

## Original Research Article

# Simultaneous debridement, soft tissue coverage and application of Ilizarov ring external fixator in the management of open complex limb injuries

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## ABSTRACT

**Background:** Open complex limb injuries with significant bone and soft tissue defects present substantial reconstructive challenges. Traditional staged management prolongs recovery and increases complication risks. This study evaluated the outcomes of simultaneous debridement, soft tissue coverage, and Ilizarov ring external fixation in managing such injuries.

**Methods:** This quasi-experimental study was conducted at NITOR, Dhaka, from March 2023 to September 2025. Thirty-five patients with open complex limb injuries underwent single-stage debridement, Ilizarov fixation, and soft tissue coverage. Outcomes assessed included radiological union, complications, and bone and functional results using ASAMI criteria.

**Results:** The mean age was  $35.2 \pm 10.35$  years, with males predominating (89%). Motor vehicle accidents were the leading cause (86%). Radiological union was achieved in 94.3% ( $n=33$ ) at a mean of  $6.61 \pm 0.93$  months. Complications occurred in 11.4% ( $n=4$ ), with pin tract infection being most common (8.6%). According to ASAMI criteria, excellent bone outcomes were seen in 60% and functional outcomes in 60%. Complete flap survival was observed in 62.9% ( $n=22$ ), with no total flap failures. The mean soft tissue defect size was  $76.74 \pm 34.54$  cm<sup>2</sup>.

**Conclusions:** Simultaneous debridement, soft tissue coverage, and Ilizarov reconstruction is a safe and effective strategy for open complex limb injuries, achieving high union rates, acceptable complications, and favorable functional outcomes.

**Keywords:** External fixation, Ilizarov technique, Limb salvage, Open complex limb injuries, Soft tissue coverage

## INTRODUCTION

The tibia is one of the largest bones in the body and serves as a major weight-bearing bone in the lower limb.<sup>1</sup> Its position, structure, and limited soft tissue coverage on the anteromedial side make it prone to injury.<sup>2,3</sup>

Globally, the incidence of open fractures is increasing, especially in low- and middle-income countries.<sup>4</sup> Open fractures of long bones occur at a rate of approximately 11.5 per 100,000 people annually.<sup>5</sup> Tibial fractures are the

most frequent among long bone fractures, with about a quarter being open injuries.<sup>6</sup> These open fractures often occur in the middle third of the tibia.<sup>7</sup> The annual incidence of open tibial shaft fractures is 3.4 per 100,000 individuals, showing two peaks in young men and older women.<sup>8</sup> Nearly 45% of these open fractures are classified as Gustilo-Anderson type III, which involve contaminated wounds larger than 10 cm.<sup>9</sup>

High-energy trauma, primarily from road traffic accidents and falls, accounts for over half of these injuries.<sup>10</sup>

Compared to closed fractures, open fractures carry a much higher risk of infection, non-union, and wound healing problems, often necessitating multiple surgical interventions.<sup>11,12</sup> Infection occurs because the skin barrier is compromised when injured, allowing microbes to invade underlying tissues.<sup>13</sup>

Open tibial fractures are complex injuries with varied outcomes, often resulting in extended hospital stays and higher injury severity scores.<sup>14</sup> The severity grading of these fractures plays a crucial role in guiding treatment and predicting patient outcomes.<sup>15</sup> The Gustilo and Anderson system categorizes open fractures based on the extent of soft tissue damage and evaluates its correlation with infection risk.<sup>16</sup>

A GIIIB open tibial shaft fracture represents a high-energy injury characterized by extensive periosteal stripping and significant loss of skin and muscle, requiring soft tissue reconstruction.<sup>17,18</sup> Treating severely injured limbs remains a significant challenge for orthopedic surgeons due to increased risks of limb loss, nonunion, infection, multiple surgeries, and psychological issues.<sup>19</sup> Patients with open lower extremity injuries must be evaluated initially following the advanced trauma life support (ATLS) protocol.<sup>10</sup>

