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Surgical Management of Femoral Shaft Fractures: A Systematic Review

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ABSTRACT

Background: Intramedullary femoral nailing (IMN) is the gold standard for managing femoral shaft fractures. This systematic review aims to evaluate the current practices in the surgical management of femoral shaft fractures, focusing on the effectiveness of closed versus open reduction techniques.

Methods: This systematic review was conducted according to guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The literature search encompassed an extensive database including PubMed, ScienceDirect, Google Scholar, and Cochrane library. Studies published after the year 2013 were included in the analysis. The quality of the included studies was evaluated using the proper tools suited to the study design. The synthesis and analysis of data included a narrative summary of study characteristics, aims and objectives, surgical technique, and main study results/conclusions.

Results: Sample sizes in the selected studies ranged from 18 to 398 participants. The most common surgical techniques used for femoral shaft fractures were Closed and open intramedullary (IM) nailing. Generally, the studies found that closed techniques, such as closed nailing and closed reduction, had similar or better outcomes compared to open techniques in terms of union rates, blood loss, infection rates, and functional outcomes. Overall, the studies suggest that closed techniques and novel minimally invasive reduction methods can be effective alternatives to traditional open approaches for the treatment of femoral shaft fractures.

Conclusion: This systematic review concludes that closed reduction for intramedullary nailing of femoral shaft fractures is associated with better outcomes in terms of union rates and recovery times. Open reduction remains an acceptable alternative, particularly in challenging cases.

Keywords: Femoral shaft fractures, intramedullary nailing, closed and open intramedullary nailing, closed reduction, open reduction.

INTRODUCTION

Femoral shaft fractures are significant injuries that commonly result from high-energy trauma, such as motor vehicle accidents. The surgical management of these fractures primarily involves intramedullary nailing, which is generally preferred due to its minimally invasive nature and favorable

outcomes. This systematic review aims to evaluate the current practices in the surgical management of femoral shaft fractures, focusing on the effectiveness of closed versus open reduction techniques.

Surgical management of femoral shaft fractures is a critical component of orthopedic trauma care, particularly due to the high-energy mechanisms often involved in these injuries, such as motor vehicle accidents. These fractures can lead to significant morbidity, including complications like extensive bleeding and muscle injury, which necessitate prompt and effective treatment strategies. The current gold standard for surgical intervention is intramedullary nailing (IMN) [1,2,3,4,5], which boasts a high union rate of approximately 97% [6] but is also associated with potential complications such as malrotation and postoperative pain [7,8,9].

The management of femoral shaft fractures is influenced by various factors, including the patient's age, the fracture's characteristics, and the presence of concomitant injuries. In younger patients, high-energy trauma typically results in more complex fracture patterns, while older individuals may sustain fractures from lower-energy falls. This bimodal distribution underscores the importance of tailored surgical approaches that consider the unique circumstances of each patient [1].

In addition to IMN, alternative surgical techniques such as open reduction internal fixation (ORIF) and external fixation may be employed based on the specific fracture type and the patient's overall health status. While IMN remains the preferred method in most cases, external fixation can serve as a temporary solution, particularly in polytrauma scenarios where immediate stabilization is required [10].

Overall, the surgical management of femoral shaft fractures requires a comprehensive understanding of the injury's mechanics, the surgical options available, and the potential complications that may arise. As orthopedic practices continue to evolve, ongoing research into optimizing surgical techniques and patient positioning is essential for improving outcomes in this challenging area of trauma care [1, 10].

METHOD

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline [11]. We only included studies that focused on surgical management of femoral shaft fractures in adults.

Search Strategy

To identify relevant studies, we searched PubMed, ScienceDirect, Google Scholar, and Cochrane library databases using the following keywords and their derivatives: femoral shaft fractures, surgical management, closed reduction, open reduction, intramedullary nailing. Searches on PubMed and Google Scholar were done by employing the Boolean Logic (AND, OR and NOT) to generate different combinations of search strings. After the identification of relevant studies duplicates were removed. Manual searches of reference list of included articles were undertaken to search for possible studies not captured by the electronic searches. The title and abstract were screened for eligibility. Finally, the full text research articles were assessed to verify whether the study met the inclusion criteria.

