

Elastic stable intramedullary nail fixation versus submuscular plate fixation of pediatric femur shaft fractures in school age patients

A PRISMA-compliant systematic review and meta-analysis

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Abstract

Background: Studies of clinical outcomes that compare the elastic stable intramedullary nail (ESIN) with the submuscular plate (SMP) were controversial. The meta-analysis was performed to summarize existing evidence, aiming to determine whether ESIN was superior to SMP in pediatric femur shaft fractures.

Methods: Search strategies followed the recommendations of the Cochrane collaboration. Electronic searches such as PubMed, Embase, Web of Science, Cochrane were systematically searched for publications concerning ESIN and SMP from the inception date to March 2023. Two investigators independently searched, screened, and reviewed the full text of the article. Disagreements generated throughout the process were resolved by consensus, and if divergences remain, they were arbitrated by a third author.

Results: This study included 8 articles, comprising a total of 561 patients with a similar baseline. Compared to the SMP, the ESIN had shorter operation time (mean difference = -16.16; 95% CI = -22.83 to -9.48, $P < .00001$), and less intraoperative blood loss (mean difference = -53.62; 95% CI = -58.89 to -48.36, $P < .00001$), but had a higher incidence of implant irritation (odds ratio [OR] = 6.49; 95% CI = 3.01 to 13.98, $P < .0001$), lower limb malalignment (OR = 2.60; 95% CI = 1.12 to 6.04, $P = .96$) and overall complications (OR = 4.14; 95% CI = 2.51 to 6.84, $P < .0001$). And there was no significant difference in radiation time, length of hospital stay, limb length discrepancy, infection rate, delayed union rate and unplanned revised surgery rate ($P > .05$).

Conclusions: Compared to the SMP, the ESIN offers shorter operative time, and less blood loss. However, the SMP is superior to ESINs in complication rates, especially regarding implant irritation and malalignment. Both methods could achieve excellent satisfactory functional outcomes. Thus, the SMP is an alternative choice in the pediatric femur shaft fracture.

Abbreviations: CI = confidence interval, ESIN = elastic stable intramedullary nail, LLD = limb length discrepancy, MD = mean difference, NOS = The Newcastle-Ottawa scale, OR = odds ratio, SMP = submuscular plate.

Keywords: elastic stable intramedullary nail, meta-analysis, pediatric femur shaft fracture, submuscular plate.

1. Introduction

Femur shaft fractures are the major pediatric fractures, with an estimated annual incidence of 20 per 100,000, accounting for between 1.4% and 1.7% of all pediatric fractures and generally resulting in lengthy hospitalizations.^[1,2] Pediatric femur fractures occur by mechanisms that are typically energetic, such as falls from heights or motor vehicle crashes.^[3] Numerous treatment options have been reported for pediatric femur fractures, and the ideal treatment for pediatric femur fractures depends on the child's age, location, and type of fracture. For children younger than 5, conservative treatment including traction and

spica casting is normally effective.^[4] While for children older than 5, surgery is recommended.^[5,6] The American Academy of Orthopedic Surgeon (AAOS) states there are several techniques for pediatric femur fractures including rigid intramedullary nail, flexible intramedullary nail, external fixation and submuscular plate.^[5,6]

The external fixator may have been used for fixation in children with polytrauma, comminuted, and long oblique fractures, but its popularity has waned due to frequent complications.^[7] And rigid intramuscular nails may increase the risk of vascular necrosis and early epiphyseal closure.^[8] Thus, the most

The authors have no conflicts of interest to disclose.

Data sharing not applicable to this article as no datasets were generated or analyzed during the current study.

This article does not contain any studies with human participants or animals performed by any of the authors.

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How to cite this article: Hu D, Xu Z, Shi T, Zhong H, Xie Y, Chen J. Elastic stable intramedullary nail fixation versus submuscular plate fixation of pediatric femur shaft fractures in school age patients: A PRISMA-compliant systematic review and meta-analysis. *Medicine* 2023;102:39(e35287).

Received: 16 July 2023 / Received in final form: 17 August 2023 / Accepted: 29 August 2023

<http://dx.doi.org/10.1097/MD.00000000000035287>

common treatments are still elastic stable intramedullary nail (ESIN) and submuscular plate (SMP). However, each method has advantages and disadvantages, and ideal techniques are widely debated.

Over the past 4 decades, the ESIN technique has become a popular option for femoral shaft fracture fixation, especially for length-stable fractures.^[9] The technique adapted from flexible rodding was first developed in 1988 and it is easily applied.^[10] In particular, for length-stable fracture patterns, the ESIN technique has been shown to have a high joint rate, require a relatively short time in a protected weight-bearing state, have limited surgical dissection, and are likely to have a shorter hospital stay compared to alternative surgical techniques.^[9,11] However, ESINs are limited by higher reported complication rates consisting of unplanned reoperation, limb-length discrepancy, and malunion^[8,12]; The problems were amplified in older patients and those who weighed more than 49 kg.^[5]

Plate osteosynthesis has a long history in the treatment of pediatric diaphyseal femur fractures. However, traditional open plating requires long incisions and can potentially increase infection rates, so the technique has gradually fallen out of favor. More recently, submuscular plate fixation technique has been popularized as an alternative to conventional techniques, with advantages of shorter operative time and wound lengths, as well as lower blood loss and infection rates.^[13] More importantly, Porter demonstrated that submuscular locked plating provides a biomechanically more stable construct than ESINs.^[14] Primarily indicated in length unstable fracture patterns or patients weighing > 49 kg, plating has also become an option for all diaphyseal femur fractures.

