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SYSTEMATIC REVIEW · SURGERY

Intraoperative and postoperative differences between intramedullary nailing and dynamic hip screw for trochanteric fractures: A trial sequential analysis and GRADE

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ABSTRACT

Introduction:

This study aimed to compare the intraoperative and postoperative differences between intramedullary nailing and dynamic hip screw in patients with trochanteric fracture.

Method:

The search of PubMed, Cochrane Library, Web of Science, and Scopus identified studies comparing IMN and DHS for hip fractures. The quality of the studies was assessed using appropriate tools. Meta-analysis was performed using mean difference, standardized mean difference, log odds-ratio effect sizes and random effect model. The heterogeneity was considered significant if ($I^2 > 50\%$). Subgroup analysis and meta-regression examined the impact of covariates such as age and gender. Trial Sequential Analysis (TSA) and GRADE assessed the evidence's robustness of the primary outcomes.

Results:

This meta-analysis of 60 studies, including 88256 patients, resulted in no significant difference in open reduction of fractures (log odds ratio -1.52, $p = 0.10$), while IMN significantly reduced blood loss by a mean difference of -98.80 ml ($p < 0.01$) and showed a trend toward fewer blood transfusions (log odds ratio -0.65, $p = 0.09$). Although screening time was slightly longer for IMN (MD = 0.52 minutes, $p < 0.05$), surgical time favored IMN with a significant reduction of -9.47 minutes ($p < 0.01$). Postoperatively, IMN demonstrated a modest reduction in hospital stay (SMD = -0.22, $p < 0.01$) and a significant improvement in healing time (MD = -6.92 days, $p = 0.02$). No significant differences were observed in femoral neck shortening or functional outcomes.

Conclusion:

The existing evidence till now showed IMN offers reduced blood loss and better surgical efficiency, but there are varied results on healing times and hospital stays. Ongoing research is essential for evaluating IMN techniques against DHS methods.

Intertrochanteric femur fractures – IMN – DHS – meta-analysis.

Keywords: Intertrochanteric · femur fractures · intramedullary nailing (IMN) · dynamic hip screw (DHS) · meta-analysis · blood loss · fracture reduction · trial sequential analysis · GRADE

Introduction

Hip fractures represent a significant public health concern, often leading to disability, reduced quality of life, and increased mortality, particularly in the elderly population. As the global population ages, the incidence of hip fractures is expected to rise dramatically. By 2025, the worldwide number of hip fractures is projected to reach 2.6 million, increasing further to 6.25 million by 2050 (1–3).

Trochanteric fractures involve the proximal femur, specifically the region between the femoral neck and the shaft. Subtrochanteric fractures, characterized by a fracture line extending up to 5 cm distal to the lesser trochanter, are often included in this definition. Various classification systems exist for trochanteric fractures, typically based on the location of the fracture line and the degree of displacement, which impacts external reduction techniques (4–7). Two widely recognized classifications are the Evans classification, later modified by Jensen and Michaelsen, and the AO/OTA Classification. The Evans classification categorizes fractures based on stability, ranging from non-displaced two-fragment fractures (Type I) to more complex comminuted fractures involving medial and posterolateral displacement. The AO/OTA Classification, developed by the AO Foundation and adopted by the Orthopaedic Trauma Association, further aids in the classification of these injuries. (8–13).

Trochanteric fractures are frequently addressed surgically, with sliding hip screws (SHS) and intramedullary nails (IMN) being the two most widely used fixation techniques (14). Although many studies report no significant differences in outcomes between these methods, this may be attributed to including all types of trochanteric fractures in the analysis. Recent research

tends to focus on stable and unstable fracture categories without detailed consideration of the specific AO/OTA subtypes (31A1, 31A2, 31A3), which could make findings more clinically relevant (15–17). Current guidelines, such as the Dutch Guideline, recommend extramedullary fixation for AO 31-A1 and 31-A2 fractures due to their superior cost-effectiveness, mainly driven by lower implant costs. Nonetheless, extramedullary and intramedullary fixation is acceptable for 31-A2 fractures, with no definitive evidence supporting one method over the other. Earlier studies, particularly those evaluating first-generation cephalomedullary nails, raised concerns about higher failure and reoperation rates with intramedullary devices. Despite this, the use of IMN has increased significantly in recent years, accounting for up to 90% of procedures in the US, as recent data indicates better outcomes. However, this growing preference may also be influenced by factors other than purely clinical outcomes, leaving the best treatment approach a subject of ongoing debate (18,19,19–23).

The objective of this study was to evaluate the intraoperative and postoperative differences between intramedullary nailing and dynamic hip screw fixation in patients with trochanteric fractures compare between the results of the most recent evidence and the previous published meta-analysis.

Methods

2.1 Data Sources and Search Strategy

This study adhered to the recommendations set forth by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement and the Cochrane Handbook for Systematic Reviews of Interventions. A comprehensive literature search was performed across PubMed, Scopus, Web of Science, and the Cochrane Library databases, covering publications up to September 2024. The specific search strategies employed for each database can be found in **Supplementary File 1.** The study protocol was registered in the international prospective register of systematic reviews, PROSPERO (CRD42024583373)

2.2 Eligibility Criteria and Selection Process

We included the clinical trials and observational comparative studies published in English till September 2024 and have an accessible full text focusing on the patients with trochanteric fractures who underwent IMN Vs. DHS. However, we excluded studies that were animal-based, laboratory-based, basic science, cadaveric, editorial, or published in languages other than English.

Based on the previous specific criteria, two authors independently reviewed each study's title and abstract in the prescreening process and the full text in the whole text screening process to ensure that all included studies met the inclusion criteria.

2.3 Data extraction tool and items

Another four authors were responsible for data extraction using an Excel spreadsheet. Two authors extracted a summary of the included studies, including the following items: title, study design, site, population, intervention, comparator, follow-up duration (in weeks) and sample size. The other two authors extracted baseline demographics and outcomes reported in the included studies, which included age, BMI, sex, fracture classification, American Society of Anesthesiologists (ASA) score, and side of fracture.

2.4 Outcomes measurement

Primary outcomes: open reduction of fracture, blood loose (ml), time to healing (days) and femoral neck shortening (mm)

Secondary outcomes: required blood transfusion (UNITS), Patients need Blood transfusion, screening time (min), mean surgical time (min), hospital stay (days), mean Harris hip score and mobility score and Parker Mobility Score

2.5 Quality assessment

The quality of the randomized control trials (RCTs) was assessed independently by two authors using The Cochrane Collaboration's tool for assessing the risk of bias (ROB-1) (24) and the cohort studies included were evaluated by another two authors using the Newcastle-Ottawa Scale (NOS) (25).

2.6 Statistical analysis

The meta-analysis was conducted using Stata 17, employing mean difference (MD) or standardized mean difference (SMD) effect sizes for continuous outcomes and log odds-ratio effect size for binary outcomes. A random-effects model was utilized to account for study heterogeneity. Statistical significance was determined with a p-value of less than 0.05 and a 95% confidence interval (95% CI). Heterogeneity was considered significant if I^2 was greater than 50% and the p-value was below 0.1. Subgroup analyses were performed based on study design, and meta-regression was used to assess covariates' impact, such as age and gender. Additionally, trial sequential analysis (TSA) (26) and Grading of Recommendations, Assessment, Development and Evaluation (GRADE) (27) were employed to evaluate the robustness and overall quality of the evidence for the primary outcomes.

2.7 Publication bias

Publication bias across all outcomes was evaluated using funnel plot visualization and egger test (28).