Eligibility Criteria

The eligibility criteria were predefined. Studies were included if they involved adult patients aged ≥16 years with femoral shaft fractures, were available in full text, published in English, and employed clinical trial or observational study designs, including prospective and retrospective studies. Studies were excluded if they involved paediatric patients; fractures of the femoral head or neck; patients with ipsilateral acetabular fractures or lower limb amputations; proximal or distal (non-diaphyseal) femoral fractures; periprosthetic

or pathological fractures; or animal subjects. Additionally, studies published in languages other than English, as well as case studies, commentaries, editorials, short communications, abstracts, literature reviews, and systematic reviews or meta-analyses, were excluded from the analysis.

Studies published after the year 2013 were included in this systematic review which assessed different types of surgical management of femoral shaft fractures. A pre-screening or pilot literature review was meticulously conducted to ensure the reliability and credibility of the literature selection process. This pre-screening was performed by two independent researchers, and discrepancies were settled by a third reviewer. Title and abstract of each study were thoroughly examined to ascertain its relevance to the research objectives.

Data extraction and synthesis was performed after appropriate screening of the studies based on the inclusion and exclusion criteria. The extracted data included publication year, study type, sample size, aims and objectives, surgical technique, and main study results/conclusions. The collected data were presented as findings of this systematic review after analysis.

RESULT

Initial search identified 1354 studies from the databases and other sources. 119 records were screened after initial exclusion of the studies. Following an assessment of the titles and abstracts, 30 articles were selected for further consideration. Following that, 8 studies were eliminated based on the inclusion criteria and two studies were not in English. We screened 20 studies based on the inclusion and exclusion criteria. Finally, we selected 12 studies because of non-availability of some data in the other studies. The process of selection of the studies is depicted in the PRISMA study selection diagram (Figure 1).

