ISSN 1019-8555
The Journal of
Teachers Association
RMC, Rajshahi

**Original Article**

# Clinical Outcomes of Intramedullary Interlocking Nailing via Open and Closed Reduction in AO Type 32A1–B2 Femoral Shaft Fractures: A Quasi-Experimental Study

**Dutta S[1]*, Mamun AA[2], Musa M[3], Sahid SM[4], Kundu S[5]**

**Abstract**

**Background: Shaft fractures of the femur are among the most common orthopedic injuries, and intramedullary interlocking nailing has been established as the gold standard of treatment. However, the optimal reduction technique - open or closed reduction - remains contentious. This study aimed to compare the clinical outcomes of the open and closed reduction techniques for intramedullary interlocking nailing in AO type 32A1-B2 femoral shaft fractures.**

**Methods: A quasi-experimental study was conducted at NITOR & SOMC, Dhaka, Bangladesh, from January 2021 to December 2022. Seventy adult patients (18-60 years) with AO type 32A1-B2 femoral shaft fractures were randomly assigned to two equal groups: closed reduction (n=35) and open reduction (n=35). Patients were observed at 2-, 6-, 12-, and 24-week post-surgery. Primary outcomes were time to union, infection rates, implant-related complications, and functional outcomes. Binary logistic regression analysis was carried out to identify independent predictors of successful union.**

**Results: The closed reduction group had shorter time to union (16.8 ± 2.9 vs. 18.7 ± 3.4 weeks, p<0.05) and lower infection rates (2.9% vs. 14.3%) when compared to the open reduction group. The closed reduction group also had improved functional results, with 80% having full knee motion compared with 62.9% in the open reduction group. Implant-related complications were relatively fewer in the closed reduction group (8.6% vs. 20.0%). Logistic regression revealed that open reduction reduced the odds of union by 55% (AOR: 0.45, 95% CI: 0.21-0.93, p=0.031).**

**Conclusion: Closed reduction for intramedullary interlocking nailing of AO type 32A1-B2 femoral shaft fractures has superior clinical outcomes like earlier union, fewer infections, and better functional outcome compared to open reduction, warranting its preference whenever technically feasible.**

**Keywords: Femoral shaft fractures, Intramedullary nailing, Fracture union, AO classification**

**TAJ 2023; 36: No-2: 53-60**

## Introduction

Femoral shaft fractures are among the most common orthopedic injuries, affecting approximately 1-3% of all adult fractures, with a bimodal distribution involving young adults in the context of high-energy trauma and elderly patients secondary to low-energy falls.[1] Treatment of such fractures has also evolved drastically in recent decades, and intramedullary interlocking nailing (IMN) has become the gold standard for the treatment of diaphyseal femoral fractures due to its superior biomechanics, minimal disturbance of soft tissues, and superior functional outcome.[2, 3] AO/OTA classification system categorizes femoral shaft fractures into three fundamental types: Type A (simple), Type B (wedge), and Type C (complex) fractures.[4] Of these, AO type 32A1-B2 fractures are the category from simple to moderately complex patterns, which are typically appropriate for conventional intramedullary nailing techniques. These fracture patterns include simple spiral (32A1), oblique (32A2), transverse (32A3), spiral wedge (32B1), and bending wedge (32B2) types, each with inherent challenges in reduction and fixation.[5, 6] The

1 Assistant Professor, Department of Orthopedics, Sylhet MAG Osmani Medical College Hospital,Sylhet
2 Assistant Professor, Department of Sports Medicine and Arthroscopy, Sylhet MAG Osmani Medical College Hospital, Sylhet
3. Assistant Professor, Department of Hand & Microsurgery, Sylhet MAG Osmani Medical College Hospital, Sylhet
4. Medical Officer, Teknaf Upazila Health Complex, Cox's Bazar
5. Junior Consultant, Department of Orthopedics, Upazila Health Complex, Borhanuddin, Bhola