Results

3.1 Study Selection and Data Extraction

The initial search retrieved 3,740 research papers. After removing 540 duplicates, 3,200 papers remained for title and abstract screening. After excluding 3,061 studies, 139 papers entered the full-text screening process. Based on the prespecified inclusion and exclusion criteria, we included 60 studies in the final analysis, which comprised 31 randomized controlled trials (RCTs) and 29 cohort studies. The total number of participants is 88256 patients, ranging from 39 in the most minor cohort study to 34759 in the largest cohort studies, with follow-up periods varying from 1 to 212 weeks. This process is presented in **Supplementary file 1.** The summary of the studies included is presented in **Table 1** and the baseline characteristics is presented in **Supplementary file 1.**

Table 1. Summary of the included studies

study ID	title	design	site	population	Intervention	comparator	follow up (weeks)	sample size
Adams 2001	Prospective randomized controlled trial of an intramedullary nail versus dynamic screw and plate for intertrochanteric fractures of the femur	RCT	UK	patients admitted from the local population with intertrochanteric fractured femurs	GN	DHS	48	400
Adeel 2020	Comparison of proximal femoral nail (PFN) and dynamic hip screw (DHS) for the treatment of AO type A2 and A3 pertrochanteric fractures of femur	RCT	Pakistan	patients aged 40-75 years with Arbeitsgemeinschaft für Osteosynthesefragen type A2 and A3 per trochanteric fractures	PFN	DHS	48	68
Ahmad 2019	Injury specific trauma registry: Outcomes of a prospective cohort with proximal femur fractures	Prospective Cohort	Pakistan	Patients with isolated neck of femur or intertrochanteric fractures between 2015 and 2018 at Aga Khan University	IMN	DHS	52	138
Ahrengart 2002	A randomized study of the compression hip screw and Gamma nail in 426 fractures	RCT	Sweden, Finland	Four hundred twenty-six patients with intertrochanteric fractures	GN	DHS	24	426
Aktselis 2014	Prospective randomised controlled trial of an intramedullary nail versus a sliding hip screw for intertrochanteric fractures of the femur	RCT	Greece	patients with a 31-A2.2 or A2.3 Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) intertrochanteric fracture	GN	DHS	48	71
Arshad 2021	Dynamic hip screw fxation of subtrochanteric femoral fractures	Retrospective cohort	UK	86 patients presented with a subtrochanteric fracture of the femur	IMN	DHS	-	86
Avakian 2011	Dynamic hip screws versus proximal femoral nails for intertrochanteric fractures	Retrospective cohort	Australia	144 patients with intertrochanteric fractures	PFN	DHS	-	144
Barton 2010	A comparison of the long gamma nail with the sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur: a prospective randomized trial	RCT	UK	Two hundred and ten patients presenting with an AO/OTA 31-A2 fracture of the proximal part of the femur	GN	DHS	48	210
Berney 2024	Is the increased use of intramedullary nailing over DHS for intertrochanteric hip fractures justified? – A review of the Irish hip fracture database 2016 – 2020	Retrospective cohort	Ireland	Patients with intertrochanteric fractures older than 60 years	DHS	IMN	-	5668
Butt 1995	Comparison of dynamic hip screw and gamma nail: a prospective, randomized, controlled trial	RCT	UK	95 consecutive pafients with peri-trochnteric fractures of the femur.	GN	DHS	-	95
Carruli 2017	A comparison of two fixation methods for femoral trochanteric fractures: a new generation intramedullary system vssliding hip screw	RCT	Switzerland	patients affected by a trochanteric fracture, treated between January 2007 to December 2009	PFNA	DHS	12	128
Chau 2013	Cephalomedullary nail versus sliding hip screw for unstable intertrochanteric fractures in elderly patients	cohort	Singapore	63 elderly patients aged ≥60 years with unstable intertrochanteric fractures (AO types A2 and A3)	PFNA	DHS	48	63
Chen 2013	Convergence of Outcomes for Hip	Retrospective cohort	USA	patients who sustained a hip fracture by the International Classification of Diseases	IMN	DHS	48	8924

study ID	title	design	site	population	Intervention	comparator	follow up (weeks)	sample size
	Fracture Fixation by Nails and Plates							
Das 2020	Osteosynthesis of intertrochanteric fracturesby PFN and DHS – A prospective randomized comparative study	RCT	India	150 patients of unstable ITF (AO type 31-A2, 31-A3) in elderly (with age more than 50 years)	PFN	DHS	48	150
Duan 2017	Comparison of the curative effects of PFNA and DHS fixation in treating intertrochanteric fractures in elderly patients	Retrospective cohort	China	Patients aged between 60-92 years old admitted with intertrochanteric fractures	PFNA	DHS	78	108
Dunne 2021	Comparison of outcomes after different methods of fixation for extracapsular hip fractures: An observational study	Retrospective cohort	England	Patients with stable and unstable hip fractures	PFNA	DHS	52	1335
Gawronska 2022 (Aug)	Holistic Symmetry Assessment Using Pedobarography after Treatment of Pertrochanteric Fractures in Elderly Patients	Prospective cohort	Poland	Elderly patients aged 65+ with pertrochanteric fractures	IMN	DHS	36	60
Gawronska 2022 (Feb)	Functional Symmetry after Surgical Treatment of Pertrochanteric Fractures in the Elderly	Prospective cohort	Poland	Adults with pertrochanteric femoral fractures.	IMN	DHS	24	78
Grezda 2021	Comparison of systemic inflammatory responses of proximal femoral nail versus dynamic hip screw after treatment of patients with pertrochanteric fractures: A prospective comparative study	Prospective cohort	Kosovo	patients older than 60 with trochanteric region fractures AO/OTA 31.A1–31.A2	DHS	PFN	1	40
Hardy 1998	Use of an intramedullary hip-screw compared with a compression hip-screw with a plate for intertrochanteric femoral fractures. A prospective, randomized study of one hundred patients	RCT	Belgium	elderly patients who had an intertrochanteric femoral fracture	GN	DHS	48	100
Harrington 2002	Intramedullary hip screw versus sliding hip screw for unstable intertrochanteric femoral fractures in the elderly	RCT	UK	patients with unstable trochanteric fractures above 65 years of age, without a previous proximal femoral fracture	IMN	DHS	48	102
Hoffman 1996	Intertrochanteric fractures of the femur: a randomized prospective comparison of the Gamma nail and the Ambi hip screw	RCT	New Zealand	patients over the age of 50 years with intertrochanteric femoral fractures	GN	DHS	96	67
Huang 2017	Comparison of the Clinical Effectiveness of PFNA, PFLCP, and DHS in Treatment of Unstable Intertrochanteric Femoral Fracture	RCT	China	patients with unstable intertrochanteric femoral fracture were extracted from the archived records at the department of orthopedics of Linyi Second People's Hospital	PFNA	DHS	96	60
Kassem 2022	Functional and radiological outcomes of dynamic hip screw with trochanteric stabilizing plate versus short proximal femoral nail in management of unstable trochanteric	RCT	Egypt	patients above the age of 60 years with isolated unstable trochanteric fractures (AO/OTA 31-A2).	PFN	DHS+TSP	52	68