Thus, we undertook a meta-analysis to determine whether ESIN was superior to SMP in terms of operation time, blood loss, hospital stay, radiation time, complications, and function scores.^[5]

2. Methods

2.1. Search strategy

The ethical statement is not needed because this study is based on a meta-analysis and systematic review of published studies. Search strategies followed the recommendations of the Cochrane collaboration. Electronic searches such as PubMed, Embase, Web of Science, Cochrane were systematically searched for publications concerning medical pivot and posterior stabilized prosthesis from the inception date to March 2023. Search terms “elastic stable intramedullary nail” and “submuscular plate” and “pediatric femur shaft fractures” are included during the search. Authors also manually checked and retrieved a reference list of included publications for potential studies which had not been found by the electronic searches. Two investigators (Z.H.X. and D.L.H.) independently searched, screened, and reviewed the full text of the article. Disagreements generated throughout the process were resolved by consensus, and if divergences remain, they were arbitrated by a third author (J.J.C.).

2.2. Inclusion and exclusion criteria

The inclusion criteria were as follows: (1) randomized controlled trials or cohort studies comparing ESIN and SMP in pediatric femur shaft fractures; (2) studies reporting at least one of the main outcomes, such as operative time, blood loss, length of stay, radiation time, union time, unplanned surgery rate, malunion rate, Flynn score and complications; (3) only English articles were included.

Exclusion criteria were as follows: open plating; subtrochanteric and supracondylar femur fractures; duplicated or overlapping data; review articles and scientific conference abstracts; cadaver or model studies; unreported data.

2.3. Data extraction and quality assessment

Data extraction and quality assessment were conducted by 2 researchers independently using a standardized data collection sheet. Disagreements generated throughout the process were resolved through discussion with team members, and if differences remained, they were arbitrated by a third author (J.J.C.). The extracted contents included authors, nationality, publication date, study type, male-female ratio, participant age, follow-up time.

2.4. Risk of bias assessment in included studies

The Cochrane handbook was used as the quality evaluation standard for randomized controlled trials. The Newcastle-Ottawa scale (NOS) was used to assess non-randomized controlled trial studies. A quality score ≥ 7 on the 9-point of the NOS was considered of relatively high quality for cohort studies.

2.5. Data synthesis

The RevMan 5.3 software provided by Cochrane collaboration network was used for meta-analysis. Counted data used odds ratio (OR) value and its 95% confidence interval (CI) for data analysis, and measurement data used MD (mean difference) and its 95% CI for statistical analysis. Heterogeneity between the results of the included studies was analyzed using the χ^2 test (inspection level is $\alpha = 0.1$), and I^2 was used to evaluate the heterogeneity quantitatively, the inspection standard was set to 50%. When $I^2 < 50\%$, no significant heterogeneity was considered to exist in 2 sets of data, and the fixed effect model was used for quantitative combined analysis; when $I^2 > 50\%$, it is considered that there is significant heterogeneity between the 2 sets of data, and the random effect model was used for combined analysis. Publication bias of the literature was identified using software-generated funnel plots. For the sensitivity analysis of the included literatures, one article was removed at a time during the meta-analysis to observe the changes in the combined effect to illustrate the stability and accuracy of the results.

3. Results

3.1. Study identification and selection

A total of 567 articles were retrieved from the database through the above search strategies. After reading the title and abstract, 31 articles were retained for further evaluation. After a full-text review, 22 articles were excluded. The remaining 8 articles involving 561 patients met the inclusion criteria and were included in this review.^[8,12,15–20] Figure 1 shows the results flow chart for the whole search process.

3.2. Study characteristics

Table 1 summarizes the main characteristics of the 8 studies in this review. The earliest of these studies were published in 2016, and the latest published in 2022. Three studies were conducted in the United States, and other studies were conducted in Egypt, India, British, China or Pakistan. The mean age of participants fluctuates between 5 and 12 years. The mean follow-up time for observation of postoperative results ranges from 3 month to 48 months. The sample size of each study ranges from 28 to 122. Included studies are 3 randomized controlled trials, 5 retrospective designs.

3.3. Quality assessment

We used the Cochrane risk of bias tool to categorize the included randomized controlled trials as high, unclear, and low risk of bias. This method rated bias within 6 main domains, with an additional option to report any “other” sources of bias. Two

