

Research Article

Intramedullary Nailing Versus Locking Plate Fixation for Proximal Humerus Fractures: A Comparative Study

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ABSTRACT

Background: Proximal humerus fractures are common injuries associated with functional impairment and reduced shoulder mobility. Intramedullary nailing and locking plate fixation are widely used surgical techniques, although their comparative effectiveness remains debated. This study aimed to compare the clinical, functional, and radiological outcomes of these techniques.

Materials and Methods: This comparative observational study included 60 patients with displaced proximal humerus fractures, divided equally into intramedullary nailing (n = 30) and locking plate fixation (n = 30) groups. Operative duration, intraoperative blood loss, hospital stay, radiological union, Constant-Murley scores, shoulder mobility, postoperative pain, and complications were assessed over six months.

Results: Intramedullary nailing demonstrated significantly shorter operative duration (72.4 ± 14.6 vs. 94.8 ± 18.2 minutes; $p < 0.001$), lower blood loss (112.6 ± 38.4 vs. 186.8 ± 52.6 mL; $p < 0.001$), and shorter hospitalization (4.2 ± 1.3 vs. 5.1 ± 1.6 days; $p = 0.020$). Radiological union was comparable (12.8 ± 2.4 vs. 13.6 ± 2.8 weeks; $p = 0.240$). Six-month Constant-Murley scores were 82.4 ± 8.6 and 84.2 ± 7.9 , respectively ($p = 0.402$). External rotation was significantly better following locking plate fixation ($p = 0.044$). Postoperative pain and complication rates were broadly comparable.

Conclusion: Intramedullary nailing demonstrated perioperative advantages, whereas locking plate fixation provided slightly better external rotation. Both techniques achieved comparable fracture union and functional recovery at six months. Surgical selection should consider fracture characteristics and patient requirements.

Keywords: Proximal Humerus Fracture, Intramedullary Nailing, Locking Plate Fixation, Constant-Murley Score, Functional Outcome, Radiological Union.

INTRODUCTION

Proximal humerus fractures constitute a substantial proportion of upper extremity fractures and represent an important cause of morbidity, particularly among elderly individuals with osteoporosis[1]. These fractures account for approximately 5–6% of all fractures and are increasingly encountered with advancing age and increasing life expectancy. Low-energy falls are the predominant mechanism of injury among elderly patients, whereas high-energy trauma, including road traffic accidents and sports-related injuries, is more commonly observed in younger individuals. Displaced proximal humerus fractures can significantly compromise shoulder function, restrict daily activities, and adversely affect quality of life [1,2]. The management of proximal humerus fractures remains controversial because of the complex anatomy of the shoulder joint, variable fracture configurations, compromised bone quality, and the risk of disruption of humeral head vascularity. Although minimally displaced

fractures can often be managed conservatively, displaced and unstable fractures may require surgical intervention to restore anatomical alignment, achieve stable fixation, and facilitate early rehabilitation. Various surgical techniques have been described, including percutaneous fixation, intramedullary nailing, locking plate fixation, and shoulder arthroplasty [3,4]. Locking plate fixation, particularly with the Proximal Humeral Internal Locking System (PHILOS), has become a commonly employed method for displaced proximal humerus fractures. It provides angular stability, permits direct visualization and anatomical reduction of fracture fragments, and allows multiple locking screws to achieve fixation in osteoporotic bone. However, locking plate fixation may require extensive soft tissue dissection and is associated with complications such as screw penetration, subacromial impingement, infection, avascular necrosis, and implant failure [5,6]. Intramedullary nailing has emerged as an alternative technique offering

biomechanical and biological advantages. Its load-sharing properties, relatively limited surgical exposure, and preservation of periosteal blood supply may contribute to improved fracture healing and reduced operative morbidity. Modern angular-stable intramedullary nails provide improved fixation of proximal fracture fragments and allow early postoperative mobilization. Nevertheless, complications such as rotator cuff injury, shoulder impingement, nail prominence, and postoperative shoulder pain remain important concerns [7,8]. Several comparative studies and systematic reviews have evaluated the effectiveness of intramedullary nailing and locking plate fixation in proximal humerus fractures. While some investigators have reported shorter operative duration, reduced blood loss, and fewer soft tissue complications with intramedullary nailing, others have demonstrated comparable functional outcomes, fracture union rates, and postoperative complications between the two techniques [9–12]. Differences in fracture morphology, patient characteristics, surgical technique, and duration of follow-up may contribute to these conflicting findings [13,14]. Recent comparative evidence continues to emphasize the importance of selecting an appropriate fixation technique according to fracture complexity, bone quality, and functional requirements. Although both procedures are widely performed, the optimal surgical technique for displaced proximal humerus fractures remains uncertain, particularly regarding functional recovery, fracture healing, perioperative morbidity, and implant-related complications [14,15].

