

# Outcomes of intramedullary nailing for traumatic adult femoral shaft fractures in low-and-middle-income countries; a systematic review

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## Abstract

**Objective:** This review reports on the radiologic and functional outcomes and complications of managing adult traumatic femur shaft fractures (FSFs) with intramedullary nailing (IMN) in Low-and-Middle-Income Countries (LMICs) and evaluates the quality of existing evidence.

**Methodology:** A thorough literature search was conducted across several databases, including reference lists of selected articles. Screening was done per the PRISMA guidelines. Peer-reviewed articles published in English between January 2011 and December 2022 that reported radiologic or functional outcomes in adults with isolated traumatic FSFs managed with IMN in LMICs were included for review. The quality and level of evidence were assessed using modified Critical Appraisal Skills Program checklists and the modified Oxford Centre for Evidence-Based Medicine criteria.

**Findings:** Forty studies from 13 LMICs were included in this review. The mean time to union was 15.4 weeks, with a mean union rate of 88.1%. Functional outcomes scores showed >70% excellent outcomes. The Radiographic Union Scale in Tibia score and Thoresen criteria were the most used assessment tools. Mean infection rates were 4.8%, and limb shortening (of varying amounts) occurred in 3.5% of patients. The findings revealed variability in measuring and reporting IMN outcomes in FSFs, but overall, the existing evidence was of satisfactory quality.

**Conclusion:** Despite the data limitations, methodological differences, and outcome discrepancies, this review demonstrates a trend favoring IMN for FSFs, with low failure rates in low-resources settings. However, more robust studies using standardized radiographic and functional outcomes measures in LMICs are needed.

**Keywords:** intramedullary nailing, femur fracture, outcomes, low-and-middle-income countries

## 1. Introduction

In both adult and paediatric populations, femoral shaft fractures (FSFs) are among the most common types of long bone injuries in orthopaedics and trauma practice.<sup>1</sup> Although these fractures can result from various causes such as bone pathologies, high energy trauma is the most frequent cause, often accompanied by multisystem or other life-threatening injuries.<sup>2</sup> With the current “global epidemic of road traffic injuries (RTIs),” traumatic FSFs from road traffic accidents alone account for 1.0–2.9 million cases worldwide.<sup>3,4</sup> Low-and-Middle-Income Countries (LMICs)

bear more than 90% of this burden, with an incidence of 16–46 per 100,000 people annually.<sup>3</sup> Although the exact mortality and morbidity of FSFs from all traumatic causes are unknown, it is estimated that about 10% of years lost to disability due to RTIs are because of femoral fractures.<sup>5</sup> These fractures can cause significant physical impairments resulting from disrupted fracture healing, prolonged limb immobilization, limb length discrepancy, or fracture malunion.<sup>6</sup> Nonetheless, research shows that many trauma-related morbidities and mortality can be averted with adequate surgical care.<sup>7</sup>

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The management of adult FSFs has long been a subject of interest and controversy in orthopaedic practice worldwide. Management depends on factors such as age, fracture pattern, mechanism of trauma, comminution, associated injuries, available resources, surgeon's preference, and socioeconomic status and demands of the patient.<sup>1,8</sup> Historically, FSFs were commonly managed with cast bracing, external splints, and skeletal traction. However, newer surgical techniques have evolved. Operative treatment options for fractures of the femoral shaft include fixation with intramedullary (IM) nails, plates and screws, or external fixators (EF). Irrespective of the technique, there are some agreed-upon principles for managing FSFs: preserving blood supply to the fracture site to promote healing and avoid infections, reestablishing limb alignment, rotation, and length of the limb, and restoring patient function.<sup>1</sup>

Intramedullary nailing (IMN) in adult FSF management is widely accepted and has long been considered the gold standard.<sup>1</sup> It has shown improved limb function, faster bone healing, early mobilization, reduced risk of malunion and limb discrepancy, shorter hospital stays, and fewer complications.<sup>9–11</sup> Despite a higher burden of traumatic FSFs compared with high-income countries, LMICs have less abundant literature on IMN techniques and outcomes. Due to resource and expertise constraints, many LMICs continue to use nonoperative methods to treat FSFs.

Although acknowledging that traumatic FSFs can be managed in several ways in LMICs, this paper focuses on outcomes related to IMN. It explores the literature on radiographic and functional outcomes and complications of femoral IMN in LMICs, factors affecting these outcomes, and assesses the quality of the available evidence.

