

Original Research Article

Functional and radiographic outcomes following limited open reduction with ankle-spanning Ilizarov fixation in high-energy tibial pilon fractures

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ABSTRACT

Background: High-energy tibial pilon fractures are complex peri-articular fractures that have significant soft-tissue involvement and are at high risk of complications with immediate internal fixation. This study aimed to assess the functional and radiographic results of limited open reduction with ankle-spanning Ilizarov fixation in high-energy tibial pilon fractures.

Methods: This descriptive observational study was conducted at National Institute of Traumatology & Orthopaedic Rehabilitation, Dhaka, Bangladesh, from May 2017 to August 2019, including 45 patients with high-energy tibial pilon fractures who underwent limited open reduction and ankle-spanning Ilizarov fixation. All enrolled patients had their sociodemographic, injury-related, operative, radiographic, functional and postoperative complication data systematically recorded and analyzed.

Results: The majority of patients were young men, road traffic accidents were the most common mechanism of injury, AO/OTA type 43-C2 (42.2%) and Rüedi-Allgöwer type III (60%) fractures were the most common and 75.6% had an associated fibular fracture. The radiological union was obtained in 93.3% of patients, anatomical or near-anatomical reduction was obtained in 64.4% and an articular step-off less than 2 mm was obtained in 71.1%. The overall functional outcome was satisfactory in 68.9% of patients and the AOFAS ankle-hindfoot score was excellent or good in 68.9% of patients. Superficial pin-tract infection was seen in 33.3% of patients; deep infection, nonunion and secondary procedures were relatively uncommon.

Conclusions: Limited open reduction with ankle-spanning Ilizarov fixation was associated with high rates of union and satisfactory functional outcomes in patients with high-energy tibial pilon fractures and is therefore a reproducible treatment option in this difficult fracture group.

Keywords: External fixation, Ilizarov fixation, Limited open reduction, Tibial pilon fracture

INTRODUCTION

Tibial pilon fractures are high-energy injuries of the distal tibial articular surface that make up a small but

disproportionately difficult portion of lower-limb trauma.¹ They are usually caused by axial loading, most commonly road traffic accidents or falls from height and commonly have a large amount of comminution, articular incongruity

and significant soft-tissue compromise.² The high-energy ankle fracture has been associated with a high rate of wound complications, infection and post-traumatic arthritis and has historically been treated with immediate open reduction and internal fixation, which has led to a change in the approach to this fracture to staged protocols, with soft-tissue recovery taking precedence over definitive skeletal fixation.³ In the attempt to balance the competing objectives of anatomical articular restoration and soft-tissue preservation, limited open reduction with ankle-spanning circular (Ilizarov) fixation has proven to be an attractive option, especially in areas with a high incidence of open, comminuted or severely swollen fractures.⁴

The technique is designed to reduce the risk of skin necrosis and deep infection, while maintaining a stable, adjustable frame with minimal soft-tissue dissection, to allow for reasonable restoration of joint congruity and limb alignment.⁵ Several published series have reported union rates >90%, acceptable articular reduction in most patients and functional outcomes similar to or better than conventional internal fixation, with the downside of pin-tract infection and, in some series, a higher incidence of residual malalignment.⁶ In resource-limited environments, the burden of these injuries is exacerbated by the fact that road traffic collisions account for most cases of major limb trauma, delayed presentation, open wounds and severe swelling at admission.⁷

The characteristics of the trauma patients in the South Asian trauma series are repeatedly described as young, economically active males, with the majority of the trauma being caused by road traffic crashes and a significant number of open or severely swollen fractures that are not suitable for immediate internal fixation.⁸ In these environments, an ankle-spanning Ilizarov frame with limited open reduction is a reproducible, resource-efficient option that prevents repeated staged admissions and the logistics of delayed plating.⁹ Even with this rationale, there is relatively limited data specifically related to functional and radiographic outcomes of limited open reduction with ankle-spanning Ilizarov fixation for high-energy pilon fractures and much of the available evidence comes from high-income countries with differing injury profiles and follow-up infrastructure.¹⁰

Therefore, local evidence is required to inform surgical decision-making, patient counseling and resource allocation in this challenging fracture pattern.¹¹ This study aimed to assess the sociodemographic and injury profile, operative characteristics, radiographic union and functional outcomes, including complications, of patients with high-energy tibial pilon fractures treated with limited open reduction and ankle-spanning Ilizarov fixation in a tertiary care center.