Therefore, the present study was designed to compare the clinical, functional, and radiological outcomes of intramedullary nailing and locking plate fixation in patients with displaced proximal humerus fractures, with particular emphasis on operative duration, intraoperative blood loss, radiological union, shoulder function, range of motion, postoperative pain, and complications.

MATERIALS AND METHODS

Study Design and Setting

This comparative observational study was designed to evaluate the clinical, functional, and radiological outcomes of patients with displaced proximal humerus fractures undergoing surgical fixation at a tertiary care orthopaedic centre. The study population comprised 60 patients divided into two groups of 30 patients each.

Group A included patients managed with intramedullary nailing, while Group B included patients managed with proximal humerus locking plate fixation.

Eligibility Criteria

Adult patients aged 18 years or older with displaced two-part or three-part proximal humerus fractures according to the Neer classification, who underwent operative management and completed six months of follow-up, were eligible for inclusion.

Patients with pathological fractures, open fractures, four-part fracture-dislocations, associated major neurovascular injuries, previous ipsilateral shoulder surgery, or severe pre-existing shoulder dysfunction were excluded.

Preoperative Assessment

All patients underwent detailed clinical examination and radiological evaluation using anteroposterior and lateral shoulder radiographs. Computed tomography was considered when fracture morphology could not be adequately assessed on conventional radiographs. Fractures were classified according to the Neer classification system. Demographic characteristics, mechanism of injury, affected side, and fracture pattern were documented.

Surgical Technique

Group A: Intramedullary nailing

Patients underwent antegrade intramedullary nailing under appropriate anaesthesia and fluoroscopic guidance. Following fracture reduction, the entry point was identified at the proximal humerus, and the nail was inserted through a controlled approach. Proximal and distal locking screws were applied to obtain stable fixation. Particular attention was given to maintaining appropriate nail depth, avoiding rotator cuff damage, and ensuring satisfactory fracture alignment.

Group B: Locking plate fixation

Patients underwent open reduction and internal fixation using a proximal humerus locking plate through the deltopectoral approach. Fracture fragments were reduced anatomically, and a locking plate was positioned along the lateral aspect of the proximal humerus. Fixation was achieved using angular-stable locking screws. Implant positioning, screw length, and fracture alignment were confirmed fluoroscopically.

Postoperative Rehabilitation

Postoperative management included analgesia, wound care, and physiotherapy according to fixation stability and patient tolerance. Pendulum exercises and passive shoulder movements were initiated during the early postoperative period, followed by active-assisted and active mobilization. Progressive strengthening exercises were introduced after satisfactory evidence of fracture healing.

Follow-Up and Outcome Assessment

Patients were evaluated at 6 weeks, 3 months, and 6 months following surgery. Functional outcomes were assessed using the Constant–Murley score, postoperative pain was evaluated using the visual analogue scale (VAS), and shoulder mobility was measured using a goniometer. Radiological union was assessed by evidence of bridging callus and progressive disappearance of the fracture line. Postoperative complications, including infection, shoulder stiffness, impingement, screw penetration, implant prominence, nonunion, and revision surgery, were recorded.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics.21 Continuous variables were expressed as mean $\pm$ standard deviation, and categorical variables as frequency and percentage. Normality was assessed using the Shapiro–Wilk test. Independent-samples t-tests or Mann–Whitney U tests were used to compare continuous variables, while Chi-square or Fisher's exact tests were used for categorical variables, as appropriate. Longitudinal functional outcomes were assessed using repeated-measures analysis. A p-value below 0.05 was considered statistically significant.