## 2. Methods

### 2.1. Search Strategy

This study is a descriptive review of observational and experimental studies evaluating the outcome of FSFs after IMN in LMICs. The primary keywords used in the search were “intramedullary nailing,” “femur fracture,” “outcomes,” and “Low-and-Middle-Income Countries.” MeSH terms derived from these keywords were utilized to capture a comprehensive range of relevant articles. The search targeted all countries classified as LMICs, as per World Bank classification.<sup>12</sup>

Search terms were tailored to different databases, including Medline, Embase, Cochrane, African Journals Online (AJOL), Latin American and Caribbean Health Sciences Literature (LILACS), and Web of Science. Additional literature was identified through websites of professional bodies including the Orthopaedic Trauma Association (OTA/AO) and American Academy of Orthopaedic Surgeons. Detailed search strategies and database-specific adaptations are provided in Appendix 1, <http://links.lww.com/OTAI/A124>. Reference lists of all eligible studies were screened for additional relevant citations.

### 2.2. Inclusion Criteria

Study selection followed the PICO framework:

- Population—Patients  $\geq 13$  years or those identified as having attained skeletal maturity.
- Interest—Traumatic, isolated fractures of femoral shaft treated with an IM nail.
- Context—LMICs
- Outcome—Radiologic or functional outcomes and short- or long-term complications

Eligible studies had to be peer-reviewed, published in or translated to English between January 2011 and December 2022, to reflect current practices. Both primary and secondary data studies were included if they met these criteria.

Studies involving mixed long bone injuries where FSF outcomes were not clearly distinguishable, alternative fixation techniques, or conservative management strategies were excluded. Also excluded were femoral head, neck, and distal fractures, pathological and periprosthetic fractures, animal and cadaveric studies, systematic reviews, single case reports, case series (<10 patients), descriptions of techniques, conference abstracts, posters, and treatment protocols.

### 2.3. Study Selection

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines,<sup>13</sup> identified records were screened in stages using Endnote 20 (Clarivate, Philadelphia, PA) and Covidence (Melbourne, Australia) software. Full-text articles were reviewed against the inclusion and exclusion criteria; the details of the selection process are illustrated in a PRISMA flowchart (Fig. 1).

### 2.4. Data Extraction

Data were extracted systematically using a predesigned template based on the Cochrane checklist for systematic reviews.<sup>14</sup> The template, created in Covidence, was pilot-tested on a sample of 5 studies to ensure comprehensive data capture. The final form contained 64 items, categorized into 7 sections: general study information, methodology, participants, intervention, outcomes, results, and miscellaneous.

Two reviewers independently extracted data from each study. Extracted data included general characteristics (eg, authors, publication year, location, demographic data) and study-specific characteristics (such as study aims, design, type of IM nail used, and outcome measures). In cases where studies reported 2 different approaches to IMN or compared 2 types of IM nails with different outcome measures, data were extracted separately for each group.

### 2.5. Outcome Evaluation

The treatment outcomes of interest were predetermined and categorized into primary and secondary measures. Primary measures included union times and rates, malalignment, range of motion (ROM) of the knee and hip, length of stay (LoS) in hospital, Quality of Life (QoL), and time from surgery to full unassisted weight bearing. Radiographic union was defined based on cortical continuity, callus size, and gradual loss of the fracture line on radiographs, whereas clinical union was defined as the ability to bear weight without pain.<sup>15–17</sup> Union times were converted to months and reported as weighted averages, whereas union rates were presented as weighted percentages.

Secondary outcomes included complications such as post-surgical infections, implant failure, joint stiffness, leg-length discrepancies, and pulmonary complications. All outcomes were evaluated irrespective of the surgical approach.

### 2.6. Analytic Framework

Extracted data were categorized into functional, radiologic, and complication-related outcomes and summarized using basic statistical

