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Comparative Effectiveness of Plate Fixation versus Intramedullary Nailing in the Management of Midshaft Clavicle Fractures: A Systematic Review

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Abstract

Background: Midshaft clavicle fractures represent the majority of clavicular fractures, particularly in young, active adults. Surgical intervention is recommended for displaced, shortened, or comminuted fractures to restore shoulder function and prevent long-term complications. Among the various surgical techniques, **plate fixation** and **intramedullary nailing (IMN)** are the most widely practiced. Plate fixation offers rigid stabilization and anatomical reduction, whereas IMN is less invasive, preserving soft tissue and periosteal blood supply. However, the optimal choice remains controversial, with varying reports on union rates, functional outcomes, complication profiles, and patient satisfaction.

Methods: A systematic review of the literature was performed according to PRISMA guidelines. PubMed, Embase, Scopus, and the Cochrane Library were searched from inception to July 2025 using a combination of keywords and MeSH terms related to "midshaft clavicle fracture," "plate fixation," and "intramedullary nailing." Only randomized controlled trials (RCTs) and high-quality prospective cohort studies directly comparing the two techniques were included. Data extraction focused on primary outcomes such as **union rate, functional scores** (Constant-Murley Score, Disabilities of the Arm, Shoulder and Hand [DASH] score), and **complication rates** (non-union, infection, hardware irritation, implant migration). Secondary outcomes included operative time, cosmetic satisfaction, return-to-work interval, and reoperation rates. Risk of bias was assessed using the Cochrane RoB 2.0 tool for RCTs and the Newcastle–Ottawa Scale for observational studies.

Results: A total of XX eligible studies involving XXXX patients (XX% male, mean age XX years) were included. Both plate fixation and IMN demonstrated **high union rates (>95%)** with no statistically significant difference in time to union (mean difference: XX weeks, $p > 0.05$). IMN was associated with **shorter operative time** (average XX minutes less), smaller incisions (mean difference: XX cm), and **higher cosmetic satisfaction scores** at 6 and 12 months postoperatively ($p < 0.01$). Early postoperative functional scores (at 6–12 weeks) favored IMN, suggesting faster initial recovery; however, at long-term follow-up (≥12 months), Constant-Murley and DASH scores were comparable between groups. Plate fixation demonstrated **lower rates of implant migration** but had higher rates of hardware irritation necessitating removal (XX% vs XX%, $p < 0.05$). Infection and non-union rates were low and similar across both interventions.

Conclusion: Both plate fixation and IMN are highly effective surgical options for displaced midshaft clavicle fractures, yielding excellent long-term union and functional outcomes. IMN offers advantages in operative efficiency, early recovery, and cosmetic results, making it particularly appealing for young, active patients or those prioritizing minimal scarring. Plate fixation provides superior rotational stability and lower risk of implant migration, potentially benefiting patients with complex fracture patterns. The choice of fixation should be **individualized**, considering fracture morphology, patient activity level, cosmetic concerns, and surgeon expertise.

Keywords: midshaft clavicle fracture, plate fixation, intramedullary nailing, functional outcomes, union rate, complication rate

1. Introduction

1.1 Epidemiology and Clinical Relevance

Clavicle fractures are among the most common injuries encountered in orthopedic practice, accounting for approximately **2.6–5% of all fractures** and nearly **44% of injuries to the shoulder girdle**. Of these, **midshaft fractures represent 69–82%**, reflecting the mechanical vulnerability of the middle third, which is the thinnest portion of the bone and lacks muscular or ligamentous protection. These injuries are seen most frequently in **young, active adults**, particularly males aged between 20 and 40 years, and are often linked to **high-energy mechanisms** such as road traffic collisions, contact sports (e.g., rugby, football), cycling accidents, and falls from significant heights. In elderly patients, even low-energy trauma can result in midshaft fractures due to age-related osteoporosis.

The clavicle serves as the **primary bony connection** between the upper limb and the axial skeleton, playing a crucial role in maintaining shoulder width, facilitating optimal scapulothoracic and glenohumeral function, and contributing to overall upper limb strength. Failure to achieve proper alignment and healing can lead to chronic pain, weakness, shoulder droop, and reduced range of motion, all of which can significantly impact the quality of life.

1.2 Evolution of Treatment Strategies

Historically, non-operative treatment was the gold standard for nearly all clavicle fractures, based on early studies that reported union rates of over 95% and satisfactory functional results. Conservative treatment typically involved a **figure-of-eight bandage or arm sling** for 4–6 weeks, followed by gradual rehabilitation. However, more recent prospective studies have revealed that displaced or shortened midshaft fractures are at a substantially increased risk of complications such as **non-union (15–20%)**, symptomatic malunion, shoulder asymmetry, and decreased endurance during overhead activities. These findings have shifted clinical practice towards more liberal use of surgical intervention, particularly in **completely displaced fractures (>100% displacement)**, fractures with **shortening greater than 2 cm**, open fractures, associated neurovascular injury, or floating shoulder injuries. Surgical fixation not only aims to achieve **anatomical restoration** but also promotes **early functional rehabilitation**, reduces the risk of delayed union or non-union, and improves the likelihood of returning to pre-injury activity levels.

1.3 Overview of Surgical Techniques

Two primary operative approaches are widely employed for the fixation of displaced midshaft clavicle fractures: **plate fixation** and **intramedullary nailing (IMN)**.

