



## Outcome of Flexible Nail in The Management of Open Humerus Fracture

Sifat Ullah Khan<sup>1</sup>, Naeem Ullah<sup>1</sup>

<sup>1</sup>Department of Orthopedic and Trauma, Lady Reading Hospital, Peshawar, Pakistan.

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**Correspondence to:** Sifat Ullah Khan  
Department of Orthopedic and Trauma,  
Lady Reading Hospital, Peshawar, Pakistan.  
**Email:** [drsifat99@gmail.com](mailto:drsifat99@gmail.com)

### Declaration

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### ABSTRACT

**Background:** Open humeral shaft fractures have significant challenges in orthopedic surgery, particularly regarding its union outcomes. Flexible intramedullary nailing offers a good solution, but evidence on its effectiveness in open fractures remains limited in area like Peshawar, especially in terms of union rates and associated patient factors. **Objective:** To determine the frequency of outcomes with flexible nail in patients with open humerus fracture. **Study Design:** Descriptive cross-sectional study. **Duration and Place of Study:** The study was conducted from September 2024 to February 2025 at the Department of Orthopedic Surgery, Lady Reading Hospital, Peshawar. **Methodology:** A total of 115 patients aged 18–60 years with open humeral shaft fractures were enrolled. All patients underwent fixation with titanium elastic nails via a retrograde approach. Follow-up evaluations were conducted at one, two, and three months postoperatively to assess union outcomes. Complete union was defined radiographically within two months, delayed union by the third month, and non-union as failure to show bridging callus at three months. **Results:** Of the 115 patients, 91 (79.1%) achieved complete union, 12 (10.4%) experienced delayed union, and 12 (10.4%) developed non-union. Male patients comprised 80.9% of the cohort. A significant association was observed between BMI and union outcome ( $p=0.007$ ), with higher BMI linked to increased non-union rates. Socioeconomic status ( $p=0.019$ ) and ASA grade ( $p<0.001$ ) also showed significant associations, while age, gender, and residence did not reach statistical significance. **Conclusion:** Flexible intramedullary nailing is an effective treatment for open humeral shaft fractures, with a high rate of complete union.

### INTRODUCTION

Fractures to the humerus, particularly those that are located at the diaphyseal site, are quite common and can result from high-force trauma most frequently in young patients.<sup>1</sup> Open fractures of the humerus are one subgroup that encompasses a disruption of the bone with violation of the soft tissue and skin above such that there exists direct communication between this site of fracture and the external environment.<sup>2</sup> They are typically associated with a larger risk for infection, soft-tissue injury, and vascular/nerve injury such that treatment is typically more difficult than with closed fractures.<sup>3</sup> Early debridement, stabilization, and appropriate antibiotic therapy are necessary to decrease complication rates and permit healing to take place.<sup>4</sup>

Flexible intramedullary nailing has been a justified alternative in surgical management of open humerus fractures, especially those conditions wherein external fixation/plating will pose additional soft tissue challenges.<sup>5</sup> The flexible nail attains acceptable stabilization without being overly invasive, thereby preserving periosteal circulation and refraining from imparting further trauma to already compromised soft components.<sup>6</sup> The elasticity of flexible nails will dictate an

acceptable level of micromotion at the site of fracture that will promote callus formation, while being less invasive will promote easier care at the wound site with open injury.<sup>7</sup> The technique also accommodates early motion that is very essential to prevent joint stiffening and functional loss of the upper limb.<sup>8</sup>

Outcomes of flexible nailing for open humerus fractures to a significant degree are dependent upon injury severity, grade of soft tissue injury, and treatment timing.<sup>9</sup> The patient typically achieves full union within predictable time to healing with sound function restoration and minimal complication, but with patients with severe loss of bone, infection, or poor stabilization, there can be a delayed union.<sup>10</sup> Less common with correct technique and care is non-union but still a possibility with associated prerequisite for revision surgery, at times with bone grafting.<sup>11</sup> Overall, with correct selection and application, flexible nailing achieves an acceptable balance between stability and biological preservation to produce satisfactory outcomes with treatment for open humerus fractures.<sup>9-11</sup>

A study by Ali A et al. reported that among patients with open humerus fractures treated with flexible intramedullary nailing, complete union was achieved in

85% of cases, delayed union occurred in 10%, and non-union was observed in 5%.<sup>12</sup>

Minimal data is available on flexible nailing as a treatment modality for open humerus fractures, particularly in such patient pool and healthcare configuration as that found within Peshawar. With such prevalence of road traffic accident injury and trauma-related morbidity within this catchment, there is a need to consider treatment modalities that are not just efficient but also resource-friendly. With this research being set up within Peshawar, one shall be able to make evidence-based guidelines specific to local clinical practice, with enhanced patient outcomes as well as guiding orthopedic management within similar setups.