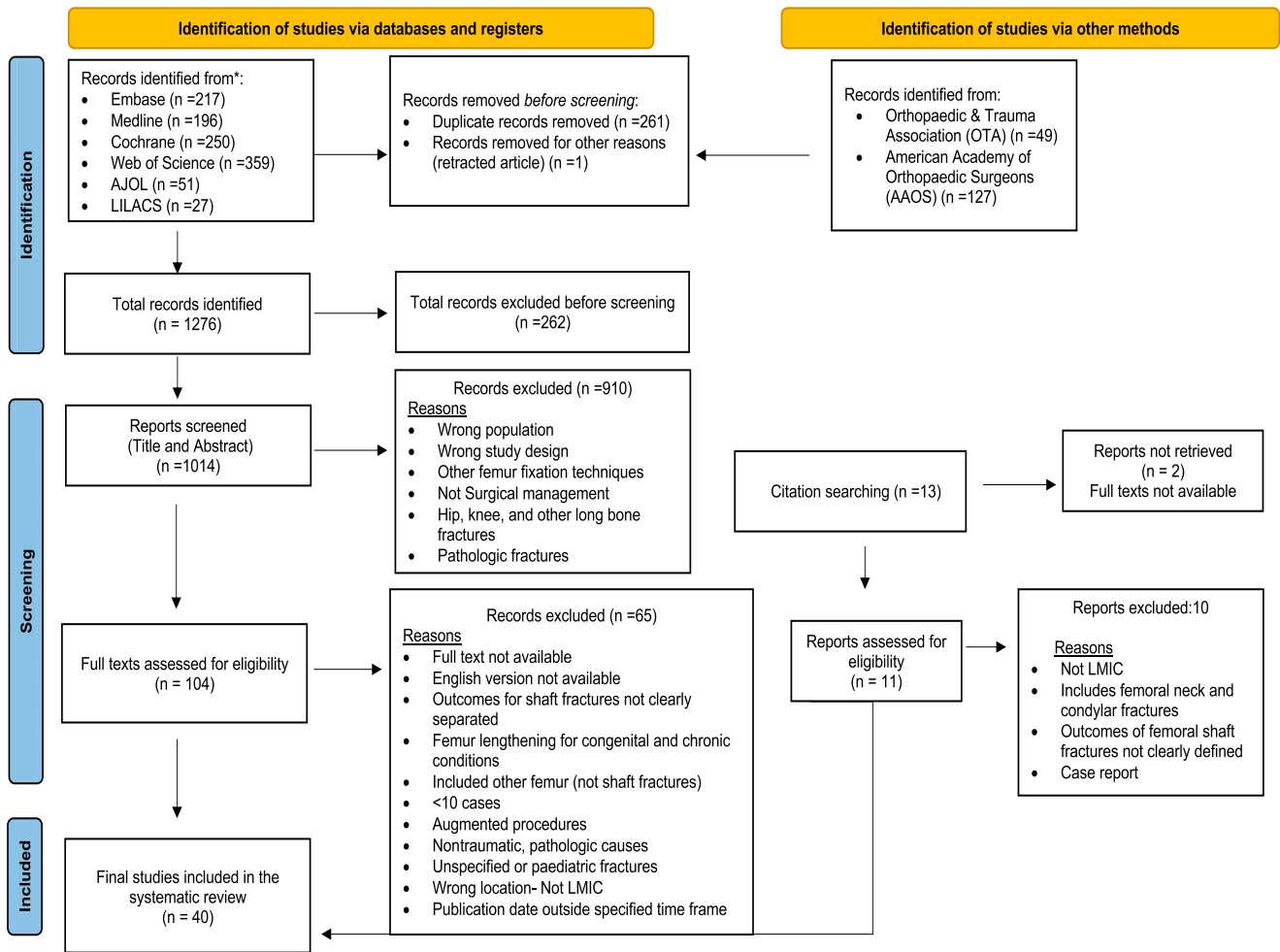


Figure 1. Prisma flowchart showing the study selection process.

measures, including means, weighted averages, percentages, and ranges in Excel. Results were presented using figures and tables, structured to address the primary research questions and objectives.

### 2.7. Quality Assessment

The quality of the studies was evaluated using a modified version of the Critical Appraisal Skills Program (CASP) checklist and the modified Oxford Centre for Evidence-Based Medicine level of evidence pyramid.<sup>18–21</sup> Two CASP checklists (Appendix 2, <http://links.lww.com/OTA/A124>) were used: an 11-item one for randomized studies and another with 14 items for nonrandomized studies. Studies were classified into levels of evidence with randomized controlled trials (RCTs) rated as level I, prospective cohort and case-control studies as level II, retrospective cohort and case-control studies as level III, and case series as level IV.

## 3. Results

The search yielded 1276 results across 8 databases with 40 studies meeting the inclusion criteria.

### 3.1. General Characteristics of the Studies

Table 1 provides an overview of the general characteristics of the studies.<sup>22–61</sup> LMICs were underrepresented, with studies conducted

in only 13 out of 138 eligible countries. Around 80% of the studies were published after 2015, indicating growing interest in this topic.

Of the 40 studies, 57.5% (n = 23) were prospective, whereas 42.5% (n = 17) were retrospective. Most were cohort studies (n = 23), with 12.5% (n = 5) being RCTs.<sup>23,31,32,35,46</sup> Overall, 4518 patients were studied, with a median age of 33.6 years (13–90 years). The weighted average follow-up time was 16.47 months (1–144 months), and the average time from admission to surgery was 8.2 days (0–40 days).

### 3.2. Fracture Characteristics

Fracture mechanisms were detailed in 57.5% (n = 23) of the studies, with RTIs (78.3%) and falls (74%) being the most common causes. Closed fractures were the sole focus in 30% (n = 12) of studies, whereas 2.5% (n = 1) focused on open fractures, and 20% (n = 8) covered both. The OTA/AO fracture classification system was used in 58% of the studies.

