# Association of Fracture Location and Pattern With Nonunion or Malunion in Tibia Fractures Managed With Intramedullary Nailing: A Retrospective Study

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## Abstract

### Background and objective

Extra-articular fractures of the tibia are common orthopedic injuries that are frequently treated with rigid intramedullary nailing. Fracture location and pattern may increase the risk of nonunion or malunion in fractures managed with intramedullary nails. This study aimed to assess the relationship between fracture pattern and location with malunion and nonunion. The primary objective was to evaluate the influence of fracture location and pattern on adverse clinical outcomes such as nonunion, delayed union, and malunion in tibial shaft fractures that are treated operatively with rigid intramedullary nails.

### Methodology

This was a retrospective cross-sectional study conducted on patients operated in a tertiary care center in the Kingdom of Bahrain. The study included patients who sustained tibia shaft fractures and were subsequently operated with intramedullary of the tibia. The primary endpoint was the rate of adverse outcomes associated with fracture patterns. Fracture characteristics were to determine which fracture patterns healed well with intramedullary nailing and which fractures ended up with malunion or nonunion and would likely benefit from additional measures to augment the nail fixation and help encourage union.

### Results

One hundred and eighty-nine patients were included in the study. The level of associated fibula fracture was significantly associated with an increased risk of nonunion and malunion ($P = 0.0034$, $P = 0.001$). The presence of a concomitant distal fibula fracture in association with tibia fractures increased the odds of nonunion (odds ratio [OR] = 4.871, $P = 0.033$, confidence interval [CI] = 1.133-20.948).

### Conclusions

The level and pattern of some tibia and fibula fractures were associated with nonunion, malunion, and delayed union. Further studies with more robust follow-up are needed to examine these findings in greater detail.

## Introduction

Extra-articular fractures of the tibia are common orthopedic injuries that account for about 2% of all adult fractures [1]. The incidence of these fractures was found to be around 16.9/100,000 in a recent large-scale study, with a bimodal distribution of peaks at ages 20 and 50 years [2]. Tibia fractures are especially prone to a prolonged healing course due to their long subcutaneous border and tenuous blood supply [3,4].

Tibial nonunion is a disabling condition and has detrimental effects on the quality of life of patients affected by it; the impact of tibia shaft nonunion on physical health was comparable to the reported impact of end-stage hip arthrosis and worse than that of congestive heart failure when looking at various mental and physical assessment scores [5]. Apart from the deleterious effect on patient outcomes, tibial nonunion has been found to significantly increase the financial burden on healthcare systems, with an estimated twofold increase in service costs when compared to patients without nonunion [6].

The significance of tibial malunion, on the other hand, is a subject of great debate, with most of the literature suggesting that corrections are reserved for patients who complain of pain, functional deficits, unacceptable cosmetic appearance, or an unacceptably high risk of degenerative osteoarthritis [7].

Various treatment modalities have been used to treat tibia fractures, such as casting, external fixators, plate fixation, and intramedullary fixation, with varying levels of success [8,9]. Rigid intramedullary nailing has emerged as the most commonly utilized modality of fixation for tibia shaft fractures, as it has been shown to be an effective and safe method of fixation for most fracture patterns [10]. Large-scale studies have established that nonunion rate may be associated with fracture location in various fractures [11]. Other studies have explored several factors that affect the union rate of tibia fractures [12,13].

Certain tibia fracture patterns and locations may require particular attention by orthopedic providers to avoid the adverse effects of nonunion and malunion. While some studies addressed factors that are associated with nonunion and reoperation rates in tibia fractures, this study focuses on the association of tibia fracture pattern with outcomes post rigid intramedullary nailing [14]. This paper aims to identify fracture patterns that are associated with a higher rate of nonunion, malunion, or delayed union.

## Materials And Methods

The study was conducted at Salmaniya Medical Complex, a tertiary referral center and the prime trauma center in the Kingdom of Bahrain. The study retrospectively assessed all extra-articular tibia fractures treated with reamed rigid intramedullary nailing between January 2019 and May 2023. The follow-up period of operated fractures extended from January 2019 to September 2023. A total of 189 patients were included in the study.

Patients included in the study had extra-articular tibia shaft fractures, which were isolated injuries and treated with operative rigid intramedullary nailing. Additionally, patients with simple malleolar fractures associated with the tibia fracture were also included in the study. The study excluded patients with articular fractures (identified through radiographs or CT scans), open fractures of Gustilo grade 3, evidence of syndesmotic injury, evidence of pathological fractures, pediatric patients, patients treated with alternative fixation modalities, those with insufficient follow-up time to assess postoperative nonunion, and patients lacking immediate operative radiology.

Patients with operative radiographs who were subsequently lost to follow-up were considered united at the normal expected time of union, and subsequent analysis was undertaken with those patients excluded to account for the findings with their inclusion.

The patients underwent operative intervention performed by an orthopedic specialist, with an implant provided by a single manufacturer. The orthopedic surgeons were all at similar levels of training, with at least one specialist supervising cases operated by trainee surgeons.

Medical records were searched for every tibia fracture that was treated in the medical center using the surgical electronic logbook. A total of 382 tibia fractures were identified. Of these, 193 patients were excluded for various reasons: 72 underwent a modality other than rigid intramedullary nailing, 48 had articular fractures, 27 had pediatric fractures, 16 lacked operative radiographs, 16 were incorrectly coded (not tibia fractures), 6 had unavailable patient medical records, 5 had open fractures of Gustilo-Anderson grade 3, and 3 were operated on too recently to allow for adequate follow-up. After exclusions, a total of 189 patients were included in the study. A breakdown of excluded patients because of exclusion is illustrated in Figure 1.
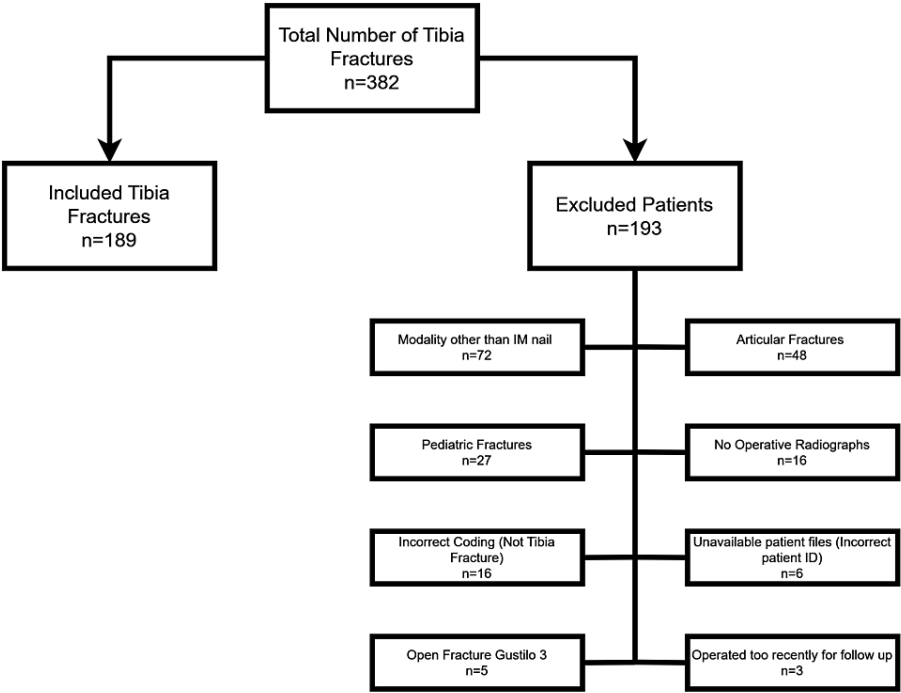
**FIGURE 1: Flowchart detailing exclusion from the study by reason and number.**

Image credits: Mahmood A. Alam and Ahmed F. Shirazi.

The authors collected data retrospectively after agreeing upon a standardized procedure for X-ray assessment and data evaluation. The definition of delayed union was established as the absence of radiological (no callus formation or cortical bridging on standard anterior-posterior [AP] and lateral radiographs) or clinical evidence of union at 16 weeks post-fixation [15-17]. The definition of nonunion was established as the absence of any radiological or clinical evidence of union at 24 weeks and/or a determination by the managing surgeon that the fracture will not progress to union without surgical intervention [5]. Earlier determinations of nonunion were based on the clinical decisions of consultants overseeing the cases. Malunion was defined as a varus/valgus angulation of more than 5° and an AP angulation of more than 10° [18].

Data were analyzed using SPSS version 26 (IBM Corp., Armonk, NY) by an independent statistician. The study received approval from the local ethics committee and the research board of the hospital.

