statistically significant differences between the two strategies in terms of functional scores, AVN, or fixation failure. Therefore, clinical decision-making should be individualized: reduction and fixation may be prioritized in younger, active patients where anatomical restoration can support long-term function, while *in situ* fixation, with its lower reoperation risk, may be preferable for elderly or low-demand individuals. The choice should be based on a comprehensive assessment of the patient’s age, activity level, fracture morphology, and personal priorities.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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