### 3.3. Interventions

More than 60% (n = 22) of the studies were comparative (Table 2). Seven studies compared IMN with other fracture fixation methods such as EF, plating, and conservative management. Seventeen studies examined variations in IM nails and nailing techniques. Intraoperative imaging was used in 45% (n =

**Table 1****General characteristics of studies.**

Author, year [in-text citation]	Country of study	Study design	Sample size	Mean age	Average follow-up (mo)
Yapıcı et al, <sup>22</sup> 2022	Turkey	Retrospective cohort	41 <sup>a</sup> 44 <sup>b</sup>	46.5 <sup>a</sup> 47.1 <sup>b</sup>	25.2 <sup>a</sup> 26.2 <sup>b</sup>
Shafi et al, <sup>23</sup> 2021	Pakistan	Prospective RCT	32	26.6	9
Musonda et al, <sup>24</sup> 2021	Zambia	Prospective cohort	109	30	3
Ma et al, <sup>25</sup> 2016	China	Retrospective observational study	425	37.6	N/R
Mahmood et al, <sup>26</sup> 2022	Pakistan	Prospective non-RCT	100	33.6	12
Liu et al, <sup>27</sup> 2019	Tanzania	Prospective cohort	85	N/R	12
Chenet et al, <sup>28</sup> 2016	China	Prospective non-RCT	43	41.7	23.8
Akar et al, <sup>2022</sup> <sup>29</sup>	Turkey	Retrospective cohort	25	33.5	29.1
Chokotho et al, <sup>2020</sup> <sup>30</sup>	Malawi	Prospective cohort	55	38	12
Ahmad et al, <sup>31</sup> 2017	Pakistan	Prospective RCT	242 <sup>a</sup> 242 <sup>b</sup>	33.5 <sup>a</sup> 33.9 <sup>b</sup>	1
Ali et al, <sup>32</sup> 2015	Unclear	Prospective RCT	195	34.3	24
Anisi et al, <sup>33</sup> 2019	Nigeria	Retrospective cohort	45	33.56	12
Anusitviwat et al, <sup>34</sup> 2021	Thailand	Retrospective cohort	185	28	N/R
Bharti et al, <sup>35</sup> 2020	India	Prospective RCT	56	34.3	18
Carsen et al, <sup>36</sup> 2015	Multinational database study	Retrospective cohort	501	33	N/R
Das et al, <sup>37</sup> 2015	India	Retrospective cohort	30	43	144
Deepak et al, <sup>38</sup> 2012	India	Prospective case series	30	27.4	24
Durigan et al, <sup>39</sup> 2019	Brazil	Retrospective cohort	123	29	12
Ekwunife, <sup>2020</sup> <sup>40</sup>	Nigeria	Prospective cohort	26	39.1 <sup>α</sup>	4.5
Eliezer, <sup>2017</sup> <sup>41</sup>	Tanzania	Prospective cohort	270	31.6	12
Ergisi, <sup>2020</sup> <sup>42</sup>	Turkey	Retrospective cohort	16	34.8	21
Ferreira, <sup>2019</sup> <sup>43</sup>	South Africa	Prospective cohort	18	29.7	13.4
Haonga, <sup>2015</sup> <sup>44</sup>	Tanzania	Prospective cohort	85	33	4.5
Ibrahim, <sup>2018</sup> <sup>45</sup>	Tanzania	Prospective cohort	270	31.6	12
Kakar, <sup>2018</sup> <sup>46</sup>	Pakistan	Prospective RCT	50 <sup>a</sup> 50 <sup>b</sup>	45.10 <sup>a</sup> 45.9 <sup>b</sup>	6
Khan, <sup>2015</sup> <sup>47</sup>	Pakistan	Prospective cohort	25 <sup>a</sup> 25 <sup>b</sup>	34.8 <sup>a</sup> 32.5 <sup>b</sup>	N/R
Nandhimandalam, <sup>2021</sup> <sup>48</sup>	India	Prospective case control	100	33.5	12
Njoroge, <sup>2013</sup> <sup>49</sup>	Kenya	Prospective cross-sectional	124	38.8	16.8
Opondo, <sup>2020</sup> <sup>50</sup>	Kenya	Prospective non-RCT	69	35	N/R
Ozdemir, <sup>2012</sup> <sup>51</sup>	Turkey	Retrospective cross-sectional	25	31.4	65.1
Polat, <sup>2018</sup> <sup>52</sup>	Turkey	Retrospective cohort	36	37.3	76.3
Reang, <sup>2019</sup> <sup>53</sup>	India	Retrospective cohort	73	N/R	15
Salawu, <sup>2017</sup> <sup>54</sup>	Nigeria	Prospective cohort	43	36.9	12
Shui et al, <sup>55</sup> 2021	China	Retrospective case series	20	38	17.5
Sipahioglu et al, <sup>56</sup> 2017	Turkey	Prospective case control	31 <sup>a</sup> 31 <sup>b</sup>	28 <sup>a</sup> 29 <sup>b</sup>	N/R
Turhan & Gorgulu, <sup>2021</sup> <sup>57</sup>	Turkey	Retrospective cohort	31 <sup>a</sup> 28 <sup>b</sup>	34.6 <sup>a</sup> 31.9 <sup>b</sup>	16.3 17.4
Ugezu et al, <sup>58</sup> 2018	Nigeria	Retrospective cohort	143	35	N/R
vonKaeppeler et al, <sup>2021</sup> <sup>59</sup>	Tanzania	Prospective cohort	141	31.30	12
Wilson et al, <sup>60</sup> 2019	Kenya	Retrospective case control	28 <sup>a</sup> 28 <sup>b</sup>	33.8 <sup>a</sup> 30.3 <sup>b</sup>	N/R
Wu et al, <sup>61</sup> 2019	Taiwan	Retrospective cross-sectional	152	53.2	9