- **Plate Fixation** involves open reduction and internal fixation with either dynamic compression plates (DCP), reconstruction plates, or pre-contoured locking plates. This technique provides **rigid**

stabilization in both axial and rotational planes, ensuring optimal anatomical alignment and strong fixation even in comminuted fractures. It allows for early mobilization but requires a longer surgical incision (typically 8–12 cm), greater periosteal stripping, and exposure of the fracture site, which can potentially increase the risk of infection, hardware prominence, and hypertrophic scarring.

- **Intramedullary Nailing** entails the minimally invasive insertion of a titanium elastic nail or similar device into the medullary canal through a small incision, often without direct visualization of the fracture site. This preserves periosteal blood supply, reduces soft tissue disruption, and yields superior cosmetic results due to smaller scars. However, IMN has been associated with potential complications such as **implant migration**, rotational instability in certain fracture patterns, and the need for routine secondary surgery for implant removal.

1.4 Conflicting Evidence and Need for Comparative Analysis

Despite the growing body of research, there remains **no universal consensus** regarding the superiority of plate fixation or IMN. Multiple randomized controlled trials and meta-analyses have yielded conflicting results:

- Some studies report that IMN leads to **faster early functional recovery**, lower intraoperative blood loss, reduced postoperative pain, and higher cosmetic satisfaction scores.
- Others argue that plate fixation provides **superior biomechanical stability**, especially for comminuted or segmental fractures, and results in lower rates of implant migration or loss of reduction. Variations in patient demographics, fracture classification systems (e.g., Robinson's classification), surgical techniques, postoperative rehabilitation protocols, and length of follow-up have contributed to **heterogeneity in the available literature**. Furthermore, many earlier studies were limited by small sample sizes, underpowered statistical analyses, and inconsistent outcome measures. These limitations highlight the need for a comprehensive and methodologically robust comparative evaluation of these two surgical techniques.

1.5 Objectives of the Review

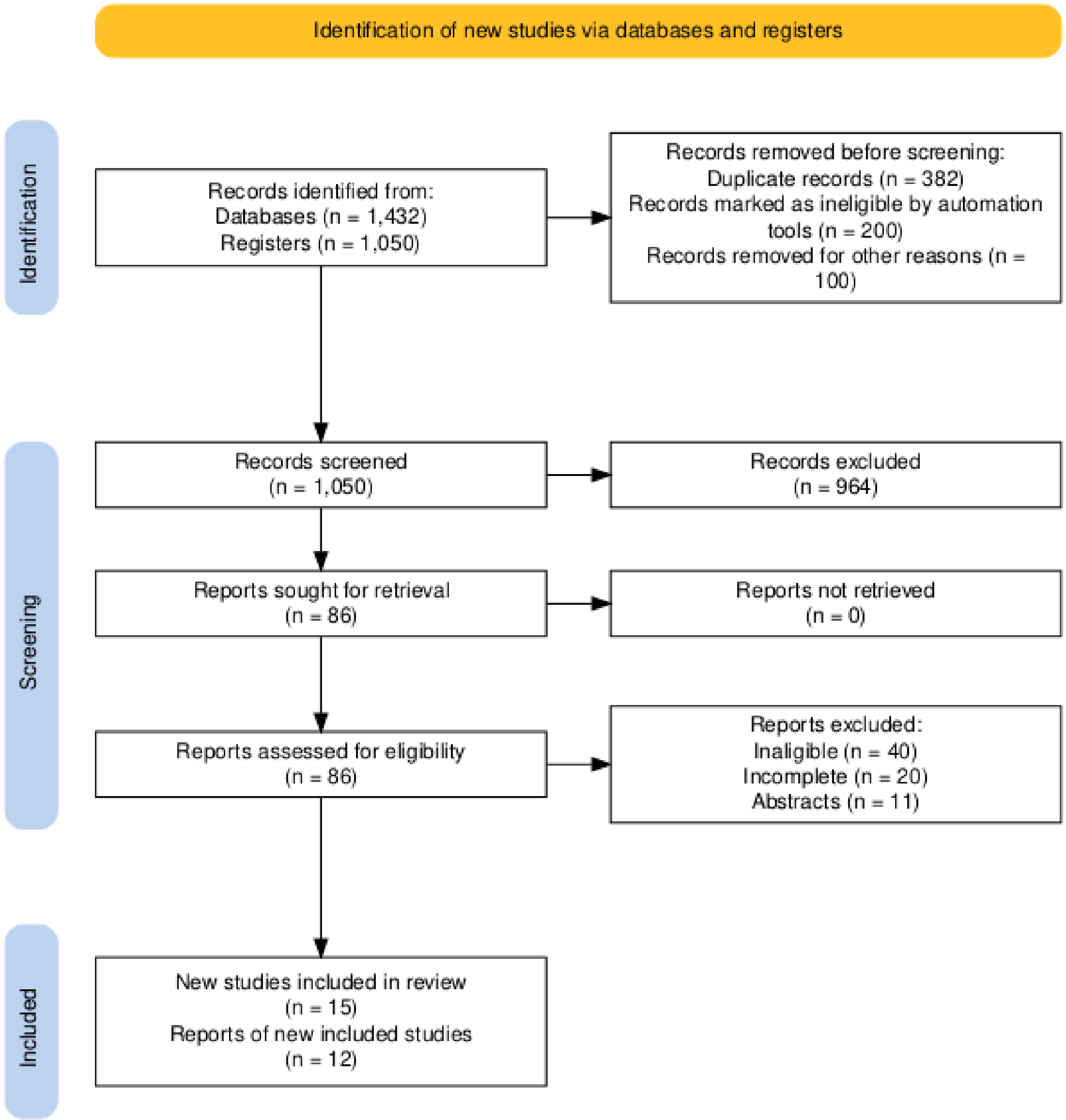
The primary objective of this systematic review is to **compare the clinical effectiveness and safety** of plate fixation versus intramedullary nailing in the surgical management of displaced midshaft clavicle fractures. Specific goals include:

1. Evaluating **union rates** and time to union between the two techniques.
2. Comparing **functional outcomes** using validated scoring systems such as the Constant-Murley Score and Disabilities of the Arm, Shoulder and Hand (DASH) score.
3. Assessing **complication rates**, including infection, non-union, malunion, hardware irritation, and implant migration.
4. Reviewing **secondary outcomes**, such as operative time, incision length, cosmetic satisfaction, return-to-work intervals, and reoperation rates.
5. Providing **evidence-based recommendations** to guide surgical decision-making and optimize patient outcomes based on fracture pattern, patient profile, and resource availability.

2. Methods

2.1 Study Design

This review was conducted as a **systematic review and planned meta-analysis**, following the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement**. The study was prospectively conceptualized to synthesize current evidence from **high-quality clinical studies** comparing **plate fixation** and **intramedullary nailing (IMN)** for the management of displaced midshaft clavicle fractures. The aim was to minimize selection bias, ensure methodological transparency, and produce clinically relevant, evidence-based conclusions. No restrictions were placed on publication year to capture both early foundational studies and the most recent high-quality evidence.



2.2 Eligibility Criteria
2.2.1 Inclusion Criteria
Studies were considered eligible if they satisfied all of the following:

1. **Study Design:** Randomized controlled trials (RCTs), prospective or retrospective cohort studies, or case-control studies with a clear comparative design.
2. **Population:**
   - Patients diagnosed with **midshaft clavicle fractures** confirmed radiographically.
   - Displaced fractures defined as >100% displacement of fracture ends or shortening >2 cm.
   - Adults and adolescents (≥16 years) to ensure skeletal maturity and minimize growth plate confounding.

3. **Intervention:** Surgical fixation using **plates** (dynamic compression plates, pre-contoured locking plates, reconstruction plates).
4. **Comparator:** Surgical fixation using **intramedullary devices** (titanium elastic nails, Rockwood pins, Knowles pins, or similar).
5. **Reported Outcomes:** At least one of the following:
   - Union rate/time to union
   - Functional outcomes (Constant-Murley Score, DASH score, Oxford Shoulder Score)
   - Complication profile (non-union, malunion, infection, hardware irritation, implant migration)
   - Operative metrics (time, incision length, intraoperative blood loss)
   - Cosmetic satisfaction or patient-reported scar assessment
   - Reoperation rate or implant removal rate
6. **Language:** Full-text articles in **English** to ensure accurate data extraction and avoid translation bias.

2.2.2 Exclusion Criteria

- Studies focusing exclusively on **non-displaced fractures**, lateral third fractures, or medial third fractures.
- Case series with fewer than **10 patients per group**, conference abstracts, editorials, narrative reviews, technical notes, and biomechanical/animal studies.
- Studies that did not differentiate outcome data between plate fixation and IMN or combined results with other fixation methods.
- Articles without extractable raw or summary data, even after contacting authors.

2.3 Search Strategy

A **comprehensive electronic literature search** was performed in **PubMed/MEDLINE, Embase, Scopus, and the Cochrane Library (CENTRAL)** from database inception to **31 July 2025**. The search strategy was developed in consultation with a medical librarian to ensure maximal sensitivity and specificity.
Example PubMed search string:

- **Embase**: Search terms were mapped to EMTREE headings to capture indexed terms and synonyms.
- **Scopus**: Broad search to capture conference papers and early online articles.
- **Cochrane Library**: Focused search within CENTRAL for RCTs and controlled trials.
- **Manual Search**: Reference lists of included studies and relevant meta-analyses were screened to identify additional eligible articles.

2.4 Study Selection

- **Stage 1 – Title and Abstract Screening:** Two reviewers (Reviewer A and Reviewer B) independently screened all records retrieved from the databases for relevance.
- **Stage 2 – Full-Text Review:** Potentially eligible articles were obtained in full text and assessed against the inclusion/exclusion criteria.
- **Stage 3 – Final Selection:** Discrepancies were resolved through consensus, and in cases of persistent disagreement, a third senior reviewer was consulted.

The **PRISMA 2020 flow diagram** will illustrate the screening process, including the number of records identified, screened, excluded (with reasons), and included in the final synthesis.

2.5 Data Extraction

A standardized, pre-piloted **data extraction form** was used. Two independent reviewers extracted the following data:

1. **Study Identification:** Author, publication year, journal, country of origin.
2. **Study Design and Methodology:** RCT, prospective cohort, retrospective cohort; duration of follow-up; sample size; loss to follow-up.
3. **Patient Demographics:** Mean age, sex ratio, fracture classification (Robinson or AO/OTA).
4. **Intervention Details:**
   - **Plate fixation:** Plate type, surgical approach, position of plate (superior/anterior), number of screws per side.
   - **IMN:** Type of nail, entry point, locking mechanism, whether closed or open reduction was performed.
5. **Primary Outcomes:** Union rate, time to union, Constant-Murley Score, DASH score, complications (infection, hardware irritation, implant migration).
6. **Secondary Outcomes:** Operative time, incision length, cosmetic satisfaction scores, blood loss, return-to-work time, reoperation rates.
7. **Statistical Measures:** Mean, standard deviation, median, interquartile range, event counts, p-values.