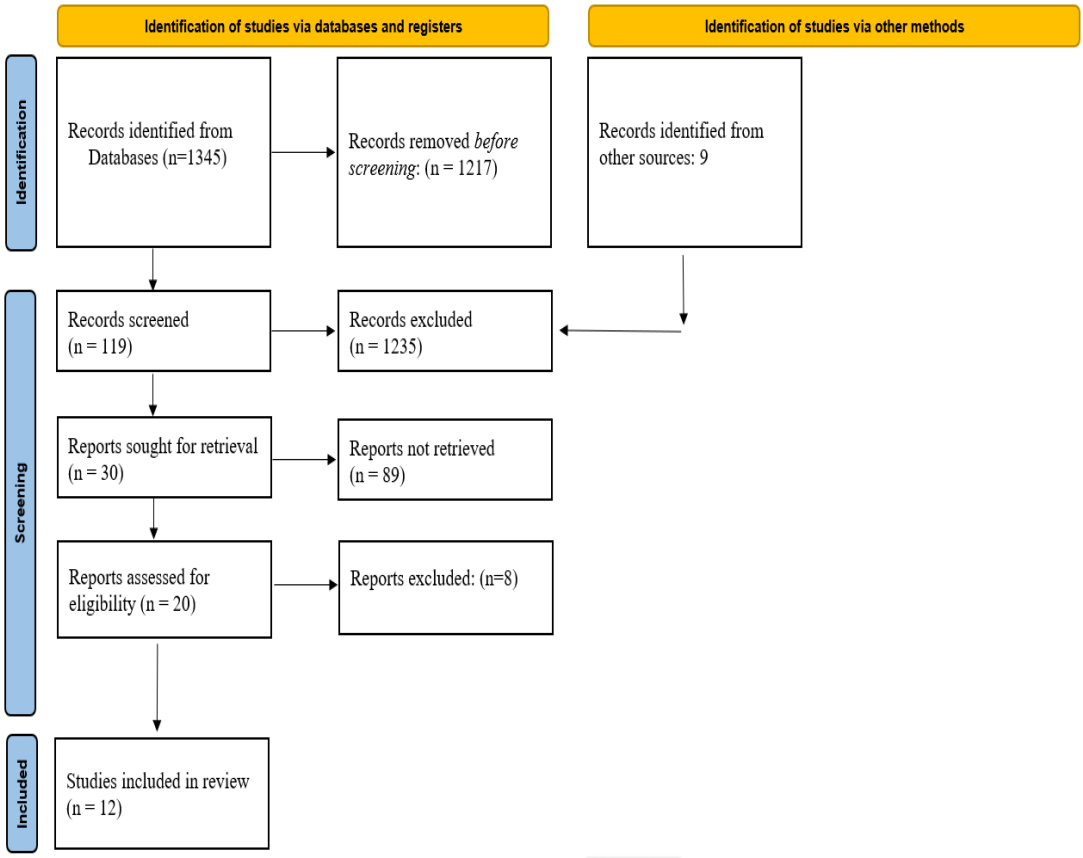

Figure 1: PRISMA Flow Chart

Table 1: Different methods of surgical management for femoral shaft fractures.

Authors & Publication Year	Sample Size/ Design of the Study	Aims	Technique	Result/Conclusion
Chen W et al. 2016 [12]	22 Prospective study	This study aims to assess the outcomes of displaced femoral shaft fractures treated by a novel minimally invasive technique that employs a rapid reductor to reduce fracture and facilitate IM nail fixation.	Fracture reduction with rapid reductor and intramedullary (IM) nail fixation	The rapid reductor can be applied to effectively achieve and maintain the reduction of displaced femoral shaft fractures in a minimally invasive fashion, which is conducive for IM nailing fixation.
Chaudhary P et al. 2017 [13]	80 RCT	To compare outcome of open versus closed interlocking nail for fracture shaft of femur in adults in term of union, blood loss, infection rate, functional outcome	Closed and open intramedullary interlocking nailing	Operating time, blood loss, and infection are higher in the open nailing group. Cost of treatment and union is comparable in both groups.
Kisan D et al. 2018 [14]	64 Retrospective study	to assess the results of intramedullary nailing of femoral shaft fractures by both open and closed methods.	Closed and open intramedullary interlocking nailing	Increased blood loss, Increased infection rate and decreased rate of union is observed in open group.
Kumar SK et al. 2018 [15]	50 Cohort	To compare the functional outcome of closed vs open intramedullary interlocking nailing of fracture shaft of femur.	Closed and open intramedullary interlocking nailing	Both the techniques are similar.
Gao Y et al. 2019 [16]	18 Prospective study	This study aims to explore the clinical efficacy of applying a new reduction brace in the closed reduction of femoral shaft fracture.	Novel reduction brace combined with closed reduction intramedullary nail insertion	All patients with femoral shaft fracture successfully received closed reduction femoral nail with the application of the novel reduction brace. The design of the closed reduction brace of the femoral shaft fracture was reasonable, simple, and convenient to use and has a short learning curve.
Hamahashi K et al. 2019 [17]	51 Retrospective study	This study evaluated the clinical outcomes of intramedullary nailing of femoral shaft fractures with third fragments and analyzed the risk factors for delayed union.	Intramedullary nailing	Only displacement of the third fragment significantly affected delayed union.
Naeem-Ul-Haq S et al. 2020 [18]	116 Retrospective study	To compare the results of closed interlocking nail shaft of femur versus open	Closed and open intramedullary interlocking nailing	Closed interlocking nail for fracture shaft of femur resulted in earlier union, better union rates