surgical procedure for intramedullary nailing may be performed with either closed or open reduction techniques. Closed reduction, carried out by indirect manipulation and traction, preserves the intact fracture hematoma and intact biological environment responsible for bone healing.[7] The operation is according to minimally invasive surgery and biological osteosynthesis concepts, and it can potentially reduce operative time, blood loss, and infection.[8] Conversely, open reduction involves direct visualization and manipulation of the fracture fragments, which can be essential where closed reduction is precluded or does not lead to acceptable alignment or in cases where anatomical reduction is called for.[9] Recent meta-analyses and systematic reviews provided compelling evidence for comparative outcomes of these techniques. Meta-analysis of 12 trials established that closed reduction is superior in terms of union rate, time to union, and overall infection rate compared to open reduction, but with similar operating times and overall complication rates.[10] These findings indicate that closed reduction has the advantages of higher union rates, reduced time to union, and lower overall infection compared to open reduction for femoral shaft intramedullary nailing.[11] The biological explanation for these differences is preservation of the fracture hematoma and periosteal blood supply with closed reduction. Intramedullary nailing with closed reduction of complex femoral shaft fractures has been found to produce better results and lower complications than open reduction.[12] Compromise of the soft tissue envelope with open reduction can compromise the healing environment and lead to nonunion, delayed union, and increased infection risk.[13] Although there are seeming advantages of closed reduction, open reduction remains a valuable technique in specific clinical contexts. When closed reduction cannot achieve acceptable alignment or anatomical reduction is crucial for optimal results, open reduction is indicated.[14] The foremost challenge is to establish the appropriate indications of each procedure and predictive factors for successful outcomes. Various parameters guide the decision to perform either open or closed reduction, such as fracture morphology complexity, operating surgeon experience, patient considerations, and institutional bias. Various studies in recent years have highlighted the role of fracture morphology, specifically third fragment displacement in wedge fractures, as a sign of healing outcome.[15] The evolution of scoring systems predicting nonunion following intramedullary nailing has also accentuated the multifactorial nature of bone healing.[16] The current study gap lies in the direct comparison of these techniques specifically for AO type 32A1-B2 fractures in a homogeneous patient population. While previous studies involved mixed fracture patterns or managed complicated fractures, few data are available comparing open versus closed reductions within the same subset of simple to moderately complex femoral shaft fractures. This study aims to address this evidence gap by providing extensive clinical information to guide surgical intervention in this common fracture pattern.

## Methods

This quasi-experimental study was conducted at National Institute of Traumatology and Orthopedic Rehabilitation (NITOR) & Sylhet MAG Osmani Medical College (SOMC), Dhaka, Bangladesh, from January 2021 to December 2022. A total of 70 adult patients, aged 18–60 years, diagnosed with femoral shaft fractures involving the middle three-fifths of the diaphysis (AO type 32A1–B2), were included and divided equally into two groups: open reduction and closed reduction, with 35 patients in each group. A purposive, non-randomized sampling technique was employed based on availability and eligibility. Inclusion criteria consisted of adult patients with closed femoral shaft fractures (AO types 32A1, A2, A3, B1, and B2) treated within 5–14 days using intramedullary interlocking nailing with primary dynamization, and those who provided informed consent. Exclusion criteria included complex AO 32C fractures, pathological fractures, and polytrauma cases. All patients underwent preoperative clinical and radiological evaluation. The surgical technique (open or closed reduction) was chosen based on intraoperative feasibility. Postoperative follow-up assessments were conducted at 2, 6, 12, and 24 weeks and included radiographic evaluation, functional scoring (Thoresen criteria), and clinical examination. Union was defined by the presence of a bridging callus across at least three cortices without implant failure. Outcomes assessed included time to union, infection, implant-related complications, range of knee motion, and weight-bearing ability. Ethical clearance was obtained from the Institutional Review Board of NITOR, and written informed consent was secured from all participants. Patients were free to withdraw at any stage of the study, and confidentiality was strictly maintained.

### Statistical Analysis

Data were analyzed using SPSS version 26.0. Categorical variables were presented as frequencies and percentages, while continuous variables were reported as mean ± standard deviation. Differences between the two groups were assessed using unpaired *t*-tests for continuous variables and Chi-square or Fisher's exact tests for categorical variables, as appropriate. Binary logistic regression analysis was performed to identify factors independently associated with successful fracture union. Odds ratios (OR) with 95% confidence intervals (CI) and corresponding *p*-values were reported. Statistical significance was set at $p < 0.05$.

