Research Article

Clinical Decision-Making and Surgical Perspectives on Intramedullary Nailing Versus Plate Osteosynthesis in Midshaft

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Abstract

Background: Midshaft (diaphyseal) fractures of the humerus account for approximately 3% of all adult fractures and roughly 14% of all humeral fractures. While most unite successfully with nonoperative functional bracing, a substantial proportion — open injuries, segmental or comminuted patterns, polytraumatised patients, pathological fractures, and fractures with associated vascular injury — require surgical stabilisation. Intramedullary nailing (IMN) and plate osteosynthesis (open reduction and internal fixation, ORIF) remain the two dominant operative strategies, yet which technique best serves a given patient continues to be debated. Aim: To synthesise the comparative clinical evidence on IMN versus plate fixation for midshaft humeral fractures and to translate that evidence into a practical framework for surgical decision-making. Methods: A focused narrative review of randomised controlled trials, prospective and retrospective comparative studies, systematic reviews and meta-analyses indexed in PubMed/MEDLINE, the Cochrane Library and Google Scholar was conducted. Data on union and nonunion, infection, iatrogenic radial nerve palsy, reoperation, operative time, intraoperative blood loss, and shoulder/elbow functional outcome were extracted. Where included meta-analyses reported pooled risk ratios (RR), odds ratios (OR) or weighted mean differences with 95% confidence intervals, these estimates were tabulated and synthesised narratively; significance was accepted at the threshold (generally $p<0.05$) reported by the source study. Results: Across the pooled comparative literature, there is no consistent difference between IMN and plate fixation in nonunion, delayed union, or infection rate. Pooled randomised data show a significantly lower reoperation rate (RR 0.26, 95% CI 0.07–0.9, p=0.03) and a markedly lower rate of shoulder-related complications (RR 0.10, 95% CI 0.03–0.4, p=0.002) with plate fixation compared with IMN. A network meta-analysis of 16 randomised trials (832 patients) comparing open plating, IMN and minimally invasive plate osteosynthesis (MIPO) confirms that shoulder impingement is more frequent after IMN than after open plating or MIPO, while iatrogenic radial nerve injury is substantially more frequent after open plating than after MIPO (OR 11.09, 95% CI 1.80–124.20). Conclusion: Neither technique is categorically superior. Fracture morphology and location within the diaphysis, radial nerve status at presentation, bone quality, polytrauma status, functional and occupational demand, and surgeon experience should jointly guide the choice of fixation. MIPO is emerging as a technique that may reconcile the lower soft-tissue morbidity of IMN with the lower shoulder-related morbidity of open plating, and merits further high-quality comparative study.

Keywords: Rational drug use, antimicrobial therapy, antimicrobial resistance, antimicrobial stewardship, microbiological investigation, Gyssens category.

1. Introduction

Fractures of the humeral diaphysis are common injuries with a bimodal age distribution: a high-energy pattern in young adults following road traffic collisions or falls from height, and a low-energy pattern in older adults, often osteoporotic women, following a simple fall. A large Swedish population-based study of 401 consecutive humeral shaft fractures reported an overall incidence of approximately 14.5 per 100,000 person-years, confirming the condition's substantial public health burden and its characteristic bimodal age and sex distribution [1].

The radial nerve's intimate relationship with the humeral diaphysis as it winds through the spiral groove on the posterior aspect of the bone, from proximo-medial to disto-lateral, makes it particularly vulnerable both to the injury itself — most notably in spiral fractures of the distal third (the classic Holstein–Lewis pattern) — and to iatrogenic injury during surgical exposure. This anatomical relationship is central to much of the comparative debate between intramedullary and plate fixation discussed in this review.

The majority of closed, isolated humeral shaft fractures unite successfully with nonoperative functional bracing, historically popularised by Sarmiento and colleagues, with reported union rates exceeding 90% in well-selected patients. A more recent randomised trial directly comparing nonoperative functional bracing with plate fixation confirmed that operative treatment achieves faster, more reliable union and better early function, at the cost of surgical morbidity, reopening the question of which patients benefit most from surgery, and which operative technique best serves them [11].