"N/R" means not reported. "α" median age group reported instead of mean. "a" and "b" were used to represent studies with 2 different IMN treatment groups whose outcomes were reported separately.

18) of studies. SIGN standard IM nails (30%) were the most used, followed by SIGN Fin nails (12.5%) and K-Nails (10%).

### 3.4. Primary Outcome Evaluation

Thirty-seven out of 40 studies stated what outcome (functional and radiographic) was measured. Over 50% (n = 21) measured both functional and radiographic outcomes.

### 3.5. Radiographic Outcome

Eighty percent (n = 32) studies measured radiographic outcomes. Union was the most measured radiographic

outcome (n = 22). The mean union time was 15.4 weeks (6–52 weeks), and union rate was 90.9% (65%–100%). Delayed union was observed in 6.1% (0–10.5) of cases, whereas nonunion and malunion rates were 6.46% and 4.8%, respectively. Fifteen studies described secondary surgical procedures including dynamization (n = 5), exchange nailing (n = 3), or combinations of bone grafting with other procedures (n = 6).

Six studies utilized scoring systems for radiographic union, with the Radiographic Union Scale for Tibia (RUST) and modified (mRUST) score (n = 4) being the most common. All 3 studies that presented RUST scoring results surpassed the threshold for bony union (a score of >9).<sup>41,59,61</sup>

**Table 2**  
**Comparative studies (needs updating).**

Authors, year	Comparison groups
Yapici et al, 2022 <sup>22</sup>	Talon fixation versus conventional fixation
Shafi et al, <sup>23</sup> 2021	Retrograde femoral interlocking nail versus dynamic condylar screw
Lui et al, 2019 <sup>27</sup>	Standard SIGN versus SIGN fin nails
Akar et al, 2022 <sup>29</sup>	Static versus dynamic locking nail
Chokocho et al, <sup>30</sup> 2020	IMN versus skeletal traction
Ahmad et al, <sup>31</sup> 2017	Reamed versus unreamed interlocking nails
Ali et al, <sup>32</sup> 2015	Percutaneous versus conventional approach
Bharti et al, <sup>35</sup> 2020	K-nail versus intramedullary interlocking nail
Durigan et al, <sup>39</sup> 2019	Antegrade versus retrograde nailing approach
Ekwunife et al, <sup>40</sup> 2020	IMN versus plate fixation
Eliezer et al, <sup>41</sup> 2017	SIGN standard nail versus SIGN fin nail versus OTA/AO universal nail versus plating
Kakar et al, <sup>46</sup> 2018	Antegrade versus retrograde IM nailing
Khan et al, <sup>47</sup> 2015	Static versus dynamic interlocking IMN
Nandhimandalam et al, <sup>48</sup> 2021	Closed versus mini-open IMN
Njoroge, et al, 2013 <sup>49</sup>	Antegrade versus retrograde approach
Opondo et al, <sup>50</sup> 2013	Surgical versus conservative management
Polat et al, <sup>52</sup> 2018	External fixator versus IMN
Sipahioglu et al, <sup>56</sup> 2017	Expandable versus standard IM nail
Turhan & Gorgulu, 2021 <sup>57</sup>	Compressive versus noncompressive nailing techniques
Ugezu et al, <sup>58</sup> 2018	Operative fixation (dynamic compression plate, K-nail, interlocking IMN) versus skeletal traction
von Kaeppler et al <sup>59</sup> , 2021	Antegrade versus retrograde approach
Wilson et al, <sup>60</sup> 2019	Standard SIGN IMN versus SIGN fin nail