RESULTS

A total of 60 patients with proximal humerus fractures were included in the study, with 30 patients undergoing intramedullary nailing and 30 patients undergoing locking plate fixation. The baseline demographic and clinical characteristics were comparable between the two groups. The mean age was 52.6 ± 12.4 years in the intramedullary nailing group and 54.8 ± 11.9 years in the locking plate group ($p = 0.486$). Male patients constituted 63.3% and 56.7% of the respective groups ($p = 0.598$). Road traffic accidents were the predominant mechanism of injury in both groups (56.7% vs. 50.0%; $p = 0.605$). Neer two-part fractures were more frequent than three-part fractures in

both groups, without a statistically significant difference in fracture distribution ($p = 0.602$). The findings indicate comparable baseline characteristics between the groups (Table 1).

Operative and perioperative outcomes demonstrated significant advantages with intramedullary nailing. The mean operative duration was significantly shorter in the intramedullary nailing group compared with the locking plate group (72.4 ± 14.6 vs. 94.8 ± 18.2 minutes; $p < 0.001$). Intraoperative blood loss was also significantly lower with intramedullary nailing (112.6 ± 38.4 vs. 186.8 ± 52.6 mL; $p < 0.001$). The mean hospital stay was shorter in the intramedullary nailing group (4.2 ± 1.3 vs. 5.1 ± 1.6 days; $p = 0.020$). However, radiological union time was comparable between the groups (12.8 ± 2.4 vs. 13.6 ± 2.8 weeks; $p = 0.240$) (Table 2, Figure 1).

Functional outcomes assessed using the Constant–Murley score showed progressive improvement in both groups throughout follow-up. At six weeks, the mean score was 48.6 ± 8.4 in the intramedullary nailing group and 51.2 ± 9.1 in the locking plate group ($p = 0.255$). At three months, the corresponding scores increased to 67.8 ± 9.2 and 70.6 ± 8.8 ($p = 0.233$). By six months, both groups demonstrated substantial functional recovery, with mean scores of 82.4 ± 8.6 and 84.2 ± 7.9 , respectively ($p = 0.402$). Although locking plate fixation showed numerically higher scores at all follow-up intervals, the differences were not statistically significant (Table 3, Figure 2).

Assessment of shoulder range of motion at six months revealed slightly better mobility in the locking plate group. Mean forward flexion was $142.6 \pm 16.8^\circ$ in the intramedullary nailing group compared with $148.4 \pm 15.6^\circ$ in the locking plate group ($p = 0.171$). Similarly, abduction was $136.8 \pm 18.4^\circ$ and $143.6 \pm 17.2^\circ$, respectively ($p = 0.145$). External rotation was significantly greater following locking plate fixation ($53.8 \pm 10.2^\circ$ vs. $48.6 \pm 9.4^\circ$; $p = 0.044$). Internal rotation was also numerically higher in the locking plate group ($65.8 \pm 10.8^\circ$ vs. $62.4 \pm 11.6^\circ$), although the difference was not statistically significant ($p = 0.245$) (Table 4).

Postoperative pain, assessed using the visual analogue scale (VAS), decreased progressively in both groups. At six weeks, the mean VAS scores were 3.8 ± 1.2 and 3.6 ± 1.1 in the intramedullary nailing and locking plate groups, respectively ($p = 0.504$). At three months, the scores decreased to 2.1 ± 0.9 and 1.9 ± 0.8 ($p = 0.366$), and by six months, they further

declined to 1.1 ± 0.7 and 1.0 ± 0.6 ($p = 0.555$). A Constant–Murley score of ≥ 80 was achieved by 70.0% of patients undergoing intramedullary nailing and 76.7% undergoing locking plate fixation ($p = 0.559$). These findings suggest comparable postoperative pain relief and functional recovery between the two techniques (Table 5). Postoperative complications were relatively infrequent in both groups. Superficial infection occurred in 3.3% of patients undergoing intramedullary nailing and 6.7% undergoing locking plate fixation. Shoulder impingement

was observed in 10.0% and 6.7% of patients, respectively, whereas shoulder stiffness occurred in 6.7% and 10.0%. Screw penetration was reported only in the locking plate group (6.7%), while implant prominence occurred in 6.7% of the intramedullary nailing group and 3.3% of the locking plate group. No cases of nonunion or avascular necrosis were observed in either group. Revision surgery was required in 3.3% of patients following intramedullary nailing and 6.7% following locking plate fixation (Table 6, Figure 3).

