

Functional outcome in closed Type C Tibial Pilon Fracture Fixed with Hybrid External Fixator-An Observational Prospective Study

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Abstract

Background: Tibial pilon fractures are complex intra-articular injuries of the distal tibial plafond commonly associated with severe comminution and soft-tissue compromise. Hybrid external fixation provides stable fracture fixation while minimizing additional soft-tissue injury. The objective is to evaluate the functional outcome of closed AO type C tibial pilon fractures treated with hybrid external fixation using the AOFAS ankle-hindfoot score. **Material and Methods:** This prospective observational study included 20 patients with closed AO type C tibial pilon fractures treated with hybrid external fixation at Sanjay Gandhi Institute of Trauma and Orthopaedics, Bengaluru. Patients were followed for 12 months. Functional outcome was assessed using the AOFAS score at 3, 6, and 12 months. Fracture subtype, fibular fixation, union, and complications were also evaluated. **Results:** The mean AOFAS score improved from 43.10 ± 5.05 at 3 months to 65.05 ± 7.64 at 6 months and 81.25 ± 9.45 at 12 months, showing significant improvement over time ($p < 0.001$). At final follow-up, 20% of patients had excellent, 40% good, 25% fair, and 15% poor outcomes, with 60% achieving good-to-excellent results. Mean AOFAS scores differed significantly among AO C1, C2, and C3 fracture subtypes ($F=7.254$, $p=0.005$), with better functional outcomes observed in C1 fractures and poorer outcomes in the more complex C3 fractures. Pin-tract infection occurred in 20% of patients and delayed union in 10%, while no non-union was observed. **Conclusion:** Hybrid external fixation provided satisfactory functional outcomes and reliable union in closed AO type C tibial pilon fractures while minimizing extensive soft-tissue dissection. Functional outcome was significantly influenced by fracture severity, with more complex C3 fractures demonstrating comparatively poorer results.

Keywords: Tibial pilon fracture, AO type C, hybrid external fixation, AOFAS score, external fixator, functional outcome.

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INTRODUCTION

Tibial pilon fractures are complex intra-articular fractures involving the distal tibial plafond and account for some of the most challenging injuries encountered in orthopaedic trauma. They commonly result from high-energy axial loading mechanisms, such as road traffic accidents and falls from height, in which the talus is driven against the distal tibial articular surface. Rüedi and Allgöwer emphasized that restoration of articular congruity and stable fixation are important determinants of functional outcome following these injuries.^[1]

The management of tibial pilon fractures is complicated by articular comminution, metaphyseal bone loss, and significant injury to the surrounding soft-tissue envelope. Early open reduction and internal fixation, particularly in high-energy injuries, has historically been associated with wound breakdown, infection, and other soft-tissue complications. McFerran et al. and Teeny and Wiss reported considerable complication rates following operative treatment of severe pilon fractures, highlighting the importance of careful soft-tissue management.^[2,3]

Recognition of these complications led to the development of staged and less invasive treatment strategies. Sirkin et al. demonstrated the importance of allowing soft-tissue recovery

before definitive management of complex pilon fractures.^[4] External fixation also provides fracture stabilization with limited additional disruption of the already compromised soft tissues. Studies by Marsh et al. and Bone et al. demonstrated the usefulness of external fixation in complex tibial plafond fractures, although residual ankle stiffness and functional impairment may persist following severe injuries.^[5,6]

Hybrid external fixation combines tensioned wires in the distal metaphyseal fragment with proximal half-pin fixation, providing stable fixation while preserving the fracture biology and soft-tissue envelope. It also facilitates indirect reduction through ligamentotaxis and permits early ankle mobilization. Previous studies have reported encouraging functional and radiological

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outcomes with hybrid external fixation in appropriately selected distal tibial fractures.^[7,8]

Considering the complexity of AO type C tibial pilon fractures, an approach that provides adequate stability while minimizing further soft-tissue injury is desirable. Therefore, the present study was undertaken to evaluate the functional outcome of closed AO type C tibial pilon fractures treated with hybrid external fixation, using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle–hindfoot score.

MATERIALS AND METHODS

Study Design and Setting: This prospective observational study was conducted in the Department of Orthopaedics, Sanjay Gandhi Institute of Trauma and Orthopaedics, Bengaluru, Karnataka, over a period of one year. The study included patients with closed AO type C tibial pilon fractures who were managed with hybrid external fixation. The study was approved by the Institutional Ethics Committee of Sanjay Gandhi Institute of Trauma and Orthopaedics, Bengaluru. Written informed consent was obtained from all participants before enrolment.