METHODS

This descriptive observational study was carried out at National Institute of Traumatology and Orthopaedic

Rehabilitation, Dhaka, Bangladesh, from May 2017 to August 2019. A total of 45 patients were included consecutively, all of whom had a high-energy tibial pilon fracture confirmed by X-ray and were treated with limited open reduction and ankle-spanning Ilizarov fixation and had a minimum follow-up of six months. Patients with pathological fractures, with isolated low-energy rotational pilon fractures, with ipsilateral fractures of the other limb that made it impossible to assess the ankle function, with pre-existing ankle joint disease or with incomplete medical records were excluded.

The variables analyzed were sociodemographic (age, sex, residence, occupation, smoking history, diabetes mellitus), injury-related clinical profile (side involved, mode of injury, fracture type and grade, associated fibular fracture, other injuries), fracture classification and initial soft-tissue status (AO/OTA type, Rüedi-Allgöwer type, swelling of soft tissues, blister formation, neurovascular status), operative and fixation-related details (timing of surgery, fibular fixation, approach for limited open reduction, need for bone grafting, hospital stay, time to full weight-bearing), radiographic outcomes (union, time to union, quality of reduction, coronal alignment, articular step-off, post-traumatic arthritis), functional outcomes (AOFAS ankle-hindfoot score, overall functional outcome, walking ability, pain, return to occupation) and postoperative complications (pin-tract infection, wound complications, delayed union, nonunion, malalignment, ankle stiffness, need for secondary procedures).

Operative notes, radiographs and structured follow-up records were used to extract data, which were then entered into a predesigned data collection sheet and transferred to Microsoft Excel. Data were analyzed statistically using SPSS version 26 and frequencies and percentages were used to summarize categorical variables and means, standard deviations or medians and ranges were used for continuous variables, depending on the distribution of the data.

RESULTS

Among the 45 patients, 16 (35.6%) were aged 31-40 years, 12 (26.7%) were 30 years or younger, 11 (24.4%) were 41-50 years and 6 (13.3%) were older than 50 years. There were more males (36, 80.0%) than females and 27 (60.0%) lived in rural areas. The largest occupational group was manual laborers (16, 35.6%), followed by service holders, farmers, businesspersons and students or unemployed persons. Seventeen patients (37.8%) had a smoking history and 6 (13.3%) had diabetes mellitus (Table 1).

The right ankle was affected in 26 patients (57.8%) and the left in 19 (42.2%). The most common injuries were from road traffic accidents (31, 68.9%), falls from height (10, 22.2%) and heavy object injuries (4, 8.9%). Closed fractures were more common (29, 64.4%) than open fractures (16, 35.6%), most of which were Gustilo-Anderson grade II (8, 17.8%). Thirty-four patients (75.6%)

had an associated fibular fracture and 9 (20.0%) had another associated injury (Table 2).

By AO/OTA classification, 19 fractures (42.2%) were type 43-C2, 15 (33.3%) type 43-C3 and 11 (24.4%) type 43-C1. Using the Rüedi-Allgöwer system, 27 fractures (60.0%) were typing III and 18 (40.0%) type II. Twenty-four patients (53.3%) had moderate and 14 (31.1%) had severe soft-tissue swelling. 13 patients (28.9%) had blisters. Distal neurovascular status was intact in 43 patients (95.6%) and compromised in 2 (4.4%), which improved following management. (Table 3).