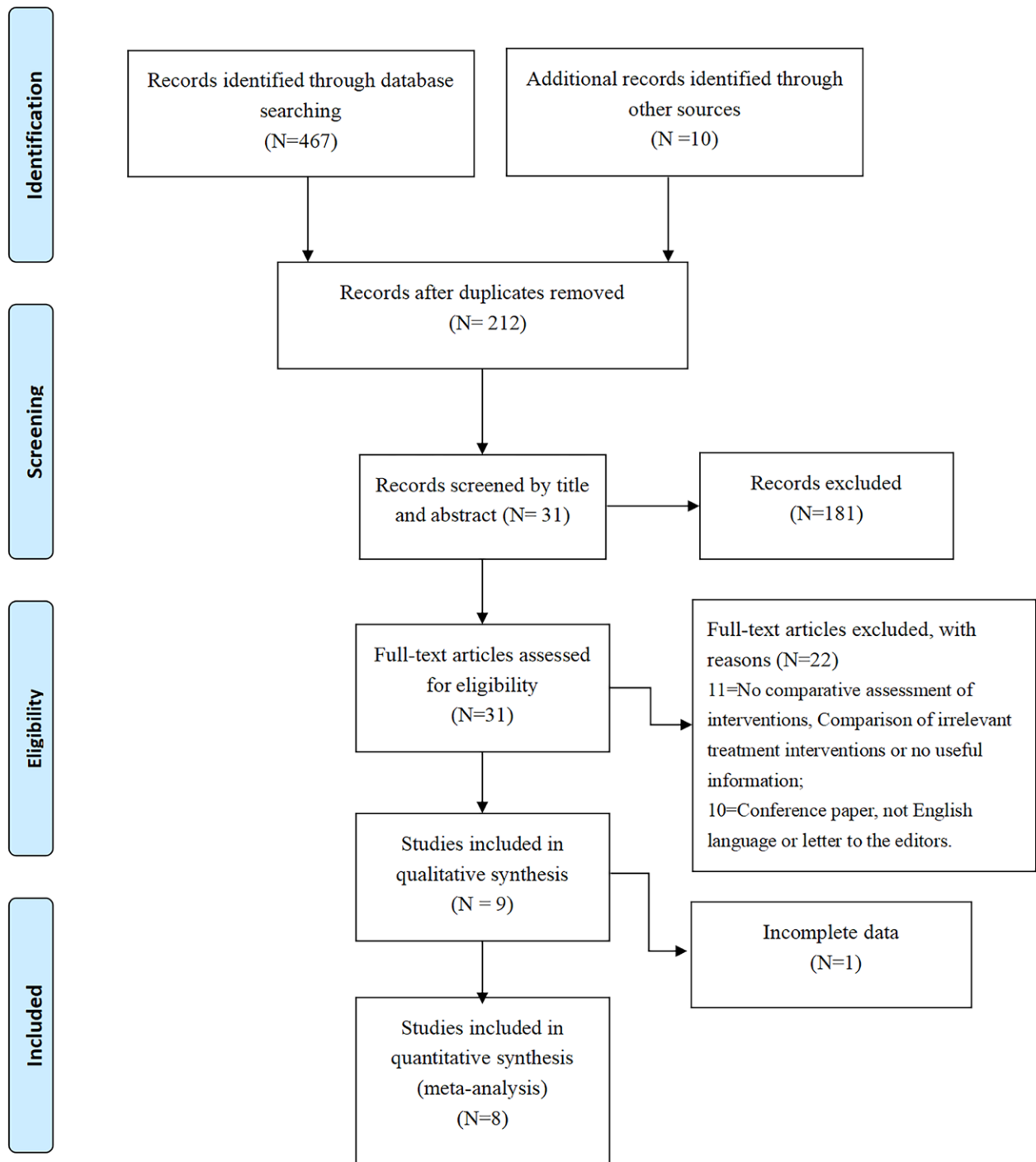


Figure 1. The flowchart of methodological search strategy and inclusion and exclusion criteria.

study authors (Z.H.X., D.L.H) independently assessed the risk of these studies. Of the 3 included trials, only one RCT was consider low risk of bias, the remainder were considered unclear risk of bias (Fig. 2). Two studies had not explained allocation concealment and blinding (Fig. 2). The 5 cohort studies were considered relatively high quality because of a score ≥ 7 according to the NOS scale criteria (Table 2).

3.4. Operation time

Data were extracted from 4 studies to evaluate the operation time.^[15,17,19,20] The difference was statistically significant between ESIN and SMP groups (MD = -16.16; 95% CI = -22.83 to -9.48, $P < .00001$) (Fig. 3A).

3.5. Blood loss

The outcome measure of blood loss during the operation was available in 4 studies.^[15,17,19,20] The meta-analysis showed a significant difference between the ESIN and SMP groups (MD = -53.62; 95% CI = -58.89 to -48.36, $P < .00001$) (Fig. 3B).

3.6. Radiation time

Three studies mentioned the outcome of radiation time.^[8,15,19] There was significant difference in the ESIN and SMP group (MD = 8.84; 95% CI = -46.42 to 64.11, $P = .0003$) (Fig. 3C).

Table 1
Characteristics of the included studies

Study (year)	Design	Country of origin	Number of patients		Gender (M/F)		Mean age (years)		Follow-up (months)
			ESIN	SMP	ESIN	SMP	ESIN	SMP	
El-Adly 2022 ^[17]	RCT	Egypt	25	25	22/3	18/7	7.96 ± 1.6	8.28 ± 1.6	12M
James 2022 ^[19]	RCT	India	20	20	13/7	13/7	9.45 ± 3.1	10.2 ± 2.7	24M
Milligan 2020 ^[12]	RCS	British	14	14	10/4	11/3	9.7 ± 1.9	7.7 ± 1.8	24M
Li 2020 ^[20]	RCS	China	77	45	45/32	26/19	8.1 ± 1.9	8.0 ± 2.2	24M
Hayat 2020	RCT	Pakistan	51	51	41/10	37/14	8.82 ± 1.62	9.27 ± 1.74	3M
Chen 2018 ^[6]	RCS	America	28	30	18/10	23/5	7.3 ± 2.0	8.1 ± 2.4	24M
Allen 2018 ^[15]	RCS	America	50	15	36/14	9/6	9.0 ± 1.9	8.0 ± 2.1	NA
Sutphen 2016 ^[8]	RCS	America	61	35	45/16	27/8	10.6	10.6	48M

ESIN = elastic stable intramedullary nail, M/F = male/female, NA = not available, RCS = retrospective cohort study, RCT = randomized controlled trial, SMP = submuscular plate.

3.7. Hospital stay

Five articles included 300 cases provided data regarding length of hospital stay.^[12,15,17,19,20] No difference was found in our study (MD = -0.50; 95% CI = -1.62 to 0.63, $P = .39$) (Fig. 3D).

3.8. Clinical complication

Clinical complications conclude implant irritation, malalignment, infection, and limb length discrepancy (LLD).

