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Review Paper

# Closed Fracture Middle Shaft Femur Treatments for Adolescent Patients, with a Focus on Union Rates and Complications: A Systematic Review

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## ABSTRACT

**Introduction:** Femoral shaft fractures are common in children, with intramedullary nailing being the "gold standard" due to its short hospital stay, fast fracture union, and early functional use. Submuscular plating is an alternative, but the choice for adolescents remains unclear. Herein, we systematically review the union rates after submuscular plate or Intramedullary elastic nail treatment to treat closed fracture middle shaft femur and the other clinical outcomes of these methods.
**Methods:** We conducted clinical data searches in PubMed, ScienceDirect, and ResearchGate. The studies included were RCT or cohort studies that assessed the outcomes of intramedullary nailing and submuscular plating in treating adolescent femur fractures with limitation studies published during the years 2008-2023 and using English as its language.
**Results:** Nine studies of 390 cases were included in this review, consisting of 155 cases treated with submuscular plating and 235 with intramedullary nailing. The average time of bone union in 155 patients was 2.71 months, while 235 cases had a faster union time, with an average of 2.37 months. The other complications reviewed were malunion, nonunion, delayed union, length-leg discrepancy, coronal angular deformity, sagittal angular deformity, decreased ROM, implant prominence, implant failure, and reoperation rates.
**Conclusion:** This study found that intramedullary nailing and submuscular plating are safe, feasible, and successful treatments for adolescent femur shaft fractures. Submuscular plating was more effective than ESIN but had a higher risk of complications. Future clinical trials should compare outcomes with a more specific population.

***Keywords:*** adolescent, intramedullary nailing, midshaft femur fracture, submuscular plating

## INTRODUCTION

The femur is one of the prominent load-bearing bones of the lower extremity and is essential for normal ambulation. The femur can be divided into three sections: the femoral shaft or diaphysis, the proximal metaphysis, and the distal metaphysis. The femoral shaft is the region of the bone between 5 cm distal to the lesser trochanter and 6 cm proximal to the most distal point of the medial femoral condyle.[1] Fractures of the femoral shaft are among the most common injuries orthopedic surgeons treat. The global incidence of femoral shaft fractures ranges from 10 to 21 per 100,000 people annually. [1,2]

Femoral shaft fractures in pediatrics are less common than in adults, accounting for less than 2% of all fractures in children. Yet, they pose a considerable burden on healthcare systems and families because they are the most prevalent fractures requiring hospitalization in children.[3] The mechanisms of injury include high-energy trauma such as road traffic accidents, falls, high-impact sports injury, and low-energy trauma such as pathological fractures, with falls from heights and road traffic accidents being the most common cause of femur shaft fractures in children. A bimodal distribution has been noted, with the first peak occurring in the age group of 1-3 years (usually low energy trauma) and the second peak during the early adolescence period (high energy trauma), which constitutes the majority of the fractures.3 Stress fractures of the femoral shaft and neck, though uncommon, are becoming more common in adolescent athletes engaged in sports such as soccer, basketball, and athletics and account for 4% of all stress fractures in children.[4]

Middle shaft femoral fracture can be classified using AO/Orthopaedic Trauma Association Classification into 27 different patterns with code 3 as femur and 2 as diaphysis. Code 32A means simple fracture and can be further classified into A1 as spiral, A2 as oblique with an angle >30 degrees, and A3 as transverse with an angle <30 degrees. Code 32B means wedge fracture and can be further classified into B1 as spiral wedge, B2 as bending wedge, and B3 as fragmented wedge. Code 32Cc means complex fracture and can be further classified into C1 as spiral fracture, C2 as segmental fracture, and C3 as irregular fracture.2 There are still many controversies in treatment options for middle shaft femoral fracture as many treatment options and algorithms exist. Possible fixation strategies include titanium elastic nails (TENs), prolonged traction followed by hip spica casting, open plating, submuscular plating, external fixation, and intramedullary nailing (IMN).[5]

Intramedullary nailing is now regarded as the "gold standard" for treating femoral shaft fractures. The proposed advantages of intramedullary nailing include a short hospital stay, fast fracture union, and early functional use of the limb. Intramedullary nailing aims to maintain the anatomical structure of fracture sites while providing a suitable environment for fracture healing. This, in turn, should enhance function and prevent long-term complications such as arthritis pain. Furthermore, nailing helps to avoid damage to soft tissues near the bone during surgery, preserving the blood flow to allow fracture healing and a satisfactory functional recovery.[6] There are few differences in the intramedullary nailing technique in adolescents compared to adults. In adolescents, the insertion point of the IM nail is in the lateral of the greater trochanter to prevent disruption of the epiphysial growth plate. The IM nail is inserted in the adult tip of the greater trochanter.[7]