study ID	title	design	site	population	Intervention	comparator	follow up (weeks)	sample size
	fractures: A randomized-controlled trial							
Kim 2020	Single screw type of lag screw results higher reoperation rate in the osteosynthesis of basicervical hip fracture	Retrospective cohort	South Korea	Patients with basicervical hip fracture of the proximal part of the femur	CMN	DHS	104	106
Kim 2022	What Is the Best Treatment Choice for Concomitant Ipsilateral Femoral Neck and Intertrochanteric Fracture? A Retrospective Comparative Analysis of 115 Consecutive Patients	Retrospective cohort	Republic of Korea	Patients diagnosed with concomitant ipsilateral femoral neck and intertrochanteric fractures (CIFNITF) who underwent surgical treatment.	PFN-A	DHS	48	84
Kleftouris 2023	Endovis Nail versus Dynamic Hip Screw for Unstable Pertrochanteric Fractures: A Feasibility Randomised Control Trial including Patients with Cognitive Impairment	RCT	Helsinki	60 consecutive patients with an unstable pertrochanteric (OTA/AO 31-A2) fracture	IMN	DHS	12	60
Konda 2021	Risk Stratification of Operatively Treated Intertrochanteric Hip Fractures Reveals Differences in Short-Term Outcomes and Procedure Costs Between Sliding Hip Screw Versus Short Cephalomedullary Nail	Retrospective cohort	USA	Geriatric patients (aged 55 years and older) with intertrochanteric hip fractures	short CMN	SHS	48	458
Kumar 2011	Comparative prospective study of proximal femoral nail and dynamic hip screw in treatment of intertrochanteric fracture femur	Prospective cohort	India	cases of intertrochanteric fractures of the femur, involving patients more than 50 years old	PFN	DHS	48	50
Little 2008	A prospective trial comparing the Holland nail with the dynamic hip screw in the treatment of intertrochanteric fractures of the hip	RCT	UK	patients who presented with an extra-capsular intertrochanteric hip fracture	Holland Nail	DHS	48	190
Marks 2021	Quality of life, walking ability and change of living situation after trochanteric femur fracture in geriatric patients-Comparison between sliding hip screw and cephalomedullary nails from the registry for geriatric trauma	Retrospective cohort	Germany	patients treated hip fractures between 2016 and 2019	CMN	SHS	17	10995
Mazzola 2022	Dynamic hip screw versus intramedullary nailing for the treatment of A1 intertrochanteric fractures: A retrospective, comparative study and cost analysis	Retrospective Cohort	Italy	patients experiencing emergency department diagnosis of proximal femoral fracture in January 1st, 2015 and December 31st, 2019.	IMN	DHS	201	85
Pajarinen 2004	Femoral shaft medialisation and neck-shaft angle in unstable pertrochanteric femoral fractures	RCT	Switzerland	patients with an unstable, low-energy, extracapsular, pertrochanteric femoral fracture (AO category 31-A, class A2)	PFN	DHS	16	48
Pajarinen 2005	Pertrochanteric femoral fractures treated with a dynamic hip screw or a	RCT	Finland	patients with a pertrochanteric femoral fracture	PFN	DHS	16	108

study ID	title	design	site	population	Intervention	comparator	follow up (weeks)	sample size
	proximal femoral nail. A randomised study comparing post-operative rehabilitation							
Parker 2012	Sliding hip screw versus the Targon PF nail in the treatment of trochanteric fractures of the hip: a randomised trial of 600 fractures	RCT	UK	598 patients with 600 trochanteric fractures of the hip	Targon PF	DHS	48	600
Parker 2017	Sliding hip screw versus intramedullary nail for trochanteric hip fractures; a randomised trial of 1000 patients with presentation of results related to fracture stability	RCT	UK	patients with stable (A1), unstable (A2), and transtrochanteric (A3) fractures, excluding pathological and subtrochanteric fractures.	IMN	SHS	-	1000
Parker-Cawley 2017	Sliding hip screw versus the Targon PFT nail for trochanteric hip fractures: a randomised trial of 400 patients	RCT	UK	patients with trochanteric hip fractures	Targon PF	DHS	48	400
PehlivanoĞlu 2021	Proximal femoral nailing versus dynamic hip screw in management of stable intertrochanteric femur fractures: a comparison of clinical and radiological outcomes	Retrospective Cohort	turkey	Patients who underwent surgical treatment for a SIFF in the department	PFNA	DHS	24	122
Reindl 2015	Intramedullary Versus Extramedullary Fixation for Unstable Intertrochanteric Fractures: A Prospective Randomized Controlled Trial	RCT	Canada	patients aged 55 and older with Type-A2 intertrochanteric fractures	IMN	DHS	48	194
Saarenpää 2006	Treatment of subtrochanteric fractures. A comparison of the Gamma nail and the dynamic hip screw: short-term outcome in 58 patients	Cohort	Finland	1,511 patients with 1,624 femoral hip fractures, aged over 49 years, treated between 1991 and 1999.	GN	DHS	52	58
Sadowski 2002	Treatment of Reverse Oblique and Transverse Intertrochanteric Fractures with Use of an Intramedullary Nail or a 95° Screw-Plate	RCT	Switzerland	elderly patients with AO/OTA 31-A3 intertrochanteric femur fractures	PFN	DCH	48	39
Sahin 2012	Dynamic hip screw versus proximal femoral nail for treatment of trochanteric hip fractures: an outcome analyses with a minimum 2 years of follow-up	Retrospective Cohort	Turkey	patients who underwent surgery for extracapsular pertrochanteric hip fractures between 2005 and 2010	PFNA	DHS	96	181
Saleem 2020	Comparison of unstable inter-trochanteric femur fracture treated with Dynamic Hip Screw and Proximal Femur Nail	RCT	Pakistan	Patients aged 40-80 years with radiological evidence of unstable inter-trochanteric fracture not more than three weeks old and willing to provide informed consent	PFN	DHS	24	108
Sanders 2017	A Multicenter Randomized Control Trial Comparing a Novel Intramedullary Device (InterTAN) Versus Conventional Treatment (Sliding Hip Screw) of Geriatric Hip Fractures	RCT	Canada	Two hundred forty-nine patients 55 years of age or older with AO/OTA 31A1 (43) and OA/OTA 31A2 (206) fractures were prospectively enrolled and followed for 12 months.	InterTAN	DHS	48	249
Saudan 2002	Pertrochanteric fractures: is there an advantage to an intramedullary nail?: a	RCT	Switzerland	All patients over the age of fifty-five years presenting with fractures of the trochanteric region caused by a	PFN	DHS	48	206

study ID	title	design	site	population	Intervention	comparator	follow up (weeks)	sample size
	randomized, prospective study of 206 patients comparing the dynamic hip screw and proximal femoral nail			lowenergy injury, classified as AO/OTA Type 31-A1 and A2				
Schemitsch 2023	Intramedullary Nailing vs Sliding Hip Screw in Trochanteric Fracture Management: The INSITE Randomized Clinical Trial	RCT	INSITE Investigators	patients aged 18 years and older with low-energy trochanteric fractures (AO/OTA type 31-A1 or 31-A2)	IMN	DHS	52	833
Singh 2019	Is PFNA-II a better implant for stable intertrochanteric fractures in elderly population ? A prospective randomized study	RCT	India	elderly patients with stable intertrochanteric fractures treated with DHS and PFNA-II between August 2014 to Dec 2016	PFNA	DHS	48	60
Talmac 2019	Examining implant superiority in the treatment of simple pertrochanteric fractures of the proximal femur in elderly patients	Retrospective Cohort	turkey	elderly patients diagnosed with simple pertrochanteric fractures (AO/OTA 31A1)	PFNA	DHS	52	141
tarantino 2005	A comparative prospective study of dynamic variable angle hip screw and Gamma nail in intertrochanteric hip fractures	Prospective cohort	Italy	patients with AO/OTA Type 31-A1; A2; A3 and B2 intertrochanteric hip fractures	GN	DMS	52	142
Tian 2022	A Retrospective Study of 98 Elderly Patients with High-Risk Lateral Femoral Wall Intertrochanteric Hip Fractures to Compare Outcomes Following Surgery with Proximal Femoral Nail Antirotation (PFNA) Versus Dynamic Hip Screw (DHS)	Retrospective Cohort	China	patients with high-risk intertrochanteric fractures of the lateral wall who underwent surgery from January 2019 to December 2020	PFNA	DHS	26	98
Utrilla 2005	Trochanteric gamma nail and compression hip screw for trochanteric fractures: a randomized, prospective, comparative study in 210 elderly patients with a new design of the gamma nail	RCT	Spain	patients older than 65 years with trochanteric femoral fractures	GN	DHS	48	210
Warren 2019	Cephalomedullary nailing versus sliding hip screws for Intertrochanteric and basicervical hip fractures: a propensity-matched study of short-term outcomes in over 17,000 patients	Retrospective Cohort	US	patients with a BC femoral neck fracture or a peritrochanteric hip fracture	CMN	SHS	4	17000
Werner 2015	Trends in the management of intertrochanteric femur fractures in the United States 2005-2011	Retrospective cohort	Nationwide database of Medicare patients	Patients with proximal femur fractures from 2005 to 2011	IMN	SHS	-	34759
Xu 2010	A comparison of the proximal femoral nail antirotation device and dynamic hip screw in the treatment of unstable pertrochanteric fracture	RCT	China	patients with unstable proximal femoral fractures (AO category 31-A2) admitted to a hospital between August 2006 and June 2008.	PFNA	DHS	48	106
Yeganeh 2016	Comparing the Intramedullary Nailing Method Versus Dynamic Hip Screw in	Retrospective cohort	Iran	patients with unstable Intertrochanteric fracture	PFN	DHS	24	114