The standard approach to managing open fractures includes thorough assessment, antibiotics and tetanus prophylaxis, surgical debridement with irrigation, fracture stabilization, soft tissue closure, rehabilitation, and follow-up. Surgeons may also use adjunct treatments such as local antibiotics, vacuum-assisted closure, free tissue transfer, or bone grafting.<sup>15,20,21</sup> Optimal results require a multidisciplinary approach.<sup>22</sup> Current treatment options include casting, plating, intramedullary nailing, and external fixation.<sup>23,24</sup> For Gustilo IIIB fractures, reconstructive techniques commonly involve skin grafts, local flaps, and free tissue transfer.<sup>25</sup>

Due to limited blood supply and insufficient soft tissue around the tibial shaft, these fractures are particularly prone to non-union and infection.<sup>26</sup> While grade I and II wounds can be safely closed after debridement, the optimal method for grade III open fractures remains controversial.<sup>12</sup> Managing Gustilo IIIB tibial fractures is challenging due to high complication rates, with infection risk as high as 52%.<sup>14</sup>

The Ilizarov method uses a circular external fixator with rings accepting K-wires or half pins that provide stable fixation while allowing axial micromotion, promoting bone regeneration.<sup>27,28</sup> It permits three-dimensional correction of deformities while resisting shear forces, creating an optimal environment for healing. However, drawbacks include pin tract infections, patient discomfort, bulky equipment, and complex assembly.<sup>27-29</sup>

A common trend is to perform osteosynthesis first while postponing wound closure.<sup>30</sup> This is challenging in

developing countries like Bangladesh, where late presentation, inadequate facilities, and poor hygiene affect outcomes.<sup>18</sup> The BOA and BAPRAS recommend debridement within 24 hours and definitive coverage within 72 hours.<sup>31</sup> A single-stage “fix and flap” approach has demonstrated improved outcomes with lower infection rates compared to staged procedures.<sup>32</sup> Nonetheless, several aspects remain debated.<sup>33</sup> So, this study aimed to assess the functional outcome of simultaneous debridement, soft tissue coverage, and Ilizarov reconstruction in the management of open complex limb injuries.

## METHODS

This quasi-experimental study was conducted at the National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, Bangladesh, from March 2023 to September 2025 to evaluate the outcomes of simultaneous radical debridement, soft tissue coverage, and Ilizarov ring external fixation for open complex limb injuries. Using a non-randomized purposive sampling technique, a calculated sample size of 35 patients was enrolled, accounting for an anticipated 10% follow-up loss.

Eligible participants included patients of both genders, aged 11 to 60 years, presenting within three weeks of sustaining an open complex limb injury involving any long bone (tibia, femur, humerus, or forearm) with significant bone and soft tissue defects requiring Ilizarov reconstruction. The tibia was the most commonly involved bone in this series. Conversely, individuals presenting with major neurovascular injuries, pathological fractures, polytrauma, fractures extending into the joints of the same limb, or involvement of the metaphyseal or epiphyseal portions of the bone were excluded. Following the single-stage intervention, a structured postoperative rehabilitation protocol was implemented, consisting of daily isometric and range-of-motion exercises combined with progressive, stability-dependent weight-bearing ambulation. Regular follow-up assessments monitored wound healing, flap viability, and progressive bone union. Comprehensive demographic, injury, treatment, and complication variables were documented using a pre-tested questionnaire, with final bone and functional outcomes quantified according to the Association for the Study and Application of Methods of Ilizarov (ASAMI) criteria. All collected data were processed using SPSS version 26. Ethical clearance was granted by the Institutional Review Board of NITOR, and voluntary, written informed consent was obtained from all participants before enrollment in strict compliance with the ethical tenets of the Declaration of Helsinki.

## RESULTS

Table 1 shows the distribution of patients based on age. The participants ranged from 18 to 55 years, with a mean age of  $35.2 \pm 10.35$  years. The majority of patients (31.4%)

were in the 31-40 years age group, followed by 25.7% in the 41-50 years group and 22.9% in the 21-30 years group. A smaller proportion of patients belonged to the 11-20 years (11.4%) and 51-60 years (8.6%) age groups.