Submuscular plating is an alternative treatment option for managing length-unstable fractures of the femur and proximal and distal third fractures of the femoral shaft. Submuscular plate fixation can be used in children with weight >49 kg and older children (age ≥11 years) with femoral canals that are too narrow to accept rigid nails. Recent studies also reported excellent outcomes with submuscular plating of these fractures in a pediatric population. Submuscular plating provides relative fracture stability without disrupting the soft-tissue envelope at the fracture site secondary to the minimally invasive insertion technique.[8]

It remains unclear whether submuscular plate or intramedullary elastic nail treatment should be used to treat closed fractures in the middle shaft of the femur that develops in adolescents. Herein, we systematically review the union rates after submuscular plate or Intramedullary elastic nail treatment to treat closed fracture middle shaft femur. We mainly focused on bone union rates, wound healing problems, post-surgical infection, and rotational or angular deformity.

## METHODS

### Literature Search

All of the clinical data was searched up to 14 September 2023 by two reviewers: PubMed, ScienceDirect, and ResearchGate using keywords of (middle shaft femur fracture) OR (midshaft femur fracture) AND (submuscular plate) AND (Intramedullary nailing) AND (adolescent) with limitation of randomized control trials or clinical trials published during the year 2008-2023 and using English as its language.

### Selection Criteria

The inclusion criteria of the studies were (1) Adolescent patients (10-18 years old) with closed middle shaft femoral fracture, (2) primarily treated with a submuscular plate, or (3) primarily treated with intramedullary nailing. (4) RCTs, non-randomized or quasi-experimental controlled trials, retrospective chart reviews, cohort studies, and case-control studies. Meanwhile, the exclusion criteria of the studies were (1) open femoral fracture, (2) case report, reviews, and animal study (3) sample size <10.

### Data Abstraction and Analysis

Two reviewers extracted relevant data and checked the accuracy. The abstracted data included study design, patient demographics (sample size, mean age, gender, weight, height), mean follow-up period, intervention, and outcome measurements. Authors of the included trial were listed to identify duplicate publications.

### Assessment of Quality

All of the studies that surpassed abstract selection will undergo an assessment of quality using the Modified Jadad Scale for RCT studies. Points that can be assessed are randomization, concealment, blinding, and withdrawal/dropout numbers. The NHLBI quality assessment tool for observational cohort and cross-sectional studies was used for cohort, retrospective chart review, and case-control studies.

## RESULT

### Study Identification

The initial database search yielded 130 articles, including two duplicates, after the removal of which 128 articles remained. Of these, 93 were excluded because they needed to fulfill our selection criteria based on the evaluation of the titles. The remaining 35 articles' abstracts were reviewed, and 22 met the requirements to be further studied. The full texts of the 22 papers were examined, and nine articles were finally included (Figure 1). The included studies were predominantly comprised of retrospective chart reviews (77%), with the rest of the literature containing one prospective cohort study and one RCT.

### Patient Characteristics and Interventions

Patient characteristics and the intervention used in all studies are shown in Table 1. There were seven retrospective chart review studies (12, 14, 9, 10, 11, 13, 17), one prospective study (15), and 1 RCT (16). 3 of 9 (12,14, 16) studies compared submuscular plating and intramedullary nailing. 1 study (12) compared flexible intramedullary nailing, rigid intramedullary nailing, and submuscular plating. 1 study (16) compared ESIN and submuscular plating. All studies had samples >10 patients. In total, 390 cases were included in this review, consisting of 155 cases treated with submuscular plating and 235 cases treated with intramedullary nailing. The majority of patients in this study were male, with a ratio of 273/100, with 1 study (17) not stating the gender ratio. The mean follow-up duration was 18.3 months with range (9-25 months). 1 study (11) didn't state the mean follow-up period.