## Results

The age distribution of the 70 study patients in both treatment groups has been provided in Table 1. The information shows that both closed and open reduction had a high representation of young adults, with the age group 18-25 years being the highest percentage in both closed reduction (51.4%) and open reduction (45.7%) groups. The age was evenly spread in both the groups (30.74±14.22 years in the closed reduction group and 30.66±11.74 years in the open reduction group), indicating successful demographic matching. Ages varied between 18 and 60 years in both groups, with even distribution in higher age groups.

**Table 1: Distribution of age of the study patients (n=70)**

| Age Group (In years) | Closed Reduction group (n=35) | | Open Reduction group (n=35) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| 18-25 | 18 | 51.4 | 16 | 45.7 |
| 26-35 | 6 | 17.1 | 9 | 25.7 |
| 36-45 | 5 | 14.3 | 5 | 14.3 |
| 46-60 | 6 | 17.1 | 5 | 14.3 |
| Statistics | Mean±SD = 30.74±14.22<br>Minimum= 18, Maximum= 60 | | Mean±SD = 30.66±11.74<br>Minimum= 18, Maximum= 60 | |

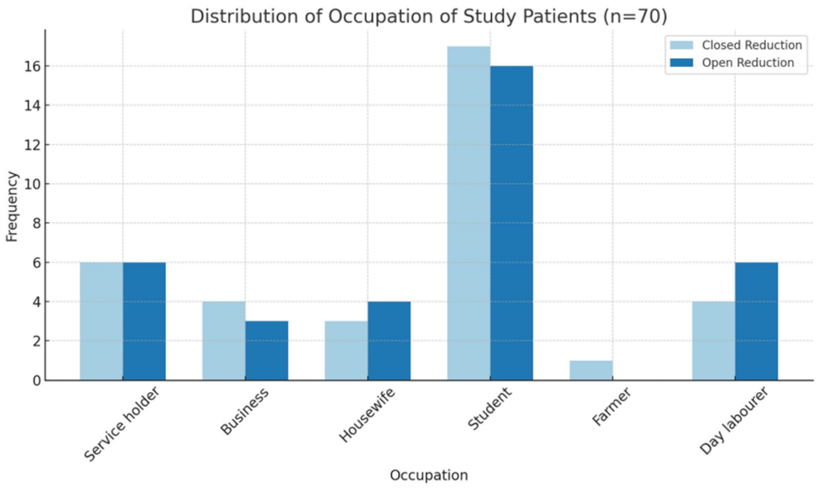


**Figure 1: Distribution of Occupation of the Study Patients**

The occupation distribution of the study's population's closed reduction group and open reduction group is shown in Figure 1. With 17 in the closed group and 16 in the open group, students have made up the majority of both groups. The other categories of occupations, such as day labor, business, homemaker, and service holder, were essentially the same for each group.

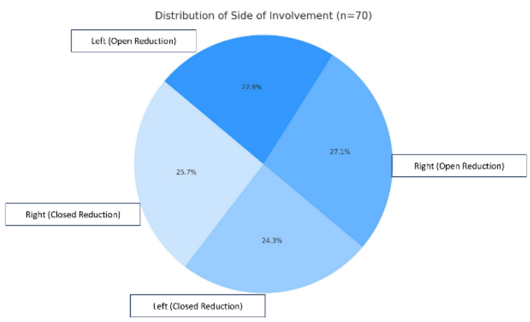


**Figure 2: Distribution of Side of Involvement**

The studied population's side of involvement distribution is shown in Figure 2. 22.9% of people were left-sided in their open reduction engagement, whereas 27.1% of people were right-sided. 24.3% people's engagement was found in left-sided closed reduction, and 25.7% were engaged in right-sided closed reduction.

Table 2 summarizes the fracture patterns according to the AO classification system, demonstrating the pattern of fracture types in each treatment group. The data reveal a relatively even division in fracture patterns, with simple spiral fractures (32A1) being most common in both groups (28.6% closed vs. 25.7% open reduction), followed by simple oblique fractures (32A2). The similar distribution of fracture complexity between groups (from simple fractures 32A1-A3 to wedge fractures 32B1-B2) avoids either group from being disadvantaged due to the presence of more complex fracture patterns.