**3.6. Functional Outcomes**

Half of the studies (n = 20) assessed functional outcomes, often using scoring systems (Fig. 2). Thoresen’s criteria was the most common functional score, showing average excellent outcome rate of 85.1% (65.4%–96.2%), whereas poor outcomes averaged 8.6% (0%–19.2%). Two studies reported Lower Extremity Function Score (LEFS) of 61.0 and 64.2.<sup>42,52</sup> The average weighted LoS was 9.3 days (0–40 days). The mean time to full weight bearing was 9.4 weeks (4.6–18.56 weeks), whereas time to partial weight bearing ranged from 2 to 84 days.

Hip function was assessed in 5 studies using the Harris Hip Score (HHS) and Hip disability & Osteoarthritis Outcome

Score<sup>23,32,35,42,52</sup> with about 80% (50%–94.9%) of patients showing good to excellent outcomes. Knee function evaluated using Knee Society Score, Hospital for Special Surgery, and Knee Injury and the Osteoarthritis Outcome Score also showed good to excellent outcomes in up to 98.3% (79.2%–98.3%) of patients.

Twenty percent (n = 9) of studies measured health-related QoL<sup>23,27,28,30,41,45,51,59</sup> with the EuroQoL EQ-5D-3L index tool, Visual Analogue Scale, Patient Reported Outcome Measures, and Short Form-36 (SF-36) scale. EQ-5D scores ranged from 0.91 to 0.94 (close to 1 meaning total health) at 1-year follow-up,<sup>27,30,45,59</sup> and SF-36 scores exceeded 85 in all dimensions.<sup>51</sup>

**3.7. Secondary Outcome Evaluation**

The complications of union have already been presented earlier on. The remaining complications reported are shown in Table 3.

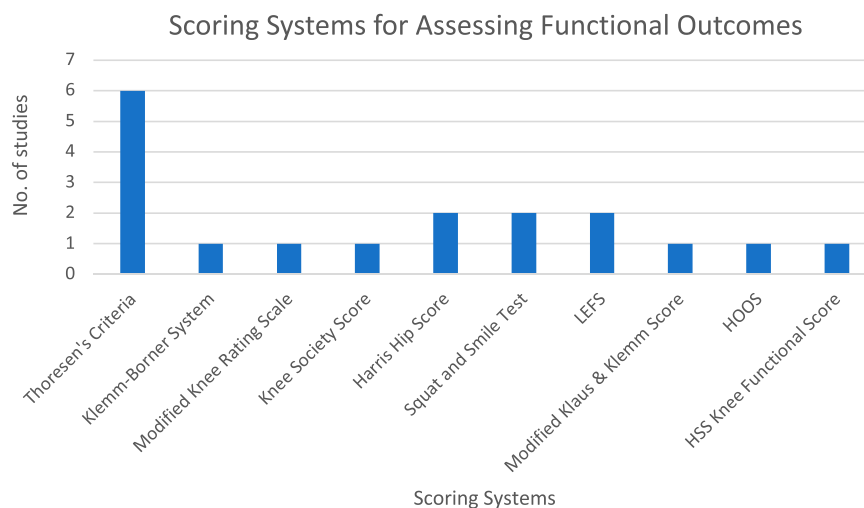
The most common complication was postsurgical infection, reported in 50% (n = 20) of studies, with an average infection rate of 4.8% (0%–16.6%). Nineteen studies (47.5%) reported leg length discrepancy between 0.5 and 3 cm in 0%–17% of their patients. Pooling the data from these 19 studies together, the overall incidence of leg length discrepancy greater than 0.5 cm is 3.5% of patients. The average time to surgery in this review was 6.4 days with average hospital stay of 9.3 days.

**3.8. Factors Affecting the Outcome**

Factors affecting outcomes were identified in 16 (40%) studies. Lower socioeconomic status was shown to be related to poorer outcomes.<sup>35,41</sup> Small nail diameter, unreamed nail, infection, and loss of fracture site hematoma were linked to poorer bony union outcomes.<sup>25,35,38,41,51</sup> Fracture comminution and injury severity, proximal and distal shaft fractures, and retrograde IMN approaches were associated with poor fracture alignment and knee function outcomes.<sup>36,39–41,44,45,49,59</sup> Availability of physiotherapy postsurgery was also a key factor influencing recovery.<sup>44,49</sup>

**3.9. Quality Assessment of Studies**

The reviewed studies’ quality assessment findings are summarized in the Tables 4 and 5. Almost half (n = 19) studies were level III