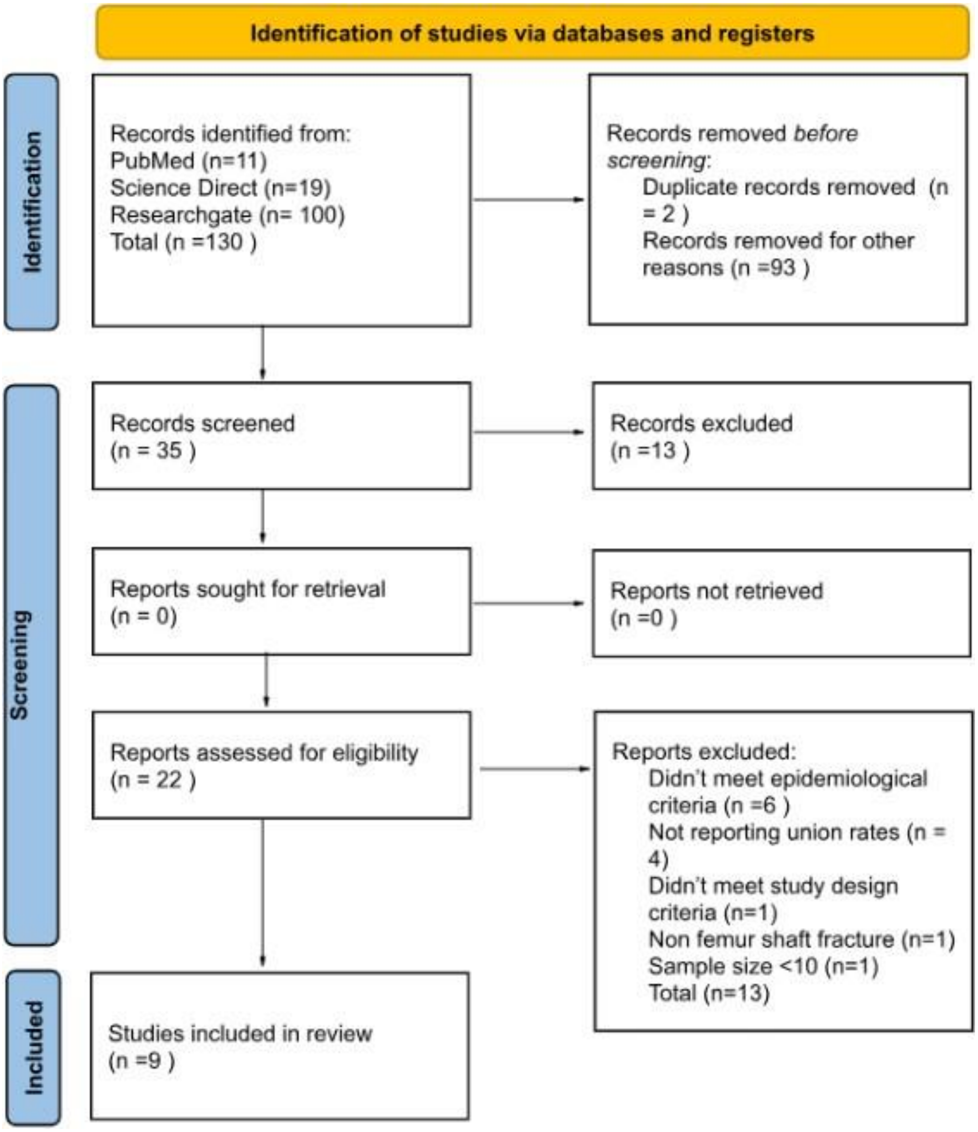


**Figure 1. PRISMA 2020 flow diagram for new systematic reviews**

## Outcomes

Table 2 shows the outcome measurements of all the studies. All studies (9-17) reported data on time of union, mal-unions, and complications. From all this literature, the average time of bone union in 155 patients treated with submuscular plating was 2.71 months, while 235 cases treated with intramedullary nailing have a faster union time with an average of 2.37 months. Mal-union was discovered in Sunthep et al., where flexible intramedullary nailing reported more cases compared to rigid intramedullary nailing and submuscular plating, with the number of cases respectively 13 (22%), 2 (2%), and 4 (12%). Other studies (14,17) also reported single non-union and delayed union cases.