Accepted indications for primary operative fixation include open fractures, segmental or markedly comminuted fracture patterns, associated vascular injury, bilateral humeral fractures, polytrauma and "floating elbow" injuries, pathological fractures, fractures in patients for whom bracing is impractical (severe obesity, non-compliance, inability to maintain an upright posture), and radial nerve palsy that develops or worsens during a trial of closed treatment, which typically mandates exploration. Once the decision for surgery has been made, the two dominant options are intramedullary nailing (antegrade or retrograde, locked) and open reduction with plate osteosynthesis, most commonly with a 4.5 mm narrow dynamic compression plate or locking compression plate; minimally invasive plate osteosynthesis (MIPO) has more recently emerged as a third strategy that attempts to combine the biological advantages of closed, indirect reduction with the biomechanical stability of a plate construct.

The relative merits of IMN and plate ORIF have been investigated in randomised trials for over two decades, beginning with the prospective randomised comparison of dynamic compression plating and intramedullary nailing reported by McCormack and colleagues [2], and continuing through a series of subsequent randomised and comparative studies [3–6] and systematic syntheses of this evidence [7,8]. Despite this considerable body of work, orthopaedic surgeons continue to select fixation method substantially on the basis of training and institutional habit rather than an explicit, evidence-based decision framework. The aim of this review is to synthesise the comparative clinical evidence on IMN versus plate osteosynthesis for midshaft humeral fractures, and to translate that evidence into a structured, clinically usable framework for surgical decision-making.

2. Materials and Methods

2.1 Study Design

This is a focused narrative and comparative review of the published literature on operative fixation of midshaft humeral fractures, undertaken to synthesise existing comparative evidence rather than to generate new primary patient data. The review follows the general reporting logic of a systematic narrative synthesis: an explicit search strategy, defined inclusion and exclusion criteria, structured data extraction, and transparent reporting of the quantitative effect estimates (risk ratios, odds ratios and mean differences with 95% confidence intervals) exactly as presented in the source publications.

2.2 Search Strategy and Sources

PubMed/MEDLINE, the Cochrane Database of Systematic Reviews, and Google Scholar were searched for English-language publications using combinations of the terms "humeral shaft fracture," "humeral diaphyseal fracture," "intramedullary nailing," "plate osteosynthesis," "open reduction internal fixation," "minimally invasive plate osteosynthesis," "radial nerve palsy," "nonunion," and "randomised controlled trial." Reference lists of identified randomised trials, systematic reviews and meta-analyses were hand-searched for additional eligible studies.

2.3 Inclusion and Exclusion Criteria

Randomised controlled trials, prospective and retrospective comparative cohort studies, and systematic reviews or meta-analyses that directly compared intramedullary nailing with plate osteosynthesis (open or minimally invasive) for closed or open diaphyseal (midshaft) humeral fractures in skeletally mature adults were eligible for inclusion. Studies restricted to pathological fractures, periprosthetic fractures, paediatric patients, isolated case reports, or fixation of the proximal or distal humerus without diaphyseal involvement were excluded, as were studies that did not report a direct comparison between the two fixation strategies.

2.4 Data Extraction and Statistical Synthesis

For each included comparative study, the following outcome domains were extracted where reported: union rate and time to radiological union, nonunion and delayed union, superficial and deep infection, iatrogenic (postoperative) radial

nerve palsy, unplanned reoperation, operative time, intraoperative blood loss, and shoulder and elbow functional outcome, most commonly assessed with the Constant–Murley shoulder score [9,10], the Mayo Elbow Performance Score, or the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire.

Where a meta-analysis reported a pooled effect estimate — a risk ratio, odds ratio or weighted mean difference, with its accompanying 95% confidence interval and p-value — that estimate was reproduced and tabulated directly from the source publication (Table 2) rather than recalculated, since re-deriving pooled estimates would require access to the individual-patient data of every primary trial, which lies outside the scope of a narrative synthesis. Statistical significance was accepted at the threshold used by each source study (in all cases, $p<0.05$, or a 95% confidence interval excluding the null value for an OR/RR of 1.0). No new inferential statistical testing was performed on unpublished or individual-patient data for this review, and no claim is made to original primary-data analysis; the contribution of this review lies in the synthesis, tabulation and clinical interpretation of effect estimates already established in the peer-reviewed literature.

3. Results

3.1 Overview of the Comparative Evidence Base

Table 1 summarises the principal comparative studies and evidence syntheses addressing IMN versus plate osteosynthesis for midshaft humeral fractures identified for this review, spanning the original 2000 randomised trial by McCormack et al. [2] through to the 2017 network meta-analysis by Zhao et al. [7], which remains among the most comprehensive syntheses of this literature, pooling 16 randomised trials and 832 patients across three fixation strategies (open plating, IMN, and MIPO).

Table 1. Principal comparative studies and evidence syntheses on intramedullary nailing (IMN) versus plate osteosynthesis for midshaft humeral fractures.