Qualitative variables were analyzed using the chi-square, Fisher's exact test, and multivariate regression analysis testing. Linear regression analysis was performed for quantitative variables. When qualitative variables were calculated using chi-square and more than 20% of expected values were less than 5, Fisher's exact test was used where feasible. Where Fisher's exact test was not feasible, the significance value was not included in the tables to avoid erroneous assumptions.

## Results

### Data description and demographics of the dataset

The study included the data of 189 tibia shaft fractures that were operated on with intramedullary nails, irrespective of the presence or pattern of fibula fracture. A total of 160 individuals (84.7%) were male and 29 (15.3%) were female, with a mean age of 40.1 ± 11.9 years.

Of the 189 total patients, 15 (7.9%) sustained a proximal tibia fracture, 61 (32.3%) sustained a midshaft tibia fracture, and 113 (59.8%) sustained distal tibia fractures according to the AO Foundation/Orthopedic Trauma Association (OTA) classification, with articular fractures being excluded. When assessing associated fibular fractures, 41 (21.7%) had proximal fibular fractures, 36 (19%) had midshaft fibular fractures, 82 (43.4%) had distal fibular fractures, and 30 (15.9%) had no associated fibular fracture. The pattern of tibia fractures was transverse (50, 26.5%), oblique (36, 19%), spiral (65, 34.4%), segmental (9, 4.8%), and comminuted in 29 (15.3%) patients. Of particular interest, fractures involving the distal third of both the tibia and fibula, referred to as combined distal tibia and fibula fractures, were observed in 108 patients (57.1%). All other

combinations of fracture locations constituted the remaining cases. The mean number of days to operation was short, at 1.7, with a median of one. The average number of days to weight-bearing was 3.1, with a median of zero, indicating immediate weight-bearing (Table 1).

| Risk factors | n (%) |
|---|---|
| **Gender** | |
| Male | 160 (84.7) |
| Female | 29 (15.3) |
| **Age in years (Mean ± SD)** | 40.1 ± 11.9 |
| **Comorbidities** | |
| None | 159 (84.1) |
| One | 25 (13.2) |
| Multiple | 5 (2.6) |
| **Level of tibia fracture** | |
| Proximal | 15 (7.9) |
| Midshaft | 61 (32.3) |
| Distal | 113 (59.8) |
| **Level of fibular fracture** | |
| Proximal | 41 (21.7) |
| Midshaft | 36 (19) |
| Distal | 82 (43.4) |
| None | 30 (15.9) |
| **Pattern of tibia fracture** | |
| Transverse | 50 (26.5) |
| Oblique | 36 (19) |
| Spiral | 65 (34.4) |
| Segmental | 9 (4.8) |
| Comminuted | 29 (15.3) |
| **Pattern of fibula fracture** | |
| Transverse | 74 (39.2) |
| Oblique | 23 (12.2) |
| Spiral | 35 (18.5) |
| Segmental | 11 (5.8) |
| Comminuted | 16 (8.5) |
| None | 30 (15.9) |
| **Hemoglobin (Mean ± SD)** | 13.6 ± 1.6 |
| **Size of nail in mm** | |
| 8.5 | 22 (11.6) |
| 10 | 120 (63.5) |
| 11.5 | 47 (24.9) |
| **Days to operation [Mean, Median (IQR)]** | 1.7, 1 (1) |

| | |
|---|---|
| **Days to weight bearing [Mean, Median (IQR)]** | 3.1, 0 (0) |
| **Lock of nail** | |
| Static | 179 (94.7) |
| Dynamic | 10 (5.3) |
| **Combined subgroup (distal fibula and tibia)** | |
| Other fracture patterns | 108 (57.1) |
| Distal tibia and fibula | 81 (42.9) |
| **Combined subgroup (only distal third tibia)** | |
| Other tibial patterns | 124 (65.6) |
| Distal tibia fracture | 65 (34.4) |
| **Large or small nail** | |
| Small nail | 142 (75.1) |
| Large nail | 47 (24.9) |
| **Combined subgroup (nail size and distal tibia)** | |
| Other fracture patterns | 173 (91.5) |
| Large nail and distal tibia | 16 (8.5) |

**TABLE 1: Frequency and percentage distribution of risk factors (n = 189).**

IQR, interquartile range

When examining the outcomes, of the total number of patients, 20 (10.6%) required subsequent dynamization, 42 (22.2%) developed nonunion, 40 (21.2%) developed malunion, 55 (29.1%) developed delayed union, and persistent nonunion noted in 10 (5.3%) patients.

The average degrees of malunion was measured to be 10.7°, with a median of 10° and an interquartile range (IQR) of 3. The average time to union was 13.4 weeks, with a median of 8 and an IQR of 12. The majority of patients (159, 84.1%) had no comorbidities, while 25 (13.2%) patients had one comorbidity, and 5 (2.6%) had two or more comorbidities.

Preoperative hemoglobin was 13.6 ± 1.6, and nail sizes were varied, with the majority (120, 63.5%) receiving 10 mm nails, 22 (11.6%) receiving 8.5 mm nails, and 47 (24.9%) receiving 11.5 mm nails.

Most of the nails were statically locked irrespective of fracture pattern or location, with 179 (94.7%) being statically locked at index surgery (Table 2).

| Outcomes | n (%) |
|---|---|
| **Subsequent dynamization** | |
| Yes | 20 (10.6) |
| No | 169 (89.4) |
| **Nonunion (yes/no)** | |
| Yes | 42 (22.2) |
| No | 147 (77.8) |
| **Time to nonunion in weeks [Mean, Median (IQR)]** | 5.1, 0 (0) |
| **Malunion (yes/no)** | |
| Yes | 40 (21.2) |
| No | 149 (78.8) |
| **Delayed union (yes/no)** | |
| Yes | 55 (29.1) |
| No | 134 (70.9) |
| **Persistent nonunion (yes/no)** | |
| Yes | 10 (5.3) |
| No | 179 (94.7) |
| **Degrees of malunion [Mean, Median (IQR)]** | 10.7, 10 (3) |
| **Complications** | |
| None | 99 (52.4) |
| One | 71 (37.6) |
| Multiple | 19 (10.1) |
| **Time to union in weeks [Mean, Median (IQR)]** | 13.4, 8 (12) |

**TABLE 2: Frequency and percentage distribution of outcomes (n = 189).**

IQR, interquartile range

The mean duration of follow-up in the study was 34.6 weeks, with a standard deviation of 42.9 weeks. The mean number of follow-up visits was 3.2, with a standard deviation of 2.8 visits (Table 3).

| Statistics | Mean ± SD | Median (IQR) |
|---|---|---|
| Duration of follow-up in weeks | 34.6 ± 42.9 | 18.0 (42) |
| Number of follow-up visits | 3.2 ± 2.8 | 3.0 (4) |

**TABLE 3: Follow-up duration descriptive.**

IQR, interquartile range; SD, standard deviation

## Risk factors and association with outcomes

Primary analysis showed a significant association between the presence of comorbidities and an increased risk of the need for subsequent dynamization; 8 out of 22 (27%) patients with comorbidities required

dynamization, while 12 out of 147 (7.5%) patients with no comorbidities required dynamization ($P$ = 0.005). The level of fibula fracture was also significantly associated with an increased risk of nonunion and malunion; fractures associated with distal one-third of fibular fractures developed nonunion in 29 (35%) cases and malunion in 27 (33%) cases, respectively, while other locations had a lower rate of nonunion and malunion ($P$ = 0.001, $P$ = 0.007) (Table 4).