		interlocking nail in terms of union, non-union and infection rate.		and less infection rate than open interlocking nail.
Ghouri SI et al. 2020 [19]	110 Retrospective study	This study aims to assess the results of open versus closed reduction in intramedullary nailing for femoral fractures.	open versus closed reduction in intramedullary nailing	There is no statistical difference between the healing rates in closed and open reduction in femoral shaft fractures.
Tahir M et al. 2021 [20]	398 Retrospective study	The study aims to assess the clinical and functional outcomes of open and closed nailing for closed femoral shaft fractures.	Open and closed nailing	Fixation of femoral shaft fractures with open nailing has similar outcomes in union rates, time to union, and rates of significant complication similar to those of close nailing.
Shui W et al. 2021 [21]	20 Retrospective study	In this study, a fracture table was used to restore limb length, and long, curved haemostatic forceps and the lever principle were utilized to achieve minimally invasive reduction and intramedullary nail fixation of femoral shaft fractures.	closed reduction technique with intramedullary nails, haemostatic forceps and the lever principle	Displaced femoral shaft fractures in adults can be treated by a labour-saving lever technique involving fragments, 2 haemostatic forceps and soft tissue envelope-assisted closed reduction and intramedullary nail fixation.
Nandhimandalam B et al. 2021 [22]	100 Cohort	To compare the closed IM nailing and mini-open technique in femoral-diaphyseal fractures (FDF) in terms of radiation exposure, surgical duration, radiological and functional outcome.	Closed intramedullary (IM) nailing and mini-open IM nailing	Closed intramedullary nailing is better treatment for acute femoral shaft fractures. Percutaneous technique associated with minimal open reduction is helpful in treating the complex fractures, polytrauma patients in poor resource set-up, and segmental fractures.
Lin S et al. 2022 [23]	63 Retrospective study	To compare the efficacy of small-incision clamp-assisted reduction with open reduction for the treatment of femoral shaft fractures by anterograde intramedullary nailing.	Small-incision clamp-assisted reduction and open reduction	compared with open reduction, clamp reduction is a safer reduction method with shorter operation time, less intraoperative blood loss, less postoperative pain, shorter hospital stay and fewer postoperative complications.

Table 1 summarizes 12 studies related to the treatment of femoral shaft fractures. The studies were conducted by various authors and published between 2016 and 2022. The sample sizes range from 18 to 398 patients. The majority of the studies were retrospective in nature, with 3 being original/prospective studies and 2 being cohort studies.

The studies aimed to compare the outcomes of various techniques for the treatment of femoral shaft fractures, including open vs. closed intramedullary nailing, open vs. closed reduction, and the use of novel reduction methods. Some studies also looked at factors affecting delayed union and functional outcomes. The main techniques evaluated were: Closed vs. open intramedullary interlocking nailing and novel reduction techniques, such as the use of a rapid reductor, a reduction brace, and a lever technique with haemostatic forceps.

Generally, the studies found that closed techniques, such as closed nailing and closed reduction, had similar or better outcomes compared to open techniques in terms of union rates, blood loss, infection rates, and functional outcomes. Novel reduction techniques, like the rapid reductor and reduction brace, were effective in achieving and maintaining fracture reduction in a minimally invasive manner, facilitating intramedullary nail fixation. Factors such as displacement of third fragments were identified as risk factors for delayed union.

Overall, the studies suggest that closed techniques and novel minimally invasive reduction methods can be effective alternatives to traditional open approaches for the treatment of femoral shaft fractures.

Risk of Bias Assessment

Quality assessment of the included studies was critically appraised using the appropriate tools. Nine studies were assessed using the Risk of Bias in Non-randomized Studies - of Interventions (ROBINS-I) tool [24], one study of Chaudhary P et al. 2017 [13] was evaluated using the Cochrane Risk of Bias (RoB 2) tool [25] which was found to be of high risk of bias in all the domains except low risk in one domain of random sequence generation. Two studies were assessed using the Newcastle-Ottawa scale (NOS) [26]. Nandhimandalam B et al. 2021 [22] was found to be of good quality because of low risk of bias with total NOS score 8 while Kumar SK et al. 2018 [15] was of high risk of bias with total NOS score 4.