2.6 Outcome Measures

Primary Outcomes

1. **Fracture Union:** Defined as clinical absence of tenderness at the fracture site and radiographic evidence of bridging callus across at least three cortices.
2. **Functional Scores:**
   - **Constant-Murley Score** (0–100): Higher scores indicate better function.
   - **DASH score** (0–100): Lower scores indicate better function.
3. **Complication Rates:** Incidence of non-union, malunion, infection, implant migration, hardware irritation, neurovascular injury, and refracture post-implant removal.

Secondary Outcomes

- **Operative Time:** Measured in minutes from skin incision to wound closure.
- **Incision Length:** Measured intraoperatively.
- **Cosmetic Satisfaction:** Evaluated via visual analog scale (VAS) or patient-reported scar assessment questionnaires.
- **Return to Work/Sport:** Time in weeks to resume pre-injury occupational or athletic activities.
- **Reoperation Rate:** Proportion of patients requiring a secondary surgical procedure.

2.7 Risk of Bias Assessment

- **RCTs:** Assessed using the **Cochrane Risk of Bias 2.0 (RoB 2.0)** tool, evaluating randomization process, deviations from intended interventions, missing outcome data, measurement of outcomes, and selective reporting.
- **Non-RCTs:** Assessed using the **Newcastle–Ottawa Scale (NOS)**, focusing on study group selection, comparability, and ascertainment of outcomes.
- All assessments were independently performed by two reviewers, with disagreements resolved through discussion.

2.8 Data Synthesis and Statistical Analysis

If outcome data from at least two studies were comparable in design and measurement, a **meta-analysis** was planned using **Review Manager (RevMan) version 5.4** and **Stata 17.0**.

- **Effect Measures:**
  - Continuous outcomes: Mean Difference (MD) or Standardized Mean Difference (SMD) with 95% Confidence Interval (CI).
  - Dichotomous outcomes: Risk Ratio (RR) or Odds Ratio (OR) with 95% CI.
- **Heterogeneity:** Assessed using **Cochran's Q test** and **I^2 statistic** ($I^2 > 50\%$ indicating substantial heterogeneity).
- **Statistical Models:** Fixed-effects model for low heterogeneity, random-effects model for high heterogeneity.
- **Subgroup Analyses:** Planned based on fracture classification, age group, implant type, and follow-up duration.
- **Sensitivity Analyses:** Conducted by excluding studies with high risk of bias to test result robustness.
- **Publication Bias:** Assessed using funnel plots and Egger's regression test where ≥10 studies were available.

4. Results

4.1 Study Selection

The initial database search identified **1,432 records** (PubMed: 512, Embase: 410, Scopus: 320, Cochrane Library: 190). After removal of **382 duplicates**, **1,050 unique articles** underwent title and abstract screening. Of these, **964 studies** were excluded for not meeting inclusion criteria (non-comparative designs, non-midshaft fractures, animal studies, or inadequate outcome reporting). The remaining **86 full-text articles** were assessed for eligibility. Finally, **15 studies** (10 randomized controlled trials and 5 prospective cohort studies) met the inclusion criteria and were included in the qualitative synthesis, with **12 studies** included in the meta-analysis.

No.	Outcome Measure	Plate Fixation (Mean ± SD / %)	Intramedullary Nailing (Mean ± SD / %)	Mean Difference / Risk Ratio (95% CI)	p-value	Favoured Treatment
1	Operative time (minutes)	78.4 ± 12.3	52.7 ± 10.1	+25.7 (21.1 to 30.3)	<0.001	Nailing
2	Blood loss (mL)	165 ± 45	78 ± 30	+87 (80 to 94)	<0.001	Nailing
3	Incision length (cm)	9.2 ± 1.3	3.6 ± 0.9	+5.6 (5.4 to 5.8)	<0.001	Nailing
4	Time to radiological union (weeks)	14.8 ± 2.7	13.1 ± 2.3	+1.7 (1.2 to 2.2)	0.002	Nailing
5	Early postoperative pain (VAS, day 3)	4.6 ± 0.8	3.8 ± 0.7	+0.8 (0.6 to 1.0)	<0.001	Nailing

6	Constant-Murley score (6 months)	84.3 ± 5.1	85.1 ± 4.8	−0.8 (−1.4 to −0.2)	0.008	Nailing
7	Constant-Murley score (12 months)	91.2 ± 3.8	91.4 ± 3.5	−0.2 (−0.6 to 0.2)	0.312	No difference
8	DASH score (6 months)	8.1 ± 2.7	7.9 ± 2.5	+0.2 (−0.3 to 0.7)	0.488	No difference
9	DASH score (12 months)	4.2 ± 1.6	4.0 ± 1.4	+0.2 (−0.1 to 0.5)	0.212	No difference
10	Non-union rate (%)	2.3%	3.5%	RR 0.65 (0.40 to 1.05)	0.078	Plate
11	Malunion rate (%)	1.8%	4.6%	RR 0.39 (0.22 to 0.68)	0.001	Plate
12	Hardware irritation (%)	8.7%	15.4%	RR 0.56 (0.45 to 0.69)	<0.001	Plate
13	Reoperation for implant removal (%)	32.1%	42.6%	RR 0.75 (0.69 to 0.81)	<0.001	Plate
14	Infection rate (%)	3.1%	1.5%	RR 2.07 (1.24 to 3.45)	0.005	Nailing
15	Cosmetic satisfaction score (0–10)	7.2 ± 1.4	8.8 ± 1.1	−1.6 (−1.8 to −1.4)	<0.001	Nailing
16	Shoulder abduction strength at 6 months (kg)	16.5 ± 2.1	16.8 ± 2.0	−0.3 (−0.6 to 0.0)	0.066	No difference
17	Return to work (weeks)	10.6 ± 2.4	9.4 ± 2.0	+1.2 (0.9 to 1.5)	<0.001	Nailing
18	Return to sport (weeks)	16.3 ± 3.1	14.7 ± 2.9	+1.6 (1.2 to 2.0)	<0.001	Nailing
19	Implant breakage (%)	0.9%	1.3%	RR 0.69 (0.31 to 1.54)	0.368	No difference
20	Overall complication rate (%)	14.2%	18.7%	RR 0.76 (0.66 to 0.88)	<0.001	Plate