study ID	title	design	site	population	Intervention	comparator	follow up (weeks)	sample size
	Treatment of Unstable Intertrochanteric Fractures							
Yu 2016	Proximal femoral nails anti-rotation versusdynamic hip screws for treatment of stable intertrochanteric femur fractures: an outcome analyses with a minimum 4 yearsof follow-up	Retrospective cohort	China	patients age of 60–92 years, good cognitive function, a stable IFF(type AO/ OTA 31.A1.1, 1.2, 1.3)	PFNA	DHS	212	222
Zang 2018	A comparative study of proximal femoral locking compress plate, proximal femoral nail antirotation and dynamic hip screw in intertrochanteric fractures	Retrospective cohort	china	patients with intertrochanteric femur fractures admitted between January 2015 and December 2016	PFNA	DHS	26	100
Zehir 2015	Proximal femoral nail antirotation against dynamic hip screw for unstable trochanteric fractures; a prospective randomized comparison	RCT	Turkey	Patients with AO type 31.A2 fracture on plain radiographs and aged above 65 years	PFNA	DHS	24	198
zeng 2017	Proximal femoral nail antirotation versus dynamic hip screw fixation for treatment of osteoporotic type 31-A1 intertrochanteric femoral fractures in elderly patients	Retrospective cohort	China	Patients aged 60–92 years with osteoporotic 31-A1 intertrochanteric femoral fractures	PFNA	DHS	48	222
Zou 2009	A comparison of proximal femoral nail antirotation and dynamic hip screw devices in trochanteric fractures	RCT	China	patients with low-energy trochanteric femoral fractures	PFNA	DHS	48	121

3.2 Quality assessment

The quality assessment of the included RCTs indicates a generally high methodological rigor. Specifically, 24 of 31 RCTs received a "high quality" rating (29–52). Six studies were rated "moderate quality" (53–58), indicating some potential limitations in methodology. Only one study was rated "low" (59) suggesting more significant methodological concerns that could affect the study's reliability. **Supplementary file 1.**

The quality assessment of the included cohort studies reveals a strong overall standard. Out of the 29 studies evaluated, 26 received a "Good" rating (60–85), while three studies were rated as "Fair" (86–88). The "Fair" rating indicates the presence of some methodological limitations that may affect the reliability or generalizability of the findings. **Supplementary file 1.**

3.3 Intraoperative differences

The meta-analysis revealed the following results: For open reduction of fracture, the log odds ratio was -1.52 (95% CI [-3.31; 0.28], I^2 = 86.07%, p-value = 0.10), indicating no statistically significant difference **Figure 1A**. Regarding the need for blood transfusions, the log odds ratio was -0.65 (95% CI [-1.40; 0.09], I^2 = 95.85%, p-value = 0.09), suggesting a trend favoring IMN, though not statistically significant **Figure 1B**. The analysis also revealed a mean difference of -0.06 units (95% CI [-0.14; 0.03], I^2 = 21.05%, p-value = 0.18) for required blood transfusions, indicating minimal clinical relevance **Figure 1C**. Screening time was slightly longer for IMN, with a mean difference of 0.52 minutes (95% CI [0.03; 1.02], I^2 = 99.75%, p-value < 0.05) **Figure 1D**. In terms of blood loss, IMN showed a significant reduction with a mean difference of -98.80 ml (95% CI [-127.96; -69.64], I^2 = 99.51%, p-value < 0.01), demonstrating a clear advantage for this technique in minimizing intraoperative hemorrhage **Figure 2**. Finally, the mean surgical time favored IMN with a significant reduction of -9.47 minutes (95% CI [-14.15; -4.80], I^2 = 98.79%, p-value < 0.01) **Figure 3**.

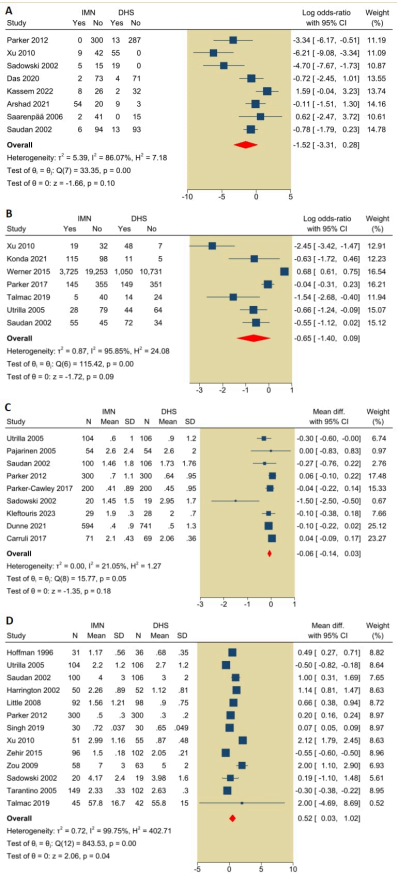


Figure 1. Forest plots of intraoperative outcomes, intramedullary nailing versus dynamic hip screw (A) Open reduction of the fracture: log odds ratio −1.52 (95% CI −3.31 to 0.28), I^2 = 86.07%, p = 0.10. (B) Patients needing blood transfusion: log odds ratio −0.65 (95% CI −1.40 to 0.09), I^2 = 95.85%, p = 0.09. (C) Required blood transfusion (units): mean difference −0.06 units (95% CI −0.14 to 0.03), I^2 = 21.05%, p = 0.18. (D) Screening time (min): mean difference 0.52 min (95% CI 0.03 to 1.02), I^2 = 99.75%, p < 0.05. Random-effects meta-analysis. IMN, intramedullary nailing; DHS, dynamic hip screw; CI, confidence interval.