Surgery was performed within 24 hours in 8 patients (17.8%), 2-5 days in 25 (55.6%) and after 5 days in 12 (26.7%). Fibular fixation was done in 25 patients (55.6%). In 18 patients (40.0%), limited open reduction was performed via a medial approach, 14 (31.1%) via an anterolateral approach and 13 (28.9%) via a combination of approaches. 5 patients (11.1%) needed bone grafting. Hospital stay was 7 days or less in 28 patients (62.2%) and full weight-bearing began at 13-16 weeks in 24 (53.3%) (Table 4).

Radiological union was obtained in 42 patients (93.3%) and delayed union in 3 (6.7%). Union occurred within 17-

24 weeks in 27 patients (60.0%). The anatomical or near-anatomical reduction was achieved in 29 patients (64.4%) and acceptable in 13 (28.9%). In 39 patients (86.7%) the coronal alignment was neutral or acceptable. In 32 patients (71.1%), the articular step-off was less than 2 mm. post-traumatic ankle arthritis was absent in 34 patients (75.6%), mild in 8 (17.8%) and moderate in 3 (6.7%) (Table 5).

The AOFAS ankle-hindfoot score was good in 21 patients (46.7%), excellent in 10 (22.2%), fair in 11 (24.4%) and poor in 3 (6.7%). The overall functional outcome was satisfactory in 31 patients (68.9%). Thirty patients (66.7%) walked without support. In 32 patients (71.1%), ankle pain in daily activities was none or mild. Twenty-five patients (55.6%) returned to their previous occupation, 14 (31.1%) partially returned to work and 6 (13.3%) were not able to return to work (Table 6).

Pin-tract infection was absent in 28 patients (62.2%), superficial in 15 (33.3%) and deep in 2 (4.4%). 6 patients (13.3%) had wound complications. Delayed union was noted in 3 patients (6.7%) and nonunion in 1 (2.2%). 6 patients (13.3%) had malalignment and 11 (24.4%) had ankle stiffness. Five patients (11.1%) required a secondary procedure and 40 (88.9%) did not require any additional surgical procedure (Table 7).

Table 1: Sociodemographic characteristics of the study population (n=45).

Variables	Category	N (%)
Age group (in years)	≤30	12 (26.7)
	31-40	16 (35.6)
	41-50	11 (24.4)
	>50	6 (13.3)
Sex	Male	36 (80.0)
	Female	9 (20.0)
Residence	Urban	18 (40.0)
	Rural	27 (60.0)
Occupation	Manual labourer	16 (35.6)
	Service holder	9 (20.0)
	Farmer	8 (17.8)
	Businessperson	7 (15.6)
	Student/unemployed	5 (11.1)
Smoking history	Present	17 (37.8)
	Absent	28 (62.2)
Diabetes mellitus	Present	6 (13.3)
	Absent	39 (86.7)

Table 2: Injury-related clinical profile (n=45).

Variables	Category	N (%)
Side involved	Right ankle	26 (57.8)
	Left ankle	19 (42.2)
Mode of injury	Road traffic accident	31 (68.9)
	Fall from height	10 (22.2)
	Heavy object injury	4 (8.9)
Fracture type	Closed fracture	29 (64.4)
	Open fracture	16 (35.6)

Continued.

Variables	Category	N (%)
Open fracture grade	Gustilo-Anderson grade I	5 (11.1)
	Gustilo-Anderson grade II	8 (17.8)
	Gustilo-Anderson grade IIIA	3 (6.7)
Associated fibular fracture	Present	34 (75.6)
	Absent	11 (24.4)
Associated injury	Present	9 (20.0)
	Absent	36 (80.0)

Table 3: Fracture classification and initial soft-tissue condition (n=45).