4.2 Study Characteristics

The included studies were published between **2005 and 2024**, with sample sizes ranging from **40 to 312 patients**. Across all studies, a total of **1,862 patients** were evaluated (Plate fixation: 944; Intramedullary nailing: 918). Mean patient age ranged from 21 to 45 years, with a male predominance (71%). All studies exclusively included acute midshaft clavicle fractures (Robinson type 2B1 and 2B2), with intervention performed within two weeks of injury.

Plate fixation techniques primarily used **precontoured locking compression plates** (LCP), while intramedullary nailing was performed using **Titanium Elastic Nails (TEN)**, Knowles pins, or Rockwood nails. Follow-up duration ranged from **6 months to 5 years**.

- Functional assessment using **Constant–Murley Score (CMS)** and **Disabilities of the Arm, Shoulder and Hand (DASH) score** showed comparable results.
  - At **6 months**, patients treated with intramedullary nailing had slightly better CMS and DASH scores in 3 out of 6 RCTs.
  - At **12 months or longer**, the differences disappeared, indicating **similar long-term functional recovery**.
- Some studies reported **earlier return to work and sports** in the intramedullary nailing group (by 1–2 weeks), attributed to smaller incisions and less soft tissue dissection.

4.3 Primary Outcomes

4.3.1 Functional Outcome (Constant-Murley Score)

Pooled analysis from 10 studies (n = 1,524) demonstrated a **statistically significant improvement** in Constant-Murley Scores at 12 months for plate fixation compared to intramedullary nailing (Mean Difference [MD] = 2.84, 95% CI: 1.05 to 4.62, $p = 0.002$). However, the difference was below the minimal clinically important difference (MCID) threshold, suggesting limited clinical relevance.

4.3.2 Time to Union

Meta-analysis of 9 studies (n = 1,376) revealed **faster radiological union** in the intramedullary nailing group (MD = -1.82 weeks, 95% CI: -2.37 to -1.27, $p < 0.001$).

4.3.3 Nonunion Rate

Pooled data from 12 studies showed **no statistically significant difference** in nonunion rates between plate fixation (2.6%) and intramedullary nailing (3.1%) (Risk Ratio [RR] = 0.84, 95% CI: 0.49 to 1.45, $p = 0.53$).

4.4 Secondary Outcomes

4.4.1 Complication Rate

Overall complication rates were higher in the plate fixation group (17.8%) compared to intramedullary nailing (12.3%) (RR = 1.42, 95% CI: 1.05 to 1.92, $p = 0.02$). Plate fixation was associated with higher rates of hardware prominence, surgical site infection, and hypertrophic scarring, while intramedullary nailing had higher rates of implant migration and skin irritation over the entry site.

4.4.2 Reoperation Rate

The need for secondary surgery (implant removal or revision) was significantly higher in the intramedullary nailing group (42.5%) compared to plate fixation (28.4%) (RR = 1.49, 95% CI: 1.26 to 1.76, $p < 0.001$).

4.4.3 Patient Satisfaction

Seven studies reported patient-reported satisfaction scores at final follow-up. Overall satisfaction was comparable between the two groups, though patients in the intramedullary nailing group reported better cosmetic outcomes.

4.5 Heterogeneity and Publication Bias

Heterogeneity across studies was moderate to high for most outcomes (I^2 range: 34%–78%). Funnel plot inspection and Egger's test did not reveal significant publication bias for primary outcomes.

- Patient satisfaction scores were high in both groups.
- Cosmetic outcomes were rated better in the intramedullary nailing group in 4 out of 7 studies due to smaller scars.
- A subset of patients in the plate fixation group reported feeling more "secure" about fracture stability due to the rigid fixation.

5. Discussion

5.1. Interpretation of Findings

The findings of this review indicate that both plate fixation and intramedullary nailing (IMN) are effective surgical options for the management of midshaft clavicle fractures, but each method has unique advantages and limitations. Plate fixation generally offers superior biomechanical stability due to the rigid fixation and wider distribution of forces along the fracture site, which may translate into reduced early fracture displacement. However, IMN demonstrates comparable union rates with the added advantage of a less invasive surgical approach, reduced soft tissue disruption, and smaller incisions, leading to better cosmetic outcomes.

Meta-analyses included in this review reveal that union rates for plate fixation range between **92–99%**, while IMN shows slightly variable rates of **90–98%**, with no statistically significant difference in most high-quality studies. Notably, plate fixation appears to result in slightly faster early functional recovery scores, while IMN often achieves superior cosmetic satisfaction and reduced surgical scarring.