Study (Ref.)	Year	Design	Comparison	Key Comparative Finding
McCormack et al. [2]	2000	Prospective RCT	DCP vs. locked IMN	First major randomised comparison; established the template for subsequent comparative trials of fixation method in the humeral diaphysis.
Bhandari et al. [3]	2006	Meta-analysis (3 RCTs, n=155)	Compression plate vs. IMN	Plate fixation associated with significantly lower reoperation (RR 0.26, p=0.03) and shoulder problems (RR 0.10, p=0.002).
Changulani et al. [4]	2007	RCT	Humeral IMN vs. DCP	Randomised comparison of union, complications and functional recovery between nailing and plating.
Putti et al. [5]	2009	Comparative study	Locked IMN vs. DCP	Comparative assessment of locked intramedullary nailing against dynamic compression plating.
Denies et al. [6]	2010	Retrospective comparative cohort	Plating vs. IMN	Institutional comparison of operative treatment outcomes between plating and intramedullary nailing.
Kurup et al. (Cochrane) [8]	2011	Systematic review	DCP vs. locked IMN	Cochrane review concluding that evidence was insufficient to establish superiority of either technique on the outcomes then available.
Matsunaga et al. [11]	2019	RCT	Functional bracing vs. plate ORIF	Operative plate fixation achieved more reliable union and better early function than nonoperative bracing, at the cost of surgical morbidity.
Zhao et al. [7]	2017	Network meta-analysis (16 RCTs, n=832)	Open plating vs. IMN vs. MIPO	No significant difference in nonunion/infection; IMN associated with more shoulder impingement; open

				plating associated with markedly higher radial nerve injury risk than MIPO (OR 11.09, 95% CI 1.80–124.20).

3.2 Union, Nonunion and Time to Union

Across the pooled randomised and comparative literature, no consistent, clinically important difference in nonunion or delayed union rate has been demonstrated between IMN and plate fixation. The 2017 network meta-analysis found no significant difference in nonunion, delayed union or infection among open plating, IMN and MIPO [7]. Where individual comparative studies have reported differences in time to radiological union, these differences have generally been small and have not consistently favoured either technique across studies, suggesting that construct-specific technical factors — fracture reduction quality, construct stability, and preservation of the fracture haematoma and periosteal blood supply — are more determinative of union than the choice of implant category per sec.

3.3 Infection and Reoperation

Infection rates have not differed significantly between IMN and plate fixation in the pooled literature [7]. Reoperation, however, was significantly less frequent with plate fixation than with IMN in the pooled analysis of three randomised trials (155 patients) by Bhandari and colleagues, who reported a risk ratio of 0.26 (95% CI 0.07–0.9, p=0.03) for reoperation with plating relative to nailing — corresponding, by the authors' calculation, to roughly one reoperation avoided for every ten patients treated with a plate rather than a nail [3]. This finding is consistent with the clinical observation that IMN constructs more often require secondary procedures for symptomatic locking-screw removal, nail-related shoulder impingement, or occasional need for dynamisation or exchange nailing for delayed union.

3.4 Radial Nerve Palsy

Iatrogenic radial nerve injury is the complication most characteristically associated with open plate fixation, reflecting the direct surgical exposure and retraction of the nerve required for safe plate application, particularly through an anterolateral or posterior triceps-splitting approach. The 2017 network meta-analysis found that open plating carried a substantially higher odds of iatrogenic radial nerve injury than minimally invasive plate osteosynthesis (OR 11.09, 95% CI 1.80–124.20) [7], a finding that underscores why MIPO was developed specifically to reduce direct nerve handling while retaining the biomechanical advantages of a plate construct. By contrast, antegrade IMN avoids direct exposure of the radial nerve at the fracture site entirely, though it carries its own, anatomically distinct risk to the axillary nerve and rotator cuff at the point of nail insertion.

3.5 Shoulder and Elbow Functional Outcome

Shoulder-related morbidity is the complication domain in which the comparative evidence most consistently favours plate fixation over IMN. In the pooled randomised-trial data reported by Bhandari et al., plate fixation was associated with a markedly lower rate of shoulder problems than IMN (RR 0.10, 95% CI 0.03–0.4, p=0.002) [3]. The 2017 network meta-analysis corroborated this pattern at a larger scale, reporting that shoulder impingement was significantly more frequent after IMN than after either open plating or MIPO [7]. This consistent signal is generally attributed to disruption of the rotator cuff and violation of the subacromial space at the antegrade nail entry point, together with prominent retained nail or locking hardware. Elbow-specific functional outcome has been less frequently and less consistently reported across the comparative literature than shoulder outcome, and no robust, pooled quantitative difference between techniques has been established for elbow function in the sources reviewed here.

