

Review Article

Locking Plate Versus Intramedullary Nailing for Displaced Proximal Humeral Fractures

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Received: 1 March 2025; Accepted: 31 May 2025; Published: 10 September 2025; DOI: 10.5281/zenodo.22327560

Citation of this article: Marchand T, Iglesias P, Petraitiene G (2025) Locking Plate Versus Intramedullary Nailing for Displaced Proximal Humeral Fractures. Int J Orthop, 6(1): 01-06.

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Abstract

Background: Displaced proximal humeral fractures are common osteoporotic injuries, and locking plate fixation and intramedullary nailing are the two dominant surgical options, yet their comparative merits remain debated.

Objective: To synthesise randomised and meta-analytic evidence comparing locking plate with intramedullary nailing, including comparisons with non-operative care and arthroplasty.

Methods: Narrative review of randomised trials, systematic reviews, meta-analyses, and biomechanical literature.

Findings: Trials and meta-analyses pooling over 1,300 patients show no consistent difference in Constant or DASH scores between plate and nail, while nailing offers shorter operative time and less blood loss. Screw perforation/cut-out (up to 9.5%) and avascular necrosis (4.6-11%) dominate plate complications; reoperation rates reach 13.8-25%.

Conclusions: Locking plate and intramedullary nail achieve broadly comparable functional outcomes; implant choice should be individualised by fracture pattern, bone quality, and surgeon experience, with arthroplasty reserved for unreconstructable or high-risk elderly fractures.

Keywords: Proximal humeral fracture; Locking plate; Intramedullary nailing; Avascular necrosis; Reverse shoulder arthroplasty

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Introduction

Proximal humeral fractures account for a substantial and rising share of osteoporotic fragility fractures, with population-based Finnish data documenting a marked increase in incidence among elderly patients over recent decades [1]. Most displaced two-, three-, and four-part fractures in physiologically younger or higher-demand patients are treated operatively, and for decades the two leading fixation strategies have been open reduction with a proximal humeral locking plate and closed or mini-open reduction with an antegrade locking intramedullary nail.

Both constructs aim to restore humeral head alignment and rotator cuff tuberosity anatomy while permitting early motion, but they differ substantially in biomechanical philosophy, soft-tissue handling, and complication profile.

Locking plates achieve angular-stable fixed-angle fixation through a fixed-angle screw-plate interface applied to the lateral proximal humerus, allowing multiple divergent screws to buttress the humeral head fragment; this design has largely supplanted non-locking plates and blade-plate constructs but carries a well-documented risk of screw perforation into the joint as the head fragment settles into varus [2,3]. Intramedullary nailing instead loads the fracture through a central endosteal implant inserted via the rotator cuff footprint, theoretically preserving periosteal blood supply and permitting a smaller incision, shorter operative time, and reduced blood loss, at the cost of a trans-tendinous entry point and a technically demanding tuberosity fixation construct [4].

The choice between these constructs is further complicated by the availability of non-operative treatment for many displaced patterns, and by the emergence of hemiarthroplasty and reverse shoulder arthroplasty as durable alternatives when fixation is unlikely to succeed. Surgeons must therefore weigh implant-specific mechanical failure modes against a growing evidence base suggesting that, for large segments of the fracture spectrum, functional outcome may be relatively insensitive to which of the two fixation constructs is chosen. This review synthesises randomised trials, meta-analyses, and mechanistic literature comparing locking plate and intramedullary nail fixation, situates them against non-operative management, and considers when hemiarthroplasty or reverse shoulder arthroplasty (RTSA) supersedes fixation altogether.

Fracture Pattern, Vascularity, and Implant Rationale

Table 1: Technical and biomechanical comparison of locking plate and intramedullary nail fixation for proximal humeral fractures [2,4,6,7].		
Characteristic	Locking plate	Intramedullary nail
Fixation principle	Fixed-angle divergent screws buttressing head fragment	Central endosteal load-sharing column
Surgical approach	Deltopectoral, lateral plate application	Trans-supraspinatus antegrade entry
Operative time/blood loss	Longer, more dissection	Shorter, less blood loss
Dominant complication	Screw perforation, varus collapse, cut-out	Subacromial impingement, entry-site tendinopathy
Reoperation rate (pooled)	13.8-25%	Comparable, procedure-specific causes

Fracture pattern and head vascularity strongly influence which fixation strategy is biomechanically sound. A calcar length under 8 mm, extensive metaphyseal head extension, and disruption of the posteromedial hinge each predict humeral head ischaemia and have been formalised into a validated predictive scoring system based on the integrity of the medial periosteal hinge, capsular attachment, and displacement pattern [5]. Comminuted surgical-neck and metaphyseal-diaphyseal fractures favour the load-sharing, intramedullary column restored by a nail, whereas fractures with a preserved but displaced calcar and greater tuberosity fragmentation are often more amenable to direct fragment-specific reduction and buttressing with a locking plate. Table 1 summarises the principal technical trade-offs between the two constructs, drawing on comparative and mechanistic literature [2,4,6,7].