Five articles^[8,16,17,19,20] involving 366 cases provided results regarding implant irritation, no heterogeneity existed among the studies ($P = .87$; $I^2 = 0\%$). The fixed effect model was used for meta-analysis. The rates of implant irritation were lower in patients who underwent SMP than those in patients who underwent ESIN (OR = 6.49; 95% CI = 3.01 to 13.98, $P < .0001$) (Fig. 4A).

Five studies^[8,12,17,19,20] compared the postoperative lower limb malalignment rate between the 2 groups. The meta-analysis showed significant difference in malalignment rate between the ESIN and SMP groups (OR = 2.60; 95% CI = 1.12 to 6.04, $P = .96$) (Fig. 4B).

Three studies^[16–18] reported infection rate. The result showed no significant difference between 2 groups (OR = 1.46; 95% CI = 0.46 to 4.63, $P = .52$) (Fig. 4C).

Four studies^[8,12,15,19] analyzed the incidence of LLD between 2 groups, no difference was observed in our meta-analysis (OR = 0.77; 95% CI = 0.23 to 2.55, $P = .67$) (Fig. 4D).

The overall complication was reported in 7 studies.^[8,12,16–20] The meta-analysis revealed a significant difference between the ESIN and SMP groups (OR = 4.14; 95% CI = 2.51 to 6.84, $P < .0001$) (Fig. 5).

3.9. Delayed union on 12th week

Data were extracted from 2 studies^[12,18] to evaluate the incidence of delayed union on 12th week. There was no significant difference between 2 groups (OR = 8.26; 95% CI = 0.98 to 69.94, $P = .05$) (Fig. 6A).

3.10. Unplanned surgery

Data were extracted from 3 studies^[8,12,19] to evaluate the incidence of unplanned surgery. There was no significant difference between 2 groups (OR = 1.57; 95% CI = 0.47 to 5.26, $P = .46$) (Fig. 6B).

3.11. Satisfaction rate

Five studies^[12,15,17,18,20] reported patient satisfaction rate through Flynn score. There was no significant difference between 2 groups (OR = 0.44; 95% CI = 0.15 to 1.24, $P = .12$) (Fig. 7).

3.12. Sensitivity analysis

Outcome indicated that operation time, radiation time and length of hospital stay were statistically heterogeneous. Observing the stability of the results after excluding each article one by one, the results showed that the heterogeneity changed while the results remained unchanged, which suggested that the results were convincing.

3.13. Publication bias

According to the recommendation of the Cochrane handbook, the number of included studies of each outcome indicator should not be <10; otherwise, the authenticity of the asymmetry cannot be judged. Therefore, no publication bias analysis was performed.

4. Discussion

In previous decades, there has been an increasing tendency to treat pediatric femoral fractures. Current guidance suggests that there is limited evidence for a variety of treatment modalities for these children.^[5,6]

The ESIN is an excellent treatment option with perceived benefits of minor wounds and minimal soft tissue injury for their insertion. Similarly, submuscular bridge plating allows healing with minimal soft tissue disruption. However, most previous studies focused on the utilization of traditional open plating, and reported significantly longer operating time and increased blood loss during surgery compared to ESIN.^[3,21,22] As we know, the technique of submuscular plating has been associated with shorter operative time, decreased blood loss and fewer complications than open plating in treating diaphyseal femur fractures.^[13] While both SMPs and ESINs have shown excellent outcomes in previous studies,^[3,23–25] they possess different biomechanical properties and few studies have compared the outcomes of these methods. Thus, we conducted a meta-analysis to compare the clinical outcomes of these 2 methods. In our study, the meta-analysis demonstrated that the ESIN was superior to the SMP group in terms of operation time, blood loss, but falls short regarding implant irritation and lower limb malalignment rate. More importantly, there was no significant difference in radiation time, length of stay, LLD, infection rate, delayed union rate, and unplanned revised surgery rate.

With the ESIN, closed reduction was attempted first, and a small incision at the fracture level would be made to assist reduction if the closed reduction is failed.^[3] Then, a small incision was made bilaterally in the distal femur metaphysis for insert intramedullary nails insertion. But for the plating technique, a lateral approach was usually used, requiring exposure and reduction of the fracture, which might lengthen the operative time and increase intraoperative blood loss.^[3] The reported

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
EI-Adly 2022	+	?	?	?	+	+	+
Hayat 2020	+	?	?	?	+	+	+
James 2022	+	+	+	?	+	+	+

Figure 2. Summary of the risk of bias of each included randomized controlled trial. low risk: - ; high risk: +; unclear: ?

operative times for ESIN are 0.9 hours for ESIN, and 1.5 to 1.9 hours for SMP.^[20] The result of our meta-analysis demonstrated that the ESIN had shorter operative time (MD = -16.16; 95% CI = -22.83 to -9.48, $P < .00001$) and less intraoperative bleeding (MD = -53.62; 95% CI = -58.89 to -48.36, $P < .00001$) compared to SMP. Currently, as mentioned by scholars, the non-invasiveness of ESIN cannot be matched by any other implant, including the submuscular bridge plate.^[3]

As we know, except for that kind of implant, numerous factors affect the operation time and the amount of blood loss, including experience and technology. Compared to a beginner, a more experienced surgeon who is more conversant with submuscular plate technology might do the internal fixation in quicker time. Thus, the experience factor must be considered in future research.