**Figure 2.** Scoring systems for assessing functional outcomes of IMN in FSFs.

**Table 3**  
**Complications associated with IMN of FSFs.**

Complication	No. of studies reported	Avg (weighted) rate (range) (%)
Infection	20	4.1 (0–16.6)
Leg length discrepancy	19	3.5 (0–17)
Implant failure	9	1.8 (0–7)
Knee stiffness	9	8 (0–33.3)
Refracture	1	3.3
Pulmonary complications	4	1 (0–3)

studies; only 12.5% were deemed to be level I studies. Only 5 studies (12.5%) were RCTs.<sup>23,31,32,35,46</sup> No study met all the criteria on the checklist. However, 2 met more than 80% of the checklist criteria (Table 4).<sup>32,35</sup> Items 1, 2, 3, and 6 were the most met, whereas item 4 (blinding of participants and personnel) was the least met criteria for the RCTs.

Table 5 summarizes the quality assessment of non-RCTs in this review. Twenty-six (74.2%) studies met more than 60% of the criteria in the checklist. Although no quality indicator had 100% reporting, the items most met in the non-RCT quality assessment checklist were items 1, 2, 3, 5, 13, and 14 (clear statement of aims, appropriate methodology, study design and data collection, and clear statement of findings and research value). Indicators assessing the quality of the methods were the least reported; items 6, 7, and 9 (researcher’s role, ethical considerations, and follow-up data). In about one-third of studies, there was incomplete follow-up data.

**4. Discussion**

This review highlights the limited data on femoral shaft fractures treated with intramedullary nailing in LMICs. Despite the gaps in available evidence, IMN demonstrates good functional and radiographic outcomes with fewer complications, such as infection, implant failure, and leg length discrepancy. In addition, variations in reporting and outcome assessment tools were observed, pointing to the need for more standardized research methodologies in LMICs.

Thirteen LMICs, mostly from lower-middle-income countries, were represented in this review. This contrasts with a review of outcomes for conservative management of FSFs in LMICs, where 50% of studies were conducted in low-income countries.<sup>62</sup> The underrepresentation of low-income countries may stem from the perceived cost of orthopaedic procedures and lack of equipment and limited expertise.<sup>63,64</sup>

The average time to surgery in this review was 6.4 days. Current data support IM nailing for most FSFs within the first 24 hours of injury, as this promotes early mobility, reduces pain and LoS, and decreases morbidity.<sup>1</sup> However, in many LMICs, delay in surgery is common due to hospital payment policies, lack of expertise, and infrastructure limitations.<sup>65,66</sup> The average hospital stay of 9.3 days is significantly shorter than reported for conservative management, which can exceed 50 days in other LMIC studies.<sup>50,62</sup>

Union was achieved at an average of 15.4 weeks with an average union rate of 90.9% at 12 months, aligning with the typical healing period of 12–24 weeks for adult femur fractures.<sup>65,67</sup> Nonunion occurred in 5.6% of cases, which is also consistent with reported nonunion rates of <10% after IMN for FSFs.<sup>68,69</sup> Malunion was noted in 20% of cases, but

differentiating between nail types and techniques was limited by inconsistent data.

Malalignment rates varied, with some studies reporting a rate of 9.7% for angulation >10°. Factors influencing alignment included proximal or distal shaft fractures, fracture comminution, time to surgery, injury mechanism, and antegrade nailing techniques. Similar findings have been observed in higher-income settings, where proximal shaft fractures are more prone to malalignment with antegrade nailing.<sup>70</sup>

Functional outcomes were assessed using several scoring systems, with Thoresen’s criteria<sup>71</sup> being the most common. The review found that 74.6% of IMN patients achieved excellent functional outcomes, whereas 8.6% had poor outcomes. Other functional scores, such as LEFS,<sup>72</sup> HHS,<sup>73</sup> and the Squat and Smile test,<sup>74</sup> also demonstrated good to excellent results for most patients. Notably, IMN outperformed skeletal traction at 3 and 6 months, although not at 1 year, in a Malawi study using the SMFA index. However, one-third of the conservatively managed patients eventually underwent IMN, which may explain the change in outcome scores at 1 year.<sup>64</sup>

Femoral fractures significantly impact on quality of life (QoL). In this review, EQ-5D<sup>75</sup> and SF-36<sup>76</sup> tools were used. EQ-5D scores were consistently high, nearing a perfect score of 1, whereas SF-36 scores averaged 99/100 for simple and 97/100 for complex fractures. However, results for conservative management versus IMN varied. One study reported lower QoL for patients on skeletal traction due to emotional distress, pain, and economic burdens, whereas another found no difference in EQ-5D scores between conservatively managed and IMN patients.<sup>64,77</sup>