3.6 Operative Time and Blood Loss

IMN is generally reported in the comparative literature to be associated with a shorter operative time and reduced intraoperative blood loss relative to open plate fixation, consistent with its closed or limited-exposure technique and the absence of a formal soft-tissue dissection to the fracture site in straightforward, closed fracture patterns. These intraoperative advantages, however, have not translated into a consistent advantage in the clinically weighted outcome domains of union, reoperation, or shoulder function summarised above, and should be weighed against those domains rather than considered in isolation.

Table 2. Pooled quantitative outcome comparisons reported in the included meta-analyses.

Outcome	Comparison	Effect Estimate (95% CI)	p-value	Favours	Source
Reoperation	Plate vs. IMN	RR 0.26 (0.07–0.9)	0.03	Plate	Bhandari et al. [3]
Shoulder-related problems	Plate vs. IMN	RR 0.10 (0.03–0.4)	0.002	Plate	Bhandari et al. [3]
Shoulder impingement	IMN vs. open plating	OR 0.13 (0.03–0.37)	—	Open plating	Zhao et al. [7]
Shoulder impingement	IMN vs. MIPO	OR 0.08 (0.00–0.69)	—	MIPO	Zhao et al. [7]
Iatrogenic radial nerve injury	Open plating vs. MIPO	OR 11.09 (1.80–124.20)	—	MIPO	Zhao et al. [7]
Nonunion / delayed union / infection	Open plating vs. IMN vs. MIPO	No significant difference	n.s.	—	Zhao et al. [7]

CI, confidence interval; IMN, intramedullary nailing; MIPO, minimally invasive plate osteosynthesis; OR, odds ratio; RR, risk ratio; n.s., not significant. Effect estimates for shoulder impingement and radial nerve injury are Bayesian network meta-analytic odds ratios with 95% credible intervals as reported in Zhao et al. [7]; the source abstract did not report exact p-values for these estimates.

4. Discussion

4.1 Interpreting the Comparative Evidence

Taken together, the pooled comparative evidence does not support the categorical superiority of either intramedullary nailing or plate osteosynthesis for the surgical management of midshaft humeral fractures. Where differences do emerge, they are concentrated in two complication domains with opposite directionality: plate fixation carries a lower risk of shoulder-related morbidity and reoperation, while it carries a materially higher risk of iatrogenic radial nerve injury relative to minimally invasive techniques, and open plating specifically requires direct handling of a nerve that antegrade nailing can largely avoid. Union, nonunion and infection rates, which might be expected to be the primary determinants of implant choice, show no consistent difference between techniques in the pooled literature [7]. This pattern reframes the clinical question: rather than asking which implant achieves better union, the more clinically productive question is which complication profile — shoulder-related morbidity and reoperation on one hand, or nerve injury risk on the other — is more acceptable for a given patient and a given fracture.

4.2 A Framework for Clinical Decision-Making

Drawing on the evidence synthesised above together with established clinical principles of fracture fixation, three broad categories of factors should jointly inform the choice between IMN and plate osteosynthesis for an individual patient.

4.2.1 Fracture-Related Factors

Simple transverse, short oblique or spiral fracture patterns amenable to anatomical open reduction are well suited to compression plating, which restores length, rotation and alignment under direct vision. Segmental fractures, markedly comminuted patterns, and fractures with poor proximal or distal bone stock for plate purchase favour a nail construct, which achieves fixation through the medullary canal independent of the fracture zone's comminution. Fractures with an associated radial nerve palsy present at the time of injury, particularly in the distal-third, spiral (Holstein–Lewis) pattern, are commonly managed with open exploration and plate fixation, both to achieve stable reduction and to directly inspect nerve continuity, although the evidence that primary exploration improves neurological recovery compared with expectant management remains debated and is not the focus of this review. Proximal- or distal-third extension of the fracture line, where there may be insufficient isthmus for secure nail interlocking, also tends to favour plate fixation or an extended/MIPO construct.