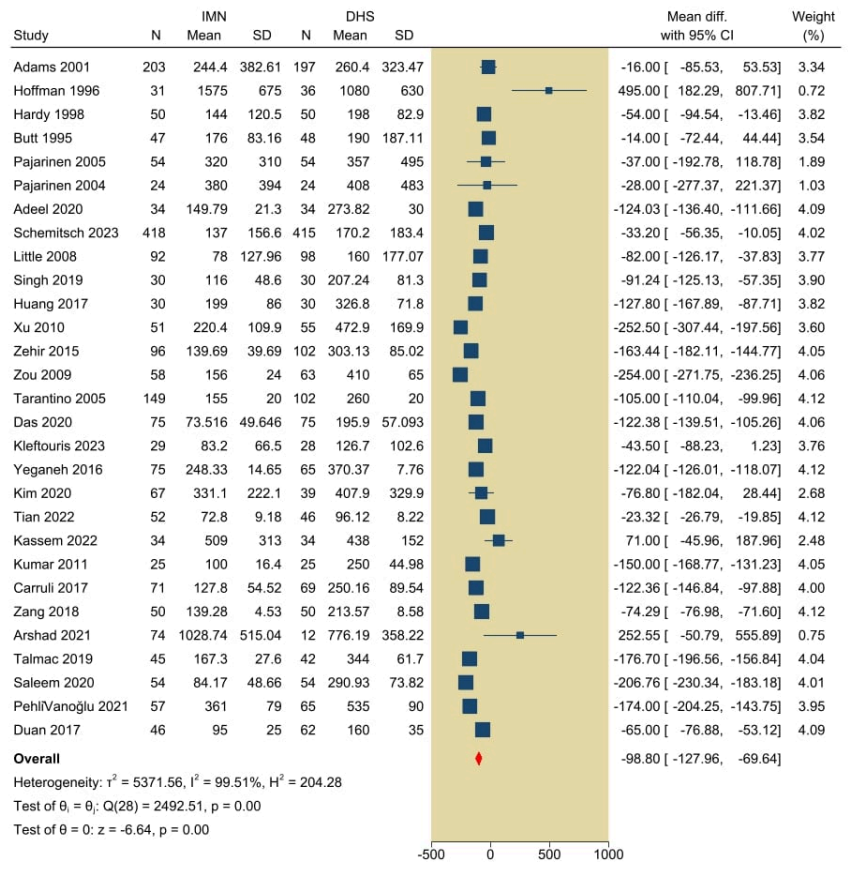


Figure 2. Forest plot of intraoperative blood loss (ml), intramedullary nailing versus dynamic hip screw Mean difference −98.80 ml (95% CI −127.96 to −69.64), I^2 = 99.51%, p < 0.01, favouring intramedullary nailing. Random-effects meta-analysis. IMN, intramedullary nailing; DHS, dynamic hip screw; CI, confidence interval.

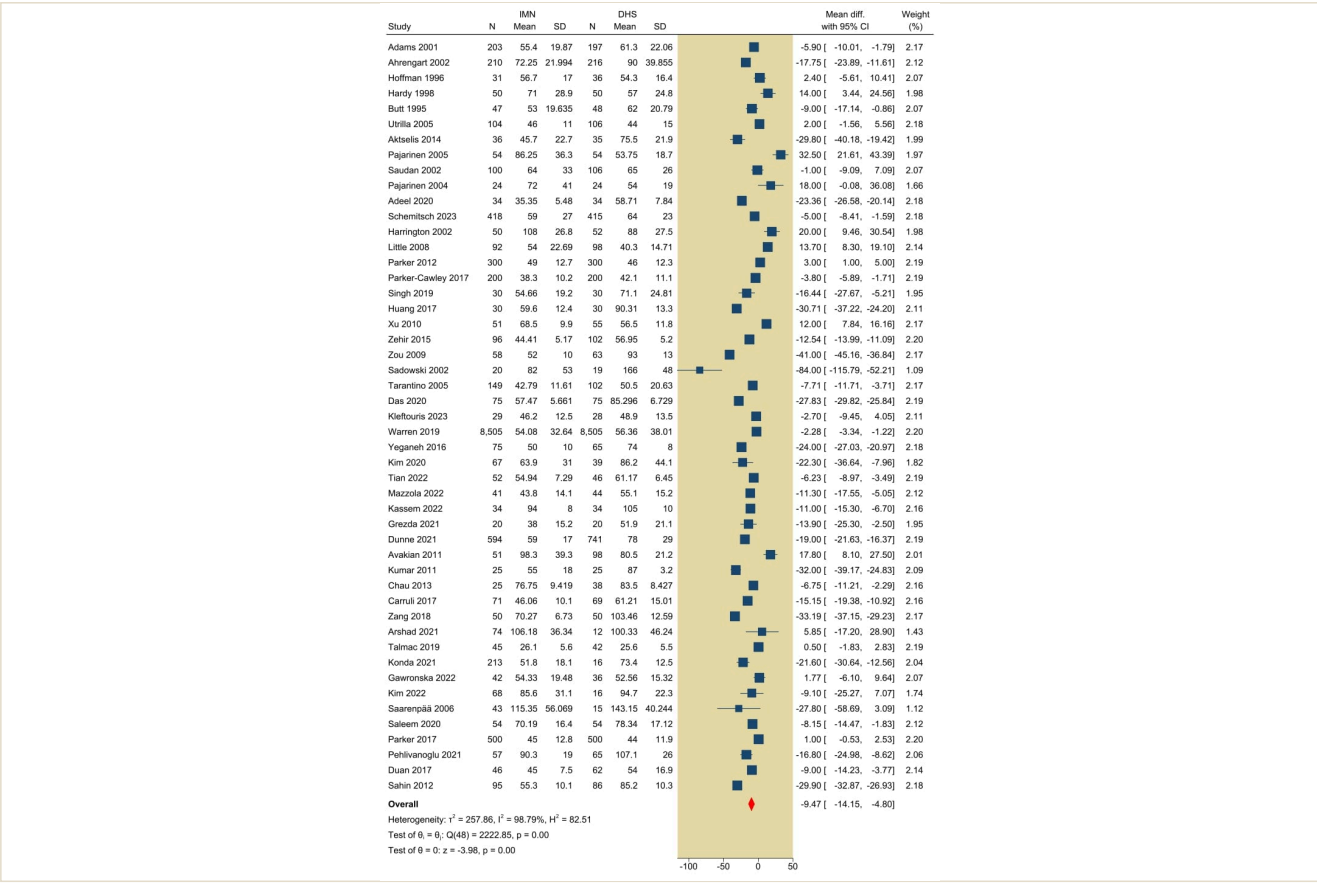


Figure 3. Forest plot of mean surgical time (min), intramedullary nailing versus dynamic hip screw Mean difference −9.47 min (95% CI −14.15 to −4.80), I^2 = 98.79%, p < 0.01, favouring intramedullary nailing. Random-effects meta-analysis. IMN, intramedullary nailing; DHS, dynamic hip screw; CI, confidence interval.

3.4 Postoperative differences

In terms of hospital stay, IMN demonstrated a slight advantage over DHS fixation, with a significant standardized mean difference of -0.22 (95% CI [-0.33; -0.10], I^2 = 90.71%, p < 0.01), indicating a modest reduction in hospital days for IMN patients **Figure 4**. For time to healing, IMN showed a statistically significant improvement with a mean difference of -6.92 days (95% CI [-12.55; -1.29], I^2 = 95.04%, p = 0.02), suggesting a quicker recovery period compared to DHS **Figure 5A**. However, no significant difference was observed in femoral neck shortening, with a mean difference of -1.19 mm (95% CI [-4.21; 1.83], I^2 = 99.76%, p = 0.44) **Figure 5B**. Mean PMS did not differ significantly between IMN and DHS, with a standardized mean difference of 0.18 (95% CI [-0.17; 0.53], I^2 = 85.30%, p = 0.31), indicating comparable functional outcomes for both techniques **Figure 5C**. Similarly, mean HHS did not differ significantly, with a standardized mean difference of 0.01 (95% CI [-0.70; 0.72], I^2 = 97.41%, p = 0.97) **Figure 6**.