Randomised Trials Comparing Plate and Nail

Several randomised trials have directly compared locking plate and intramedullary nail fixation (Table 2). An early three-year minimum follow-up trial in two-part surgical-neck fractures found comparable Constant scores and complication rates between locking plate and locking nail, with the nail group showing shorter operating time

[8]. A subsequent randomised trial in two- and three-part fractures similarly found no significant functional difference between constructs at two years, though nailing again reduced operative time and fluoroscopy exposure [9]. In an elderly cohort with three- or four-part fractures, a randomised comparison reported equivalent Constant and University of California Los Angeles scores between plate and nail, with a trend toward fewer soft-tissue complications in the nail group [10]. Most recently, a large randomised trial comparing the Multiloc nail with the PHILOS plate for displaced three- and four-part fractures found no clinically important difference in patient-reported outcomes at two years, while a secondary cost-effectiveness analysis of the same trial found plating to be substantially less costly than nailing, driven by a higher revision-surgery burden after nailing, without a significant difference in quality-adjusted life-years [11].

Table 2: Selected randomised trials and meta-analyses comparing locking plate and intramedullary nail fixation reviewed here [8,9,10,11,12,13,14].				
Study	Design	Fracture pattern	Follow-up	Key outcome
Zhu 2011	RCT	2-part surgical neck	Minimum 3 years	Comparable Constant score; shorter nail operative time
Gracitelli 2016	RCT	2- and 3-part	2 years	No functional difference; nail shorter operative time
Song 2020	RCT	3- and 4-part, elderly	Not stated	Equivalent Constant/UCLA scores
Wikeroy 2025	RCT (secondary analysis)	3- and 4-part	2 years	No PROM difference; plate more cost-effective
Wang 2015	Meta-analysis	Mixed	Pooled	No difference in Constant score/complications
Li 2018	Meta-analysis (1384 patients)	Mixed	Pooled	No difference in Constant score; nail faster healing
Shi 2019	Updated meta-analysis	Mixed	Pooled	Equivalent function; nail operative efficiency advantage

Meta-Analytic Synthesis

Pooled analyses reinforce the trial-level picture of clinical equipoise. An early meta-analysis found no significant difference between locking plate and intramedullary nail in Constant score or overall complication rate [12]. A larger synthesis of 1,384 patients confirmed no difference in Constant score or postoperative complications, but found nailing superior for incision length, perioperative blood loss, operative time, and fracture-healing time [13]. An updated systematic review and meta-analysis corroborated these findings, reporting equivalent functional scores between constructs while intramedullary nailing retained advantages in operative efficiency and blood loss (Figure 1 summarises complication-type data from a related systematic review) [14]. Across these syntheses, the absence of a consistent functional advantage for either implant suggests that operative-efficiency gains with nailing, and the more established fragment-specific reduction afforded by plating, may reasonably drive implant choice as much as any anticipated difference in patient-reported outcome.

Complications of Locking Plate Fixation

Locking plate fixation carries a well-characterised complication spectrum. A systematic review of 3,422 fractures across 57 studies found intra-articular screw penetration in 9.5%, varus collapse in 6.8%, subacromial impingement in 5.0%, avascular necrosis in 4.6%, and reoperation in 13.8% of cases [7]. Screw perforation arises both as a primary intraoperative event and as a secondary phenomenon as the head fragment subsides into varus; biomechanical testing has shown that shorter calcar and posteromedial screws reduce secondary perforation risk without compromising initial fixation strength [15]. A dedicated review of causative factors identified inadequate medial column support, screw length miscalculation, and osteoporotic bone quality as the

principal drivers, proposing calcar screw placement and structural bone grafting as mitigation strategies [3]. A systematic review focused specifically on late screw-related complications found that revision rates attributable to delayed screw perforation and cut-out remained clinically significant even after excluding early technical failures [16]. Contemporary reviews estimate overall surgical revision rates after locking plate fixation of up to 25% in unselected series, underscoring the persistence of implant-related failure despite iterative plate design improvements [6].

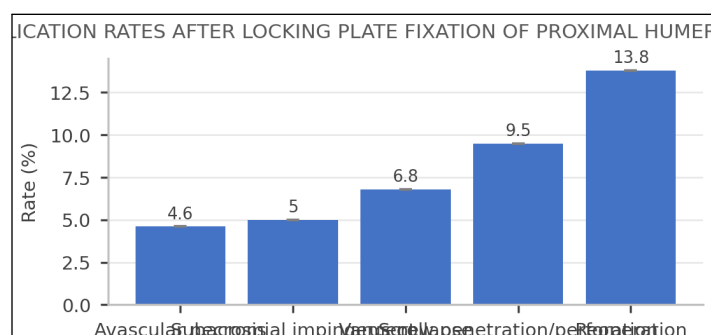


Figure 1: Complication rates after locking plate fixation of proximal humeral fractures, from a systematic review of 3,422 fractures across 57 studies [7].