**Table 2: Distribution of AO Type 32A1–B2 Femoral Shaft Fractures (n=70)**

| AO Fracture Type | Closed Reduction Group (n=35) | | Open Reduction Group (n=35) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| 32A1 (Simple spiral) | 10 | 28.6% | 9 | 25.7% |
| 32A2 (Simple oblique) | 8 | 22.9% | 10 | 28.6% |
| 32A3 (Simple transverse) | 7 | 20.0% | 6 | 17.1% |
| 32B1 (Wedge spiral) | 5 | 14.3% | 6 | 17.1% |
| 32B2 (Wedge bending) | 5 | 14.3% | 4 | 11.4% |
| Total | 35 | 100% | 35 | 100% |

Table 3 shows the primary outcome measure of the comparison of fracture times for healing between the two methods. The data provides a clear benefit to the closed reduction, as 62.9% of the patients from that category united in 16 weeks and merely 40.0% united in the open reduction subgroup. A higher percentage of open reduction patients (22.9%) united later than 20 weeks compared to closed reduction patients (11.4%). The mean time to union was significantly less in the closed reduction group (16.8 ± 2.9 weeks) compared to open reduction (18.7 ± 3.4 weeks).

**Table 3: Distribution of Time to Union (weeks) (n=70)**

| Time to Union (weeks) | Closed Reduction group (n=35) | | Open Reduction group (n=35) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| ≤16 | 22 | 62.9% | 14 | 40.0% |
| 17–20 | 9 | 25.7% | 13 | 37.1% |
| >20 | 4 | 11.4% | 8 | 22.9% |
| Mean±SD | 16.8 ± 2.9 | | 18.7 ± 3.4 | |

Table 4 compares the infection rates of each surgical method and is a key safety outcome. The figure demonstrates a much lower rate of infection in the closed reduction group (2.9%) compared to the open reduction group (14.3%), with a five-fold decrease in risk of infection. This is as would be expected from the biological principle that closed reduction preserves soft tissue integrity and reduces the risk of bacterial contamination. The single infection in the closed reduction group is most likely to be superficial wound complications, while the five in the open reduction group can be superficial as well as deep infections.

**Table 4: Distribution of Postoperative Infection (n=70)**

| Infection Status | Closed Reduction group (n=35) | | Open Reduction group (n=35) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Yes | 1 | 2.9% | 5 | 14.3% |
| No | 34 | 97.1% | 30 | 85.7% |

Table 5 evaluates functional outcomes by patient knee range of motion at three months post-op, illustrating the effect of surgical technique on joint motion. The closed reduction group had a superior outcome with 80.0% of the patients achieving full knee function at 2 weeks post-reduction (≥120°) as opposed to 62.9% in the open reduction group. Additionally, fewer of these patients in the closed reduction group had severe restriction (<90°) at 2.9% as opposed to 8.6% in the open reduction group.

**Table 5: Distribution of Range of Knee Motion at 3 Months (n=70)**

| Knee ROM (Degrees) | Closed Reduction group (n=35) | | Open Reduction group (n=35) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Full (≥120°) | 28 | 80.0% | 22 | 62.9% |
| Limited (90°–119°) | 6 | 17.1% | 10 | 28.6% |
| Severe restriction (<90°) | 1 | 2.9% | 3 | 8.6% |

Table 6 documents hardware complications in both treatment groups, enabling us to more accurately judge the technical success of both methods. The closed reduction group experienced fewer total implant-related complications (8.6%) than the open reduction group (20.0%). Of interest, nail fracture was noted only in the open reduction group (2.9%), possibly reflecting issues with the quality of reduction or the stress to the implant. Malalignment was greater in the open reduction group (11.4% vs. 5.7%), and open reduction may paradoxically have less than optimal fracture alignment despite direct visualization. Back-out of the screw did occur in both groups but occurred more frequently with open reduction (5.7% vs. 2.9%).

**Table 6: Distribution of Implant-related Complications (n=70)**

| Complication Type | Closed Reduction group (n=35) | | Open Reduction group (n=35) | |
|---|---|---|---|---|
| | Frequency | Percentage | Frequency | Percentage |
| Nail breakage | 0 | 0% | 1 | 2.9% |
| Screw back-out | 1 | 2.9% | 2 | 5.7% |
| Malalignment | 2 | 5.7% | 4 | 11.4% |
| No complication | 32 | 91.4% | 28 | 80.0% |

Table 7 illustrates the multivariate analysis to identify independent predictors of the union of fractures. The analysis reveals that open reduction decreases the likelihood of successful union by 55% compared with closed reduction (AOR: 0.45, 95% CI: 0.21-0.93, p=0.031). Postop infection is another risk factor that decreases union likelihood by 68% (AOR: 0.32, 95% CI: 0.10-0.78, p=0.008). Among the fracture patterns, 32B2 fractures had significantly reduced rates of union compared to 32A1 fractures (AOR: 0.29, p=0.012), and 32B1 fractures were on the borderline (AOR: 0.44, p=0.096).