| Risk factors | Subsequent dynamization | | Nonunion | | Malunion | |
|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No |
| | *n* (%) | *n* (%) | *n* (%) | *n* (%) | *n* (%) | *n* (%) |
| **Gender** | | | | | | |
| Male | 12 (7.5) | 148 (92.5) | 33 (20.6) | 127 (79.4) | 37 (23.1) | 123 (76.9) |
| Female | 8 (27.6) | 21 (72.4) | 9 (31) | 20 (69) | 3 (10.3) | 26 (89.7) |
| ***P*-value** | 0.004[a] | | 0.215[b] | | 0.121[b] | |
| **Comorbidities** | | | | | | |
| Yes | 8 (26.7) | 22 (73.3) | 9 (30) | 21 (70) | 5 (16.7) | 25 (83.3) |
| No | 12 (7.5) | 147 (92.5) | 33 (20.8) | 126 (79.2) | 35 (22) | 124 (78) |
| ***P*-value** | 0.005[a] | | 0.264[b] | | 0.511[b] | |
| **Level of tibia fracture** | | | | | | |
| Proximal | 2 (13.3) | 13 (86.7) | 2 (13.3) | 13 (86.7) | 2 (13.3) | 13 (86.7) |
| Midshaft | 5 (8.2) | 56 (91.8) | 18 (29.5) | 43 (70.5) | 8 (13.1) | 53 (86.9) |
| Distal | 13 (11.5) | 100 (88.5) | 22 (19.5) | 91 (80.5) | 30 (26.5) | 83 (73.5) |
| ***P*-value** | 0.745[b] | | 0.217[b] | | 0.087[b] | |
| **Level of fibular fracture** | | | | | | |
| Proximal | 4 (9.8) | 37 (90.2) | 3 (7.3) | 38 (92.7) | 5 (12.2) | 36 (87.8) |
| Midshaft | 2 (5.6) | 34 (94.4) | 6 (16.7) | 30 (83.3) | 5 (13.9) | 31 (86.1) |
| Distal | 13 (15.9) | 69 (84.1) | 29 (35.4) | 53 (64.6) | 27 (32.9) | 55 (67.1) |
| None | 1 (3.3) | 29 (96.7) | 4 (13.3) | 26 (86.7) | 3 (10) | 27 (90) |
| ***P*-value** | - | | 0.001[b] | | 0.007[b] | |
| **Pattern of tibia fracture** | | | | | | |
| Transverse | 6 (12) | 44 (88) | 13 (26) | 37 (74) | 10 (20) | 40 (80) |
| Oblique | 5 (13.9) | 31 (86.1) | 6 (16.7) | 30 (83.3) | 7 (19.4) | 29 (80.6) |
| Spiral | 6 (9.2) | 59 (90.8) | 9 (13.8) | 56 (86.2) | 12 (18.5) | 53 (81.5) |
| Segmental | 0 (0) | 9 (100) | 3 (33.3) | 6 (66.7) | 2 (22.2) | 7 (77.8) |
| Comminuted | 3 (10.3) | 26 (89.7) | 11 (37.9) | 18 (62.1) | 9 (31) | 20 (69) |
| ***P*-value** | - | | 0.076[b] | | 0.720[b] | |
| **Pattern of fibula fracture** | | | | | | |
| Transverse | 9 (12.2) | 65 (87.8) | 20 (27) | 54 (73) | 15 (20.3) | 59 (79.7) |
| Oblique | 4 (17.4) | 19 (82.6) | 4 (17.4) | 19 (82.6) | 4 (17.4) | 19 (82.6) |
| Spiral | 5 (14.3) | 30 (85.7) | 6 (17.1) | 29 (82.9) | 9 (25.7) | 26 (74.3) |
| Segmental | 1 (9.1) | 10 (90.9) | 3 (27.3) | 8 (72.7) | 3 (27.3) | 8 (72.7) |
| Comminuted | 0 (0) | 16 (100) | 5 (31.3) | 11 (68.8) | 6 (37.5) | 10 (62.5) |

| | | | | | | |
|---|---|---|---|---|---|---|
| None | 1 (3.3) | 29 (96.7) | 4 (13.3) | 26 (86.7) | 3 (10) | 27 (90) |
| P-value | - | | 0.534[b] | | - | |
| **Size of nail in mm** | | | | | | |
| 8.5 | 2 (9.1) | 20 (90.9) | 6 (27.3) | 16 (72.7) | 7 (31.8) | 15 (68.2) |
| 10 | 12 (10) | 108 (90) | 28 (23.3) | 92 (76.7) | 23 (19.2) | 97 (80.8) |
| 11.5 | 6 (12.8) | 41 (87.2) | 8 (17) | 39 (83) | 10 (21.3) | 37 (78.7) |
| P-value | - | | 0.564[b] | | 0.410[b] | |
| **Lock of nail** | | | | | | |
| Static | 20 (11.2) | 159 (88.8) | 39 (21.8) | 140 (78.2) | 37 (20.7) | 142 (79.3) |
| Dynamic | 0 (0) | 10 (100) | 3 (30) | 7 (70) | 3 (30) | 7 (70) |
| P-value | 0.603[a] | | 0.695[a] | | 0.443[a] | |
| **Distal fibula and tibia (combined subgroup)** | | | | | | |
| Other fracture patterns | 10 (9.3) | 98 (90.7) | 18 (16.7) | 90 (83.3) | 14 (13) | 94 (87) |
| Distal tibia and fibula | 10 (12.3) | 71 (87.7) | 24 (29.6) | 57 (70.4) | 26 (32.1) | 55 (67.9) |
| P-value | 0.495[b] | | 0.034[b] | | 0.001[b] | |
| **Only distal third tibia (Combined subgroup)** | | | | | | |
| Other tibial patterns | 14 (11.3) | 110 (88.7) | 33 (26.6) | 91 (73.4) | 28 (22.6) | 96 (77.4) |
| Distal tibia fracture | 6 (9.2) | 59 (90.8) | 9 (13.8) | 56 (86.2) | 12 (18.5) | 53 (81.5) |
| P-value | 0.662[b] | | 0.045[b] | | 0.510[b] | |
| **Large or small nail (combined subgroup)** | | | | | | |
| Small nail | 14 (9.9) | 128 (90.1) | 34 (23.9) | 108 (76.1) | 30 (21.1) | 112 (78.9) |
| Large nail | 6 (12.8) | 41 (87.2) | 8 (17) | 39 (83) | 10 (21.3) | 37 (78.7) |
| P-value | 0.589[a] | | 0.322[b] | | 0.983[b] | |
| **Nail size and distal tibia (combined subgroup)** | | | | | | |
| Other fracture patterns | 17 (9.8) | 156 (90.2) | 42 (24.3) | 131 (75.7) | 38 (22) | 135 (78) |
| Large nail and distal tibia | 3 (18.8) | 13 (81.3) | 0 (0) | 16 (100) | 2 (12.5) | 14 (87.5) |
| P-value | 0.385[a] | | 0.025[a] | | 0.530[a] | |
| **Same versus different levels of fracture** | | | | | | |
| Same level | 13 (12) | 95 (88) | 28 (25.9) | 80 (74.1) | 31 (28.7) | 77 (71.3) |
| Different level | 7 (8.6) | 74 (91.4) | 14 (17.3) | 67 (82.7) | 9 (11.1) | 72 (88.9) |
| P-value | 0.453[b] | | 0.157[b] | | 0.003[b] | |
| **Fibula fixed** | | | | | | |
| Yes | 2 (14.3) | 12 (85.7) | 6 (42.9) | 8 (57.1) | 8 (57.1) | 6 (42.9) |
| No | 18 (11.5) | 139 (88.5) | 34 (21.7) | 123 (78.3) | 31 (19.7) | 126 (80.3) |
| P-value | 0.670[a] | | 0.097[a] | | 0.004[a] | |
| **Open fracture** | | | | | | |
| Yes | 6 (17.1) | 29 (82.9) | 11 (31.4) | 24 (68.6) | 10 (28.6) | 25 (71.4) |
| No | 14 (9.1) | 140 (90.9) | 31 (20.1) | 123 (79.9) | 30 (19.5) | 124 (80.5) |

| | | | | |
|---|---|---|---|---|
| P-value | 0.218[a] | 0.147[b] | 0.235[b] | |

**TABLE 4: Association between risk factors and each of subsequent dynamization, nonunion, and malunion.**

[a]Fisher's exact test.

[b]Chi-square test.

A specific pattern of interest (distal tibia with a concomitant distal fibula fracture) was significantly associated with an increased risk of nonunion and malunion. Fractures of this pattern developed nonunion in 24 (29.6%) cases and malunion in 26 (32.1%) cases, which was significantly higher than other fracture patterns that developed nonunion in 18 (17.6%) cases and malunion in 14 (13%) cases ($P = 0.034$, $P = 0.001$). The patterns of tibia and associated fibula fractures were not associated with nonunion or malunion ($P = 0.076$, $P = 0.53$) (Table 4).

Analysis of a fracture pattern where the fibula and tibia fractures occurred at the same level revealed a significant association with malunion. Those with fractures at the same level developed malunion in 31 cases (28.7%), compared to those with fractures at different levels who developed malunion in 9 cases (11%) ($P = 0.003$). Fixation of fibular fractures was significantly associated with an increased rate of malunion; 8 out of 14 (57%) cases with fibula fixed developed malunion, while 31 out of 126 (19.7%) cases without fibular fixation developed malunion ($P = 0.004$) (Table 4).