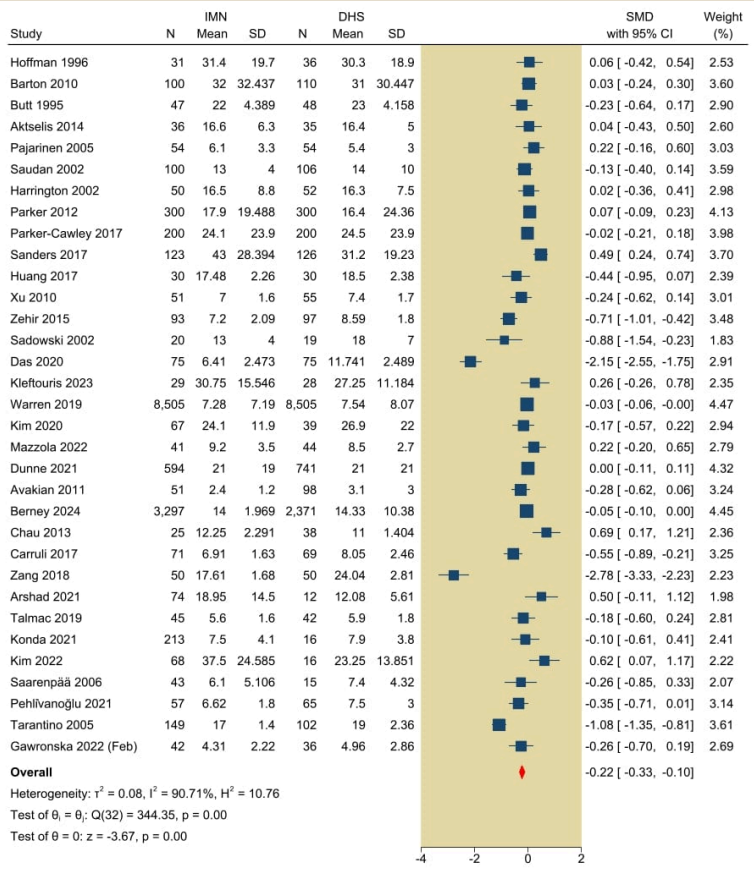


Figure 4. Forest plot of hospital stay (days), intramedullary nailing versus dynamic hip screw Standardised mean difference −0.22 (95% CI −0.33 to −0.10), I^2 = 90.71%, p < 0.01, favouring intramedullary nailing. Random-effects meta-analysis. IMN, intramedullary nailing; DHS, dynamic hip screw; CI, confidence interval.

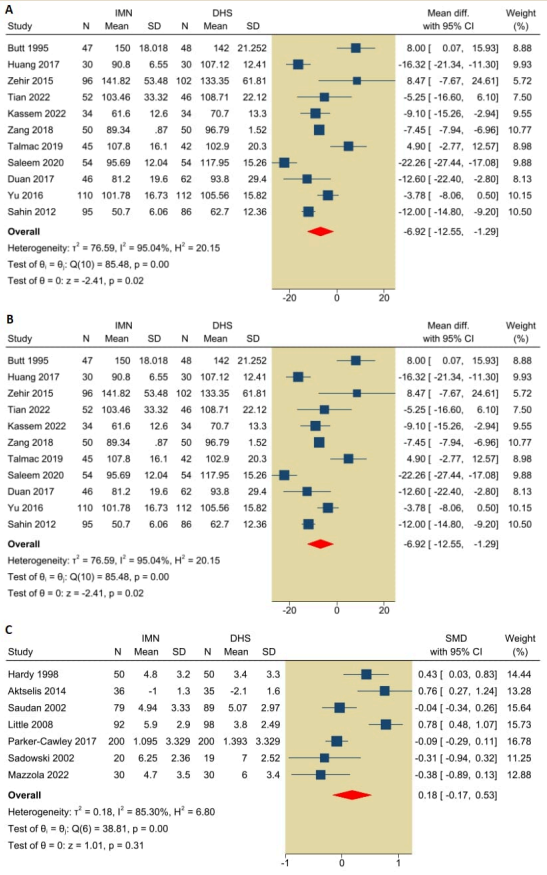


Figure 5. Forest plots of postoperative outcomes, intramedullary nailing versus dynamic hip screw (A) Time to healing (days): mean difference −6.92 days (95% CI −12.55 to −1.29), I^2 = 95.04%, p = 0.02. (B) Femoral neck shortening (mm): mean difference −1.19 mm (95% CI −4.21 to 1.83), I^2 = 99.76%, p = 0.44. (C) Parker Mobility Score: standardised mean difference 0.18 (95% CI −0.17 to 0.53), I^2 = 85.30%, p = 0.31. Random-effects meta-analysis. IMN, intramedullary nailing; DHS, dynamic hip screw; CI, confidence interval.

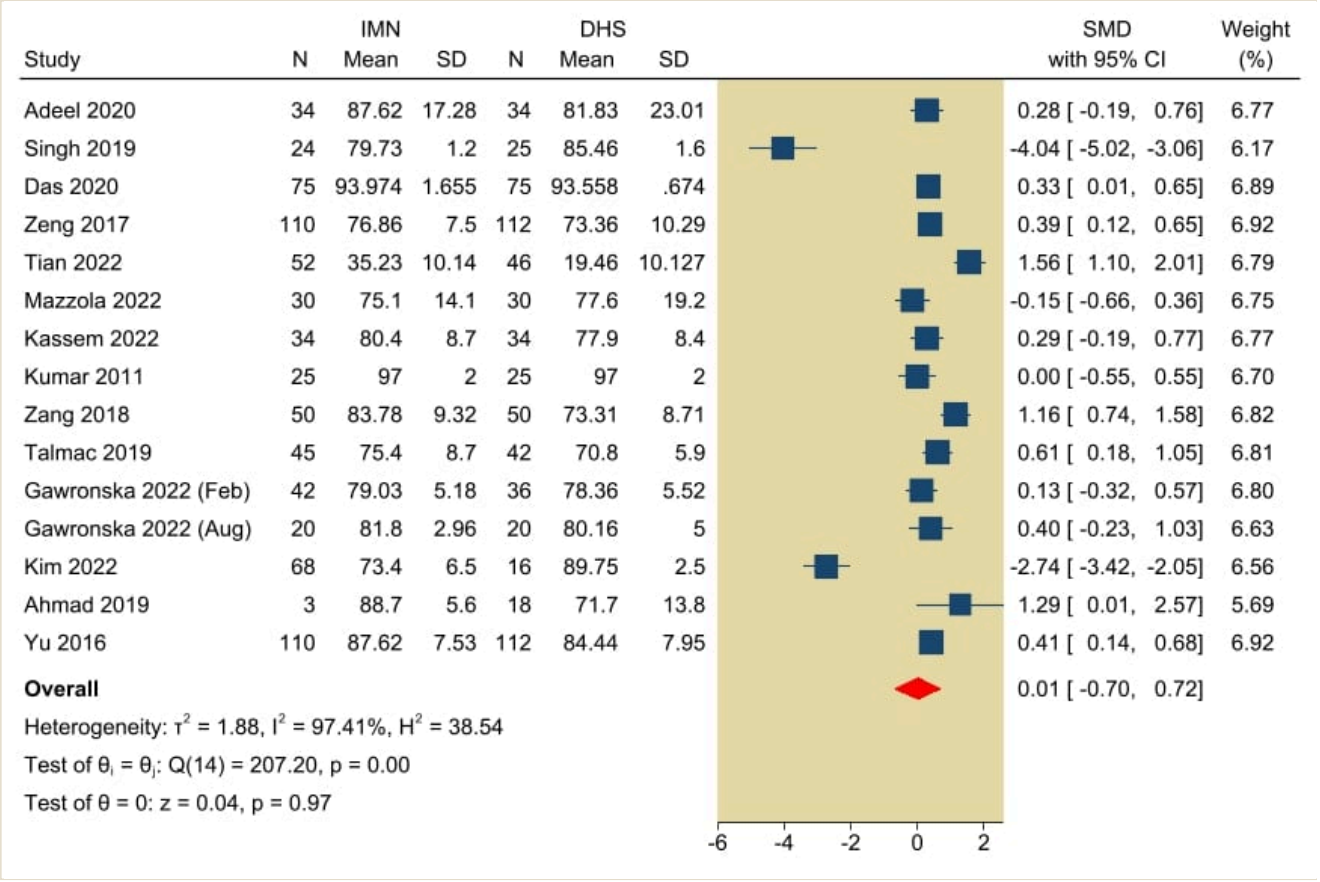


Figure 6. Forest plot of mean Harris Hip Score, intramedullary nailing versus dynamic hip screw Standardised mean difference 0.01 (95% CI −0.70 to 0.72), I^2 = 97.41%, p = 0.97; no significant difference. Random-effects meta-analysis. IMN, intramedullary nailing; DHS, dynamic hip screw; CI, confidence interval.