Figure 2 summarizes the risk of bias of the included non-randomized studies as assessed using the ROBINS-I tool. Chen W et al. (2016) [12] and Gao Y et al. (2019) [16], both prospective studies, demonstrated an overall moderate risk of bias, primarily due to moderate concerns in Domains 1, 3, 5, and 6, while other domains were rated as low risk. Among the retrospective studies, Hamahashi K et al. (2019) [17], Tahir M et al. (2021) [20], and Shui W et al. (2021) [21] also showed an overall moderate risk of bias, largely driven by moderate bias related to confounding (Domain 1), deviations from intended interventions or outcome measurement (Domains 4–6). In contrast, Kisan D et al. (2018) [14], Naeem-Ul-Haq S et al. (2020) [18], Ghouri SI et al. (2020) [19], and Lin S et al. (2022) [23] were assessed as having an overall low risk of bias, with low risk ratings across most domains except for moderate concerns related to confounding and missing data. Overall, Domain 1 (bias due to confounding) and Domain 6 (bias in measurement of outcomes) were the most frequent sources of moderate bias across studies, whereas Domains 2 and 7 were consistently rated as low risk.

Figure 2. Traffic lights plot for the risk of bias for included prospective and retrospective studies [12,14,16-21,23].

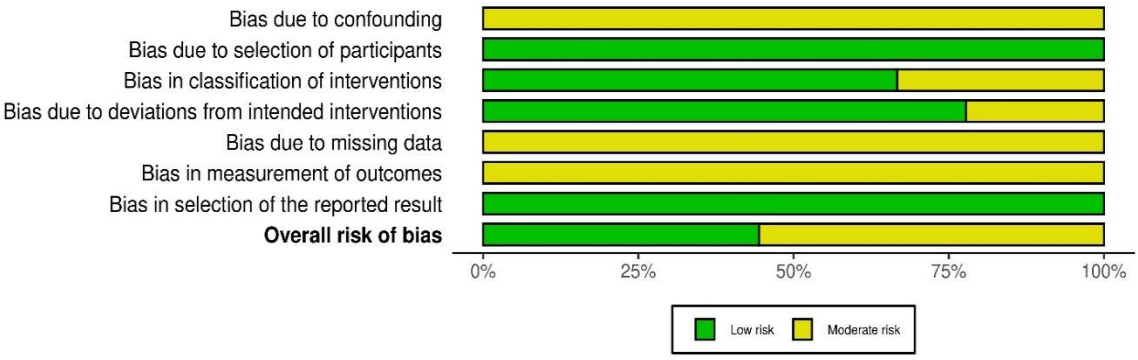

Figure 3. Summary of risk of bias assessment of included prospective and retrospective studies.

DISCUSSION

The findings of the present study suggest that closed intramedullary nailing generally has better outcomes compared to open nailing, with reduced blood loss, infection rates, and earlier union. Novel minimally invasive reduction techniques, such as the use of specialized reduction devices or braces, can facilitate successful closed reduction and intramedullary nail fixation. Mini-open nailing may also have advantages over open nailing in certain scenarios, while the displacement of the

third fragment appears to be a risk factor for delayed union.

Our findings of the present study are consistent with other researches which proved that closed reduction and interlocking intramedullary nail fixation is a standard treatment for femoral shaft fracture [27, 28]. Chaudhary et al. (2017), Kisan et al. (2018), and Naeem-Ul-Haq et al. (2020) found that closed intramedullary nailing had better outcomes compared to open nailing, with reduced blood loss, infection rates, and earlier union. In contrast, Ghouri et al. (2020) and Tahir et al. (2021) reported no significant difference in healing rates and complication rates between open and closed nailing.

Chen et al. (2016) and Shui et al. (2021) described successful minimally invasive closed reduction techniques using a "rapid reductor" device and the "lever principle" with hemostatic forceps, respectively. These techniques facilitated closed reduction and intramedullary nail fixation. Gao et al. (2019) evaluated the use of a novel reduction brace that enabled closed reduction and intramedullary nail insertion in all their patients, with the brace being simple, convenient, and having a short learning curve. Nandhimandalam et al. (2021) found that closed intramedullary nailing was better than mini-open nailing in terms of reduced radiation exposure, shorter surgical duration, and better radiological and functional outcomes. Hamahashi et al. (2019) identified that only the displacement of the third fragment significantly affected the risk of delayed union in femoral shaft fractures treated with intramedullary nailing. Some study compared small-incision clamp-assisted reduction versus open reduction. Lin et al. (2022) reported that small-incision clamp-assisted reduction had better outcomes compared to open reduction, with shorter operation time, less blood loss, less postoperative pain, shorter hospital stay, and fewer complications.