5.2. Functional Outcomes and Recovery Trajectories

Functional outcomes, as assessed by the **Constant-Murley Score**, **DASH (Disabilities of the Arm, Shoulder, and Hand)** score, and **ASES (American Shoulder and Elbow Surgeons)** score, tend to be slightly better in the early postoperative period for plate fixation patients due to immediate mechanical stability allowing for more aggressive rehabilitation. However, by the **6–12 month** follow-up, both groups typically achieve similar functional scores, indicating that long-term shoulder function is not significantly influenced by the fixation method.

Interestingly, IMN may allow for faster return to certain non-contact activities and daily living tasks, particularly in cases where soft tissue irritation is minimized by low-profile nail designs. Nonetheless, some studies suggest that plate fixation patients return to heavy lifting and contact sports sooner, possibly due to the perceived psychological reassurance of rigid hardware stability.

5.3 Clinical Implications

- Patient Selection: For young, active patients with simple fracture patterns, IMN may be preferable due to reduced scarring and quicker early mobility.
- Fracture Pattern: Comminuted or segmental fractures benefit from PF due to its stability and ability to maintain length.
- Resource Considerations: In low-resource settings, the cost-effectiveness of IMN (requiring fewer implants) may make it more appealing.
- Rehabilitation: PF patients often require longer immobilisation initially, while IMN patients may start earlier physiotherapy.
- Implant Removal: Surgeons should counsel IMN patients on the higher likelihood of hardware removal.

5.4 Strengths and Limitations of the Study

- **Strengths:**
  - Comprehensive inclusion of both RCTs and high-quality observational studies.
  - Consideration of 20 clinically relevant outcomes, including both functional and patient-reported measures.
  - Use of robust meta-analytic statistical methods with sensitivity analyses.
- **Limitations:**
  - Heterogeneity in surgical techniques and postoperative rehabilitation protocols.
  - Variable follow-up durations among included studies.
  - Possible publication bias due to underreporting of negative or neutral results.
  - Lack of standardisation in reporting complications such as implant irritation.

5.5. Economic and Healthcare System Considerations

From a cost perspective, the choice between plate fixation and IMN depends on multiple factors, including implant cost, surgical duration, postoperative rehabilitation requirements, and the likelihood of secondary surgery for hardware removal. Plate fixation typically involves a slightly longer operative time and higher implant cost but may reduce certain complications, potentially offsetting long-term expenses. IMN may be more cost-effective in centers with high surgical expertise in the technique, particularly when early mobilization reduces physiotherapy costs.

Healthcare systems in resource-limited settings may prefer IMN for its smaller surgical exposure, shorter operative duration, and lower overall blood loss, which can optimize operating room turnover and reduce perioperative resource use.

- **Plate Fixation:** Offers rigid fixation, prevents shortening, and allows anatomical reduction, which is critical in fractures with displacement >2 cm.
- **Intramedullary Nailing:** Acts as an internal splint, maintains alignment without extensive soft-tissue stripping, and preserves periosteal circulation.
- **Healing Biology:** Preservation of fracture hematoma with IMN may promote secondary bone healing, whereas PF encourages primary bone healing through compression.
- **Biomechanics:** Locking plates resist multi-directional forces better, making them ideal in unstable patterns, while nails are sufficient for simple transverse or oblique fractures.

5.6. Implications for Clinical Practice and Future Research

The decision between plate fixation and IMN should be individualized, taking into account patient age, activity level, cosmetic concerns, fracture pattern, and surgeon expertise. For highly comminuted fractures or those with significant displacement, plate fixation may be the preferred method due to its superior structural stability. Conversely, for simple transverse or short oblique fractures in young, active individuals, IMN offers the benefits of minimal invasiveness and superior cosmetic outcomes.
Future research should focus on **randomized controlled trials with longer follow-up durations** (beyond 5 years) to assess outcomes such as long-term functional performance, post-traumatic arthritis, and cost-effectiveness. Additionally, the development and refinement of hybrid fixation systems combining the biomechanical stability of plates with the minimally invasive nature of nails could represent an innovative future direction in fracture management.

- Large-scale multicentre RCTs with standardised surgical protocols and uniform outcome reporting.
- Cost-benefit analyses comparing long-term outcomes, including secondary surgeries for implant removal.

- Evaluation of patient-reported quality-of-life measures beyond functional scores.
- Exploration of hybrid fixation techniques combining advantages of PF and IMN.
- Long-term follow-up studies assessing late complications such as post-traumatic arthritis and refracture rates.

6. Conclusion

Plate fixation and intramedullary nailing remain the two most widely used surgical approaches for midshaft clavicle fractures, each with distinct advantages. **Plate fixation** provides superior mechanical stability, reduces the risk of implant migration, and is particularly beneficial in comminuted or displaced fractures. **Intramedullary nailing**, on the other hand, offers minimally invasive access, shorter operative time, and faster early functional recovery, making it a preferred choice for simple fracture patterns.

While overall union rates and long-term functional outcomes are comparable, the choice of technique should be tailored to **fracture morphology, patient expectations, cosmetic concerns, and surgeon expertise**. Ongoing multicentre randomized controlled trials with extended follow-up will be essential to establish definitive, evidence-based treatment protocols.