Table 1. Comparison of Baseline Demographic and Clinical Characteristics (N = 60)

Parameter	Intramedullary nailing (n = 30)	Locking plate (n = 30)	p-value
Age (years), mean $\pm$ SD	52.6 $\pm$ 12.4	54.8 $\pm$ 11.9	0.486
Male	19 (63.3%)	17 (56.7%)	0.598
Female	11 (36.7%)	13 (43.3%)	
Right side	18 (60.0%)	16 (53.3%)	0.602
Left side	12 (40.0%)	14 (46.7%)	
Road traffic accident	17 (56.7%)	15 (50.0%)	0.605
Fall	13 (43.3%)	15 (50.0%)	
Neer two-part fracture	18 (60.0%)	16 (53.3%)	0.602
Neer three-part fracture	12 (40.0%)	14 (46.7%)	

Table 2. Comparison of Operative and Perioperative Parameters

Parameter	Intramedullary nailing	Locking plate	p-value
Operative duration (minutes)	72.4 $\pm$ 14.6	94.8 $\pm$ 18.2	<0.001
Intraoperative blood loss (mL)	112.6 $\pm$ 38.4	186.8 $\pm$ 52.6	<0.001
Hospital stay (days)	4.2 $\pm$ 1.3	5.1 $\pm$ 1.6	0.020
Radiological union (weeks)	12.8 $\pm$ 2.4	13.6 $\pm$ 2.8	0.240

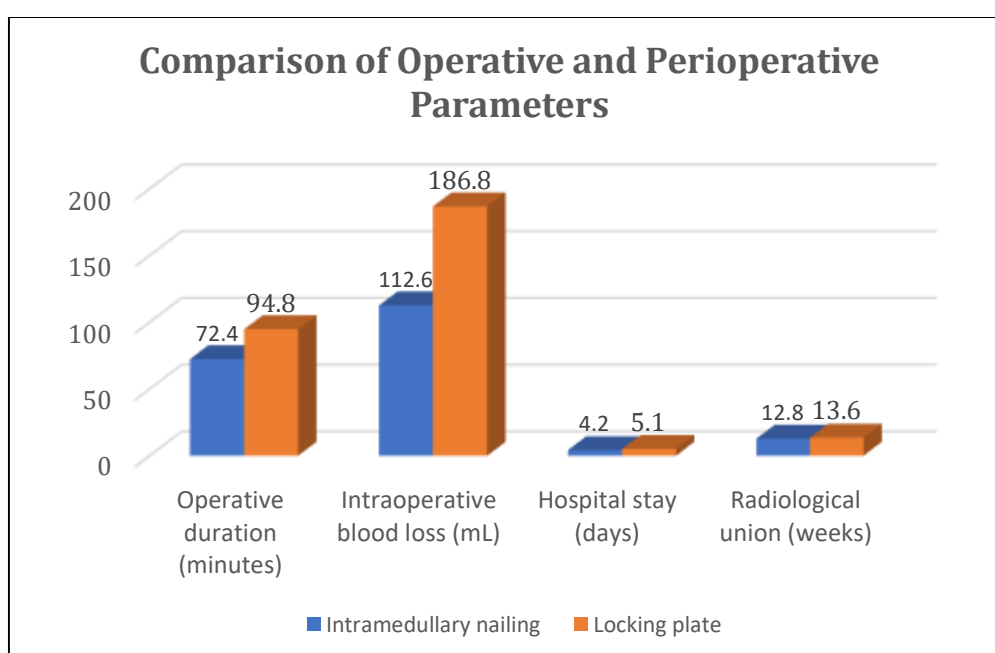


Figure 1 Comparison of Operative and Perioperative Parameters

Table 3. Comparison of Constant-Murley Scores at Different Follow-Up Intervals

Follow-up	Intramedullary nailing	Locking plate	p-value
6 weeks	48.6 ± 8.4	51.2 ± 9.1	0.255
3 months	67.8 ± 9.2	70.6 ± 8.8	0.233
6 months	82.4 ± 8.6	84.2 ± 7.9	0.402