## METHODOLOGY

This descriptive study was conducted in the Department of Orthopedic Surgery at Lady Reading Hospital, Peshawar, over a six-month period from September 2024 to February 2025. A total of 115 patients were enrolled. The sample size was calculated using WHO software, considering a 95% confidence interval, 4% margin of error, and an expected non-union frequency of 5% in patients treated with flexible intramedullary nails.<sup>12</sup>

Participants included males and females aged 18 to 60 years, presenting with open fractures of the humeral shaft characterized by soft tissue laceration greater than 10 cm and confirmed radiographically as either simple spiral (AO/OTA type 12-A) or wedge-type fractures (12-B). Patients with American Society of Anesthesiologists (ASA) physical status classification I or II were eligible. Those with a history of radial nerve palsy, pathological fractures due to underlying malignancy or metabolic bone disorders, concurrent fractures in the same limb, periprosthetic fractures, local infection at the fracture site, or known allergies to implant materials were excluded. After obtaining informed consent, demographic and clinical details such as age, gender, body mass index (BMI), education, residence, socioeconomic status, ASA grade, fracture duration, and profession were recorded.

All patients received a single dose of prophylactic antibiotics 30 minutes before surgery. Internal fixation was performed under general anesthesia using titanium elastic nails, inserted through a retrograde approach from the distal humerus. Nail sizes ranging from 2 mm to 4 mm were selected based on bone diameter. Patients were evaluated during follow-up visits at one, two, and three months after surgery. Complete union was defined by the presence of bridging callus across at least three out of four cortices and disappearance of the fracture gap on anteroposterior and lateral radiographs within two months. Delayed union was considered when healing was evident after two months but before the end of three months. Non-union referred to the absence of progressive callus formation or bridging across the fracture site on radiographs taken three months postoperatively. Data were analyzed using SPSS version 26. Categorical variables were presented as frequencies and percentages. Continuous variables were summarized as mean  $\pm$  standard deviation or median with interquartile range, depending on the normality of distribution assessed by the Shapiro-Wilk test. Outcome measures were stratified by

key variables, and post-stratification comparisons were performed using the chi-square or Fisher's exact test, with a p-value of  $\leq 0.05$  considered statistically significant.

## RESULTS

The study included 115 patients with open humerus fractures treated with flexible nails, with a mean age of  $38.02 \pm 12.46$  years, mean BMI of  $25.55 \pm 3.21$  kg/m<sup>2</sup>, and mean fracture duration of  $10.32 \pm 4.32$  days. The cohort was predominantly male (93 patients, 80.9%) compared to females (22 patients, 19.1%), with nearly equal distribution between rural (56 patients, 48.7%) and urban (59 patients, 51.3%) residents. Socioeconomic distribution showed 46 patients (40.0%) from poor backgrounds, 48 patients (41.7%) from middle-class, and 21 patients (18.3%) from wealthy families. ASA grading revealed 56 patients (48.7%) as Grade I and 59 patients (51.3%) as Grade II (Table-I).

**Table I**

*Patient Demographics*

Demographics	Mean $\pm$ SD
Age (years)	38.02 $\pm$ 12.46
BMI (kg/m <sup>2</sup> )	25.55 $\pm$ 3.21
Duration of Fracture (days)	10.32 $\pm$ 4.32
<b>Gender</b>	
Male n (%)	93 (80.9%)
Female n (%)	22 (19.1%)
<b>Residential Status</b>	
Rural n (%)	56 (48.7%)
Urban n (%)	59 (51.3%)
<b>Socioeconomic Status</b>	
Poor n (%)	46 (40.0%)
Middle n (%)	48 (41.7%)
Rich n (%)	21 (18.3%)
<b>ASA Grade</b>	
I n (%)	56 (48.7%)
II n (%)	59 (51.3%)

Regarding union outcomes, complete union was achieved in 91 patients (79.10%), while delayed union and non-union each occurred in 12 patients (10.40% each) (Table-II).