**Table 7: Logistic Regression for Clinical Outcome**

| Variable | Adjusted Odds Ratio (AOR) | 95% CI | p-value | Interpretation |
|---|---|---|---|---|
| **Type of Reduction** | | | | |
| Open (vs Closed) | 0.45 | 0.21 – 0.93 | 0.031* | Open reduction was associated with 55% lower odds of achieving successful union compared to closed reduction (statistically significant). |
| Age (per year increase) | 0.96 | 0.91 – 1.02 | 0.183 | For each 1-year increase in age, the odds of union decreased by 4%, but this was not statistically significant. |
| Postoperative Infection (Yes vs No) | 0.32 | 0.10 – 0.78 | 0.008* | Patients who developed postoperative infection had 68% lower odds of union, and this was statistically significant. |
| Fracture Type | | | | |
| 32A2 (vs 32A1) | 0.84 | 0.33 – 2.11 | 0.710 | No significant difference in union odds between 32A2 and 32A1 fracture types. |
| 32A3 (vs 32A1) | 0.58 | 0.22 – 1.56 | 0.278 | Patients with 32A3 had 42% lower odds of union, but this was not statistically significant. |
| 32B1 (vs 32A1) | 0.44 | 0.17 – 1.16 | 0.096 | Suggests delayed union tendency (56% lower odds) in 32B1 fractures with borderline significance. |
| 32B2 (vs 32A1) | 0.29 | 0.11 – 0.76 | 0.012* | Patients with 32B2 fractures had 71% lower odds of achieving union compared to 32A1 – statistically significant. |

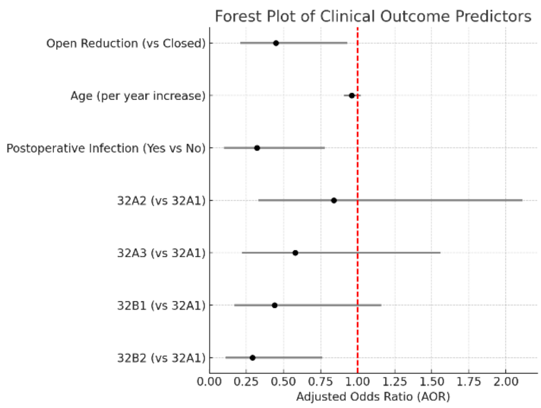


**Figure 3: Forest Plot of Clinical Outcome Predictors**

This forest plot visually confirms the odds ratios and confidence intervals for all factors that affect fracture union from logistic regression analysis. The plot simply shows that postoperative infection and open reduction both highly reduce the likelihood of successful union, with their confidence intervals not crossing the line of no effect (OR=1.0). Significantly decreased odds of union with open reduction (AOR: 0.45, *p*=0.031) and postoperative infection (AOR: 0.32, *p*=0.008) are among the key findings. Fractures such as 32B2 also showed lower odds of union (AOR: 0.29, *p*=0.012). Infection is identified as a critical negative predictor, and the figure graphically supports the advantages of closed reduction.

## Discussion

This quasi-experimental study's outcomes provide good evidence in favor of closed reduction over open reduction for AO type 32A1-B2 femoral shaft fractures treated with intramedullary interlocking nailing. Improved outcomes in the closed reduction group are in line with the fundamental principles of biological osteosynthesis and modern fracture management philosophies emphasizing the maintenance of fracture biology.[17, 18] The narrow clinically important time to union of the closed reduction group (16.8 ± 2.9 weeks versus 18.7 ± 3.4 weeks) is a clinically significant difference that impacts patient quality of life and healthcare cost. This finding is consistent with contemporary systematic reviews that have documented union rates of 97% (95% CI: 94–99%) for intramedullary nailing and validates the biological rationale that closed reduction preserves periosteal blood supply.[19, 20] The preservation of the fracture hematoma and the minimal disruption of the soft tissue envelope with closed reduction gives the best healing environment that is conducive to faster bone remodeling and regeneration.[21] The five-fold infection rate difference between open reduction (14.3%) and closed reduction (2.9%) is possibly the most significant observation of this study. This excessive discrepancy is more than what can be anticipated in the literature, with infection rates of 2.22% [95%CI: 1.90–2.58] being most commonly reported after treatment of femoral shaft fracture.[22]