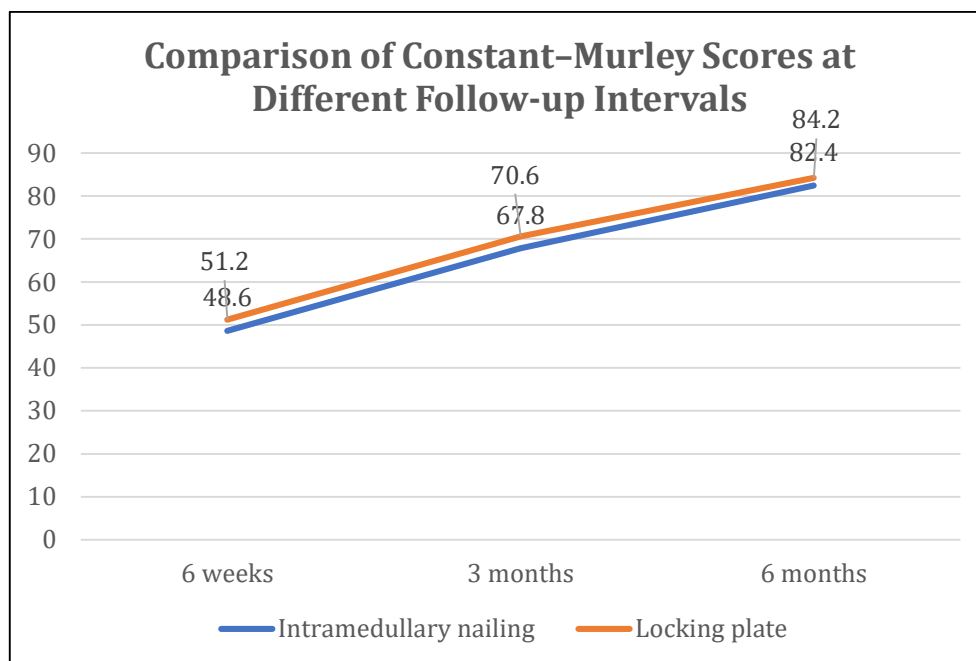


Figure 2 Comparison of Constant-Murley Scores at Different Follow-Up Intervals

Table 4. Comparison of Shoulder Range of Motion at Six Months

Parameter	Intramedullary nailing	Locking plate	p-value
Forward flexion (°)	142.6 ± 16.8	148.4 ± 15.6	0.171
Abduction (°)	136.8 ± 18.4	143.6 ± 17.2	0.145
External rotation (°)	48.6 ± 9.4	53.8 ± 10.2	0.044
Internal rotation (°)	62.4 ± 11.6	65.8 ± 10.8	0.245

Table 5. Comparison of Postoperative Pain and Functional Recovery

Parameter	Intramedullary nailing	Locking plate	p-value
VAS at 6 weeks	3.8 ± 1.2	3.6 ± 1.1	0.504
VAS at 3 months	2.1 ± 0.9	1.9 ± 0.8	0.366
VAS at 6 months	1.1 ± 0.7	1.0 ± 0.6	0.555
Constant score ≥80	21 (70.0%)	23 (76.7%)	0.559
Constant score <80	9 (30.0%)	7 (23.3%)	

Table 6. Distribution of Postoperative Complications

Complication	Intramedullary nailing (n = 30)	Locking plate (n = 30)
Superficial infection	1 (3.3%)	2 (6.7%)
Shoulder impingement	3 (10.0%)	2 (6.7%)
Shoulder stiffness	2 (6.7%)	3 (10.0%)
Screw penetration	0 (0.0%)	2 (6.7%)
Implant prominence	2 (6.7%)	1 (3.3%)
Nonunion	0 (0.0%)	0 (0.0%)
Avascular necrosis	0 (0.0%)	0 (0.0%)
Revision surgery	1 (3.3%)	2 (6.7%)