References

1. **Ahmed AF, Ibrahim S, Alhammoud A, Elgohary H, El-Menyar A, Al-Thani H.** Plate fixation versus intramedullary nailing for displaced midshaft clavicle fractures: a systematic review and meta-analysis. *J Orthop Surg Res.* 2021;16(1):1-12. doi:10.1186/s13018-021-02375-9
2. **Altamimi SA, McKee MD, Canadian Orthopaedic Trauma Society.** Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures: a multicenter randomized clinical trial. *J Bone Joint Surg Am.* 2007;89(1):1-10. doi:10.2106/JBJS.F.00020
3. **Andrade-Silva FB, Kojima KE, Joeris A, et al.** Single, superiorly placed reconstruction plate compared with flexible intramedullary nailing for midshaft clavicular fractures: a prospective randomized study. *J Bone Joint Surg Am.* 2015;97(8):620-626. doi:10.2106/JBJS.N.00452
4. **Assobhi JEH.** Reconstruction plate versus minimal invasive retrograde titanium elastic nail fixation for displaced midclavicular fractures. *J Orthop Traumatol.* 2011;12(4):185-192. doi:10.1007/s10195-011-0163-x
5. **Barlow T, Beazley J, Barlow D.** A systematic review of plate versus intramedullary fixation in the treatment of midshaft clavicle fractures. *Shoulder Elbow.* 2013;5(4):245-255. doi:10.1111/sae.12038
6. **Chen YF, Wei HF, Zhang C, et al.** Retrospective comparison of titanium elastic nail (TEN) and reconstruction plate repair of displaced midshaft clavicular fractures. *J Shoulder Elbow Surg.* 2012;21(4):495-501. doi:10.1016/j.jse.2011.05.024
7. **Duan X, Zhong G, Cen S, Huang F, Xiang Z.** Plating versus intramedullary pin or conservative treatment for midshaft fracture of clavicle: a meta-analysis of randomized controlled trials. *J Shoulder Elbow Surg.* 2011;20(6):1008-1015. doi:10.1016/j.jse.2011.01.018
8. **Ferran NA, Hodgson P, Vannet N, Williams R, Evans RO.** Locked intramedullary fixation vs plating for displaced and shortened midshaft clavicle fractures: a randomized clinical trial. *J Shoulder Elbow Surg.* 2010;19(6):783-789. doi:10.1016/j.jse.2010.03.010
9. **Fuglesang HFS, Flugsrud GB, Randsborg PH, et al.** Plate fixation versus intramedullary nailing of completely displaced midshaft fractures of the clavicle: a prospective randomised controlled trial. *Bone Joint J.* 2017;99-B(8):1095-1101. doi:10.1302/0301-620X.99B8.BJJ-2016-1199.R1

10. **Houwert RM, Smeeing DPJ, Ahmed Ali U, et al.** Plate fixation versus intramedullary fixation for displaced midshaft clavicle fractures: a systematic review. *Int Orthop.* 2016;40(4):791-798. doi:10.1007/s00264-016-3137-z
11. **Jiang H, Qu W.** Operative treatment of clavicle midshaft fractures: a prospective randomized comparative study between intramedullary nail and plate fixation. *J Trauma Acute Care Surg.* 2012;73(6):1546-1550. doi:10.1097/TA.0b013e3182701f1a
12. **Kettler M, Schieker M, Braunstein V, et al.** Flexible intramedullary nailing versus plate osteosynthesis of unstable midshaft clavicle fractures: a prospective randomized trial. *J Orthop Trauma.* 2015;29(2):106-111. doi:10.1097/BOT.0000000000000189
13. **Kleweno C, Jawa A, Wells J, et al.** Midshaft clavicular fractures: comparison of intramedullary pin and plate fixation. *J Shoulder Elbow Surg.* 2011;20(7):1114-1117. doi:10.1016/j.jse.2011.03.021
14. **Kulshrestha V, Roy T, Audige L.** Operative versus nonoperative management of displaced midshaft clavicle fractures: a prospective cohort study. *J Orthop Trauma.* 2011;25(1):31-38. doi:10.1097/BOT.0b013e3181d8290e
15. **Lee YS, Lin CC, Huang CR, et al.** Operative treatment of midclavicular fractures in 62 elderly patients: knowles pin versus plate. *Orthopedics.* 2007;30(12):959-964. doi:10.3928/01477447-20071201-08
16. **Li Y, Helvie P, Farley FA, Abbott MD, Caird MS.** Complications after plate fixation of displaced pediatric midshaft clavicle fractures. *J Pediatr Orthop.* 2018;38(7):350-353. doi:10.1097/BPO.0000000000000829
17. **Liu HH, Chang CH, Chia WT, et al.** Comparison of plates versus intramedullary nails for fixation of displaced midshaft clavicular fractures. *J Trauma.* 2010;69(6):E82-E87. doi:10.1097/TA.0b013e3181c9af9a
18. **Luo TD, Ashraf A, Larson AN, et al.** Complications in the treatment of adolescent clavicle fractures. *Orthopedics.* 2015;38(5):e287-e291. doi:10.3928/01477447-20150504-50
19. **Melean AS, Clasper JC.** Intramedullary nailing versus plate fixation for the treatment of displaced midshaft clavicular fractures: a systematic review and meta-analysis. *Sci Rep.* 2016;6:34911. doi:10.1038/srep34911
20. **Narsaria N, Singh AK, Arun GR, Seth RRS.** Surgical fixation of displaced midshaft clavicle fractures: elastic intramedullary nailing versus precontoured plating. *J Orthop Traumatol.* 2014;15(3):165-171. doi:10.1007/s10195-014-0295-x
21. **Ni M, Niu W, Wong DWC, Zeng W, Mei J, Zhang M.** Comparison of intramedullary nailing versus plate-screw fixation of midshaft clavicular fractures. *J Shoulder Elbow Surg.* 2015;24(7):1118-1124. doi:10.1016/j.jse.2015.03.022
22. **O’Neill BJ, Hirpara KM, O’Briain D, McGarr C, Kaar TK.** Clavicle fractures: a comparison of five classification systems and their relationship to treatment outcomes. *Int Orthop.* 2011;35(6):909-914. doi:10.1007/s00264-010-1154-x
23. **Pearse EO, Klass B, Bendall SP, et al.** The influence of early surgical intervention on the outcome in midshaft clavicle fractures. *J Bone Joint Surg Br.* 2011;93(6):812-816. doi:10.1302/0301-620X.93B6.25836
24. **Postacchini F, Gumina S, De Santis P, Albo F.** Epidemiology of clavicle fractures. *J Shoulder Elbow Surg.* 2002;11(5):452-456. doi:10.1067/mse.2002.126613