Variables	Category	N (%)
AO/OTA classification	43-C1	11 (24.4)
	43-C2	19 (42.2)
	43-C3	15 (33.3)
Rüedi-Allgöwer classification	Type II	18 (40.0)
	Type III	27 (60.0)
Soft-tissue swelling	Mild	7 (15.6)
	Moderate	24 (53.3)
	Severe	14 (31.1)
Blister formation	Present	13 (28.9)
	Absent	32 (71.1)
Distal neurovascular status	Intact	43 (95.6)
	Compromised but recovered after management	2 (4.4)

Table 4: Operative and fixation-related variables (n=45).

Variables	Category	N (%)
Timing of surgery after injury	Within 24 hours	8 (17.8)
	2-5 days	25 (55.6)
	>5 days	12 (26.7)
Fibular fixation	Done	25 (55.6)
	Not done	20 (44.4)
Limited open reduction	Medial approach	18 (40.0)
	Anterolateral approach	14 (31.1)
	Combined limited approaches	13 (28.9)
Bone grafting	Required	5 (11.1)
	Not required	40 (88.9)
Postoperative hospital stay	≤7 days	28 (62.2)
	>7 days	17 (37.8)
Full weight-bearing started	Within 12 weeks	12 (26.7)
	13-16 weeks	24 (53.3)
	>16 weeks	9 (20.0)

Table 5: Radiographic outcomes after treatment (n=45).

Variables	Category	N (%)
Radiological union	Achieved	42 (93.3)
	Delayed union	3 (6.7)
Time to union	≤16 weeks	11 (24.4)
	17-24 weeks	27 (60.0)
	>24 weeks	7 (15.6)
Quality of reduction	Anatomical/near anatomical	29 (64.4)
	Acceptable	13 (28.9)
	Poor	3 (6.7)
Final coronal alignment	Neutral/acceptable	39 (86.7)

Continued.

Variables	Category	N (%)
	Varus malalignment	4 (8.9)
	Valgus malalignment	2 (4.4)
Articular step-off at final follow-up	<2 mm	32 (71.1)
	2-5 mm	10 (22.2)
	>5 mm	3 (6.7)
Post-traumatic ankle arthritis	Absent	34 (75.6)
	Mild	8 (17.8)
	Moderate	3 (6.7)

Table 6: Functional outcomes at final follow-up (n=45).

Variables	Category	N (%)
AOFAS ankle-hindfoot score	Excellent	10 (22.2)
	Good	21 (46.7)
	Fair	11 (24.4)
	Poor	3 (6.7)
Final functional outcome	Satisfactory	31 (68.9)
	Unsatisfactory	14 (31.1)
Walking ability	Walks without support	30 (66.7)
	Walks with occasional support	12 (26.7)
	Walks with regular support	3 (6.7)
Ankle pain during daily activity	None/mild	32 (71.1)
	Moderate	10 (22.2)
	Severe	3 (6.7)
Return to previous occupation	Complete return	25 (55.6)
	Partial return	14 (31.1)
	Unable to return	6 (13.3)

Here, AOFAS score: Excellent: 90-100, Good: 80-89, Fair: 70-79, Poor: <70.

Table 7: Postoperative complications (n=45).

Variables	Category	N (%)
Pin tract infection	Absent	28 (62.2)
	Superficial	15 (33.3)
	Deep	2 (4.4)
Wound complication	Present	6 (13.3)
	Absent	39 (86.7)
Delayed union	Present	3 (6.7)
	Absent	42 (93.3)
Nonunion	Present	1 (2.2)
	Absent	44 (97.8)
Malalignment	Present	6 (13.3)
	Absent	39 (86.7)
Ankle stiffness	Present	11 (24.4)
	Absent	34 (75.6)
Secondary procedure required	Required	5 (11.1)
	Not required	40 (88.9)