The open approach has certain drawbacks as well, such as the need to take skin scars into account, the loss of fracture hematoma, which is crucial for fracture healing, and the loss of bone shavings from reaming the canal. If a locking nail is employed, infection rates rise, union rates fall, and image intensification can still be necessary [29]. While intramedullary nailing is the most common surgical treatment for femoral shaft fractures, external fixation and plate fixation are also used in certain situations.

There are several new minimally invasive techniques being developed and tested for the treatment of femoral shaft fractures:

Novel Closed Reduction Technique

A recent study introduced a novel closed reduction technique that utilizes intramedullary nails, long curved haemostatic forceps, and the lever principle [21]. This method aims to achieve minimally invasive reduction and nail fixation without the need for open procedures. In a retrospective analysis of 20 patients, all fractures were successfully reduced in a closed fashion, with excellent alignment achieved after nailing. The technique demonstrated reduced operative time, blood loss, and fluoroscopy exposure compared to traditional methods.

Minimally Invasive Plate Fixation

Minimally invasive plate fixation (MIPF) is another approach being explored for femoral shaft fractures [30]. In this technique, the plate is inserted through isolated proximal and distal incisions only, passing behind the vastus lateralis muscle. This minimizes soft tissue disruption compared to open plating techniques. While not as commonly used as nailing, MIPF can be considered in certain situations such as segmental fractures or when nailing is not feasible.

Percutaneous Reduction Techniques

The use of percutaneous reduction tools and techniques is gaining traction to facilitate minimally invasive nailing of complex femoral fractures [31]. These include the use of reduction clamps, Schanz pins, and blocking screws applied through small

incisions to neutralize deforming muscle forces. Mastery of these percutaneous reduction maneuvers is crucial to extend the indications of intramedullary nailing to more complex fracture patterns while respecting the soft tissue envelope.

In summary, novel closed reduction techniques utilizing specialized instruments, minimally invasive plating, and advanced percutaneous reduction methods are examples of new minimally invasive approaches being developed and studied for the treatment of femoral shaft fractures. These techniques aim to improve outcomes by reducing surgical trauma while maintaining the benefits of stable fixation.

Although our present study focused on the surgical management of femoral shaft fractures in adults, there are other procedures applied in pediatric patients. There are four main interventions used in pediatric femoral shaft fractures: cast (C), plate fixation (PF), titanium elastic nail (TEN) and external fixation (EF) [32].

CONCLUSION

The present systematic review concluded that closed reduction for intramedullary nailing of femoral shaft fractures is associated with better outcomes in terms of union rates and recovery times. Open reduction remains an acceptable alternative, particularly in challenging cases. Future research should focus on long-term outcomes and the development of standardized protocols to optimize the management of femoral shaft fractures.