Leg length discrepancy (LLD) above 1 cm was more common in the ESIN method, with a total of 20 cases (38%) compared to other methods discussed. LLD was also found in submuscular plating, yet most are less than 1 cm. Coronal angular deformity was reported in ESIN by Karuppal et al., with 1 case of over 100 degrees anteroposterior (AP) angulation, while 3 cases had AP angulation less than 100 degrees. The most common sagittal angular deformity from the studies we have collected is a valgus deformity, which was found higher in the intramedullary nailing group compared to the submuscular plating group (3:1). Data regarding post-operative limitation of mobility was narrow. Still, one study (15) reported 3 cases of decreased range of motion in patients treated with ESIN. Implant prominence was more common in intramedullary nailing, with 6 cases (6/235) compared to 1 in submuscular plating (1/155). These prominences were also accompanied by pain around the site of the implants, with a similar number of cases. 2/20 in the ESIN group had implant failure. Suboptimal nail diameter was the suspected cause of implant failure in both cases. Park et al. reported 2 cases (2/22) in intramedullary nailing patients that needed reoperation, one due to malrotation and the other due to deep infection that caused non-union. Reoperation was also reported in 1 case (1/16) due to non-locking plates.

## Literature Quality and Risk of Bias

Seven retrospective chart review studies were assessed using the NHLBI Quality Assessment tool for observational cohort and cross-sectional studies. Six of the studies had good quality, and only 1(11) study had fair quality because the participation rate of eligible persons was less than 50%. The studies didn't include sample size justification, power description, or variance. All of the studies didn't examine different levels of exposure related to the outcome because the exposures didn't vary in amount or level. All of the studies only assessed the exposure once at the end of the review. There was no blinding in all of the studies included. The studies included didn't measure any confounding variable nor adjusted it statistically.

One randomized controlled trial study (16) was evaluated using the modified Jadad scale to assess its methodological quality. It scored 5 out of 8, which is considered a high-quality trial. This study didn't mention the blinding process or describe withdrawals or dropouts, which led to some points from the Jadad scoring system not being fulfilled.

**Table 1. Study descriptions, patient characteristics, and intervention of the studies**

| Author | Study Design | Patient or cases | Mean age (yr) | Gender (M/F) | Follow-up (months) | Fracture location in femur | Fracture pattern | Treatment |
|---|---|---|---|---|---|---|---|---|
| **Non-comparison Study** | | | | | | | | |
| Wilson, 2012[9] | retrospective chart review | 16 | 8.9 | 13/3 | 25 | 6 subtrochanteric to proximal femur fracture<br>7 midshaft<br>3 distal third | NR | submuscular locked plate |
| Waghela, 2023[10] | retrospective chart review | 15 | 10.8 | 9/4 | 19.4 | 15 proximal femur fractures | 13 long obliques<br>2 comminuted | submuscular nonlocked plate |
| Valenza 2019[1] | retrospective chart review | 13 | 10.2 | 12/1 | NR | 6 proximal third<br>4 midshaft<br>3 distal third | 7 long obliques<br>2 spiral bending wedges<br>4 comminuted | submuscular bridge plating |
| Samora, 2013[12] | retrospective chart review | 32 patients with 33 fractures | 7.5 | 25/7 | implant removal 10.17 | 12 proximal third<br>18 midshaft<br>3 distal third | 13 comminuted<br>5 spirals<br>9 long obliques<br>6 short obliques | submuscular bridge plating |
| Karuppal, 2017[13] | prospective cohort | 20 | 7.9 | 16/4 | without implant removal 9.0 | 7 proximal third<br>13 midshaft | NR | Elastic Stable Intramedullary Nailing (ESIN) technique with |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | titanium elastic nails |
| Busch, 2019[14] | retrospective chart review | 12 | 9.3 | NR | 18 | 4 proximal third<br>7 midshaft<br>1 distal | 5 long obliques<br>3 spirals<br>4 comminuted | Quartet ESIN |
| **Comparison Study** | | | | | | | | |
| Sutphen, 2016[15] | retrospective chart review | 198 fractures in 196 patients | 11.9 | 150/46 | 11.2 | midshaft 134 (68%)<br>proximal third 40 (20%)<br>distal third 24 (12%) | 93 (47%) transverse<br>46 (23%) comminuted<br>43 (22%) oblique<br>16 (8%) spirals | |
| | | 61 | 10.6 | | | 83 % distal third | 41 (67%) transverse<br>3 (6%) comminuted<br>17 (27%) oblique<br>0 (0%) spiral | Flexible intramedullary nailing |
| | | 35 | 10.6 | | | 28% proximal third<br>34% distal third<br>38% midshaft | 3 (8.5%) transverse<br>10 (28.5%) comminuted<br>9 (25.7%) oblique<br>13 (37.1%) spirals | submuscular plating |
| | | 100 | 13.9 | | | 68% midshaft | 49 (43.7%) transverse<br>33 (29.4%) comminuted<br>17 (15.2%) oblique<br>13 (11.6%) spirals | rigid intramedullary nailing |
| Park, 2012[16] | retrospective chart review | 45 | | | | | | |
| | | 22 | 14.2 | 16/5 | 22.4 | 7 proximal third<br>12 midshaft<br>3 distal third | NR | intramedullary nailing |
| | | 23 | 13.6 | 18/4 | 20.9 | 6 proximal third<br>13 midshaft<br>4 distal third | NR | submuscular plate |
| James, 2022[17] | Randomized controlled trial (RCT) | 40 | | | | | | |
| | | 20 | 9.45 | 7/13 | 24 | 5 proximal third<br>13 midshaft<br>2 distal third | 13 transverse<br>7 short obliques | ESIN |
| | | 20 | 10.2 | 7/13 | 24 | 6 proximal third<br>9 midshaft<br>6 distal third | 15 transverse<br>6 short obliques | Submuscular plate |