**Table 1: Age distribution of the study patients (n=35).**

| Age (in years) | Frequency         | Percentage |
|----------------|-------------------|------------|
| 11-20          | 4                 | 11.4       |
| 21-30          | 8                 | 22.9       |
| 31-40          | 11                | 31.4       |
| 41-50          | 9                 | 25.7       |
| 51-60          | 3                 | 8.6        |
| <b>Total</b>   | <b>35</b>         | <b>100</b> |
| <b>Mean±SD</b> | <b>35.2±10.35</b> |            |
| <b>Range</b>   | <b>18-55</b>      |            |

In this study, motor vehicle accident accounted for 30 (86%) cases which was the most common cause of injury. Fall from height was accounted for 5 (14%) cases (Figure 1).

Out of the total cases, 21 (60%) involved the right side, while 14 (40%) involved the left side (Figure 2).

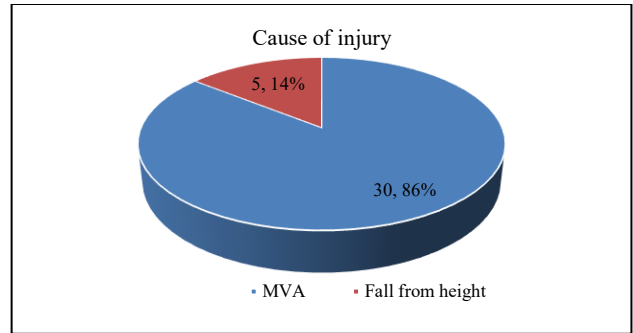


**Table 1: Age distribution of patients.**

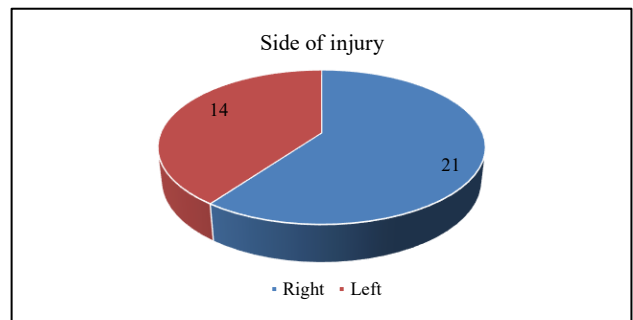


**Figure 2: Distribution of cases according to side of injury (n=35).**

**Table 2: Duration of radiological union among patients (n=35).**

| Duration of radiological union (months) | Frequency | Percentage | Mean±SD          |
|-----------------------------------------|-----------|------------|------------------|
| <b>Not united</b>                       | 2         | 5.7        | 6.61±0.93 months |
| <b>Union</b>                            | 33        | 94.3       |                  |
| <b>5-7 months</b>                       | 29        | 82.9       |                  |
| <b>8-10 months</b>                      | 4         | 11.4       |                  |

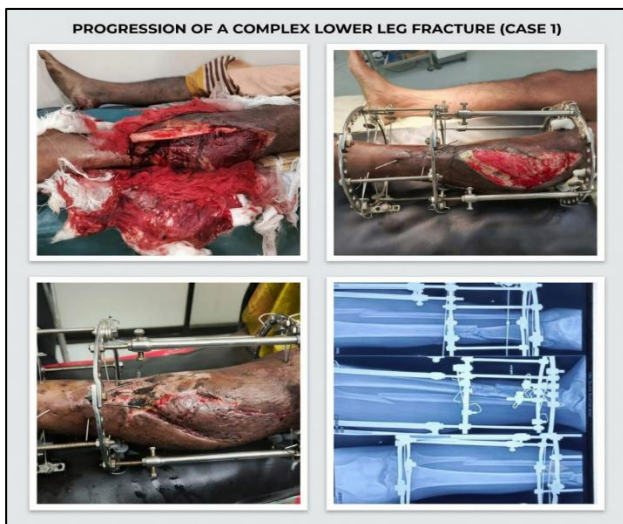


**Figure 3: Serial management of an open complex tibia fracture using single-stage Ilizarov fixation and simultaneous soft tissue coverage (case 1).**