3.5 Subgroup analysis

In the subgroup analysis by study design (RCTs vs. NRCTs), no statistically significant differences were observed between RCTs and NRCTs across most outcomes. Specifically, tests of subgroup differences outcomes such as open reduction of fracture (p = 0.11) **Supplementary File 1**, blood loss (p = 0.74) **Supplementary File 1**, patients needing blood transfusion (p = 0.58) **Supplementary File 1**, mean surgical time (p = 0.24) **Supplementary File 1**, hospital stay (p = 0.89) **Supplementary File 1**, mean HHS (p = 0.36) **Supplementary File 1**, and healing time (p = 0.89) showed similar results between RCTs and NRCTs, with p-values consistently above the 0.05 threshold, indicating non-significance **Supplementary File 1**. An exception was noted in screening time, where results reached statistical significance for RCTs (p = 0.0) but remained non-significant for NRCTs (p = 0.5) **Supplementary File 1**. This suggests that study design may influence specific outcomes, such as screening time, but overall, the effect of IMN versus DHS did not substantially differ based on the study design**.**

3.6 Sensitivity analysis

The sensitivity analysis, conducted using a leave-one-out test, provided valuable insights into the robustness of the meta-analysis. In most cases, removing individual studies did not significantly change the overall results, indicating stability in the findings. However, certain studies did have an impact on specific outcomes. For open reduction of the fracture, statistical significance favoring IMN over DHS (p = 0.029) was observed only after excluding the study by Kassem et al. (2022) **Supplementary File 1.** Blood loss (ml) demonstrated consistent nonsignificant results across all iterations, with no single study exclusion altering the overall findings **Supplementary File 1.** Patients requiring blood transfusion showed a statistically significant advantage for IMN (p = 0.01) exclusively after omitting Werner et al. (2015) **Supplementary File 1.** Conversely, required blood transfusion units remained unaffected by any study exclusion **Supplementary File 1**. Screening time (min) exhibited heterogeneity; removing specific studies (Utrilla, 2005; Saudan, 2002; Parker, 2012; Singh, 2019; Tarantino, 2005; Talmac, 2019) individually yielded p-values < 0.05, indicating these trials collectively influenced the pooled effect's significance **Supplementary File 1.** Mean surgical time (min) and hospital stay (days) maintained nonsignificant results regardless of excluded studies **Supplementary File 1**. Time to healing (days) was only not statistically significant AFTER excluding Huang 2017 (p= 0.051) **Supplementary File 1.** Femoral neck shortening (mm) achieved statistical significance (p = 0.026) solely after excluding Harrington et al. (2002) **Supplementary File 1.** Notably, HHS and PMS remained stable, with no single-study exclusion impacting their overall results **Supplementary File 1.**

3.7 Cumulative analysis

The cumulative analysis revealed several important trends. Initially, while IMN demonstrated significant benefits over DHS for specific outcomes, such as open reduction of fractures, the significance and magnitude of these effects tended to diminish as more studies, particularly Kassem 2022, were included **Supplementary File 2**. Regarding blood loss, the evidence favoring IMN became statistically significant after incorporating Little 2008 (p = 0.011), with subsequent studies further reinforcing this trend **Supplementary File 2**. For patients

needing blood transfusions, earlier studies supported IMN significantly; however, the addition of more recent studies diluted this significance **Supplementary File 2.** The analysis also showed that the statistical significance for required blood transfusion units emerged after including Pajarinen 2005 (p = 0.006), but again, it was lost with the addition of newer studies **Supplementary File 2.** Notably, statistically significant results for screening time increased with the addition of more studies **Supplementary File 2**. For a mean surgical time, the first statistically significant result appeared when Duan 2017 was added (p = 0.043) **Supplementary File 2**, while for a hospital stay, the first significant result was observed after including Zang 2018 (p = 0.024) **Supplementary File 2.** The time to healing showed a similar trend, with the first significant result appearing after adding Tian 2022 (p = 0.039) **Supplementary File 2.** In contrast, the results for femoral neck shortening, mean HHS, and PMS remained robust and unchanged across the cumulative evidence, suggesting consistency in these findings despite including new data **Supplementary File 2.**

3.8 Meta regression

In the meta-regression analysis examining the influence of mean age and sex (male), most outcomes showed no statistically significant associations with these variables. For age, a significant coefficient was observed only for mean surgical time (coefficient = 0.969, p = 0.001), suggesting that age may influence surgical duration, potentially extending it. Hospital stay also demonstrated significance with age (coefficient = 0.069, p = 0.000), indicating longer hospital stays with increasing age in this treatment context. For sex (male), a borderline significance was noted for patients needing blood transfusions (coefficient = 0.000175, p = 0.050), suggesting that the male sex might slightly impact transfusion requirements. However, all other associations between age or sex and the various outcomes were non-significant, indicating a limited influence of these demographic factors on the overall effect of IMN versus DHS across most outcomes. **Supplementary File 2.**

3.9 Trial Sequential Analysis (TSA)

The Trial Sequential Analysis (TSA) results provided critical insights into the robustness of the findings from the meta-analysis. For the outcome of open reduction of fractures, the analysis revealed a sample size of 1313 with a required information size (RIS) of 6977, indicating that the current evidence is insufficient to draw definitive conclusions, as the Z-curve did not reach the upper significance boundary or the futility boundary **Supplementary File 2.** Regarding blood loss, the TSA reached an RIS of 449, confirming that the accumulated sample size is adequate for evaluating the effectiveness of IMN compared to DHS in this outcome **Supplementary File 2.** However, for the time to healing, despite a sample size of 1325, the current cumulative sample is below the RIS of 2791, indicating a need for further research to strengthen the conclusions regarding the healing duration associated with each surgical method **Supplementary File 2.** Lastly, the analysis for femoral neck shortening presented a sample size of 1577 with a high RIS of 29494, suggesting that the evidence remains inconclusive, as the cumulative Z-score has not crossed any efficacy or futility boundary **Supplementary File 2.**

3.10 GRADE approach

The GRADE approach identified varying levels of evidence quality **Table 2.** All outcomes exhibited high heterogeneity (I^2 > 80%). For the outcome of open reduction of the fracture, evidence was rated as very low due to the inclusion of studies using diverse techniques of IMN. In contrast, the blood loss (ml) outcome received a high rating, indicating robust evidence; however, significant heterogeneity in effect estimates was noted. Additionally, there was evidence of publication bias, supported by a significant Egger test p-value of 0.0001. Conversely, time to healing and femoral neck shortening were rated as low, primarily due to high heterogeneity and small sample sizes relative to the required information size.

Table 2. GRADE evidence profile

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	**Study design**	**Risk of bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Other considerations**	**IMN**	**DHS**	**Relative (95% CI)**	**Absolute (95% CI)**		
Open reduction of fracture												
8	RCTs = 6NRCTs = 2	not serious	very serious[a]	not serious[b]	very serious[c,d]	none	86/697 (12.3%)	115/616 (18.7%)	**Log odds-ratio -1.52** (-3.31 to 0.28)	**-- per 1,000** (from -- to --)	⨁◯◯◯ Very low[a,b,c,d]	IMPORTANT
Blood loose (ml)												
29	RCTs = 19NRCTs = 10	not serious	not serious[e]	not serious[b]	not serious	publication bias strongly suspected very strong association[f]	2121	2004	-	MD **98.8 ml lower** (127.96 lower to 69.64 lower)	⨁⨁⨁⨁ High[b,e,f]	CRITICAL
Time to healing (days)												
11	RCTs = 5NRCTs = 6	not serious	serious[a]	not serious[b]	serious[d]	none	659	666	-	MD **6.92 days lower** (12.55 lower to 1.29 lower)	⨁⨁◯◯ Low[a,b,d]	IMPORTANT
Femoral neck shortening (mm)												
8	RCTs	not serious	serious[a]	not serious	serious[d]	none	759	782	-	MD **1.19 mm lower** (4.21 lower to 1.83 higher)	⨁⨁◯◯ Low[a,d]	IMPORTANT