**Table 2. Details of outcome measures of the studies**

| Author | Treatment | Time of Union (Mo) | Mal/ Non-union | Limb Length Discrepancy | Angular/ Rotational Deformity | Reduce in Mobility | Wound Infection | Implant Prominence | Implant Failure | Re-operation | Local Pain / Irritation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson, 2012[9] | Submuscular locked plating | 2.6 | 0 | 1 patient had an overgrowth of the fracture extremity, resulting | 0 | NR | 0 | NR | 1 patient who was initially treated at an | 1 patient who was initially treated at an | NR |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | in a discrepancy of 1.5 cm | | | | | outside institution with a nonlocked plate had a failure of fixation | outside institution with a nonlocked plate | |
| Waghela, 2023[10] | submuscular nonlocked plating | 2.75 | 0 | 2 patients had LLD <2 cm | 0 | NR | 0 | NR | 0 | 0 | NR |
| Valenza 2019[1] | submuscular bridge plating | 3 | 0 | 2 patients had LLD <2 cm | NR | NR | 0 | NR | 0 | 0 | NR |
| Samora, 2013[12] | submuscular bridge plating | 2.76 | 0 | 0 | no cases of varus or valgus malalignment >10 degrees | NR | 0 | NR | 0 | 0 | 1 patient reported implant irritation |
| Karuppal, 2017[13] | Elastic Stable Intramedullary Nailing (ESIN) technique with titanium elastic nails | 1.91 | 0 | 6 (30%) 1-2 cm 9 (45%) < 1 cm | 1 case AP angulation > 10° 3 case AP angulation < 10° | 3 | 1 | 3 | 0 | 0 | 1 |
| Busch, 2019[14] | Quartet ESIN | NR (mean hardware removal at 9.4 months | 1 delayed union | 0 | 0 | 0 | NR | 1 | 0 | 1 (due to fall, not because of adverse effects) | 1 |
| | submuscular plating | 1.4 | 4 (12%) | 1 patient | NR | NR | 0 | NR | 0 | 0 | NR |
| | flexible intramedullary nailing | 1 | 13 (22%) | 3 patients | NR | NR | 0 | NR | 0 | 0 | NR |
| | rigid intramedullary nailing | 2.21 | 2 (2%) | 5 patients | NR | NR | 0 | NR | 0 | 0 | NR |
| | intramedullary nailing n= 22 | 3.75 | 1 case of non-union and 1 of delayed union | no case > 1 cm | malrotation case | NR | 1 | NR | 0 | 2 | NR |
| | submuscular plating n=23 | 3.84 | 1 case of delayed union | no case > 1 cm | 0 | NR | 0 | NR | 0 | 0 | NR |
| | Elastic Stable Intramedullary Nailing (ESIN) | 3 | 1 | 2 case (1 patient > 1.5 cm, 1 patient = 1 cm) | 1 case genu valgum | NR | 0 | 2 | 2 | 0 | 2 |
| | Submuscular plating (SMP) | 2.64 | 1 | 1 case (1.5 cm) | 1 case genu valgum | NR | 1 | 1 | 0 | 1 | 1 |

## DISCUSSION

To the best of our knowledge, previous systematic reviews have compared intramedullary nailing and submuscular plating for managing femoral fractures; however, to differentiate, we limited our study to focus on the outcomes in adolescent patients, specifically on union rates and complications. We evaluated the surgical results of submuscular plating and intramedullary nailing for femur fracture repair. We established inclusion and exclusion criteria, critically appraised all studies, conducted quantitative analysis, and discovered probable explanations for all of the outcomes in the studies evaluated. The fact that we strictly followed the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions (version 5.0.2) and the PRISMA 2020 checklist adds to the validity of our findings.