The higher infection rate in the open reduction group will likely be caused by the higher risk of bacterial contamination from the greater surgical exposures and longer operative times. The disruption of soft tissue planes with open reduction violates natural infection defense barriers and creates dead space that can be a site for bacterial proliferation.[23] The better functional outcomes, as evidenced by increased knee range of motion in the group that had closed reduction, underscore the importance of maintaining soft tissues. That 80.0% of the closed reduction patients had a full knee motion compared with 62.9% in the open reduction group suggests that the additional soft tissue trauma associated with open reduction creates adhesions and scar tissue that limit joint movement.[24] This is significant since stiffness of the knee is a well-known complication of the treatment of femoral shaft fracture and has an important influence on functional outcome.[25] The logistic regression analysis also provides strong statistical support for these clinical observations. The 55% reduction in union odds per open reduction (AOR: 0.45, 95% CI: 0.21-0.93) again indicates that the method of reduction is an independent predictor of successful healing. Similarly, the 68% reduction in union odds per postoperative infection (AOR: 0.32, 95% CI: 0.10-0.78) emphasizes the imperative role of preventive methods against infection.

The finding that 32B2 fractures had significantly lower rates of union (AOR: 0.29) compared to 32A1 fractures is a reflection of the inherent difficulty in reducing bending wedge fractures, which may have a special bearing on treatment planning.[26] Implant-related complications in the present study, like malalignment and screw back-out, were more common in the group with open reduction despite a theoretical benefit from direct visualization. This paradoxical result suggests that disrupted soft tissues and altered biomechanics of open reduction may compromise fracture reduction and implant stability.[27] The solitary case of fracture of the nail in the open reduction group may reflect suboptimal fracture reduction or late healing that subjected the implant to increased mechanical stress.[28] These findings need to be considered within the context of the current literature. Subsequent, more recent meta-analyses have consistently demonstrated the benefit of closed reduction with femoral shaft fractures, with closed reduction preserving perfusion but requiring a significant amount of fluoroscopy and technical expertise.[29] The technical demands of closed reduction should not be underestimated because effective use requires appropriate training, adequate equipment, and experience by the surgeon.[30] The learning curve for the closed reduction techniques can at first result in longer operative time and exposure to radiation but is offset by improved clinical outcomes achieved.[31]

This study contributes to the growing evidence base for minimally invasive treatment of orthopedic trauma. The biotherapeutic advantages of closed reduction extend beyond the results of early healing to reduce scarring, improve preservation of muscle function, and potentially lower rates of chronic pain.[32] All of these benefits cumulatively increased patient satisfaction and earlier return to full activities. Though the obvious advantage of closed reduction observed in this study should be recognized, it is also a fact that open reduction can be a valuable technique in specific clinical contexts. Complex patterns of fractures, severe comminution, or anatomical deformity may necessitate open reduction to achieve satisfactory reduction of the fracture. The key lies in the appropriate selection of patients and knowing when closed reduction is technically not feasible or will not provide satisfactory results.

**Limitations of the Study**

This study is limited by its non-randomized quasi-experimental design and therefore is likely to introduce selection bias. It has a single-center study and the relatively small sample size and might lead to compromised generalizability to other patient groups and diverse health care settings. The study was also confined to AO type 32A1-B2 fractures, thus compromising applicability to more complex fracture patterns.

## Conclusion

This study provides strong evidence that closed reduction takes precedence over open reduction for intramedullary interlocking nailing in AO type 32A1-B2 femoral shaft fractures. The improved results for healing time, rate of infection, and functional recovery in support of the biological principles of fracture management that support maintenance of the fractured environment provide strong evidence. While open reduction remains the choice in certain situations, closed reduction must be the first treatment where technically possible because of its significant clinical advantages.