Declaration by Authors

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REFERENCES

1. Gupte D, Axelrod D, Worthy T, Woolnough T, Selznick A, Johal H. Management of Femoral Shaft Fractures: The Significance of Traction or Operative Position. Cureus. 2023 Jan 14;15(1):e33776. doi: 10.7759/cureus.33776. PMID: 36798626; PMCID: PMC9925393.
2. Gänsslen A, Gösling T, Hildebrand F, Pape HC, Oestern HJ. Femoral shaft fractures in adults: treatment options and controversies. Acta Chir Orthop Traumatol Cech. 2014; 81:108–117.
3. Bone LB, Johnson KD, Weigelt J, Scheinberg R. Early versus delayed stabilization of femoral fractures: a prospective randomized study. 1989. Clin Orthop Relat Res. 2004 May;(422):11-6. PMID: 15187827.
4. Browner B, Edwards CC. Baltimore, MD: Williams & Wilkins; 1996. The Science and Practice of Intramedullary Nailing, Second Edition.
5. O'Brien PJ, Meek RN, Powell JN, Blachut PA. Primary intramedullary nailing of open femoral shaft fractures. J Trauma. 1991 Jan;31(1):113-6. doi: 10.1097/00005373-199101000-00022. PMID: 1986115.
6. Saleeb H, Tosounidis T, Papakostidis C, Giannoudis PV. Incidence of deep infection, union and malunion for open diaphyseal femoral shaft fractures treated with IM nailing: A systematic review. Surgeon. 2019 Oct;17(5):257-269. doi: 10.1016/j.surge.2018.08.003. Epub 2018 Aug 27. PMID: 30166239.
7. Sanders DW, MacLeod M, Charyk-Stewart T, Lydestad J, Domonkos A, Tieszer C. Functional outcome and persistent disability after isolated fracture of the femur. Can J Surg. 2008 Oct;51(5):366-70. PMID: 18841213; PMCID: PMC2556524.
8. Lindsey JD, Krieg JC. Femoral malrotation following intramedullary nail fixation. J Am Acad Orthop Surg. 2011 Jan;19(1):17-26. doi: 10.5435/00124635-201101000-00003. PMID: 21205764.
9. Archdeacon M, Ford KR, Wyrick J, Paterno MV, Hampton S, Ludwig MB, Hewett TE. A prospective functional outcome and motion analysis evaluation of the hip abductors after femur fracture and antegrade nailing. J Orthop Trauma. 2008 Jan;22(1):3-9. doi: 10.1097/BOT.0b013e31816073b6. PMID: 18176158.
10. Denisiuk M, Afsari A. Femoral Shaft Fractures. [Updated 2023 Jan 2]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from:

https://www.ncbi.nlm.nih.gov/books/NBK556057/
11. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021 Mar 29; 372: n71.
12. Chen W, Zhang T, Wang J, Liu B, Hou Z, Zhang Y. Minimally invasive treatment of displaced femoral shaft fractures with a rapid reductor and intramedullary nail fixation. Int Orthop. 2016 Jan;40(1):167-72. doi: 10.1007/s00264-015-2829-0.
13. Chaudhary P, Maharjan R, Kalawar RPS, Baral P, Shah AB. Randomized controlled trial comparing open versus closed interlocking nail for closed fracture shaft of femur in adults. Int J Orthop Sci. 2017;3(1):591–595.
14. Kisan D, Samant S. A comparison of closed intramedullary nailing with open intramedullary nailing in femoral shaft fractures of adults. Int J Orthop Sci. 2018;4(2):88–90. doi: 10.22271/ortho.2018.v4.i2b.13.
15. Santosh Kumar K, Kiran Kumar HV. Comparative study of surgical management of fracture shaft of femur with intramedullary interlocking nail Z: Open VS closed type. Nat. J. Clin. Orthop. 2018;2(1):22-25. DOI: https://doi.org/10.33545/orthor.2018.v2.i1a.31
16. Gao Y, Qiao NN, Zhang YH, Lv X, Liu JY. Application of fracture-sustaining reduction frame in closed reduction of femoral shaft fracture. J Orthop Surg Res. 2019 May 22;14(1):147. doi: 10.1186/s13018-019-1145-6.
17. Hamahashi K, Uchiyama Y, Kobayashi Y, Ebihara G, Ukai T, Watanabe M. Clinical outcomes of intramedullary nailing of femoral shaft fractures with third fragments: a retrospective analysis of risk factors for delayed union. Trauma Surg Acute Care Open. 2019 Mar 27;4(1):e000203. doi: 10.1136/tsaco-2018-000203.
18. Naeem-Ul-Haq S, Abidi SAR, Jalil SA, Ahmed SA, Tunio ZH, Umer MF, Khan TJ. Comparison of closed versus open interlocking nail femur: a retrospective cohort study in a tertiary care hospital. J Pak Orthop Assoc. 2020;32(03):125–130.
19. Ghouri SI, Alhammoud A, Alkhayarin MM. Does Open Reduction in Intramedullary Nailing of Femur Shaft Fractures Adversely Affect the Outcome? A Retrospective Study. Adv Orthop. 2020 May 20; 2020:7583204. doi: 10.1155/2020/7583204.
20. Tahir M, Ahmed N, Faraz A, Shafiq H, Khan MN. Comparison of Open and Closed Nailing for Femoral Shaft Fractures: A Retrospective Analysis. Cureus. 2021 Jun 29;13(6):e16030. doi: 10.7759/cureus.16030.
21. Shui W, Yang Y, Pi X, Luo G, Qiao B, Ni W, Guo S. A novel closed reduction technique for treating femoral shaft fractures with intramedullary nails, haemostatic forceps and the lever principle. BMC Musculoskelet Disord. 2021 Feb 15;22(1):187. doi: 10.1186/s12891-021-04055-5.
22. Nandhimandalam B, Das S, Zalariya S, Azam MQ, Mittal A. Is mini-open intramedullary nailing an effective intervention for adult femoral diaphyseal fractures in odd hours? A prospective case-control functional outcome and radiation safety study. Injury. 2021 Apr;52(4):971-976. doi: 10.1016/j.injury.2020.10.097.
23. Lin S, Zhang Z, Yan Y, Li Y, Lin J, Ye H. Comparison of the efficacy of small-incision clamp-assisted reduction and open reduction for the treatment of femoral shaft fractures with an anterograde intramedullary nail: a retrospective study. J Orthop Surg Res. 2022 Mar 28;17(1):188. doi: 10.1186/s13018-022-03067-8.
24. Sterne JA, Hernán MA, Reeves BC, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. BMJ. 2016 Oct 12;355: i4919. doi: 10.1136/bmj. i4919.
25. Higgins JP, Altman DG, Gøtzsche PC, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ. 2011 Oct 18;343: d5928. doi: 10.1136/bmj. d5928.
26. Wells GA, O'Connell D, Peterson J, et al. The Newcastle-Ottawa scale (NOS) for assessing the quality if nonrandomized studies in meta-analyses. 2011, https://ohri.ca/en/who-we-are/core-facilities-and-platforms/ottawa-methods-centre/newcastle-ottawa-scale (accessed 15 March 2025).
27. Wild M, Gehrmann S, Jungbluth P, Hakimi M, Thelen S, Betsch M, et al. Treatment strategies for intramedullary nailing of femoral shaft fractures. Orthopedics.

2010;33(10):726. doi: 10.3928/01477447-20100826-15.
28. Liu Y, Tao R, Liu F, Wang Y, Zhou Z, Cao Y, et al. Mid-term outcomes after intramedullary fixation of peritrochanteric femoral fractures using the new proximal femoral nail antirotation (PFNA) Injury. 2010;41(8):810–817. doi: 10.1016/j.injury.2010.03.020.
29. Terry Canale S., Beaty J. Campbell's Operative Orthopaedics. 11th. Amsterdam, Netherlands: Elsevier; 2007.
30. Wenda K, Runkel M, Degreif J, Rudig L. Minimally invasive plate fixation in femoral shaft fractures. Injury. 1997;28 Suppl 1: A13-9. doi: 10.1016/s0020-1383(97)90111-x.
31. Rhorer AS. Percutaneous/minimally invasive techniques in treatment of femoral shaft fractures with an intramedullary nail. J Orthop Trauma. 2009 May-Jun;23(5 Suppl): S2-5. doi: 10.1097/BOT.0b013e31819f2569.
32. Chen Z, Han D, Wang Q, Li L. Four interventions for pediatric femoral shaft fractures: Network meta-analysis of randomized trials. Int J Surg. 2020 Aug; 80:53-60. doi: 10.1016/j.ijsu.2020.06.032.

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