Implant irritation is common after placement of elastic nails, usually resulting from skin irritation at the nail tip, with incidence ranging from 10% to 52%.^[26,27] This may lead to pain, but is generally minor in most cases and relieved with implant removal. For the SMP group, irritation was caused by the size of the plate and by the plate serving as a stress riser.^[16] Our meta-analysis found a higher incidence of implant irritation in the ESIN group 27.5% (58/211) compared to the SMP group 5.2% (8/155). Narayanan et al^[16] reported that children with nail ends that were more than 1 cm prominent were 4.5 times more likely to report pain or irritation in the knee. Thus, surgeons should focus on the length of nails ends and avoid the incidence of implant prominence as far as possible.

The choice of internal fixation for femur shaft fractures in children depends on the type of fracture, weight, and age.

Table 2

Quality assessment of included cohort studies using the Newcastle-Ottawa Scale.

Author	Selection of non-Exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not Present at Start of Study	Comparability		Outcome			Total quality score
				Preoperative demographic risks	Other surgery risk factors	Assessment of outcome	Follow-up > 1 year	Loss to follow-up rate <=10%	
Milligan 2020 ^[12]	1	1	1	0	1	1	1	1	8
Li 2020 ^[20]	1	1	1	1	1	1	1	1	9
Chen 2018 ^[16]	1	1	1	1	1	1	1	1	9
Allen 2018 ^[15]	1	1	1	1	1	1	0	1	8
Sutphen 2016 ^[9]	1	1	1	0	0	1	1	1	7

Preoperative demographic risks included age, weight, sex, if all characteristics were comparable, 1 point was assigned; other surgery risk factors included single surgeon, fracture type, anyone was comparable, 1 point was assigned.

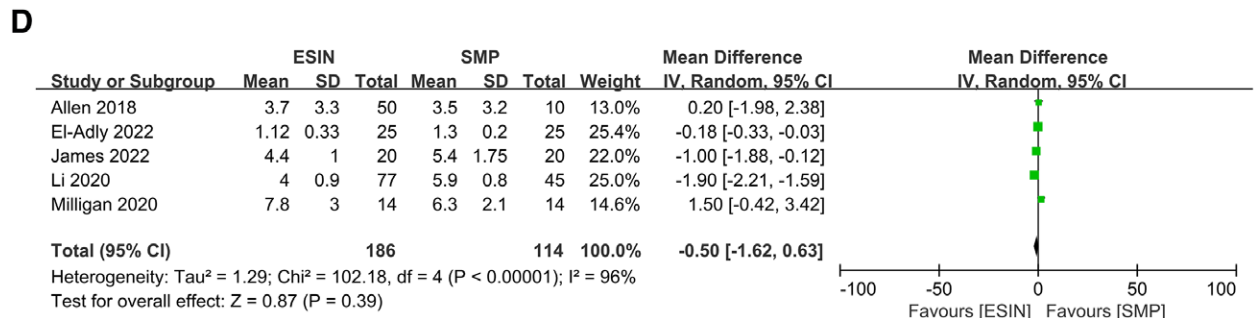
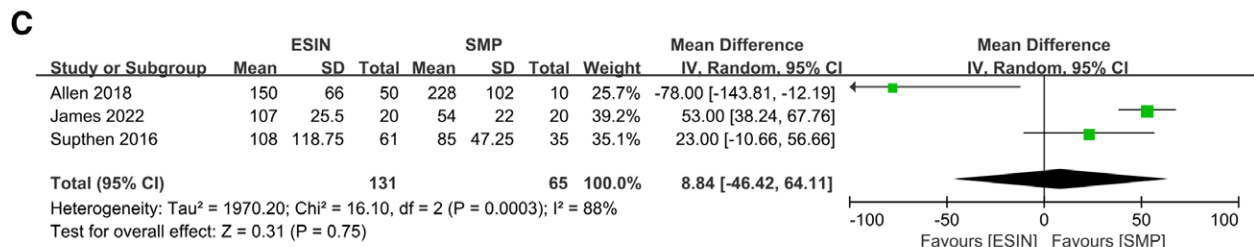
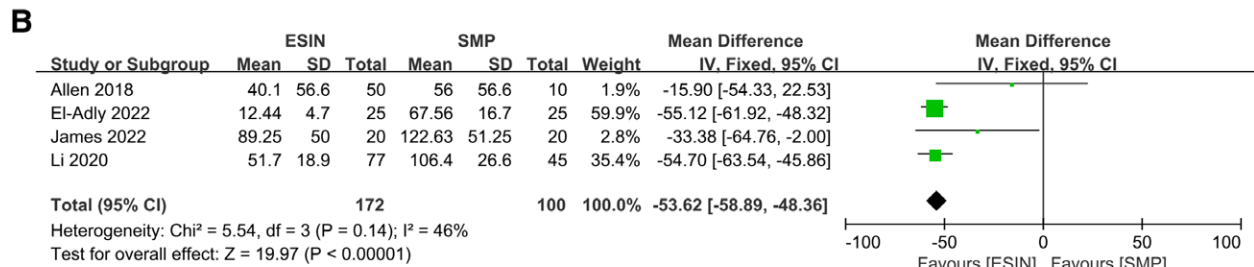
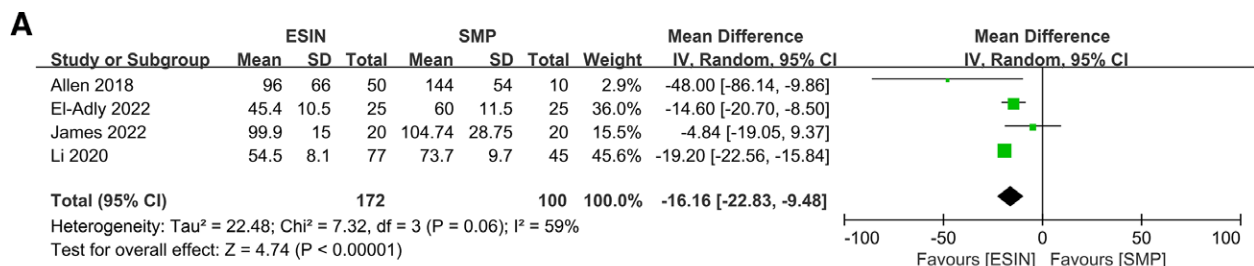
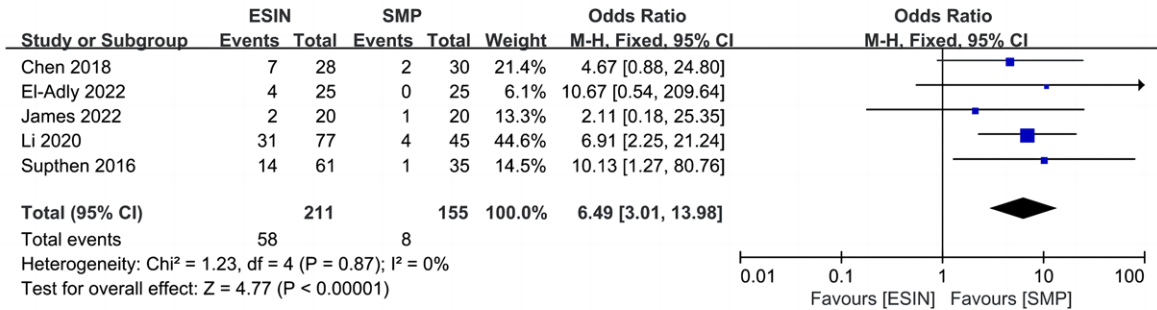
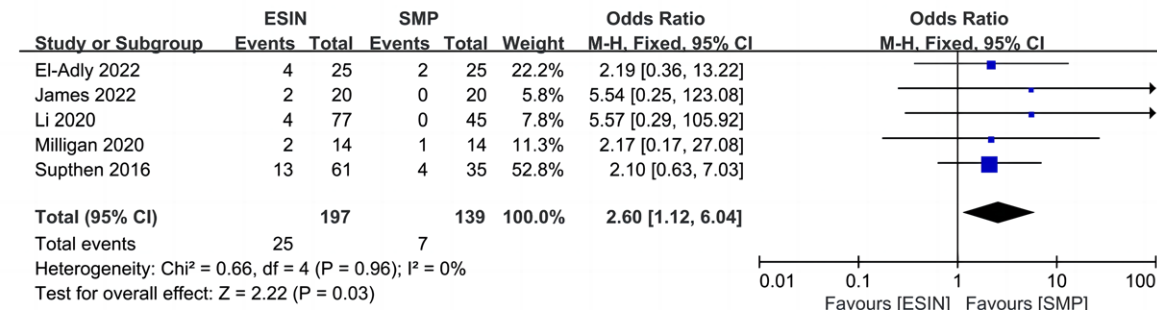