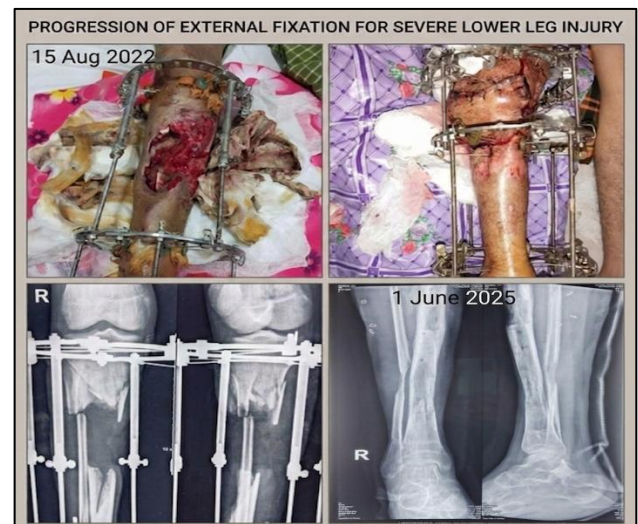


**Figure 4: Reconstruction progression of a severe grade IIIB open leg injury with composite bone and soft tissue loss (case 2).**

Table 2 summarizes the duration required to achieve radiological union in the study population. Among the 35 patients, 94.3% (n=33) achieved union, while 5.7% (n=2) remained ununited. The majority of patients (82.9%, n=29) attained union within 5 to 7 months, and the remaining 11.4% (n=4) did so between 8 to 10 months. The mean time to radiological union was  $6.61 \pm 0.93$  months.

**Table 3: Postoperative complications at final follow-up (n=35).**

| Complication at last follow up | Frequency | Percentage |
|--------------------------------|-----------|------------|
| <b>Absent</b>                  | 31        | 88.6       |
| <b>Present</b>                 | 4         | 11.4       |
| <b>Pin tract infection</b>     | 3         | 8.6        |
| <b>Wire loosening</b>          | 1         | 2.9        |

**Table 3: Bone outcome according to ASAMI criteria at final follow-up (n=35).**

| Bone outcome at last follow up | Frequency | Percentage |
|--------------------------------|-----------|------------|
| <b>Excellent</b>               | 21        | 60         |
| <b>Good</b>                    | 9         | 25.7       |
| <b>Fair</b>                    | 2         | 5.7        |
| <b>Poor</b>                    | 3         | 8.6        |
| <b>Total</b>                   | 35        | 100        |

Table 3 outlines the complications observed at the last follow-up. The majority of patients (88.6%, n=31) had no postoperative complications. However, 11.4% (n=4) experienced complications, with pin tract infection being

the most common (8.6%, n=3), followed by wire loosening in 1 patient (2.9%).

Table 4 shows the distribution of bone outcomes assessed using the ASAMI criteria. The majority of patients had favorable outcomes, with 60% (n=21) classified as excellent and 25.7% (n=9) as good. Fair results were seen in 5.7% (n=2) of cases, while 8.6% (n=3) had poor outcomes.

**Table 5: Functional outcome according to ASAMI criteria at final follow-up (n=35).**

| Functional outcome at last follow up | Frequency | Percentage |
|--------------------------------------|-----------|------------|
| <b>Excellent</b>                     | 21        | 60         |
| <b>Good</b>                          | 9         | 25.7       |
| <b>Fair</b>                          | 2         | 5.7        |
| <b>Poor</b>                          | 3         | 8.6        |
| <b>Total</b>                         | 35        | 100        |

Table 5 summarizes the functional outcomes of patients based on the ASAMI criteria. At final follow-up, 60% (n=21) of patients had an excellent outcome, while 25.7% (n=9) achieved good results. Fair and poor outcomes were seen in 5.7% (n=2) and 8.6% (n=3) of cases, respectively.

Table 6 presents the soft tissue defect dimensions among the study patients. The majority had defect sizes between 51-80 cm<sup>2</sup> (31.4%, n=11) and 81-110 cm<sup>2</sup> (28.6%, n=10). Defects measuring 21-50 cm<sup>2</sup> were found in 25.7% (n=9) of patients, while the largest defects, ranging from 111-150 cm<sup>2</sup>, were observed in 14.3% (n=5). The mean defect size was  $76.74 \pm 34.54$  cm<sup>2</sup>, with a range from 24 to 150 cm<sup>2</sup>.