Our main finding is that union rates in the intramedullary nailing group had a higher value compared to the submuscular plating group (2.37 months vs 2.71 months). According to James et al., SMP enhanced biomechanical stability while preserving fracture biology, especially in heavier children and length unstable femur fractures.[17] Mal-union was discovered in Sutphen et al., where flexible intramedullary nailing reported more cases compared to rigid intramedullary nailing and submuscular plating, with the number of cases respectively 13 (22%), 2 (2%), and 4 (12%). According to Sutphen et al., some factors associated with the poor outcomes of malunion included fractures of unstable length and increased patient weight. In Sutphen's study, two malunions occurred in a patient weighing more than 45 kg, one malunion happened in a patient with an unstable length fracture, and one malunion occurred in a child with heavier weight (>45 kg) accompanied by an unstable length fracture.[15]

Previous studies reported that rigid intramedullary nailing with a trochanteric starting point displays quicker mobilization, high union rates, and early weight bearing in larger patients with fractures of unstable length. This finding was consistent with the findings of Sutphen et al., who discovered that rigid nailing was associated with a much shorter time to complete weight bearing than elastic nailing. Other investigations [14,16] revealed a single incidence of non-union and delayed union related to delayed deep infection. A prior study with 246 participants looked at the risk of malunion between the SMP and ESIN.[18] The difference between the two procedures was not statistically significant (RR 1.06; 95% CI 0.44, 2.55; p 1/4 0.89). While not statistically significant, those treated with ESIN had a greater incidence of limb length discrepancy. According to the previous study conducted by Karuppal et al., the limb-length discrepancy was the most common complication of elastic stable intramedullary nailing. This review showed 20 LLD >1 cm cases in the elastic stable intramedullary nailing group. Karuppal's study concluded that this minimal length discrepancy produced no functional disability during the follow-up functional assessment.[13]

In younger patients, some degree of angular deformity is common after femoral shaft fractures, but this remodels typically during growth. The difficulty in precisely assessing the torsion alignment of the femur during the operation is one of the reasons for the high frequency of femoral malrotation following nailing. There are numerous intraoperative procedures for determining femoral ante-torsion, most of which are based on comparison with the contralateral, undamaged femur. However, none of them are 100% accurate in diagnosing the correct rotation of the damaged femur.[19] Karuppal et al. found anteroposterior angulations in four patients, with three (15%) having 5-100 and one having 120. None of the subjects in the research had severe rotational deformity as clinically measured by foot out-toeing or in-toeing. The four cases' minor anteroposterior angulations caused no impairment and were minimized during follow-up visits.[13] The most common sagittal angular deformity from the studies we have collected is a valgus deformity, which was found higher in the intramedullary nailing group compared to the submuscular plating group (3:1). All of the studies included didn't describe the reason for angular deformity. A previous study by Heinrich et al. described angular deformity in ESIN resulting from failure to stack the femoral canal with multiple nails or achieve various fixation points.[20]

In one study, participants treated with ESIN displayed a decreased range of motion after surgery. Six (30%) of the patients in this study experienced terminal 100 limitation of knee motions (flexion), possibly due to nail protrusion, which was treated with immediate physiotherapy. Two (10%) children had restricted knee flexion (less than 100 - 1100 arc) at 4 months, but with further physiotherapy, a standard range of knee flexion was achieved at 8 months. There were no reports of a loss in the range of motion in patients treated with Submuscular plating in the studies we reviewed. Previous research indicates that, regardless of the surgical approach employed, the ROM of the hip and knee returns to normal over time with good physiotherapy.[21] Most included studies didn't report any implant prominence. Three studies reported implant prominence. Six cases from the ESIN group were reported by Karuppal et al.[13], Busch et al.[14], and James et al.[17], and one case from the submuscular plating group was reported by James et al.[17] According to Salonen et al.[22], nail prominence is one of the pitfalls of elastic nailing. Nail prominence can lead to more serious complications such as skin breakdown, superficial or deep infection, early implant removal, and risk of re-fracture.