Avascular Necrosis and Nail-Specific Complications

Avascular necrosis (AVN) is a shared but variably reported complication of both constructs, driven primarily by fracture pattern rather than implant choice. Using a lateral locking plate combined with an endosteal fibular or bone-substitute strut, one series reported no complete AVN and only 2.8% partial osteonecrosis, suggesting that preserving vascularity during reduction may outweigh implant-specific risk [17]. A comparison of classification systems found an overall 11% AVN incidence after locking plate fixation, with Neer four-part, Russo type IVB, and multiple adverse Hertel criteria each independently predicting necrosis [18,5]. Intramedullary nailing carries a distinct complication signature related to its

trans-rotator-cuff entry point: subacromial and supraspinatus-tendon impingement, entry-site tendinopathy, and proximal screw backout are reported more frequently with nails, whereas plates more often fail through articular screw perforation; contemporary straight, lateral-entry nail designs with locking tuberosity sutures have been developed specifically to mitigate cuff-related morbidity [4].

Comparison with Non-Operative Management

Both fixation strategies must be weighed against non-operative treatment, particularly in older patients. The PROFHER trial randomised displaced fractures across the two-, three-, and four-part spectrum to surgery (predominantly locking plate) or sling immobilisation and found no significant difference in Oxford Shoulder Score at two years, a result sustained at five-year follow-up [19,20]. A subsequent multicentre trial restricted to displaced two-part fractures similarly found no significant difference in DASH score between operative and non-operative treatment at two years (18.5 versus 17.4), with all serious adverse events requiring revision occurring in the surgical group [21]. A meta-analysis and meta-regression of randomised trials found that surgery modestly improved function and Constant score but carried substantially higher complication (odds ratio 4.20) and reoperation (odds ratio 5.31) risk, with the surgical advantage increasing with patient age [22]. These findings support selective rather than routine operative fixation, particularly for two-part and impacted patterns.

Comparison with Hemiarthroplasty and Reverse Shoulder Arthroplasty

For unreconstructable head-split, four-part, and fracture-dislocation patterns, arthroplasty remains an alternative to fixation. Hemiarthroplasty was historically favoured for these injuries, but tuberosity healing problems have limited its functional ceiling [23]. RTSA has increasingly supplanted hemiarthroplasty and, in a

five-year follow-up of a randomised trial in elderly patients with displaced fractures, produced superior Constant scores and fewer reoperations than locking plate fixation [24]. A systematic review and network meta-analysis found comparable pooled Constant-Murley scores between RTSA and locked plate fixation (Figure 2; 66.1 versus 64.3) despite RTSA ranking highest by probability score, while noting a wide range of reported complication rates for both procedures and a lower revision burden after RTSA [25]. A retrospective comparison in geriatric patients likewise found RTSA associated with fewer reoperations than open reduction and internal fixation, at the cost of arthroplasty-specific risks [26]. Collectively, these data support a fracture-pattern- and age-stratified algorithm, reserving arthroplasty for cases unlikely to tolerate fixation-related complication rates, while continuing to offer fixation to physiologically younger patients with reconstructable head fragments and preserved rotator cuff integrity.

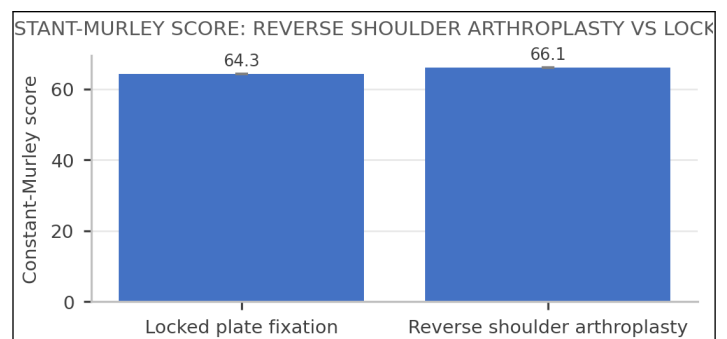


Figure 2: Pooled Constant-Murley score for reverse shoulder arthroplasty (66.1) versus locked plate fixation (64.3) in elderly patients with proximal humeral fractures, from a systematic review and network meta-analysis [25].

Conclusion

Randomised trials and meta-analyses spanning more than fifteen years show that locking plate and intramedullary nail fixation achieve broadly equivalent Constant and DASH outcomes for displaced proximal humeral fractures, with nailing offering procedural efficiency advantages and plating offering more familiar

fragment-specific reduction. Complication profiles differ in mechanism rather than overall burden: plates are dominated by screw perforation, cut-out, and varus collapse, while nails carry a more nail-entry- and cuff-related morbidity signature. Non-operative treatment remains appropriate for many displaced two-part fractures, and reverse shoulder arthroplasty is increasingly preferred for unreconstructable or elderly high-risk injuries. Implant selection should therefore be individualised by fracture morphology, bone quality, and surgeon experience rather than dictated by a uniform superiority of either fixation method.

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