The level of tibia and fibula fractures was significantly associated with delayed union; midshaft tibia fractures developed delayed union in 24 (39.3%) cases, and distal fibula fractures developed delayed union in 33 (40%) cases ($P = 0.028$, $P = 0.004$). The level of fibula fracture was also associated with increased overall complications; fractures associated with distal fibula fracture developed complications in 52 (63.4%) cases ($P = 0.001$) (Table 5).

| | Delayed union | | Persistent nonunion | | Complications | |
|---|---|---|---|---|---|---|
| **Risk factors** | Yes | No | Yes | No | Yes | No |
| | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) |
| **Gender** | | | | | | |
| Male | 45 (28.1) | 115 (71.9) | 9 (5.6) | 151 (94.4) | 75 (46.9) | 85 (53.1) |
| Female | 10 (34.5) | 19 (65.5) | 1 (3.4) | 28 (96.6) | 15 (51.7) | 14 (48.3) |
| P-value | 0.488[b] | | 1.000[a] | | 0.630[b] | |
| **Comorbidities** | | | | | | |
| Yes | 10 (33.3) | 20 (66.7) | 2 (6.7) | 28 (93.3) | 17 (56.7) | 13 (43.3) |
| No | 45 (28.3) | 114 (71.7) | 8 (5) | 151 (95) | 73 (45.9) | 86 (54.1) |
| P-value | 0.578[b] | | 0.661[a] | | 0.279[b] | |
| **Level of tibia fracture** | | | | | | |
| Proximal | 1 (6.7) | 14 (93.3) | 1 (6.7) | 14 (93.3) | 5 (33.3) | 10 (66.7) |
| Midshaft | 24 (39.3) | 37 (60.7) | 4 (6.6) | 57 (93.4) | 30 (49.2) | 31 (50.8) |
| Distal | 30 (26.5) | 83 (73.5) | 5 (4.4) | 108 (95.6) | 55 (48.7) | 58 (51.3) |
| P-value | 0.028[b] | | - | | 0.512[b] | |
| **Level of fibular fracture** | | | | | | |
| Proximal | 5 (12.2) | 36 (87.8) | 0 (0) | 41 (100) | 12 (29.3) | 29 (70.7) |
| Midshaft | 12 (33.3) | 24 (66.7) | 3 (8.3) | 33 (91.7) | 17 (47.2) | 19 (52.8) |
| Distal | 33 (40.2) | 49 (59.8) | 5 (6.1) | 77 (93.9) | 52 (63.4) | 30 (36.6) |

| | | | | | | |
|---|---|---|---|---|---|---|
| None | 5 (16.7) | 25 (83.3) | 2 (6.7) | 28 (93.3) | 9 (30) | 21 (70) |
| *P*-value | 0.004[b] | | - | | 0.001[b] | |
| **Pattern of tibia fracture** | | | | | | |
| Transverse | 18 (36) | 32 (64) | 3 (6) | 47 (94) | 26 (52) | 24 (48) |
| Oblique | 10 (27.8) | 26 (72.2) | 1 (2.8) | 35 (97.2) | 15 (41.7) | 21 (58.3) |
| Spiral | 14 (21.5) | 51 (78.5) | 1 (1.5) | 64 (98.5) | 23 (35.4) | 42 (64.6) |
| Segmental | 2 (22.2) | 7 (77.8) | 1 (11.1) | 8 (88.9) | 6 (66.7) | 3 (33.3) |
| Comminuted | 11 (37.9) | 18 (62.1) | 4 (13.8) | 25 (86.2) | 20 (69) | 9 (31) |
| P-value | 0.368[b] | | - | | 0.022[b] | |
| **Pattern of fibula fracture** | | | | | | |
| Transverse | 25 (33.8) | 49 (66.2) | 5 (6.8) | 69 (93.2) | 39 (52.7) | 35 (47.3) |
| Oblique | 4 (17.4) | 19 (82.6) | 1 (4.3) | 22 (95.7) | 9 (39.1) | 14 (60.9) |
| Spiral | 9 (25.7) | 26 (74.3) | 0 (0) | 35 (100) | 15 (42.9) | 20 (57.1) |
| Segmental | 3 (27.3) | 8 (72.7) | 2 (18.2) | 9 (81.8) | 7 (63.6) | 4 (36.4) |
| Comminuted | 8 (50) | 8 (50) | 0 (0) | 16 (100) | 10 (62.5) | 6 (37.5) |
| None | 6 (20) | 24 (80) | 2 (6.7) | 28 (93.3) | 10 (33.3) | 20 (66.7) |
| *P*-value | 0.212[b] | | - | | 0.239[b] | |
| **Size of nail in mm** | | | | | | |
| 8.5 | 5 (22.7) | 17 (77.3) | 1 (4.5) | 21 (95.5) | 11 (50) | 11 (50) |
| 10 | 32 (26.7) | 88 (73.3) | 8 (6.7) | 112 (93.3) | 54 (45) | 66 (55) |
| 11.5 | 18 (38.3) | 29 (61.7) | 1 (2.1) | 46 (97.9) | 25 (53.2) | 22 (46.8) |
| *P*-value | 0.259[b] | | - | | 0.617[b] | |
| **Lock of nail** | | | | | | |
| Static | 50 (27.9) | 129 (72.1) | 10 (5.6) | 169 (94.4) | 83 (46.4) | 96 (53.6) |
| Dynamic | 5 (50) | 5 (50) | 0 (0) | 10 (100) | 7 (70) | 3 (30) |
| *P*-value | 0.158[a] | | 1.000[a] | | 0.197[a] | |
| **Distal fibula and tibia (combined subgroup)** | | | | | | |
| Other fracture patterns | 26 (24.1) | 82 (75.9) | 4 (3.7) | 104 (96.3) | 41 (38) | 67 (62) |
| Distal tibia and fibula | 29 (35.8) | 52 (64.2) | 6 (7.4) | 75 (92.6) | 49 (60.5) | 32 (39.5) |
| *P*-value | 0.079[b] | | 0.331[a] | | 0.002[b] | |
| **Only distal third tibia (combined subgroup)** | | | | | | |
| Other tibial patterns | 41 (33.1) | 83 (66.9) | 9 (7.3) | 115 (92.7) | 67 (54) | 57 (46) |
| Distal tibia fracture | 14 (21.5) | 51 (78.5) | 1 (1.5) | 64 (98.5) | 23 (35.4) | 42 (64.6) |
| P-value | 0.098[b] | | 0.168[a] | | 0.015[b] | |
| **Large or small nail (combined subgroup)** | | | | | | |
| Small nail | 37 (26.1) | 105 (73.9) | 9 (6.3) | 133 (93.7) | 65 (45.8) | 77 (54.2) |
| Large nail | 18 (38.3) | 29 (61.7) | 1 (2.1) | 46 (97.9) | 25 (53.2) | 22 (46.8) |
| *P*-value | 0.109[b] | | 0.456[a] | | 0.378[b] | |

| **Nail size and distal tibia (combined subgroup)** | | | | | | |
|---|---|---|---|---|---|---|
| Other fracture patterns | 53 (30.6) | 120 (69.4) | 10 (5.8) | 163 (94.2) | 87 (50.3) | 86 (49.7) |
| Large nail and distal tibia | 2 (12.5) | 14 (87.5) | 0 (0) | 16 (100) | 3 (18.8) | 13 (81.3) |
| *P*-value | 0.158[a] | | 1.000[a] | | 0.016[b] | |
| **Same versus different levels of fracture** | | | | | | |
| Same level | 36 (33.3) | 72 (66.7) | 8 (7.4) | 100 (92.6) | 62 (57.4) | 46 (42.6) |
| Different level | 19 (23.5) | 62 (76.5) | 2 (2.5) | 79 (97.5) | 28 (34.6) | 53 (65.4) |
| *P*-value | 0.139[b] | | 0.193[a] | | 0.002[b] | |
| **Fibula fixed** | | | | | | |
| Yes | 5 (35.7) | 9 (64.3) | 1 (7.1) | 13 (92.9) | 10 (71.4) | 4 (28.6) |
| No | 45 (28.7) | 112 (71.3) | 8 (5.1) | 149 (94.9) | 73 (46.5) | 84 (53.5) |
| *P*-value | 0.554[a] | | 0.545[a] | | 0.074[b] | |
| **Open fracture** | | | | | | |
| Yes | 9 (25.7) | 26 (74.3) | 4 (11.4) | 31 (88.6) | 18 (51.4) | 17 (48.6) |
| No | 46 (29.9) | 108 (70.1) | 6 (3.9) | 148 (96.1) | 72 (46.8) | 82 (53.2) |
| *P*-value | 0.625[b] | | 0.091[a] | | 0.617[b] | |

**TABLE 5: Association between risk factors and each of delayed union, persistent nonunion, and complications.**

[a]Fisher's exact test.