Figure 3. Comparison of general indicators between the ESIN group and SMP group. (A) Forest plot diagram of operation time; (B) forest plot diagram of intraoperative blood loss; (C) forest plot diagram of intraoperative radiation time; (D) forest plot diagram of length of hospital stay.

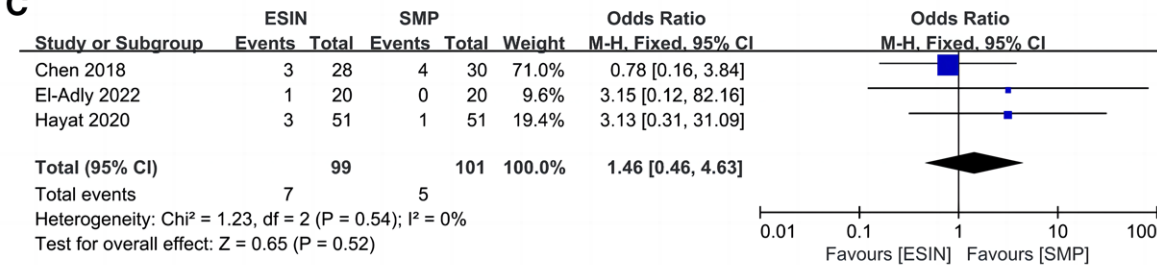
A



B



C



D

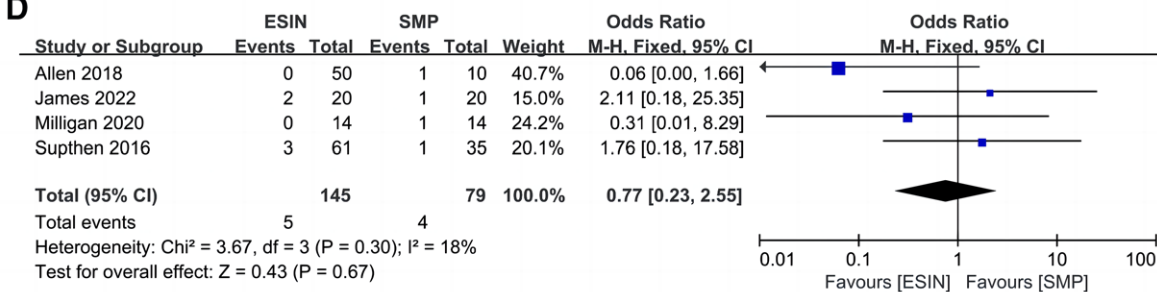


Figure 4. Comparison of major complications between the ESIN group and SMP group. (A) Forest plot diagram of implant irritation rate; (B) forest plot diagram of lower limb malalignment rate; (C) forest plot diagram of infection rate; (D) forest plot diagram of lower limb discrepancy rate.