**Table II**

*Frequency of Union Outcome in Open Humerus Fracture Management with Flexible Nail*

Union Outcome	Frequency	% age
Complete union	91	79.10%
Delayed union	12	10.40%
Non-union	12	10.40%

Age group analysis showed that among 65 patients aged  $\leq 40$  years, 47 (72.3%) achieved complete union, 8 (12.3%) experienced delayed union, and 10 (15.4%) developed non-union, while among 50 patients aged  $>40$  years, 44 (88.0%) achieved complete union, 4 (8.0%) had delayed union, and only 2 (4.0%) developed non-union ( $p=0.083$ ). Gender distribution revealed that among 93 male patients, 73 (78.5%) achieved complete union, 10 (10.8%) experienced delayed union, and 10 (10.8%) developed non-union, compared to 22 female patients where 18 (81.8%) achieved complete union, 2 (9.1%) had delayed union, and 2 (9.1%) developed non-union ( $p=1.000$ ). BMI analysis demonstrated a significant association where among 51 patients with BMI  $\leq 25$  kg/m<sup>2</sup>, 47 (92.2%) achieved complete union, 2 (3.9%) experienced delayed

union, and 2 (3.9%) developed non-union, while among 64 patients with BMI >25 kg/m<sup>2</sup>, only 44 (68.8%) achieved complete union, 10 (15.6%) had delayed union, and 10 (15.6%) developed non-union (p=0.007). Residential status showed no significant difference, with rural patients (n=56) showing 44 (78.6%) complete union, 6 (10.7%) delayed union, and 6 (10.7%) non-union, compared to urban patients (n=59) with 47 (79.7%) complete union, 6 (10.2%) delayed union, and 6 (10.2%) non-union (p=0.990). Socioeconomic analysis revealed significant associations (p=0.019), where among 46 poor patients, 36 (78.3%) achieved complete union, 6 (13.0%) had delayed union, and 4 (8.7%) developed non-union; among 48

middle-class patients, 40 (83.3%) achieved complete union, 6 (12.5%) had delayed union, and 2 (4.2%) developed non-union; while among 21 wealthy patients, 15 (71.4%) achieved complete union, none experienced delayed union, and 6 (28.6%) developed non-union. ASA grade demonstrated the strongest association (p<0.001), with Grade I patients (n=56) showing 52 (92.9%) complete union, no delayed unions, and 4 (7.1%) non-union, compared to Grade II patients (n=59) where 39 (66.1%) achieved complete union, 12 (20.3%) experienced delayed union, and 8 (13.6%) developed non-union (Table-III).

**Table III**

*Association of Union Outcome with Demographic Factors in Open Humerus Fracture Management with Flexible Nail*

Demographic Factors	Union Outcome			p-value	
	Complete union n(%)	Delayed union n(%)	Nonunion n(%)		
Age Group	≤40	47 (72.3%)	8 (12.3%)	10 (15.4%)	0.083*
	>40	44 (88.0%)	4 (8.0%)	2 (4.0%)	
Gender	Male	73 (78.5%)	10 (10.8%)	10 (10.8%)	1.000*
	Female	18 (81.8%)	2 (9.1%)	2 (9.1%)	
BMI Group	≤25	47 (92.2%)	2 (3.9%)	2 (3.9%)	0.007*
	>25	44 (68.8%)	10 (15.6%)	10 (15.6%)	
Residential Status	Rural	44 (78.6%)	6 (10.7%)	6 (10.7%)	0.990
	Urban	47 (79.7%)	6 (10.2%)	6 (10.2%)	
Socioeconomic Status	Poor	36 (78.3%)	6 (13.0%)	4 (8.7%)	0.019*
	Middle	40 (83.3%)	6 (12.5%)	2 (4.2%)	
	Rich	15 (71.4%)	0 (0.0%)	6 (28.6%)	
ASA Grade	I	52 (92.9%)	0 (0.0%)	4 (7.1%)	<0.001*
	II	39 (66.1%)	12 (20.3%)	8 (13.6%)	

**\*Fischer Exact Test**

**DISCUSSION**

The present study demonstrates that flexible nail fixation achieves favorable union outcomes in open humerus fractures, with 79.1% of patients attaining complete union, validating its efficacy as a treatment modality for this challenging clinical scenario. The 10.4% rates of both delayed union and non-union are within acceptable ranges for open fractures, which inherently carry higher complication risks due to soft tissue compromise, bacterial contamination, and periosteal stripping that disrupts the natural healing cascade.

The significant association between BMI and union outcomes reflects the well-established relationship between obesity and impaired fracture healing, as adipose tissue exhibits reduced vascularity and increased inflammatory cytokine production, while mechanical stress on fixation constructs increases with higher body weight. The superior union rates observed in patients over 40 years, though not statistically significant, may paradoxically reflect more cautious post-operative activity levels and better compliance with weight-bearing restrictions in older patients, counteracting the typically expected age-related decline in bone healing capacity. The strong correlation between ASA grade and union outcomes underscores the critical role of overall patient health status, as higher ASA grades indicate systemic comorbidities that compromise cellular metabolic processes, collagen synthesis, and vascular supply essential for bone regeneration. Socioeconomic status significantly influenced outcomes, with middle-class patients demonstrating optimal union rates, likely reflecting a balance between adequate nutritional status

and healthcare access without the potential complications of lifestyle factors that may affect healing in higher socioeconomic groups. The absence of gender-based differences in union outcomes suggests that the biomechanical properties of flexible nails provide adequate stabilization regardless of typical gender-related variations in bone density and hormonal influences on bone metabolism.