[b]Chi-square test.

Other factors, including open fractures, were not significantly associated with any of the outcome measures of the study (Tables *4-5*).

## Multivariate regression analysis

Upon subsequent multivariate regression analysis, the presence of distal fibula fractures was found to have increased odds of nonunion (odds ratio [OR] = 4.871, confidence interval [CI] = 1.133-20.948; *P* = 0.033), and delayed union (OR = 3.778, CI = 1.092-13.070; *P* = 0.036). The level of fibula fracture was, however, not significantly associated with malunion or overall complications. The distal level of tibia fracture had increased odds of delayed union (OR = 0.285, *P* = 0.014). No factor was significantly associated with increased odds of malunion or complications.

Days to operation (*P* = 0.022) and hemoglobin levels (*P* = 0.045) were significantly associated with nonunion and not significantly associated with any of the other outcomes (Tables *6-9*).

| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
| --- | --- | --- | --- | --- |
| | | | Lower | Upper |
| **Age (years)** | 0.450 | 0.986 | 0.952 | 1.022 |
| **Level of fibular fracture** | | | | |
| None | Reference | | | |
| Proximal | 0.428 | 0.483 | 0.080 | 2.926 |
| Midshaft | 0.861 | 1.150 | 0.239 | 5.536 |
| Distal | 0.033 | 4.871 | 1.133 | 20.948 |
| **Pattern of tibia fracture** | | | | |
| Transverse | Reference | | | |
| Oblique | 0.376 | 0.582 | 0.176 | 1.929 |
| Spiral | 0.566 | 0.727 | 0.245 | 2.156 |
| Segmental | 0.896 | 0.889 | 0.153 | 5.159 |
| Comminuted | 0.829 | 1.136 | 0.357 | 3.620 |
| **Hemoglobin** | 0.045 | 0.743 | 0.556 | 0.994 |
| **Days to operation** | 0.022 | 1.226 | 1.030 | 1.460 |
| **Days to weight-bearing** | 0.309 | 1.023 | 0.979 | 1.070 |
| **Combined subgroup (distal fibula and tibia)** | | | | |
| Other fracture patterns | Reference | | | |
| Distal tibia and fibula | 0.276 | 0.506 | 0.149 | 1.721 |
| **Combined subgroup (nail size and distal tibia)** | | | | |
| Other fracture patterns | Reference | | | |
| Large nail and distal tibia | 0.998 | 0.000 | 0.000 | - |

**TABLE 6: Binary logistic regression between risk factors and nonunion.**

CI, confidence interval

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| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
|---|---|---|---|---|
| | | | Lower | Upper |
| Age | 0.465 | 1.013 | 0.978 | 1.049 |
| **Level of tibia fracture** | | | | |
| Midshaft | Reference | | | |
| Proximal | 0.859 | 1.279 | 0.085 | 19.354 |
| Distal | 0.925 | 0.938 | 0.246 | 3.578 |
| **Level of fibula fracture** | | | | |
| None | Reference | | | |
| Proximal | 1.000 | - | - | - |
| Midshaft | 1.000 | - | - | - |
| Distal | 1.000 | - | - | - |
| **Pattern of fibula fracture** | | | | |
| None | Reference | | | |
| Transverse | 1.000 | - | - | - |
| Oblique | 1.000 | - | - | - |
| Spiral | 1.000 | - | - | - |
| Segmental | 1.000 | - | - | - |
| Comminuted | 1.000 | - | - | - |
| **Hemoglobin** | 0.827 | 1.029 | 0.794 | 1.335 |
| **Days to operation** | 0.460 | 1.086 | 0.872 | 1.352 |
| **Days to weight-bearing** | 0.953 | 0.998 | 0.950 | 1.050 |
| **Distal fibula and tibia (combined subgroup)** | | | | |
| Other fracture patterns | Reference | | | |
| Distal tibia and fibula | 0.573 | 2.068 | 0.165 | 25.855 |
| **Same versus different levels of fracture** | | | | |
| Same level | Reference | | | |
| Different level | 0.728 | 0.688 | 0.083 | 5.677 |
| **Fibula fixed** | | | | |
| No | Reference | | | |
| Yes | 0.065 | 3.207 | 0.932 | 11.033 |

**TABLE 7: Binary logistic regression between risk factors and malunion.**

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| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
| --- | --- | --- | --- | --- |
| | | | Lower | Upper |
| **Age** | 0.990 | 1.000 | 0.970 | 1.032 |
| **Level of tibia fracture** | | | | |
| Midshaft | Reference | | | |
| Proximal | 0.130 | 0.180 | 0.019 | 1.661 |
| Distal | 0.014 | 0.285 | 0.105 | 0.773 |
| **Level of fibular fracture** | | | | |
| None | Reference | | | |
| Proximal | 0.864 | 0.863 | 0.161 | 4.622 |
| Midshaft | 0.496 | 1.661 | 0.386 | 7.152 |
| Distal | 0.036 | 3.778 | 1.092 | 13.070 |
| **Hemoglobin** | 0.095 | 0.818 | 0.646 | 1.036 |
| **Days to operation** | 0.903 | 0.990 | 0.844 | 1.162 |
| **Days to weight-bearing** | 0.546 | 1.013 | 0.972 | 1.055 |
| **Combined subgroup (distal fibula and tibia)** | | | | |
| Other fracture patterns | Reference | | | |
| Distal tibia and fibula | 0.620 | 1.362 | 0.402 | 4.619 |

**TABLE 8: Binary logistic regression between risk factors and delayed union.**

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| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
| --- | --- | --- | --- | --- |
| | | | Lower | Upper |
| **Age** | 0.615 | 1.008 | 0.978 | 1.038 |
| **Level of fibula fracture** | | | | |
| None | Reference | | | |
| Proximal | 0.960 | 0.966 | 0.249 | 3.751 |
| Midshaft | 0.354 | 2.139 | 0.429 | 10.673 |
| Distal | 0.076 | 3.035 | 0.890 | 10.345 |
| **Pattern of tibia fracture** | | | | |
| Transverse | Reference | | | |
| Oblique | 0.327 | 0.631 | 0.251 | 1.586 |
| Spiral | 0.478 | 0.728 | 0.302 | 1.751 |
| Segmental | 0.554 | 1.630 | 0.323 | 8.235 |
| Comminuted | 0.448 | 1.519 | 0.516 | 4.469 |
| **Hemoglobin** | 0.718 | 0.960 | 0.771 | 1.196 |
| **Days to operation** | 0.082 | 1.232 | 0.974 | 1.558 |
| **Days to weight-bearing** | 0.497 | 1.015 | 0.972 | 1.061 |
| **Distal fibula and tibia (combined subgroup)** | | | | |
| Other fracture patterns | Reference | | | |
| Distal tibia and fibula | 0.666 | 1.317 | 0.378 | 4.587 |
| **Nail size and distal tibia (combined subgroup)** | | | | |
| Other fracture patterns | Reference | | | |
| Large nail and distal tibia | 0.306 | 0.466 | 0.108 | 2.009 |
| **Same versus different levels of fracture** | | | | |
| Same level | Reference | | | |
| Different level | 0.868 | 0.915 | 0.318 | 2.630 |

**TABLE 9: Binary logistic regression between risk factors and complications.**

### Subgroup analysis

The authors conducted a subgroup analysis, excluding those who had no follow-up and were considered united, as outlined in the Materials and Methods section. These comprised 28 (14.8%) patients of the sample size. The authors repeated all the previous statistics after the exclusion. The results were then compared with previous analyses to validate the initial results.

The results of the primary analysis indicated that the majority of significant factors remained statistically significant even after the exclusion. Regression analysis, however, showed that the level of fibula fracture is no longer significantly associated with nonunion (OR = 3.502, $P = 0.101$), while the level of tibia fracture remained significantly associated with delayed union (OR = 0.3, $P = 0.015$). Level of hemoglobin (OR = 0.708, $P = 0.034$) and days to operation (OR = 1.208, $P = 0.034$) remained significantly correlated with nonunion. This may be attributed to the reduction of sample size and further studies are needed to determine this conclusively. The authors included all replicated analyses in the Appendices.

## Discussion

Optimal fracture healing has long been a unique challenge that every orthopedic provider is concerned with.

Various fracture patterns have been shown to influence the union rate independent of reduction and stabilization techniques [19]. This study aimed to examine the effect of fracture pattern and location on the rate of nonunion, malunion, and delayed union in tibia fractures treated with intramedullary nailing.