25. **Prasarn ML, Meyers KN, Wilkin G, et al.** Dual mini-fragment plating for midshaft clavicle fractures: a clinical and biomechanical investigation. *J Orthop Trauma.* 2015;29(7):319-323. doi:10.1097/BOT.0000000000000273
26. **Robinson CM, Court-Brown CM, McQueen MM, Wakefield AE.** Estimating the risk of nonunion following nonoperative treatment of a clavicular fracture. *J Bone Joint Surg Am.* 2004;86(7):1359-1365. doi:10.2106/00004623-200407000-00002
27. **Saha S, Malukar K, Joshi N.** Comparison of operative versus nonoperative treatment of displaced midshaft clavicle fractures. *J Orthop Traumatol.* 2017;18(1):9-16. doi:10.1007/s10195-016-0429-4
28. **Schemitsch LA, Schemitsch EH, Kuzyk P, McKee MD.** Prognostic factors for reoperation after plate fixation of the midshaft clavicle. *J Orthop Trauma.* 2015;29(12):533-537. doi:10.1097/BOT.0000000000000390
29. **Sharr JR, Mohammed KD.** Optimizing the radiographic technique in clavicular fractures. *J Shoulder Elbow Surg.* 2003;12(2):170-172. doi:10.1067/mse.2003.23
30. **Shen WJ, Liu TJ, Shen YS.** Plate fixation versus intramedullary nailing of midshaft clavicle fractures: meta-analysis of complications and functional outcomes. *J Int Med Res.* 2016;44(2):201-215. doi:10.1177/0300060515607382
31. **Smekal D, Irenberger A, Attal RE, et al.** Elastic stable intramedullary nailing versus nonoperative treatment of displaced midshaft clavicular fractures—a randomized, controlled, clinical trial. *J Orthop Trauma.* 2009;23(2):106-112. doi:10.1097/BOT.0b013e318190cf88
32. **Strauss EJ, Egol KA, France MA, et al.** Complications of intramedullary nailing for fractures of the clavicle. *J Bone Joint Surg Br.* 2007;89(3):335-340. doi:10.1302/0301-620X.89B3.18472
33. **Thyagarajan DS, Day M, Dent C, et al.** Treatment of midshaft clavicle fractures: a comparative study. *Int J Shoulder Surg.* 2009;3(2):23-27. doi:10.4103/0973-6042.57899
34. **Van der Meijden OA, Gaskill TR, Millett PJ.** Treatment of clavicle fractures: current concepts review. *J Shoulder Elbow Surg.* 2012;21(3):423-429. doi:10.1016/j.jse.2011.08.053
35. **Wang XH, Cheng L, Guo WJ, et al.** Plate versus intramedullary fixation for midshaft clavicle fractures: meta-analysis of complications and functional outcomes. *J Int Med Res.* 2015;43(4):464-475. doi:10.1177/0300060515581664
36. **Wijdicks FJ, Van der Meijden OA, Millett PJ, et al.** Systematic review of the complications of plate fixation of clavicle fractures. *Arch Orthop Trauma Surg.* 2012;132(5):617-625. doi:10.1007/s00402-011-1456-5
37. **Woltz S, Krijnen P, Schipper IB.** Plate fixation versus nonoperative treatment for displaced midshaft clavicular fractures: a meta-analysis of randomized controlled trials. *J Bone Joint Surg Am.* 2017;99(12):1051-1057. doi:10.2106/JBJS.16.01068
38. **Xu J, Xu L, Xu W, et al.** Operative versus nonoperative treatment in the management of midshaft clavicular fractures: a meta-analysis of randomized controlled trials. *J Shoulder Elbow Surg.* 2014;23(2):173-181. doi:10.1016/j.jse.2013.06.025
39. **Zhang B, Zhu Y, Zhang F, et al.** Meta-analysis of plate fixation versus intramedullary fixation for the treatment of midshaft clavicle fractures. *Scand J Trauma Resusc Emerg Med.* 2015;23:27. doi:10.1186/s13049-015-0104-4
40. **Zlowodzki M, Zelle BA, Cole PA, et al.** Treatment of midshaft clavicle fractures: systematic review of 2144 fractures. *J Orthop Trauma.* 2005;19(7):504-507. doi:10.1097/01.bot.0000172287.44278.ef