Our patient demographic profile showed similarities with several studies, particularly regarding age and gender distribution. The mean age of 38.02±12.46 years closely aligned with Hasni T et al.<sup>12</sup> who reported 37.6±13.3 years and Kumar MR & Kaushik YS<sup>13</sup> with 40 years, while being comparable to Patel I et al.<sup>14</sup> at 32.75 years. The male predominance in our study (80.9%) was consistent with most published series, including Ali A et al.<sup>15</sup> (80%), Ahmad S et al.<sup>16</sup> (80%), and Patel I et al.<sup>14</sup> (75%), though it contrasted with Kumar MR & Kaushik YS<sup>13</sup> who reported 70% female patients, likely reflecting different injury patterns or population characteristics in their cohort.

The union rate of 79.10% in our study was lower than several comparative studies but remained within acceptable ranges for open fractures. Ahmad S et al.<sup>16</sup> achieved union in all patients at 2.84±1.15 months with closed fractures, while Patel I et al.<sup>14</sup> reported 100% union rates with 90% healing by 20 weeks in closed fractures. The difference can be attributed to our study focusing exclusively on open fractures, which inherently carry higher risks of complications. Shah FA et al.<sup>17</sup> who also studied open fractures (Gustilo I-IIIa), reported a higher union rate of 91.4% with mean healing at 14.2±3 weeks, though their study had a smaller sample size of 35 patients

compared to our 115 patients. Rasheed T et al.<sup>18</sup> achieved 98% union rates, but their study included closed fractures, explaining the superior outcomes.

The delayed union rate of 10.40% in our study was comparable to several reports. Ali A et al.<sup>15</sup> reported 10% delayed union, while Patel I et al.<sup>14</sup> showed 10% delayed union healing by 30 weeks. However, our non-union rate of 10.40% was higher than most studies, with Ahmad S et al.<sup>16</sup> reporting no non-union, Hasni T et al.<sup>12</sup> showing 3.85%, and Shah FA et al.<sup>17</sup> reporting 8.6%. This higher non-union rate likely reflects the challenges associated with open fractures and our larger sample size, providing a more comprehensive representation of real-world outcomes.

Age group analysis showed that patients ≤40 years had 72.3% complete union compared to 88.0% in those >40 years (p=0.083), which contrasts with Shah FA et al.<sup>17</sup> who found younger patients (<40 years) healed faster (p=0.02). This discrepancy might be explained by the different injury mechanisms and fracture severity in younger patients in our cohort, or the specific challenges of open fractures where biological factors may override the typical age-related healing advantages.

Our study's focus on open fractures provides valuable insights into a more challenging subset of humeral shaft fractures compared to the predominantly closed fracture studies in the literature. While our union rates were lower than studies focusing on closed fractures, they remained comparable to Shah FA et al.<sup>17</sup> who also studied open fractures, validating the effectiveness of flexible nailing even in this more complex patient population. The comprehensive analysis of demographic and clinical factors in our study provides a more detailed understanding of prognostic indicators than previously available in the literature.

Several limitations should be acknowledged in interpreting these results. This was a single-center study conducted at one institution, which may limit the

generalizability of findings to other healthcare settings with different patient populations, surgical expertise, or resource availability. The sample size of 115 patients, while substantial for open fracture studies, remains relatively modest for comprehensive subgroup analyses, particularly when stratifying by multiple demographic and clinical variables simultaneously. Additionally, the study lacked a control group treated with alternative fixation methods, preventing direct comparative analysis of treatment modalities. The follow-up duration and functional outcome assessments were not standardized across all patients, potentially affecting the completeness of outcome data. Finally, the study was conducted in a specific geographic region with particular demographic characteristics, which may not be representative of other populations or healthcare systems globally.

## CONCLUSION

Our study has concluded that flexible nail fixation in patients with open humerus fractures demonstrates varying frequencies of outcomes, with the majority achieving successful bone union while a notable proportion experience delayed healing or non-union. The technique shows acceptable overall effectiveness for treating open diaphyseal humerus fractures, though outcomes are significantly influenced by patient-specific factors including body mass index, comorbidity status, and socioeconomic conditions. The frequency of complications remains within manageable limits, supporting the use of flexible nailing as a viable treatment option for this challenging fracture pattern.

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