There remains a lack of consensus on the definitions of nonunion and delayed union [20]; various authors advocated different timeframes as suggestive of nonunion, ranging from as early as eight weeks to as late as nine months [13,21]. The significance of nonunion, however, is a point of agreement between orthopedic providers, with various studies demonstrating a significantly deleterious effect on patients' quality of life and a significant increase in healthcare costs [5,6].

While intramedullary nailing has long been established as an effective modality for treating extraarticular tibia fractures [22], our data suggest that it should be performed while paying particular attention to tibial and fibular fracture location. The data suggest that the presence of a distal fibular fracture should raise the attention of the surgeon to the increased likelihood of nonunion; however, further study is needed to validate this finding as this was not observed when excluding patients with no follow-up. Careful operative fixation of the fracture with optimization of reduction and consideration of using an autograft or bone-stimulating agents may be indicated [23,24]. The use of bone-stimulating agents should be balanced in light of their novelty and the controversy surrounding their efficacy [25]. A recent meta-analysis advocated the use of bone-stimulating agents in the acute setting, citing a higher rate of union and a reduced rate of revision surgery. This is a concept that may be difficult for orthopedic surgeons to adapt to initially but could find increasing acceptance as more evidence becomes available [26]. While these novel agents may not yet enjoy the full support of the orthopedic community, they certainly belong in the conversation that aims to tackle complex and serious clinical conditions, including tibia fracture nonunion.

Consideration of dynamic locking is probably prudent in certain fracture patterns that permit it. The data in this study suggest an increase in the need for subsequent dynamization in fractures with associated distal fibular fractures. If the tibia fracture pattern is axially stable, leaving the nail in dynamic or unlocked mode may facilitate healing and decrease the need for subsequent surgery to dynamize the nail [27].

It is also worth noting that the presence of both distal tibia and distal fibula fractures together significantly raises the risk of complications, according to the data explored in this study, which again places significant emphasis on extra careful consideration of methods of fixation in such fractures.

In the center where this study was conducted, it is standard practice to leave the fibula unfixed when using intramedullary nailing for tibial shaft fractures due to concerns about nonunion and varus malunion. It is interesting to note that fibular fixation appeared unrelated to malunion or nonunion in our study, a finding that is of great relevance to practice and may support leaving the fibula unfixed unless clinically indicated for other reasons. This must be opposed to evidence in recent studies that have shown that fixation of the fibula in distal third tibia fractures is not associated with increased complications and may serve to obtain better reduction and augment the tibial fixation [28]. The operating surgeon should exercise his judgment and individualize cases when deciding to fix the fibula in the distal one-third of fractures of the tibia.

The authors acknowledge some limitations of the study. A small proportion of the data collected was for patients who had inconsistent, infrequent, or sporadic follow-up. Patients with good evidence of union on follow-up postoperative X-rays, albeit incomplete radiological union that was subsequently lost to follow-up, were marked as united at the normal expected time of union. Patients with no evidence of union at nine months who had not received surgical intervention were labeled as persistent nonunions. The exclusion of patients with no follow-up reduced the sample size and may have affected the interpretation of initially significant results on primary analysis, the retrospective study design limited access to these excluded patients for further follow-up.

Patients who had poor follow-up are unlikely to be random as most patients who suffer tibia fractures are young expatriate workers in the setting of the study and patients with uneventful postoperative courses are more likely to be lost to follow-up when compared to those with complications. The authors have attempted to run the statistics twice to adjust for this and included subsequent results in the Appendices for reference. There are also confounding factors that cannot be controlled due to the retrospective study design - a limitation that is inherent to this type of study design.

This was a single-center study with a limited sample size, which may affect the interpretation of the data.

## Conclusions

The level and pattern of some tibia and fibula fractures were associated with nonunion, malunion, and delayed union. Orthopedics providers should consider additional fixation of fibula fractures, bone-healing stimulating agents, dynamic locking of nails, and overall meticulous care for alignment and reduction intraoperatively in selected high-risk fracture patterns. Further studies with close and regular follow-up are needed to clarify certain relationships that are nonsignificant after the exclusion of patients with no follow-up. Careful preoperative planning would be advised, particularly for patients with high-risk fracture

patterns.

# Appendices

| Risk factors | Subsequent dynamization | | Nonunion | | Malunion | |
|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No |
| | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) |
| Gender | | | | | | |
| Male | 11 (8.3) | 122 (91.7) | 33 (24.8) | 100 (75.2) | 33 (24.8) | 100 (75.2) |
| Female | 8 (28.6) | 20 (71.4) | 9 (32.1) | 19 (67.9) | 3 (10.7) | 25 (89.3) |
| P-value | 0.006[a] | | 0.422[b] | | 0.104[b] | |
| Comorbidities | | | | | | |
| Yes | 7 (25.9) | 20 (74.1) | 9 (33.3) | 18 (66.7) | 5 (18.5) | 22 (81.5) |
| No | 12 (9) | 122 (91) | 33 (24.6) | 101 (75.4) | 31 (23.1) | 103 (76.9) |
| P-value | 0.021[a] | | 0.347[b] | | 0.599[b] | |
| Level of tibia fracture | | | | | | |
| Proximal | 2 (15.4) | 11 (84.6) | 2 (15.4) | 11 (84.6) | 2 (15.4) | 11 (84.6) |
| Midshaft | 5 (9.4) | 48 (90.6) | 18 (34) | 35 (66) | 8 (15.1) | 45 (84.9) |
| Distal | 12 (12.6) | 83 (87.4) | 22 (23.2) | 73 (76.8) | 26 (27.4) | 69 (72.6) |
| P-value | 0.775[b] | | 0.235[b] | | 0.187[b] | |
| Level of fibula fracture | | | | | | |
| Proximal | 4 (10.5) | 34 (89.5) | 3 (7.9) | 35 (92.1) | 5 (13.2) | 33 (86.8) |
| Midshaft | 2 (6.7) | 28 (93.3) | 6 (20) | 24 (80) | 4 (13.3) | 26 (86.7) |
| Distal | 12 (16.9) | 59 (83.1) | 29 (40.8) | 42 (59.2) | 25 (35.2) | 46 (64.8) |
| None | 1 (4.5) | 21 (95.5) | 4 (18.2) | 18 (81.8) | 2 (9.1) | 20 (90.9) |
| P-value | - | | 0.001[b] | | 0.007[b] | |
| Pattern of tibia fracture | | | | | | |
| Transverse | 6 (13.6) | 38 (86.4) | 13 (29.5) | 31 (70.5) | 9 (20.5) | 35 (79.5) |
| Oblique | 4 (13.3) | 26 (86.7) | 6 (20) | 24 (80) | 7 (23.3) | 23 (76.7) |
| Spiral | 6 (11.3) | 47 (88.7) | 9 (17) | 44 (83) | 10 (18.9) | 43 (81.1) |
| Segmental | 0 (0) | 9 (100) | 3 (33.3) | 6 (66.7) | 2 (22.2) | 7 (77.8) |
| Comminuted | 3 (12) | 22 (88) | 11 (44) | 14 (56) | 8 (32) | 17 (68) |
| P-value | -------- | | 0.110[b] | | 0.769[b] | |
| Pattern of fibula fracture | | | | | | |
| Transverse | 8 (12.5) | 56 (87.5) | 20 (31.3) | 44 (68.8) | 14 (21.9) | 50 (78.1) |
| Oblique | 4 (21.1) | 15 (78.9) | 4 (21.1) | 15 (78.9) | 3 (15.8) | 16 (84.2) |
| Spiral | 5 (16.1) | 26 (83.9) | 6 (19.4) | 25 (80.6) | 8 (25.8) | 23 (74.2) |
| Segmental | 1 (10) | 9 (90) | 3 (30) | 7 (70) | 3 (30) | 7 (70) |
| Comminuted | 0 (0) | 15 (100) | 5 (33.3) | 10 (66.7) | 6 (40) | 9 (60) |
| None | 1 (4.5) | 21 (95.5) | 4 (18.2) | 18 (81.8) | 2 (9.1) | 20 (90.9) |