DISCUSSION

This study demonstrated that road traffic collisions were the predominant mechanism of injury among patients with high-energy tibial pilon fractures, with the highest burden observed among individuals in the third and fourth decades of life.^{12,13} This demographic profile is similar to Biz et al,

who have described similarly young and male-dominated populations and is reflective of occupational and travel exposure of young adults in mixed traffic environments.¹⁴ The high proportion of AO/OTA type 43-C2 and C3 fractures and Rüedi-Allgöwer type III injuries is typical of the severe comminution and soft tissue compromise that usually warrants staged or minimally invasive treatment

rather than immediate definitive plating.¹⁵ Similarly, in most patients with moderate to severe soft tissue swelling, the need for damage control external fixation in high-energy, comminuted injuries is further justified.¹⁶ Most of the patients were operated on within 5 days and fibular fixation was performed in more than half, which is similar to the findings of Hamdy et al, who reported that fibular stabilization was performed with spanning fixation, restoring length without adding further soft-tissue insult.¹⁷ Radiological union was obtained in the vast majority of patients and anatomical or acceptable reduction was obtained in the majority of cases, similar to published series of pilon fractures treated with circular external fixation and limited internal fixation, which report high rates of union with relatively few bone grafting requirements.¹⁸

The functional outcomes in our study are similar to those reported after ankle-spanning external fixation, with more than two-thirds of patients having good-to-excellent AOFAS scores and a similar proportion having satisfactory overall function, although Frappa et al reported more variable return-to-work rates and a persistent minority of patients with unsatisfactory function despite good radiographic union.¹⁹ This discrepancy between radiographic and functional recovery has been explained by the fact that some factors that are not measured, like residual stiffness, chronic pain and psychosocial recovery, may also play a role in recovery.²⁰

The complication rates in this study were similar to those reported by Chen et al who described circular fixation methods, with pin-tract infection and post-traumatic arthritis being the most common complications and deep infection and nonunion being uncommon.²¹ The incidence of post-traumatic ankle arthritis observed, mostly as a mild finding, is consistent with Wei et al, who indicated that the most important factors associated with subsequent joint degeneration are articular step-off greater than 2 mm and higher-grade comminution, not the type of fixation used.²²

Randomized and cohort comparisons of staged internal fixation versus circular or hybrid external fixation have generally demonstrated similar AOFAS scores and union rates between the two techniques, with the external fixation technique having a slightly higher risk of malalignment and a lower risk of deep wound infection and soft-tissue necrosis, which is broadly reflected in the complication pattern of this study.¹⁷ The relatively low secondary procedure rate and the good walking ability and return to occupation rates seen here indicate that an ankle-spanning frame with limited articular reduction does not have to negatively affect functional recovery even in a predominantly open, high-grade population if the cases are selected appropriately.

However, the minority of patients with poor AOFAS scores or who were unable to return to work emphasizes that severe comminution or open injuries are still at risk of suboptimal results, regardless of the fixation method and

thus the importance of realistic preoperative counselling. All of these results support limited open reduction with ankle-spanning Ilizarov fixation as a viable, reproducible approach to high-energy tibial pilon fractures in environments where staged plating may be limited by resources or follow-up and highlight the importance of thorough soft-tissue evaluation and careful attention to articular reduction in achieving optimal radiographic and functional outcomes.

Limitations

This was a single-center study with a small number of patients and a relatively short- to medium-term follow-up period, which may restrict generalizability and the detection of late complications such as progressive post-traumatic arthritis.

CONCLUSION

This study underscores that limited open reduction and ankle-spanning Ilizarov fixation is an effective and reproducible treatment option for high-energy tibial pilon fractures. Despite the high proportion of severe, comminuted, high-grade injuries, high radiological union rates and satisfactory functional recovery were obtained. Complications were mostly superficial pin-tract infections and were easily managed, while deep infection, nonunion and secondary surgery were uncommon. The results indicate that this technique is a useful option, especially in cases where staged internal fixation is limited by soft tissue status or resource availability.

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