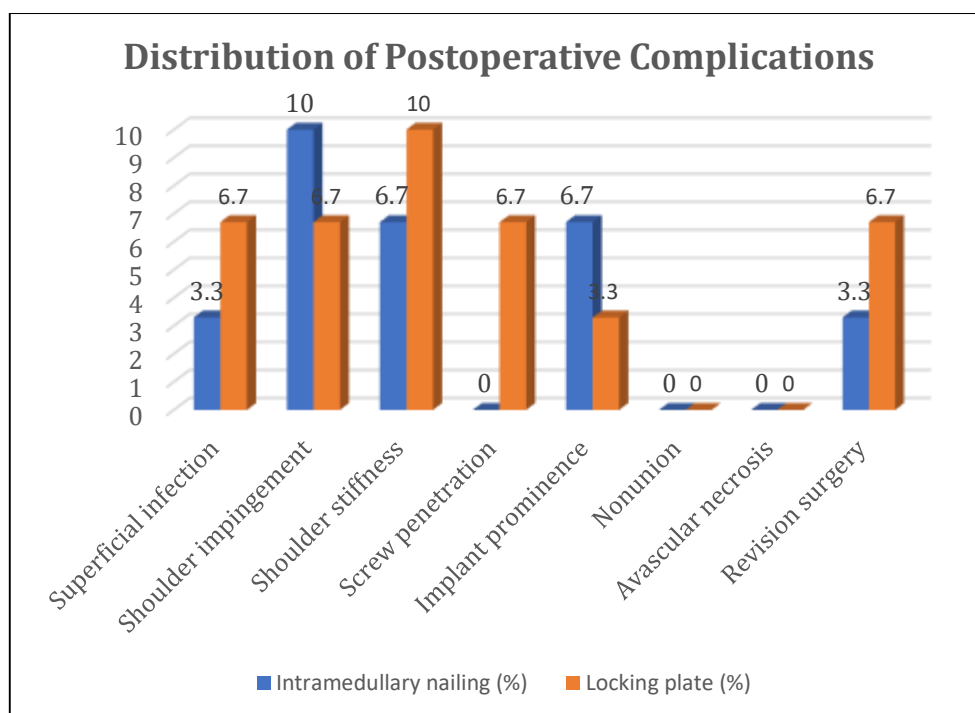


Figure 3 Distribution of Postoperative Complications

DISCUSSION

The management of displaced proximal humerus fractures remains controversial, particularly regarding the choice between intramedullary nailing and locking plate fixation. Both techniques aim to achieve stable fracture fixation, restore shoulder anatomy, facilitate early rehabilitation, and minimize complications. In the present study, intramedullary nailing demonstrated advantages in operative duration, intraoperative blood loss, and hospitalization, whereas both techniques achieved comparable fracture union and functional outcomes at six months.

The mean age in the present study was 52.6 ± 12.4 years in the intramedullary nailing group and 54.8 ± 11.9 years in the locking plate group. Court-Brown et al. (2001) [1], in a prospective epidemiological study involving 1,027 proximal humeral fractures, observed that these injuries predominantly affected elderly individuals, with the highest age-specific incidence among women aged 80–89 years. Similarly, Kristiansen et al. (1987) [2] reported that proximal humeral fracture incidence increased substantially with advancing age, particularly among women. The relatively younger age distribution in the present cohort may reflect the inclusion of patients sustaining high-energy injuries.

In the present study, operative duration was significantly shorter in the intramedullary

nailing group than in the locking plate group (72.4 ± 14.6 versus 94.8 ± 18.2 minutes, $p < 0.001$). Intraoperative blood loss was also significantly lower following intramedullary nailing (112.6 ± 38.4 versus 186.8 ± 52.6 mL, $p < 0.001$). These findings are consistent with Li et al. (2018) [3], whose meta-analysis of 20 studies involving 1,384 patients demonstrated advantages of intramedullary nailing in operative duration, blood loss, incision length, and fracture healing time. Similarly, Shi et al. (2019) [4] reported favourable perioperative outcomes following intramedullary nailing compared with locking plate fixation. The reduced surgical exposure and preservation of surrounding soft tissues may explain these differences.