| | | | | | | |
|---|---|---|---|---|---|---|
| *P*-value | - | | - | | - | |
| **Size of nail in mm** | | | | | | |
| 8.5 | 2 (10.5) | 17 (89.5) | 6 (31.6) | 13 (68.4) | 7 (36.8) | 12 (63.2) |
| 10 | 12 (12.4) | 85 (87.6) | 28 (28.9) | 69 (71.1) | 19 (19.6) | 78 (80.4) |
| 11.5 | 5 (11.1) | 40 (88.9) | 8 (17.8) | 37 (82.2) | 10 (22.2) | 35 (77.8) |
| *P*-value | 0.961[b] | | 0.317[b] | | 0.256[b] | |
| **Lock of nail** | | | | | | |
| Static | 19 (12.5) | 133 (87.5) | 39 (25.7) | 113 (74.3) | 33 (21.7) | 119 (78.3) |
| Dynamic | 0 (0) | 9 (100) | 3 (33.3) | 6 (66.7) | 3 (33.3) | 6 (66.7) |
| *P*-value | 0.600[a] | | 0.698[a] | | 0.420[a] | |
| **Distal fibula and tibia** | | | | | | |
| Other fracture patterns | 10 (10.9) | 82 (89.1) | 18 (19.6) | 74 (80.4) | 12 (13) | 80 (87) |
| Distal tibia and fibula | 9 (13) | 60 (87) | 24 (34.8) | 45 (65.2) | 24 (34.8) | 45 (65.2) |
| *P*-value | 0.672[b] | | 0.030[b] | | 0.001[b] | |
| **Only distal third tibia** | | | | | | |
| Other tibial patterns | 13 (12) | 95 (88) | 33 (30.6) | 75 (69.4) | 26 (24.1) | 82 (75.9) |
| Distal tibia fracture | 6 (11.3) | 47 (88.7) | 9 (17) | 44 (83) | 10 (18.9) | 43 (81.1) |
| *P*-value | 0.895[b] | | 0.065[b] | | 0.456[b] | |
| **Large or small nail** | | | | | | |
| Small nail | 14 (12.1) | 102 (87.9) | 34 (29.3) | 82 (70.7) | 26 (22.4) | 90 (77.6) |
| Large nail | 5 (11.1) | 40 (88.9) | 8 (17.8) | 37 (82.2) | 10 (22.2) | 35 (77.8) |
| *P*-value | 0.866[b] | | 0.135[b] | | 0.979[b] | |
| **Nail size and distal tibia** | | | | | | |
| Other fracture patterns | 16 (11) | 130 (89) | 42 (28.8) | 104 (71.2) | 34 (23.3) | 112 (76.7) |
| Large nail and distal tibia | 3 (20) | 12 (80) | 0 (0) | 15 (100) | 2 (13.3) | 13 (86.7) |
| *P*-value | 0.390[a] | | 0.012[a] | | 0.524[a] | |
| **Same versus different** | | | | | | |
| Same level | 12 (12.8) | 82 (87.2) | 28 (29.8) | 66 (70.2) | 29 (30.9) | 65 (69.1) |
| Different level | 7 (10.4) | 60 (89.6) | 14 (20.9) | 53 (79.1) | 7 (10.4) | 60 (89.6) |
| *P*-value | 0.653[b] | | 0.205[b] | | 0.002[b] | |
| **Fibula fixed** | | | | | | |
| Yes | 2 (14.3) | 12 (85.7) | 6 (42.9) | 8 (57.1) | 8 (57.1) | 6 (42.9) |
| No | 17 (12.8) | 116 (87.2) | 34 (25.6) | 99 (74.4) | 28 (21.1) | 105 (78.9) |
| *P*-value | 1.000[a] | | 0.207[a] | | 0.006[a] | |
| **Open fracture** | | | | | | |
| Yes | 6 (22.2) | 21 (77.8) | 11 (40.7) | 16 (59.3) | 9 (33.3) | 18 (66.7) |
| No | 13 (9.7) | 121 (90.3) | 31 (23.1) | 103 (76.9) | 27 (20.1) | 107 (79.9) |
| *P*-value | 0.096[a] | | 0.057[b] | | 0.134[b] | |

**TABLE 10: Association between risk factors and each of subsequent dynamization, nonunion, and malunion (exclusion done).**

[a]Fisher's exact test.

[b]Chi-square test.

| Risk factors | Delayed union | | Persistent nonunion | | Complications | |
|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No |
| | n (%) | n (%) | n (%) | n (%) | n (%) | n (%) |
| Gender | | | | | | |
| Male | 44 (33.1) | 89 (66.9) | 9 (6.8) | 124 (93.2) | 70 (52.6) | 63 (47.4) |
| Female | 10 (35.7) | 18 (64.3) | 1 (3.6) | 27 (96.4) | 15 (53.6) | 13 (46.4) |
| P-value | 0.789[b] | | 1.000[a] | | 0.928[b] | |
| Comorbidities | | | | | | |
| Yes | 9 (33.3) | 18 (66.7) | 2 (7.4) | 25 (92.6) | 16 (59.3) | 11 (40.7) |
| No | 45 (33.6) | 89 (66.4) | 8 (6) | 126 (94) | 69 (51.5) | 65 (48.5) |
| P-value | 0.980[b] | | 0.675[a] | | 0.461[b] | |
| Level of tibia fracture | | | | | | |
| Proximal | 1 (7.7) | 12 (92.3) | 1 (7.7) | 12 (92.3) | 5 (38.5) | 8 (61.5) |
| Midshaft | 24 (45.3) | 29 (54.7) | 4 (7.5) | 49 (92.5) | 30 (56.6) | 23 (43.4) |
| Distal | 29 (30.5) | 66 (69.5) | 5 (5.3) | 90 (94.7) | 50 (52.6) | 45 (47.4) |
| P-value | 0.023[b] | | - | | 0.501[b] | |
| Level of fibula fracture | | | | | | |
| Proximal | 5 (13.2) | 33 (86.8) | 0 (0) | 38 (100) | 12 (31.6) | 26 (68.4) |
| Midshaft | 12 (40) | 18 (60) | 3 (10) | 27 (90) | 16 (53.3) | 14 (46.7) |
| Distal | 32 (45.1) | 39 (54.9) | 5 (7) | 66 (93) | 49 (69) | 22 (31) |
| None | 5 (22.7) | 17 (77.3) | 2 (9.1) | 20 (90.9) | 8 (36.4) | 14 (63.6) |
| P-value | 0.005[b] | | - | | 0.001[b] | |
| Pattern of tibia fracture | | | | | | |
| Transverse | 18 (40.9) | 26 (59.1) | 3 (6.8) | 41 (93.2) | 25 (56.8) | 19 (43.2) |
| Oblique | 9 (30) | 21 (70) | 1 (3.3) | 29 (96.7) | 14 (46.7) | 16 (53.3) |
| Spiral | 14 (26.4) | 39 (73.6) | 1 (1.9) | 52 (98.1) | 21 (39.6) | 32 (60.4) |
| Segmental | 2 (22.2) | 7 (77.8) | 1 (11.1) | 8 (88.9) | 6 (66.7) | 3 (33.3) |
| Comminuted | 11 (44) | 14 (56) | 4 (16) | 21 (84) | 19 (76) | 6 (24) |
| P-value | 0.381[b] | | - | | 0.032[b] | |
| Pattern of fibula fracture | | | | | | |
| Transverse | 24 (37.5) | 40 (62.5) | 5 (7.8) | 59 (92.2) | 37 (57.8) | 27 (42.2) |
| Oblique | 4 (21.1) | 15 (78.9) | 1 (5.3) | 18 (94.7) | 8 (42.1) | 11 (57.9) |
| Spiral | 9 (29) | 22 (71) | 0 (0) | 31 (100) | 14 (45.2) | 17 (54.8) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Segmental | 3 (30) | 7 (70) | 2 (20) | 8 (80) | 7 (70) | 3 (30) |
| Comminuted | 8 (53.3) | 7 (46.7) | 0 (0) | 15 (100) | 10 (66.7) | 5 (33.3) |
| None | 6 (27.3) | 16 (72.7) | 2 (9.1) | 20 (90.9) | 9 (40.9) | 13 (59.1) |
| *P*-value | 0.399[b] | | - | | 0.323[b] | |
| Size of nail in mm | | | | | | |
| 8.5 | 5 (26.3) | 14 (73.7) | 1 (5.3) | 18 (94.7) | 11 (57.9) | 8 (42.1) |
| 10 | 32 (33) | 65 (67) | 8 (8.2) | 89 (91.8) | 50 (51.5) | 47 (48.5) |
| 11.5 | 17 (37.8) | 28 (62.2) | 1 (2.2) | 44 (97.8) | 24 (53.3) | 21 (46.7) |
| *P*-value | 0.663[b] | | - | | 0.876[b] | |
| Lock of nail | | | | | | |
| Static | 49 (32.2) | 103 (67.8) | 10 (6.6) | 142 (93.4) | 78 (51.3) | 74 (48.7) |
| Dynamic | 5 (55.6) | 4 (44.4) | 0 (0) | 9 (100) | 7 (77.8) | 2 (22.2) |
| *P*-value | 0.164[a] | | 1.000[a] | | 0.174[a] | |
| Distal fibula and tibia | | | | | | |
| Other fracture patterns | 26 (28.3) | 66 (71.7) | 4 (4.3) | 88 (95.7) | 39 (42.4) | 53 (57.6) |
| Distal tibia and fibula | 28 (40.6) | 41 (59.4) | 6 (8.7) | 63 (91.3) | 46 (66.7) | 23 (33.3) |
| *P*-value | 0.101[b] | | 0.329[a] | | 0.002[b] | |
| Only distal third tibia | | | | | | |
| Other tibial patterns | 40 (37) | 68 (63) | 9 (8.3) | 99 (91.7) | 64 (59.3) | 44 (40.7) |
| Distal tibia fracture | 14 (26.4) | 39 (73.6) | 1 (1.9) | 52 (98.1) | 21 (39.6) | 32 (60.4) |
| *P*-value | 0.180[b] | | 0.168[a] | | 0.019[b] | |
| Large or small nail | | | | | | |
| Small nail | 37 (31.9) | 79 (68.1) | 9 (7.8) | 107 (92.2) | 61 (52.6) | 55 (47.4) |
| Large nail | 17 (37.8) | 28 (62.2) | 1 (2.2) | 44 (97.8) | 24 (53.3) | 21 (46.7) |
| *P*-value | 0.478[b] | | 0.285[a] | | 0.932[b] | |
| Nail size and distal tibia | | | | | | |
| Other fracture patterns | 52 (35.6) | 94 (64.4) | 10 (6.8) | 136 (93.2) | 82 (56.2) | 64 (43.8) |
| Large nail and distal tibia | 2 (13.3) | 13 (86.7) | 0 (0) | 15 (100) | 3 (20) | 12 (80) |
| *P*-value | 0.082[b] | | 0.600[a] | | 0.008[b] | |
| Same versus different | | | | | | |
| Same level | 35 (37.2) | 59 (62.8) | 8 (8.5) | 86 (91.5) | 59 (62.8) | 35 (37.2) |
| Different level | 19 (28.4) | 48 (71.6) | 2 (3) | 65 (97) | 26 (38.8) | 41 (61.2) |
| *P*-value | 0.240[b] | | 0.196[a] | | 0.003[b] | |
| Fibula fixed | | | | | | |
| Yes | 5 (35.7) | 9 (64.3) | 1 (7.1) | 13 (92.9) | 10 (71.4) | 4 (28.6) |
| No | 44 (33.1) | 89 (66.9) | 8 (6) | 125 (94) | 69 (51.9) | 64 (48.1) |
| *P*-value | 1.000[a] | | 1.000[a] | | 0.163[b] | |
| Open fracture | | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Yes | 9 (33.3) | 18 (66.7) | 4 (14.8) | 23 (85.2) | 17 (63) | 10 (37) |
| No | 45 (33.6) | 89 (66.4) | 6 (4.5) | 128 (95.5) | 68 (50.7) | 66 (49.3) |
| P-value | 0.980[b] | | 0.065[a] | | 0.246[b] | |