**Table 6: Distribution of patients according to defect dimension (cm<sup>2</sup>) (n=35).**

| Defect dimension (cm <sup>2</sup> ) | Frequency | Percentage | Mean $\pm$ SD (cm <sup>2</sup> ) | Range     |
|-------------------------------------|-----------|------------|----------------------------------|-----------|
| <b>21-50</b>                        | 9         | 25.7       | 76.74 $\pm$ 34.54                | 24 to 150 |
| <b>51-80</b>                        | 11        | 31.4       |                                  |           |
| <b>81-110</b>                       | 10        | 28.6       |                                  |           |
| <b>111-150</b>                      | 5         | 14.3       |                                  |           |
| <b>Total</b>                        | 35        | 100        |                                  |           |

**Table 7: Distribution of patients according to flap status at final follow-up (n=35).**

| Flap status                   | Frequency | Percentage |
|-------------------------------|-----------|------------|
| <b>Completely survived</b>    | 22        | 62.9       |
| <b>Partial necrosis</b>       | 1         | 2.9        |
| <b>Marginal flap necrosis</b> | 12        | 34.3       |
| <b>Total</b>                  | 35        | 100        |

Table 7 shows the distribution of flap status at the final follow-up. Complete flap survival was observed in 62.9% (n=22) of cases. Marginal flap necrosis occurred in 34.3%

(n=12), while partial necrosis was seen in 2.9% (n=1) of patients. No cases of complete flap loss were recorded.

## DISCUSSION

In the present study, participants ranged in age from 18 to 55 years, with a mean age of  $35.2 \pm 10.35$  years. The largest group (31.4%) was between 31 and 40 years old, followed by 25.7% in the 41-50-year range and 22.9% in the 21-30 years category. Smaller proportions were observed in the 11-20 years (11.4%) and 51-60 years (8.6%) groups. These findings are comparable to those of Abula et al, who reported an average age of 35.5 years (range 18-54), and

Singh et al, with a mean age of 35.3 years (range 18-60).<sup>18,34</sup> Cullen et al, and Aljawadi et al, reported slightly higher mean ages of 41.5 years (SD=18.3) and 43 years (range 10-96), respectively.<sup>5,32</sup> This pattern suggests that middle-aged adults are the most affected or engaged group in this context, likely reflecting a higher risk profile, increased healthcare-seeking behavior, or greater exposure to relevant risk factors within this age bracket. In the present study, the majority of participants were male, accounting for 89% (n=31), while females made up only 11% (n=3). This male predominance is consistent with several previous studies. In the current study, motor vehicle accidents were the leading cause of injury, accounting for 86% (n=30) of cases, while falls from height comprised 14% (n=5). This trend aligns with other research findings.

Abula et al, reported 6 motor vehicle accidents, 5 motorcycle accidents, and 3 falls from height.<sup>34</sup> Similarly, Aljawadi et al, identified road traffic accidents (RTAs) as the most common injury mechanism, contributing to 55.9% of cases.<sup>5</sup> Ali et al, also found RTAs as the primary cause in 16 patients, followed by assaults and falling heavy objects.<sup>11</sup> Li et al, documented vehicle accidents causing injuries in 26 patients, with falls from height and crushing injuries in 9 and 5 patients, respectively.<sup>35</sup> The consistent predominance of motor vehicle accidents underscores the ongoing public health challenge posed by road traffic incidents, likely influenced by increased vehicle use, poor road safety enforcement, high-speed driving, and inadequate infrastructure in some regions. In this study, the right side was more commonly affected, with 60% (n=21) of cases involving the right limb, compared to 40% (n=14) on the left. These findings align with previous studies. Gayakwad and Shah reported 72% (n=18) of injuries on the right leg, while Ali et al, noted 16 right limb injuries versus 4 left.<sup>11,36</sup> Li et al, observed a more balanced distribution, with 22 right and 18 left leg injuries.<sup>35</sup>