**Recommendations**
Future studies should include prospective randomized controlled trials with larger numbers of patients and multi-center designs to validate these findings in various patient groups and health care systems. Long-term follow-up studies have to be conducted to ascertain the long-term durability of functional outcomes and possible late complications. Additionally, cost-effectiveness studies both for techniques and the establishment of standard protocols for closed reduction training courses would enhance clinical application and optimize patient results.

**Funding:** No funding sources.

**Conflict of Interests:** None declared.

## References

1. Court-Brown CM, Caesar B. Epidemiology of adult fractures: a review. Injury. 2006 Aug 1;37(8):691-7.
2. Wolinsky PR, McCarty E, Shyr Y, Johnson K. Reamed intramedullary nailing of the femur: 551 cases. Journal of Trauma and Acute Care Surgery. 1999 Mar 1;46(3):392-9.
3. Thoresen BO, Alho A, Ekeland A, Strømsøe K, Follerås G, Haukebø A. Interlocking intramedullary nailing in femoral shaft fractures. A report of forty-eight cases. JBJS. 1985 Dec 1;67(9):1313-20.
4. Mahabier KC, Van Lieshout EM, Van Der Schaaf BC, Roukema GR, Punt BJ, Verhofstad MH, Den Hartog D, HUMMER trial investigators. Reliability and reproducibility of the OTA/AO classification for humeral shaft fractures. Journal of Orthopaedic Trauma. 2017 Mar 1;31(3):e75-80.
5. Park JW, Jo WL, Park BK, Go JJ, Han M, Chun S, Lee YK. Reliability of the 2018 Revised Version of AO/OTA Classification for Femoral Shaft Fractures. Clinics in Orthopedic Surgery. 2024 Jun 7;16(5):688.
6. Chen YH, Liao HJ, Lin SM, Chang CH, Rwei SP, Lan TY. Radiographic outcomes of the treatment of complex femoral shaft fractures (AO/OTA 32-C) with intramedullary nailing: a retrospective analysis of different techniques. Journal of International Medical Research. 2022 Jun;50(6):03000605221103974.
7. Claes L. Improvement of clinical fracture healing–What can be learned from mechano-biological research?. Journal of biomechanics. 2021 Jan 22;115:110148.
8. Ricci WM, Gallagher B, Haidukewych GJ. Intramedullary nailing of femoral shaft fractures: current concepts. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2009 May 1;17(5):296-305.
9. Bhandari M, Tornetta P, Sprague S, Najibi S, Petrisor B, Griffith L, Guyatt GH. Predictors of reoperation following operative management of fractures of the tibial shaft. Journal of orthopaedic trauma. 2003 May 1;17(5):353-61.
10. Salman LA, Al-Ani A, Radi MF, Abudalou AF, Baroudi OM, Ajaj AA, Alkhayarin M, Ahmed G. Open versus closed intramedullary nailing of femur shaft fractures in adults: a systematic review and meta-analysis. International orthopaedics. 2023 Dec;47(12):3031-41.
11. Korytkowski PD, Panzone JM, Aldahamsheh O, Alkhayarin MM, Almohamad HO, Alhammoud A. Open and closed reduction methods for intramedullary nailing of femoral shaft fractures: A systematic review and meta-analysis of comparative studies. Journal of clinical orthopaedics and trauma. 2023 Sep 1;44:102256.
12. Chen YH, Liao HJ, Lin SM, Chang CH, Rwei SP, Lan TY. Radiographic outcomes of the treatment of complex femoral shaft fractures (AO/OTA 32-C) with intramedullary nailing: a retrospective analysis of different techniques. Journal of International Medical Research. 2022 Jun;50(6):03000605221103974.
13. Winquist RA, Hansen Jr ST, Clawson DK. Closed intramedullary nailing of femoral fractures: a report of five hundred and twenty cases. JBJS. 2001 Dec 1;83(12):1912.
14. Tornetta P3, Tiburzi D. Antegrade or retrograde reamed femoral nailing: a prospective, randomised trial. The Journal of Bone & Joint Surgery British Volume. 2000 Jul 1;82(5):652-4.
15. Louka JG, Seligson D, Vig KS, Zamora R, Zou J, Carlson JB, Daccarett M. Femoral shaft fracture with a third fragment treated with an intramedullary nail: Is the displacement of the third fragment predictive of nonunion?. European Journal of Orthopaedic Surgery & Traumatology. 2024 Nov 25;35(1):27.
16. Kraus KR, Flores JW, Slaven JE, Sharma I, Arnold PK, Mullis BH, Natoli RM. A scoring system for predicting nonunion after intramedullary nailing of femoral shaft fractures. JAAOS Global Research & Reviews. 2024 Sep 1;8(9):e24.
17. Perren SM. Evolution of the internal fixation of long bone fractures: the scientific basis of biological internal fixation: choosing a new balance between stability and biology. The Journal of Bone & Joint Surgery British Volume. 2002 Nov 1;84(8):1093-110.