**TABLE 11: Association between risk factors and each of delayed union, persistent nonunion, and complications (exclusion done).**

[a]Fisher's exact test.

[b]Chi-square test.

| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
|---|---|---|---|---|
| | | | Lower | Upper |
| Age | 0.377 | 0.983 | 0.948 | 1.021 |
| Level of fibula fracture | | | | |
| None | Reference | | | |
| Proximal | 0.228 | 0.319 | 0.050 | 2.045 |
| Midshaft | 0.885 | 0.885 | 0.168 | 4.652 |
| Distal | 0.101 | 3.502 | 0.782 | 15.692 |
| Pattern of tibia fracture | | | | |
| Transverse | Reference | | | |
| Oblique | 0.459 | 0.627 | 0.182 | 2.157 |
| Spiral | 0.653 | 0.769 | 0.245 | 2.412 |
| Segmental | 0.627 | 0.642 | 0.107 | 3.844 |
| Comminuted | 0.805 | 1.167 | 0.341 | 3.990 |
| Hemoglobin | 0.034 | 0.708 | 0.514 | 0.974 |
| Days to operation | 0.034 | 1.208 | 1.014 | 1.439 |
| Days to weight bearing | 0.183 | 1.035 | 0.984 | 1.090 |
| Distal fibula and tibia | | | | |
| Other fracture patterns | Reference | | | |
| Distal tibia and fibula | 0.316 | 0.519 | 0.144 | 1.871 |
| Nail size and distal tibia | | | | |
| Other fracture patterns | Reference | | | |
| Large nail and distal tibia | 0.998 | 0.000 | 0.000 | - |

**TABLE 12: Binary logistic regression between risk factors and nonunion (exclusion done).**

CI, confidence interval

| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
| --- | --- | --- | --- | --- |
| | | | Lower | Upper |
| Age | 0.746 | 1.006 | 0.971 | 1.042 |
| Level of fibula fracture | | | | |
| None | Reference | | | |
| Proximal | 0.463 | 0.432 | 0.046 | 4.057 |
| Midshaft | 0.340 | 0.259 | 0.016 | 4.155 |
| Distal | 0.722 | 0.692 | 0.091 | 5.267 |
| Hemoglobin | 0.751 | 0.956 | 0.725 | 1.261 |
| Days to operation | 0.661 | 1.052 | 0.838 | 1.322 |
| Days to weight bearing | 0.891 | 1.004 | 0.953 | 1.056 |
| Distal fibula and tibia | | | | |
| Other fracture patterns | Reference | | | |
| Distal tibia and fibula | 0.930 | 1.095 | 0.146 | 8.205 |
| Same versus different | | | | |
| Same level | Reference | | | |
| Different level | 0.236 | 0.378 | 0.076 | 1.886 |
| Fibula fixed | | | | |
| No | Reference | | | |
| Yes | 0.060 | 3.247 | 0.953 | 11.066 |

**TABLE 13: Binary logistic regression between risk factors and malunion (exclusion done).**

| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
| --- | --- | --- | --- | --- |
| | | | Lower | Upper |
| Age | 0.729 | 0.994 | 0.962 | 1.027 |
| Level of tibia fracture | | | | |
| Midshaft | Reference | | | |
| Proximal | 0.108 | 0.156 | 0.016 | 1.500 |
| Distal | 0.015 | 0.300 | 0.114 | 0.789 |
| Level of fibula fracture | | | | |
| None | Reference | | | |
| Proximal | 0.434 | 0.553 | 0.126 | 2.435 |
| Midshaft | 0.802 | 1.187 | 0.310 | 4.539 |
| Distal | 0.079 | 3.115 | 0.876 | 11.084 |
| Hemoglobin | 0.073 | 0.793 | 0.615 | 1.022 |
| Days to operation | 0.605 | 0.955 | 0.801 | 1.138 |
| Days to weight bearing | 0.241 | 1.029 | 0.981 | 1.079 |

**TABLE 14: Binary logistic regression between risk factors and delayed union (exclusion done).**

| Risk factors | P-value | Odds ratio | 95% CI for odds ratio | |
| --- | --- | --- | --- | --- |
| | | | Lower | Upper |
| Age | 0.795 | 0.996 | 0.964 | 1.029 |
| Level of fibula fracture | | | | |
| None | Reference | | | |
| Proximal | 0.871 | 0.883 | 0.195 | 4.004 |
| Midshaft | 0.404 | 2.181 | 0.349 | 13.635 |
| Distal | 0.171 | 2.581 | 0.665 | 10.014 |
| Pattern of tibia fracture | | | | |
| Transverse | Reference | | | |
| Oblique | 0.402 | 0.647 | 0.234 | 1.788 |
| Spiral | 0.620 | 0.779 | 0.290 | 2.091 |
| Segmental | 0.974 | 1.028 | 0.193 | 5.477 |
| Comminuted | 0.406 | 1.680 | 0.494 | 5.712 |
| Hemoglobin | 0.224 | 0.854 | 0.662 | 1.102 |
| Days to operation | 0.129 | 1.210 | 0.946 | 1.547 |
| Days to weight bearing | 0.151 | 1.045 | 0.984 | 1.109 |
| Distal fibula and tibia | | | | |
| Other fracture patterns | Reference | | | |
| Distal tibia and fibula | 0.583 | 1.476 | 0.368 | 5.918 |
| Nail size and distal tibia | | | | |
| Other fracture patterns | Reference | | | |
| Large nail and distal tibia | 0.212 | 0.381 | 0.084 | 1.736 |
| Same versus different | | | | |
| Same level | Reference | | | |
| Different level | 0.860 | 0.901 | 0.281 | 2.885 |

**TABLE 15: Binary logistic regression between risk factors and complications (exclusion done).**

## Additional Information

### Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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## Disclosures

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