ESIN technique is ideal for length-stable fracture, besides, as it could avoid the incidence of vascular necrosis.^[8] However, ESIN may not adequately prevent shortening or control rotation in unstable fractures, potentially increasing the risk of lower limb malalignment. Ouilette et al^[28] suggested that the length unstable group experienced more shortening at the fracture site than the patients in the length stable group. Li et al^[29] demonstrated that the complication rate was almost 4 times higher for length-unstable fractures treated with ESINs when compared with plating (56% vs 15%). But Siddiqui et al^[30] reported that there was no difference between the stable and unstable fractures groups in

the incidence of major complications requiring revision surgery and complications, and the ESIN is a safe an effective choice for length unstable femoral shaft fractures. Our study found a higher lower limb malalignment rate in the ESIN (12.7%, 25/197), compared to the SMP group (5%, 7/139). Both stable and unstable fractures were included in our meta-analysis. For all this, there are sufficient evidence to prove that the ESIN could increase the risk of postoperative malalignment rate.

Because children are in the growth and development stage and have strong bone-shaping abilities, they can self-correct later and ultimately experience less of an impact on length of

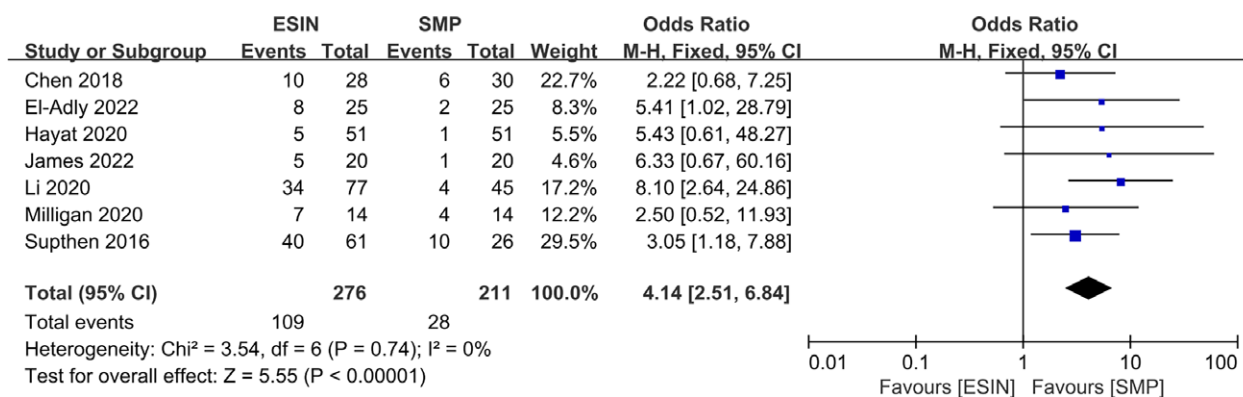


Figure 5. Comparison of overall complication rate between the ESIN group and SMP group.

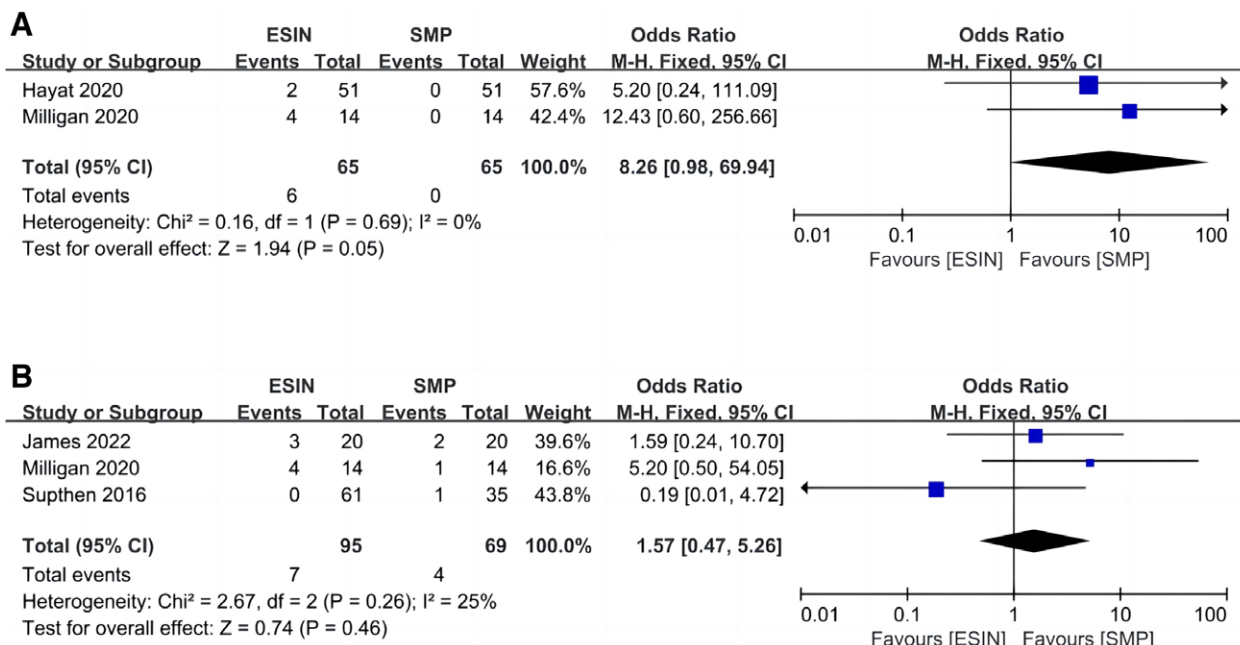


Figure 6. Comparison of unplanned indicators between the ESIN group and SMP group. (A) Forest plot diagram of delayed union rate; (B) Forest plot diagram of unplanned surgery revised rate.