At the final follow-up, 94.3% (n=33) of the 35 patients in this study achieved successful radiological union, while 5.7% (n=2) remained ununited. Most patients (82.9%, n=29) reached union within 5 to 7 months, and the remaining 11.4% (n=4) between 8 and 10 months. The mean time to radiological union was  $6.61 \pm 0.93$  months. These results are comparable to previous studies. Zhang et al., reported complete union in all 8 patients with bone defects, although their mean union time was longer at  $11.1 \pm 2.3$  months.<sup>33</sup> Gayakwad and Shah observed union in 23 of 25 fractures, with an average time of 22 weeks.<sup>36</sup> Aljawadi et al, documented primary bone healing in 86.7% of patients at a mean of 32 weeks, with 10.2% experiencing delayed union.<sup>5</sup> Overall, the high union rate and relatively timely healing in this study reflect effective management, though slight variations in healing time may be influenced by patient factors, injury severity, or treatment protocols. At the final follow-up, most patients (88.6%, n=31) experienced no postoperative complications. However, 11.4% (n=4) did develop complications, with pin tract infection being the most

common (8.6%, n=3), followed by wire loosening in one patient (2.9%). Similar patterns were reported by Abula et al., where pin tract infection, muscle contraction, and axial deviation were the main complications, all managed effectively with satisfactory outcomes.<sup>34</sup> Ali et al, also noted pin tract infections in 5 patients, along with superficial skin infections and one case of chronic osteomyelitis.<sup>11</sup> Overall, while complications were relatively infrequent, pin tract infections remain a notable concern in postoperative care, emphasizing the need for vigilant monitoring and prompt management.

The bone outcomes in this study, assessed using the ASAMI criteria, were largely positive. Sixty percent (n=21) of patients achieved excellent results, 25.7% (n=9) had good outcomes, 5.7% (n=2) were rated fair, and 8.6% (n=3) had poor outcomes. These findings are consistent with previous reports. Zhang et al, documented excellent bone results in 62.5% of patients, good in 25%, and fair in 12.5%.<sup>33</sup> Ali et al, reported 25% excellent, 45% good, and 30% fair results.<sup>11</sup> A meta-analysis by Necula et al, showed over 70% of patients achieving excellent bone outcomes.<sup>37</sup>

In contrast, Singh et al, reported that 69.6% of their patients experienced occasional difficulties with daily activities, including household tasks, family responsibilities, or leisure.<sup>18</sup> These results suggest that most patients in this study achieved a high level of functional independence, highlighting the effectiveness of the treatment and rehabilitation protocols. In comparison, Necula et al., reported that 88.4% of patients in their meta-analysis regained normal walking without limp.<sup>37</sup>

Regarding flap survival, 62.9% (n=22) of all flaps completely survived, while marginal flap necrosis occurred in a minority of cases, which were successfully managed with local wound care or minor debridement without compromising overall reconstruction goals. Total flap failure was not observed, highlighting the robustness of immediate vascularized tissue coverage. The high rate of flap survival and low complication profile in this cohort underscores the definitive advantage of the single-stage orthoplastic approach. By providing stable skeletal fixation simultaneously with well-vascularized soft tissue coverage, this paradigm effectively eliminates dead space, shields exposed bone, and optimizes local blood supply, which are vital components for successful limb salvage in severe Gustilo-Anderson Grade IIIB tibial fractures.

The present study has several limitations, including the requirement for advanced microsurgical and Ilizarov expertise, which may not be universally available; flap selection based on surgeon preference rather than a standardized protocol; the single-center design limiting generalizability; a small sample size reducing statistical power for detecting rare complications; a short-to-moderate follow-up period restricting assessment of long-term outcomes; and variable patient compliance with postoperative rehabilitation that may have influenced functional results. Notwithstanding these limitations, the

study offers meaningful evidence supporting the effectiveness of this combined approach for open complex limb injuries.

## CONCLUSION

This study demonstrates that simultaneous debridement, soft tissue coverage, and Ilizarov reconstruction is an effective treatment strategy for open complex limb injuries. The approach achieved a high rate of bone union within a relatively short time, with satisfactory alignment, minimal limb length discrepancy, and favorable functional outcomes according to ASAMI criteria. Most patients regained an active lifestyle with good joint mobility and minimal pain at final follow-up. Fasciocutaneous flaps showed superior survival compared to muscle-based flaps. Overall, this combined protocol allows for early definitive management, reduces the need for multiple staged procedures, and promotes satisfactory functional recovery in severe open complex limb injuries.

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