Fixation failure is uncommon. However, we discovered a few cases throughout our review. In James et al.'s study, two children in the ESIN group had implant failure. The hypothesized reason for implant failure in both cases was suboptimal nail diameter. One case of A 15-year-old girl youngster weighing 35 kg was fixed with two 2.5 mm TENS nails. After she developed 30° of sagittal malreduction 2 months after the index operation, TENS was reduced to 3.0 mm. Following fracture union, the 1.5 cm limb shortening was successfully treated with height-correction footwear.[17] Another case was an 11-year-old child weighing 20 kg with 15 degrees of sagittal angulation with a bent implant and fixation with two 2.5 mm nails that had an uncomplicated union after augmentation with a plaster cast. Wilson et al. described one patient who was first treated with a submuscular nonlocked plate from an outside institution and presented with fixation failure. He was immediately revised with a locked plate.[9]

In this review, we found 3 cases of reoperation in the intramedullary nailing group. Two from the Park et al. study[16] and one from the Busch et al. study[14]. In the submuscular plating group, we found 1 case of reoperation from the Wilson et al. study [9]. Two cases of reoperation in the Park et al. study were due to malrotation [16], and the other was due to deep infection that caused non-union. One patient in the Busch et al. study underwent reoperation following a refracture due to a fall.[14] In the Wilson et al. study, one case of reoperation in the submuscular locked plating group was due to fixation failure. This patient was previously treated in the outside institution with a nonlocked plate.[9]

This systematic review compiled the fast accumulating and contentious evidence on submuscular plating and intramedullary nailing outcomes for treating adolescents with femoral shaft fractures. It was carried out by the PRISMA and Cochrane guidelines, reducing the risk of bias. In contrast, various limitations should be acknowledged when interpreting the results of this study. Most of the articles collected had retrospective chart designs, indicating the possibility of selection bias. In this systematic review, just one RCT was analyzed. Furthermore, the included studies' small sample sizes and high heterogeneity may restrict the evidence. This variation may arise due to differences in demographics, assessment methods, surgical techniques, and follow-up durations. The definition of adolescent varies between studies, and most of the cases discussed involve femoral shaft fractures, yet not all specify the medial shaft region. Therefore, caution is recommended when interpreting the findings of this systematic review. A Randomized clinical trial would be golden to compare outcomes of SMP and IMN techniques to treat midshaft femur fracture. We suggest that future studies do clinical trials with a more specific population to make the study more valid.

## CONCLUSION

Similar outcomes with intramedullary nailing and submuscular plating imply that both treatments are safe, feasible, and successful for adolescent femur shaft fractures. This study emphasizes the union rates, distinct set of adverse surgical events associated with each implant, and the utility of submuscular plating compared to ESIN for this challenging patient population. Early unions were more commonly found in ESIN than SMP. However, ESIN was more related to a higher risk of complications, while SMP was associated with a low risk of adverse postoperative surgical events. SMP has the advantage of achieving more excellent functional outcomes. A Randomized clinical trial would be golden to compare outcomes of SMP and IMN techniques to treat midshaft femur fracture. We suggest that future studies do clinical trials with a more specific population to make the study more valid.

### *Declaration by Authors*

**Ethical Approval:** This study does not require ethical clearance

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**Conflict of Interest:** The authors declare no conflict of interest.