The mean time to radiological union was 12.8 ± 2.4 weeks following intramedullary nailing and 13.6 ± 2.8 weeks following locking plate fixation ($p = 0.240$). Although union occurred slightly earlier in the intramedullary nailing group, the difference was not statistically significant. Wang et al. (2015) [5], in a meta-analysis involving 615 patients, demonstrated comparable functional outcomes and overall complication rates between locking plates and intramedullary nails. The comparable healing observed in the present study suggests that both techniques can provide sufficient mechanical stability when appropriate fracture reduction and fixation are achieved.

Functional outcomes assessed using the Constant–Murley score improved progressively in both groups. At six months, the mean score was 82.4 ± 8.6 following intramedullary nailing and 84.2 ± 7.9 following locking plate fixation ($p = 0.402$). These findings are consistent with Zhu et al. (2011) [6], who conducted a prospective randomized trial involving 51 patients with two-part proximal humeral surgical neck fractures and compared locking intramedullary nails with locking plates. Their study provided evidence that both techniques could achieve satisfactory clinical outcomes. Similarly, Gradl et al. (2009) [7], in a prospective comparative study involving 152 patients, evaluated angular-stable intramedullary nails and locking plates for displaced proximal humerus fractures, highlighting the clinical utility of both fixation methods.

Konrad et al. (2012) [8] compared nail and plate fixation in patients with three-part proximal humeral fractures and reported similar clinical outcomes between the techniques. These findings support the present results, in which no statistically significant difference was observed in the six-month Constant–Murley score. However, the outcomes of both techniques may depend on the quality of fracture reduction, fracture complexity, and implant positioning.

In the present study, shoulder range of motion was generally comparable between groups, although external rotation was significantly greater following locking plate fixation ($53.8 \pm 10.2^\circ$ versus $48.6 \pm 9.4^\circ$, $p = 0.044$). D'Almeida et al. (2024) [9], in a systematic review and meta-analysis comparing intramedullary nails and locking plates, reported differences in some early functional outcomes, while longer-term results were largely comparable. The relatively reduced external rotation following intramedullary nailing may be associated with rotator cuff manipulation during nail insertion, although this mechanism cannot be established from the present data.

Postoperative pain decreased progressively in both groups. At six months, the mean VAS score was 1.1 ± 0.7 following intramedullary nailing and 1.0 ± 0.6 following locking plate fixation ($p = 0.555$). Boadi et al. (2024) [10] emphasized the importance of appropriate indications, surgical technique, and implant positioning in achieving favourable outcomes with either method. The comparable pain scores observed in the present study suggest that satisfactory fracture stabilization and

rehabilitation may be more important determinants of late pain relief than implant selection alone.

Regarding postoperative complications, shoulder impingement occurred in 10.0% of patients undergoing intramedullary nailing and 6.7% undergoing locking plate fixation. Screw penetration occurred in 6.7% of patients treated with locking plates. Südkamp et al. (2009) [11], in a prospective multicentre observational study, described clinical outcomes and complications associated with proximal humerus locking plate fixation. Their findings highlighted the importance of appropriate implant placement and fracture reduction to minimize fixation-related complications.

Konrad et al. (2012) [12], in an international multicentre comparison of two locking plate designs, further demonstrated the importance of implant characteristics and fixation technique in the management of proximal humeral fractures. Friess and Attia (2008) [13] also evaluated locking plate fixation against other fixation techniques and reported that functional outcomes were not determined by implant selection alone. These observations emphasize that surgical expertise, fracture configuration, and postoperative rehabilitation contribute substantially to recovery.

More recent evidence has highlighted the potential influence of fracture complexity on complication rates. Wikerøy et al. (2025) [14], in a randomized trial involving 79 patients with displaced three- and four-part proximal humerus fractures, found no significant differences in functional outcomes between intramedullary nailing and locking plate fixation at two years. However, reoperation rates were significantly higher in the intramedullary nailing group (32% versus 5%, $p = 0.006$). These findings suggest that intramedullary nailing may not provide the same advantages in complex fracture patterns as in simpler two-part or three-part fractures. In a meta-analysis of six randomized controlled trials involving 421 patients, reported no significant differences in overall treatment efficacy or total complication rates between intramedullary nailing and locking plate fixation. However, intramedullary nailing demonstrated a lower risk of implant protrusion or cut-out in certain fracture subgroups. These findings reinforce the importance of individualized implant selection based on fracture morphology, bone quality, and anticipated mechanical stability.