Infection rates were low, averaging 4.1%, consistent with global data that ranges from 0% to 5%.<sup>35,47,54,64</sup> Leg length discrepancies were reported in 4.6% of cases, with discrepancies greater than 2 cm being less common but potentially impactful. These findings mirror existing literature on IMN, which suggests that discrepancies up to 2 cm are generally well tolerated.<sup>62,78</sup>

The use of various assessment tools for IMN in femur fractures has led to challenges in presenting a comprehensive overall outcome or effect. Nonetheless, this review found the quality of

**Table 4**  
**Summary of the quality of reporting assessment for RCTs.**

Quality indicator	Item No.	Yes	No	Unclear
<b>Basic study design</b>				
Research addresses a clearly focused issue?	1	5	0	0
Were patients randomly assigned?	2	4	0	1
All patients accounted for in its conclusion?	3	5	0	0
<b>Methodology</b>				
Blinding of participants and personnel	4	0	4	1
Groups similar at the start of the trial?	5	2	0	3
Were the groups treated equally?	6	4	0	1
<b>Results</b>				
Were the effects of intervention reported comprehensively?	7	2	3	0
Was the precision of the estimate of the intervention or treatment effect reported?	8	2	2	1
Do the benefits of the experimental intervention outweigh the harms and costs?	9	3	0	2
<b>Are the results useful locally</b>				
Can results be generalised	10	3	2	0
Would the experimental intervention provide greater value to the people in your care than any of the existing interventions?	11	3	2	0

**Table 5**  
**Summary of the quality of reporting assessment for non-RCTs.**

Quality indicator	Item No.	Yes	No	Unclear
Basic study design				
Clear statement of aims?	1	33	2	0
Is the methodology appropriate?	2	33	0	2
Design appropriate to address aims?	3	33	0	2
Methodology				
Appropriate recruitment strategy? Were there clear criteria for inclusion?	4	29	4	2
Appropriate data collection?	5	34	0	1
Appropriate consideration of researcher/participant role?	6	11	20	4
Ethical issues considered??	7	25	10	0
Was the follow-up of subjects long enough?	8	27	1	7
Was follow-up complete. If not, were the reasons to loss to follow-up described and explored?	9	24	5	6
Sufficiently rigorous data analysis?	10	30	2	3
Were outcomes measured in a reliable way?	11	30	1	4
Results				
Were the results precise?	12	24	3	8
Clear statement of findings?	13	35	1	0
Is this research valuable?	14	33	0	2

reporting in both RCTs and non-RCTs to be satisfactory. Although the RCTs met over 70% of the CASP checklist criteria, the primary deficiency in quality assessment was the absence of blinding for both researchers and participants, a challenge often encountered in surgical intervention trials. Unblinded studies may introduce performance and ascertainment bias. Therefore, results from unblinded surgical intervention trials, as reported in this review, should be interpreted cautiously.<sup>79,80</sup>

The overall quality of the non-RCTs was also considered satisfactory, with an average score of 10 out of 14 items. However, one of the less fulfilled criteria was providing adequate follow-up data. The lack of follow-up data could potentially affect the interpretation of the results.<sup>81–84</sup>

The data reveal limited information on factors affecting IMN outcomes for FSFs. Less than half of the studies reported influencing factors, which varied significantly in both factors and outcomes. Common factors influencing FSF IMN outcomes included the availability of physiotherapy, retrograde technique affecting knee ROM, and wound infections. However, these relationships were poorly addressed in the reviewed studies. More comprehensive data are required to better understand these factors' impact.

## 5. Limitations

This review has several limitations. First, it primarily relies on observational studies, which are susceptible to confounding and not the gold standard for assessing clinical interventions. Second, the diverse tools used for assessing and reporting outcomes create heterogeneity and hinder direct result comparisons. Third, some studies may have been excluded by excluding abstracts, editorials, and non-peer-reviewed articles, introducing publication bias. Fourth, the study's limited data may not fully represent LMICs. Last, language constraints led to the exclusion of non-English studies, potentially missing relevant information and limiting the review's scope.

## 6. Conclusion

This study is the first to synthesize existing evidence on the radiographic and functional outcomes of IMN for FSFs in

LMICs, revealing disparities in data across LMICs but an overall preference for IMN due to its safe and efficient outcomes and low complication rates. No conclusive evidence supports one IM nailing approach over another. Despite methodological variations, most studies meet the quality assessment criteria. Although tools for measuring outcomes exist, standardization and reporting need improvement, and the factors affecting outcomes remain a research gap.

## Data Availability Statement

All data utilized in this study are publicly available from the sources cited in this manuscript. Complete bibliographic details, including URLs and DOIs where applicable, are provided in the references section.

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