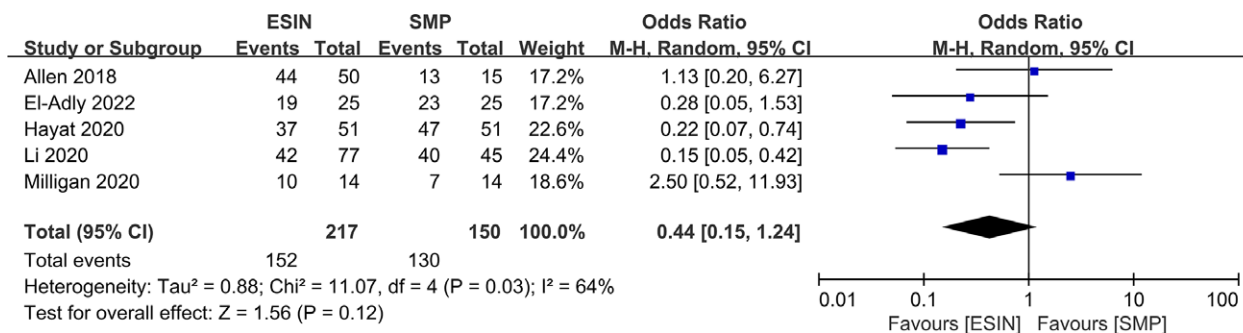


Figure 7. Comparison of satisfaction rate between the ESIN group and SMP group.

lower limb, and union time.^[11] This study also confirmed no significant differences in delayed union rate and LLD.

Based on the shortcomings of ESINs, some scholars have improved the fixation method to increase the stability of fractures. Dey et al^[31] combined titanium nailing with temporary external fixator (TNE), the result demonstrated that the varus angulation in the TNS group was 4.8 ± 3.2, while that in plating

group was 5 ± 3.1, there was no difference between 2 groups. Hong et al^[21] suggested that triple ESINs could provide better support and stability at the fracture site, especially in subtrochanteric fractures. Slongo et al^[32] suggested that End caps could avoid postoperative instability in the majority of pediatric patients with lower limb shaft fractures, even in heavier, older patients and those with unstable fracture types. Thus, surgeons

could use modified method to decrease the incidence rate of femur angulation when using the ESIN.

There is controversy regarding the effect of patient recommended the ESIN for children weighing <50 kg, and submuscular plating for those over 50 kg.^[5,6]

Some studies demonstrated that ESIN in heavier children could increase complications. Makarewich et al^[33] performed a meta-analysis to reveal the effect of ESIN in the heavier children. The result showed that overall complication rate was higher in the heavier patients compared with lighter patients (30.6% vs. 11.1%) with a relative risk of 1.20. Although this study did not include obese children, the authors believe that the SMP should be first considered in children weighting more than 50 kg.

Intraoperative radiation exposure is also a concern for surgeons, affecting the health of patients and surgeons, and increasing the risk of cancer.^[34] Allen et al^[15] demonstrated that fluoroscopy time between the ESIN and SMP did not achieve statistical difference for the primary surgery, but did for the hardware removal. James et al reported that less exposure to radiation in the SMP group, but this difference was not statistically significance when compared to the ESIN group. No difference in radiation time was found in our study, meaning that the type of implant could not affect radiation exposure and that both patients and surgeons should take protective measures to reduce radiation damage.

The implant removal is an essential factor that influences the choice of the implant by the patient or physician. So far, whether to remove the implant is decided by patients, except in those cases where the implant has to be removed due to complications. Thus, few studies reported relative data. In our study, only 2 articles compared the outcomes of implant removal. Li et al^[20] showed that the time of implant removal and the amount of blood loss in the ESIN group were significantly lower than those in the SMP group, which was similar to other results.^[16] Unfortunately, the data in these 2 articles could not be combined. But there is no doubt that the SMP group needs exposure to more soft tissues and muscles in the elective removal surgery. Therefore, the ESIN was seemingly easier than the SMP in terms of implant removal.

Patient satisfaction after operation is a crucial issue facing doctors and patients. Postoperative complications could increase the risk of unplanned revised surgery, and reduce the quality of life. Milligan et al^[12] reported that 4 children required reoperation in the ESIN group because of terrible complications, while only 1 patient in the SMP group needed to be revised. Our meta-analysis found that 7.4% of children undergoing ESINs require reoperation, while 5.8% of children in the SMP group. Thus, the type of internal fixation could not affect the rate of unplanned revised surgery rate. Flynn scores could reflect the function outcomes and satisfactory. In our study, 70% (152/217) patients in the ESIN group had excellent or satisfactory result, while 86% (130/150) in the SMP group. The pain from implant prominence might be the cause of unsatisfactory. Regretfully, no difference was found between the 2 groups.

This research had 2 main limitations. Firstly, combining randomized control trials and cohort studies may introduce bias. Secondly, the size of the sample is small. Future research should be performed considering high-quality randomized controlled studies with large sample sizes to determine whether the ESIN is superior to the SMP concerning clinical outcomes, patient satisfaction, and complications.

5. Conclusions

Our meta-analysis found that, compared to the SMP, the ESIN offers shorter operative time, and less blood loss. However, the SMP is superior to ESINs in complication rates, especially regarding implant irritation and malalignment. Both methods could achieve excellent satisfactory functional outcomes. Thus,

the SMP is an alternative choice in the pediatric femur shaft fracture.

Author contributions

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