CI: confidence interval; MD: mean difference. Explanations a. I^2 > 80% b. studies with varied techniques of IMN favored IMN over DHS c. Wide 95% CI d. Small sample size comparing to the RIS e. Most studies favoured IMN but the observed heterogeneity is in the effect estimate f. egger test p value = 0.0001

3.11 Publication bias

The results from the publication bias assessment, evaluated using Egger's test, indicate a significant publication bias for blood loss, with a p-value of 0.0001. This suggests that smaller studies with positive results are more likely to be published, which may skew the findings **Supplementary File 2**. In contrast, the mean surgical time also showed considerable evidence of bias, with a p-value of 0 **Supplementary File 2**. Other outcomes, including screening time, hospital stay, Time to Healing (in days) and Mean HHS yielded p-values of 0.2075, 0.1805, 0.1376, and 0.1467, respectively. These results suggest no significant evidence of publication bias for these outcomes **Supplementary File 2.**

Discussion

The results of this meta-analysis highlight several key findings regarding the comparative effectiveness of IMN versus DHS fixation in the management of trochanteric fractures. Notably, while there was no statistically significant difference in the open reduction of fractures, IMN demonstrated a significant reduction in intraoperative blood loss, indicating a clear advantage in minimizing hemorrhage. Additionally, IMN showed a trend towards requiring fewer blood transfusions, although this was not statistically significant. Surgical time favored IMN with a notable reduction, and patients undergoing IMN experienced a significant decrease in both hospital stay and time to healing. However, as measured by Harris hip scores and Parker Mobility scores, functional outcomes were comparable between both techniques, suggesting similar recovery trajectories despite differences in surgical parameters. Meta-regression analysis revealed limited associations between age and sex with most outcomes, although older age correlated with longer surgical times and hospital stays. While IMN presents advantages in terms of blood loss and recovery time, the high heterogeneity across outcomes and varying quality of evidence necessitate cautious interpretation of these findings.

Our findings are consistent with previous research concerning the comparative effectiveness of IMN and DHS in managing trochanteric fractures. Specifically, our meta-analysis, along with studies by Zeelenberg et al. (2024) (89) and Zeng et al. (2012) (90), demonstrates that IMN is associated with significantly reduced intraoperative blood loss and shorter surgical durations, highlighting its efficiency as a treatment modality. Furthermore, the functional outcomes observed in our study, as measured by metrics such as Harris Hip Scores, align with findings from Huang et al. (2013) (91) and Xu et al. (2022) (92). This suggests that, despite variations in surgical parameters, patients' recovery trajectories are comparable between both techniques. The convergence of evidence underscores the potential advantages of IMN in enhancing surgical efficiency and patient safety, thereby warranting further investigation into long-term outcomes and the optimization of surgical protocols for trochanteric fractures. Notably, Yu et al. (2023) (93) reported a significant reduction in intraoperative blood loss associated with IMN, as well as its effectiveness in preventing femoral neck shortening and reducing non-union rates. These findings align with our observations of fewer blood transfusions required for IMN, although this difference did not reach statistical significance.

Despite the overall alignment with existing literature, our study reveals several noteworthy discrepancies regarding healing time

and length of hospital stay. Specifically, our results indicate a significant reduction in hospital stay and healing time associated with IMN, which contrasts with the findings reported by Huang et al. (2013), where no significant differences were observed between Proximal Femoral Nail Antirotation (PFNA) and DHS. This discrepancy may be attributed to variations in patient populations, surgical techniques, or postoperative care protocols across studies. Additionally, while Zhang et al. (2023) (94) acknowledge the advantages of PFNA over DHS in various postoperative outcomes, they also highlight areas where DHS demonstrated superior performance, particularly concerning hidden blood loss. Furthermore, Yu et al. (2023) did not identify significant differences in surgical time, hospital stays, or functional scores between the two techniques. Statistical analysis comparison between our study and the previous meta-analysis is presented in **Table 3**.

Table 3. Statistical analysis comparison between our study and the previous meta-analysis

Study ID	Studies included (N)	Subgroup analysis	Leave one out test	cumulative analysis	TSA	Meta-regression	GRADE
Our study	RCTs = 31 Cohort = 29	Yes	Yes	Yes	Yes	Yes	Yes
Zeelenberg 2024	RCTs = 14 Observational = 13	No	No	No	No	No	No
Yu 2023	RCTs = 30	No	Yes	NO	No	No	No
Zhang 2023	RCTs = 5 Observational = 12	No	Yes	NO	No	No	No
Xu 2022	RCTs = 12	No	No	NO	No	No	Yes
Huang 2013	RCTs = 8	No	Yes	No	No	No	No
Zeng 2012	RCTs = 13	No	Yes	Yes	No	No	No

Future research should prioritize longitudinal studies to evaluate the long-term functional recovery and complication rates associated with IMN and DHS techniques. It is essential to conduct high-quality RCTs that compare these procedures and their varied techniques to address the observed heterogeneity while controlling for variables such as fracture type and comorbidities. Cost-effectiveness analyses should also be performed to inform healthcare decision-making. Finally, exploring innovative fixation methods or modifying existing techniques may improve patient outcomes for those with trochanteric fractures.

Our study has several strengths that enhance the credibility of our findings. First, the comprehensive literature search conducted ensures a robust foundation for our analysis. Additionally, most of the included studies demonstrated high methodological quality, which further supports the reliability of our results. The large sample size significantly increases the statistical power of our findings, allowing for more generalizable conclusions. Moreover, by evaluating multiple outcomes, we provide a comprehensive overview of the effectiveness and safety of IMN compared to dynamic hip screw DHS fixation. Finally, the incorporation of Trial Sequential Analysis (TSA) adds an extra layer of rigor to our analysis, facilitating a thorough assessment of the robustness of our conclusions.

Also, we noted several points that limit the certainty of the evidence. The heterogeneity among the included studies may restrict the generalizability of our findings, as variations in study designs, patient populations, and surgical techniques could influence the outcomes. Additionally, we observed potential publication bias, especially concerning blood loss and mean surgical time. Some outcomes were constrained by insufficient sample sizes, and there was variability in follow-up durations across studies. The sensitivity analysis indicated that certain studies had a significant impact on specific outcomes, particularly regarding the open reduction of fractures and blood transfusions. Subgroup analysis Based on surgical techniques or fractures classifications was not applicable because there was not enough data.

In summary, our meta-analysis provides valuable evidence regarding the comparative effectiveness of IMN versus DHS in treating trochanteric fractures. While existing studies widely agree on the benefits of IMN in terms of reduced blood loss and improved surgical efficiency, discrepancies persist regarding healing times and length of hospital stays. Continued research is crucial to refining treatment strategies and determining the efficacy of various IMN techniques compared to different DHS approaches.

DECLARATIONS

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None to declare.

Competing interests

None declared.

Ethical approval

Not applicable. Declaration of AI Usage To enhance this manuscript's clarity, readability, and academic tone, Language editing software was used for AI-assisted copy editing. This tool was employed solely to improve grammar, spelling, punctuation, and style, ensuring the text was free of linguistic errors while maintaining the integrity of the original content. The authors thoroughly reviewed and approved the final manuscript, taking full responsibility for its accuracy and originality.

Informed consent

Not applicable; systematic review of published studies.

Data availability

All data are from the published studies cited; extracted data are available from the corresponding author on request.

Use of AI tools

To enhance this manuscript's clarity, readability, and academic tone, Language editing software was used for AI-assisted copy editing. This tool was employed solely to improve grammar, spelling, punctuation, and style, ensuring the text was free of linguistic errors while maintaining the integrity of the original content. The authors thoroughly reviewed and approved the final manuscript, taking full responsibility for its accuracy and originality.

SUPPLEMENTARY MATERIAL

Supplementary File 1. Search strategy, study characteristics, quality assessment, subgroup and sensitivity analyses — available online with the article.

Supplementary File 2. Cumulative analyses, meta-regression, trial sequential analysis and funnel plots — available online with the article.

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