18. RÜEDI TP, BUCKLEY R, MORAN CG. AO principles of fracture management. Annals of the Royal College of Surgeons of England. 2009 Jul;91(5):448-9.
19. Korytkowski PD, Panzone JM, Aldahamsheh O, Alkhayarin MM, Almohamad HO, Alhammoud A. Open and closed reduction methods for intramedullary nailing of femoral shaft fractures: A systematic review and meta-analysis of comparative studies. Journal of clinical orthopaedics and trauma. 2023 Sep 1;44:102256.
20. Ricci WM, Gallagher B, Haidukewych GJ. Intramedullary nailing of femoral shaft fractures: current concepts. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2009 May 1;17(5):296-305.
21. Pape HC, Giannoudis P, Krettek C. The timing of fracture treatment in polytrauma patients: relevance of damage control orthopedic surgery. The American journal of surgery. 2002 Jun 1;183(6):622-9.
22. Walter N, Szymski D, Kurtz SM, Alt V, Lowenberg DW, Lau EC, Rupp M. Femoral shaft fractures in eldery patients–an epidemiological risk analysis of incidence, mortality and complications. Injury. 2023 Jul 1;54(7):110822.
23. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. JBJS. 1976 Jun 1;58(4):453-8.
24. Brumback RJ, Uwagie-Ero S, Lakatos RP, Poka A, Bathon GH, Burgess AR. Intramedullary nailing of femoral shaft fractures. Part II: Fracture-healing with static interlocking fixation. JBJS. 1988 Dec 1;70(10):1453-62.
25. Winquist RA, Hansen Jr ST, Clawson DK. Closed intramedullary nailing of femoral fractures: a report of five hundred and twenty cases. JBJS. 2001 Dec 1;83(12):1912.
26. Kraus KR, Flores JW, Slaven JE, Sharma I, Arnold PK, Mullis BH, Natoli RM. A scoring system for predicting nonunion after intramedullary nailing of femoral shaft fractures. JAAOS Global Research & Reviews. 2024 Sep 1;8(9):e24.
27. Tornetta P3, Tiburzi D. Antegrade or retrograde reamed femoral nailing: a prospective, randomised trial. The Journal of Bone & Joint Surgery British Volume. 2000 Jul 1;82(5):652-4.
28. Bhandari M, Guyatt GH, Tong D, Adili A, Shaughnessy SG. Reamed versus nonreamed intramedullary nailing of lower extremity long bone fractures: a systematic overview and meta-analysis. Journal of orthopaedic trauma. 2000 Jan 1;14(1):2-9.
29. Li Q, Wang J, Sun C, Lu L, Mu Z, Zhang X. Clinical outcomes of closed reduction vs. small-incision-assisted open reduction with intramedullary nailing in complex comminuted femoral shaft fractures (AO/OTA 32-C): a retrospective cohort study. Frontiers in Surgery. 2025 May 27;12:1550063.
30. Bong MR, Kummer FJ, Koval KJ, Egol KA. Intramedullary nailing of the lower extremity: biomechanics and biology. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2007 Feb 1;15(2):97-106.
31. Giannoudis PV, Papakostidis C, Roberts C. A review of the management of open fractures of the tibia and femur. The Journal of Bone & Joint Surgery British Volume. 2006 Mar 1;88(3):281-9.
32. Bhandari M, Zlowodzki M, Tornetta III P, Schmidt A, Templeman DC. Intramedullary nailing following external fixation in femoral and tibial shaft fractures. Journal of orthopaedic trauma. 2005 Feb 1;19(2):140-4.

All corresponds to
**Dr. Shawon Dutta**
Assistant Professor, Department of Orthopedics,
Sylhet MAG Osmani Medical College Hospital,Sylhet