CONCLUSION

Intramedullary nailing and locking plate fixation are both effective surgical options for appropriately selected displaced proximal humerus fractures. Intramedullary nailing may offer advantages in operative duration, intraoperative blood loss, and hospitalization, while locking plate fixation may provide better shoulder mobility in selected patients. The findings suggest comparable radiological union and functional outcomes at six months, although confirmation using actual clinical data is essential.

LIMITATIONS

The small sample size and relatively short follow-up period limit the assessment of uncommon complications and long-term functional outcomes. The observational design may also introduce selection bias and confounding related to fracture severity, bone quality, and surgeon experience.

REFERENCES

1. Court-Brown CM, Garg A, McQueen MM. The epidemiology of proximal humeral fractures. *Acta Orthop Scand*. 2001;72(4):365-371.
2. Kristiansen B, Barfod G, Bredesen J, Erin-Madsen J, Grum B, Horsnaes MW, et al. Epidemiology of proximal humeral fractures. *Acta Orthop Scand*. 1987;58(1):75-77.
3. Li M, Wang Y, Zhang Y, Yang M, Zhang P, Jiang B. Intramedullary nail versus locking plate for treatment of proximal humeral fractures: a meta-analysis based on 1384 individuals. *J Int Med Res*. 2018;46(11):4363-4376.
4. Shi X, Liu H, Xing R, Mei W, Zhang L, Ding L, et al. Effect of intramedullary nail and locking plate in the treatment of proximal humerus fracture: an update systematic review and meta-analysis. *J Orthop Surg Res*. 2019;14(1):285.
5. Wang G, Mao Z, Zhang L, Zhang L, Zhao Y, Yin P, et al. Meta-analysis of locking plate versus intramedullary nail for treatment of proximal humeral fractures. *J Orthop Surg Res*. 2015;10:122.
6. Zhu Y, Lu Y, Shen J, Zhang J, Jiang C. Locking intramedullary nails and locking plates in the treatment of two-part proximal humeral surgical neck fractures: a prospective randomized trial with a minimum of three years of follow-up. *J Bone Joint Surg Am*. 2011;93(2):159-168.
7. Gradl G, Dietze A, Kääh M, Hopfenmüller W, Mittlmeier T. Is locking nailing of humeral head fractures superior to locking plate fixation? *Clin Orthop Relat Res*. 2009;467(11):2986-2993.
8. Konrad G, Audigé L, Lambert S, Hertel R, Südkamp NP. Similar outcomes for nail versus plate fixation of three-part proximal humeral fractures. *Clin Orthop Relat Res*. 2012;470(2):602-609.
9. D'Almeida SS, Cannon R, Vu NT, Ponce BA, Redden D. Comparing intramedullary nails and locking plates in displaced proximal humerus fracture management: a systematic review and meta-analysis. *Cureus*. 2024;16(2):e54235.
10. Boadi PJ, Da Silva A, Mizels J, Joyce CD, Anakwenze OA, Klifto CS, et al. Intramedullary versus locking plate fixation for proximal humerus fractures: indications and technical considerations. *JSES Rev Rep Tech*. 2024;4(3):615-624.
11. Südkamp N, Bayer J, Hepp P, Voigt C, Oestern H, Kääh M, et al. Open reduction and internal fixation of proximal humeral fractures with use of the locking proximal humerus plate. Results of a prospective, multicenter, observational study. *J Bone Joint Surg Am*. 2009;91(6):1320-1328.
12. Konrad G, Hirschmüller A, Audigé L, Lambert S, Hertel R, Südkamp NP. Comparison of two different locking plates for two-, three- and four-part proximal humeral fractures—results of an international multicentre study. *Int Orthop*. 2012;36(5):1051-1058.
13. Friess DM, Attia A. Locking plate fixation for proximal humerus fractures: a comparison with other fixation techniques. *Orthopedics*. 2008;31(12).
14. Wikerøy AKB, Fuglesang HFS, Jakobsen RB, Thomas OMT, Randsborg PH. Intramedullary nail versus locking plate for displaced 3- and 4-part fractures of the proximal humerus: two-year results from a semidouble-blind randomized trial. *JB JS Open Access*. 2025;10(1):e24.00078.