## REFERENCES

1. Iyidobi EC, Ekwunife RT, Enweani UM, Nwadinigwe CU, Okwesili IC, Ekwedigwe HC. Epidemiological Pattern of Closed Femoral Shaft Fractures in a Regional Tertiary Hospital in Enugu, Nigeria. Journal of Biosciences and Medicines. 2019 May 17;7(5):180-8.
2. Denisiuk M, Afsari A. Femoral shaft fractures. Treasure Island: StatPearls Publishing; 2020
3. John R, Sharma S, Raj GN, Singh J, Varsha C, Arjun RH, Khurana A. Suppl 2: M4: Current concepts in paediatric femoral shaft fractures. The open orthopaedics journal. 2017;11:353.
4. Liau GZ, Lin HY, Wang Y, Nistala KR, Cheong CK, Hui JH. Pediatric femoral shaft fracture: an age-based treatment algorithm. Indian Journal of Orthopaedics. 2021 Feb;55:55-67.
5. Allen JD, Murr K, Albitar F, Jacobs C, Moghadamian ES, Muchow R. Titanium elastic nailing has superior value to plate fixation of midshaft femur fractures in children 5 to 11 years. Journal of Pediatric Orthopaedics. 2018 Mar 1;38(3):e111-7.
6. Duan X, Al-Qwbani M, Zeng Y, Zhang W, Xiang Z. Intramedullary nailing for tibial shaft fractures in adults. Cochrane Database of Systematic Reviews. 2012(1).
7. Kalbitz M, Fischer A, Weber B, Mayer B, Lackner I, Pressmar J. Diaphyseal Femur Fractures in Children and Adolescents—Opportunities and Limitations of the ESIN Technique. Journal of Clinical Medicine. 2022 Dec 10;11(24):7345.
8. Li Y, Hedequist DJ. Submuscular plating of pediatric femur fracture. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2012 Sep 1;20(9):596-603.
9. Wilson CH, Smith CS, Gay DM, Loveless EA. Submuscular locked plating of pediatric femur fractures. Journal of Surgical Orthopaedic Advances. 2012 Jan 1;21(3):136-40.
10. Waghela AB, Oka GA, Ranade AS. Submuscular nonlocking plates: an effective option for pediatric extra-articular proximal femur fractures. Journal of Pediatric orthopedics. Part B. 2023 Mar 20.
11. Valenza W, Soni J, Gasperin W, Faria F. Submuscular bridge plating in the treatment of unstable femur fractures in children and

adolescents. Journal of Musculoskeletal Surgery and Research. 2019 Jul 1;3:286.
12. Samora WP, Guerriero M, Willis L, Klingele KE. Submuscular bridge plating for length-unstable, pediatric femur fractures. Journal of Pediatric Orthopaedics. 2013 Dec 1;33(8):797-802.
13. Vaasan, Sabary & Karuppal, Raju & Somasundaran, Sandhya. Functional outcomes of the stable elastic intramedullary nailing for the fractures of femur in children. Indian Journal of Orthopaedics Surgery. 2017. 3. 330-334. 10.18231/2395-1362.2017.0064.
14. Busch MT, Perkins CA, Nickel BT, Blizzard DJ, Willimon SC. A quartet of elastic stable intramedullary nails for more challenging pediatric femur fractures. Journal of Pediatric Orthopaedics. 2019 Jan 1;39(1):e12-7.
15. Sutphen SA, Mendoza JD, Mundy AC, Yang JG, Beebe AC, Samora III WP, Klingele KE. Pediatric diaphyseal femur fractures: submuscular plating compared with intramedullary nailing. Orthopedics. 2016 Nov 1;39(6):353-8.
16. Park KC, Oh CW, Byun YS, Oh JK, Lee HJ, Park KH, Kyung HS, Park BC. Intramedullary nailing versus submuscular plating in adolescent femoral fracture. Injury. 2012 Jun 1;43(6):870-5.
17. James D, Martin D, Kumar A, Krishnan S, Gahukamble A, Madhuri V, David T, Palocaren T. Elastic stable intramedullary nailing versus submuscular plating in pediatric diaphyseal femur fractures: a randomized controlled trial among children in South India. Journal of Pediatric Orthopaedics B. 2021 Aug 17;31(2):e122-9.
18. Strait RT, Pankey C. Submuscular plating versus elastic intramedullary nailing in children with femoral shaft fracture; a systematic review and meta-analysis. Journal of Clinical Orthopaedics and Trauma. 2023 Jul 1:102203.
19. Vergano LB, Coviello G, Monesi M. Rotational malalignment in femoral nailing: prevention, diagnosis and surgical correction. Acta Bio Medica: Atenei Parmensis. 2020;91(Suppl 14).
20. Heinrich SD, Drvaric D, Darr K, et al. Stabilization of pediatric diaphyseal femur fractures with flexible intramedullary nails (a technique paper). J Orthop Trauma. 1992;6:452–459.
21. Vergano LB, Coviello G, Monesi M. Rotational malalignment in femoral nailing: prevention, diagnosis and surgical correction. Acta Bio Medica: Atenei Parmensis. 2020;91(Suppl 14).
22. Salonen A, Lahdes-Vasama T, Mattila VM, Välipakka J, Pajulo O. Pitfalls of femoral titanium elastic nailing. Scandinavian Journal of Surgery. 2015 Jun;104(2):121-6.

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