4.2.2 Patient-Related Factors

Osteoporotic or otherwise compromised bone quality, common in older patients sustaining low-energy fractures, favours a load-sharing nail construct, which is less dependent on screw purchase in weak cortical bone than a plate. Polytraumatised patients and those requiring damage-control orthopaedic strategies benefit from the shorter operative time and reduced blood loss generally associated with IMN. Conversely, patients with high functional or occupational demand on the shoulder — overhead athletes, manual labourers, and patients who have already sustained ipsilateral shoulder pathology — may be better served by plate fixation, given the consistent signal of IMN-associated shoulder impingement and reduced shoulder scores discussed above. Segmental or bilateral humeral fractures, obese patients in whom bracing is impractical, and patients with associated vascular injury requiring rapid, reliable skeletal stabilisation are additional scenarios in which the specific characteristics of each construct should be weighed individually rather than applying a uniform rule.

4.2.3 Surgeon- and Resource-Related Factors

Surgeon experience and comfort with a given technique remains, appropriately, a legitimate determinant of implant choice, since complication rates for both IMN and plate fixation are known to be sensitive to surgical technique and case volume. Institutional resource factors — availability of intraoperative fluoroscopy, implant inventory, and operating-room time — may also influence the practical choice between techniques, particularly in high-volume trauma settings where the shorter operative time associated with IMN carries system-level value beyond the individual patient.

4.3 The Emerging Role of Minimally Invasive Plate Osteosynthesis

Minimally invasive plate osteosynthesis has been proposed specifically to reconcile the two opposing complication profiles described above: by applying a plate construct through limited, remote incisions with indirect, biologically respectful fracture reduction, MIPO aims to preserve the lower shoulder-related morbidity of open plating while substantially reducing the direct radial nerve handling responsible for the elevated nerve-injury risk of conventional open plating. The network meta-analysis summarised in Table 2 supports this rationale, demonstrating significantly lower odds of radial nerve injury with MIPO compared with open plating, concluding that MIPO may represent the preferred technique among the three when the full complication profile is considered [7]. MIPO nonetheless requires specific technical expertise, reliable intraoperative imaging, and careful attention to indirect nerve localisation, and its comparative evidence base, while growing, remains smaller than that for conventional IMN and open plating.

4.4 Limitations of the Evidence Base

Several limitations constrain the strength of the conclusions that can be drawn from the existing comparative literature. Most included randomised trials are small, often enrolling fewer than 100 patients in total, which limits statistical power to detect differences in relatively infrequent outcomes such as nonunion or nerve injury; the largest pooled randomised dataset addressing reoperation and shoulder outcome in this review comprised only 155 patients across three trials [3]. There is substantial heterogeneity across studies in implant generation (nailing systems and plate designs have evolved considerably over the two-decade span of this literature), surgical approach, surgeon experience, rehabilitation protocol, and length and completeness of follow-up, all of which can materially affect reported complication rates independent of the implant category itself. Functional outcome has been measured with a range of different instruments (Constant–Murley, Mayo Elbow Performance Score, DASH, and others) across studies, which complicates direct pooling and may understate true between-technique differences in some domains. Finally, much of the foundational randomised evidence predates the widespread clinical adoption of MIPO, so comparative data for MIPO, although encouraging, remain less mature than those for conventional IMN and open plating.

4.5 Future Directions

A large, adequately powered, multicentre randomised trial directly comparing antegrade IMN, conventional open plating, and MIPO, using standardised, validated shoulder and elbow outcome instruments and a sufficiently long follow-up to capture reoperation and late implant-related complications, would meaningfully strengthen the evidence base underlying the framework proposed in this review. Prospective registry-based studies, which can capture larger patient numbers and a broader range of fracture morphologies than individual randomised trials, may also help clarify which specific fracture- and patient-level subgroups derive the greatest differential benefit from each technique, moving the field from a generic comparison of implant categories toward a genuinely individualised, evidence-based decision algorithm.

5. Conclusion

Intramedullary nailing and plate osteosynthesis remain clinically equivalent options for the surgical management of most midshaft humeral fractures with respect to union, nonunion and infection. The comparative evidence instead distinguishes the two techniques along complication domains with opposite clinical implications: plate fixation reduces the risk of shoulder-related morbidity and reoperation relative to IMN, while conventional open plating carries a materially higher risk of iatrogenic radial nerve injury than minimally invasive techniques. Surgical decision-making should therefore be individualised, integrating fracture morphology and location, radial nerve status, bone quality, polytrauma status, patient functional demand, and surgeon experience, rather than defaulting uniformly to a single preferred implant. Minimally invasive plate osteosynthesis is an emerging technique that may offer a favourable balance between these competing risks, and merits continued high-quality comparative study, including large, adequately powered randomised trials with standardised, validated functional outcome measures.

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