Sample Size: A total of 20 patients were included. The sample size was calculated using the formula:

$$[n = (Z_{\{\alpha/2\}} + Z_{\{1-\beta\}})^2 / d^2]$$

where ($Z_{\{\alpha/2\}}=1.96$) for a 95% confidence interval, ($Z_{\{1-\beta\}}=0.84$) for 80% power, and ($d=0.70$) represented the anticipated effect size. The calculated sample size was 16; after considering a 20% attrition rate, the final sample size was increased to 20 patients.

Inclusion Criteria

Patients aged 18 years or older with closed AO type C complete articular tibial pilon fractures treated with hybrid external fixation and willing to provide informed consent and comply with the scheduled follow-up were included.

Exclusion Criteria

Patients with open distal tibial fractures, pathological fractures, associated neurovascular injury, fractures treated primarily with internal fixation, lateral malleolar fractures treated with plate and screws, and tibial plafond fractures treated with cannulated cancellous screws alone were excluded.

Preoperative Assessment: Following enrolment, demographic characteristics, mechanism of injury, clinical findings, associated injuries, and preoperative status were recorded in a pre-designed proforma. Clinical examination was supplemented by appropriate radiological evaluation, and fractures were classified according to the AO classification into C1, C2, and C3 subtypes.

Surgical Technique: All patients underwent hybrid external fixation. Surgery was performed with the patient supine on a radiolucent operating table under fluoroscopic guidance. Traction was applied through the calcaneus to restore limb length and facilitate indirect reduction through ligamentotaxis. When required, the fibula was stabilized using percutaneous pins or Kirschner wires to restore its length, rotation, and ankle mortise alignment.

The distal tibial fragment was stabilized using appropriately

positioned tensioned K-wires/olive wires connected to a circular ring. Proximally, Schanz pins were inserted into the tibial shaft and connected to rods attached to the distal ring, thereby completing the hybrid construct. Reduction was achieved using ligamentotaxis, manual manipulation, and percutaneous techniques. Limited open reduction was performed when satisfactory articular reduction could not be achieved indirectly. Fluoroscopy was used to confirm articular reduction, limb alignment, and appropriate placement of the fixation components.

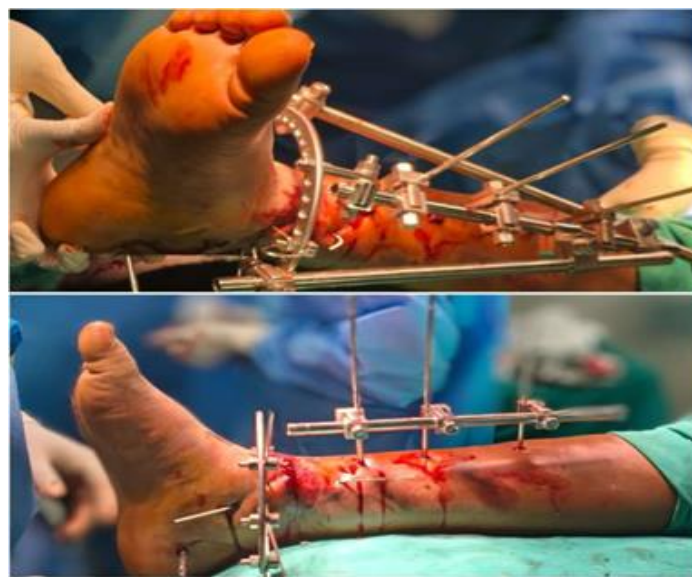


Figure 1: Intra-op pictures showing Hybrid exfix

Postoperative Management and Follow-up: Postoperatively, limb elevation and regular pin-tract care were instituted. Early ankle range-of-motion exercises were encouraged after reduction of pain and swelling. Weight bearing was initially restricted and subsequently progressed from partial to full weight bearing according to clinical and radiological evidence of fracture healing.



Figure 2: Plain radiograph of post op Hybrid exfix for pilon fracture

Patients were followed at 2 weeks, 6 weeks, 3 months, 6 months,

and 12 months. Functional outcome was assessed using the AOFAS ankle-hindfoot score, particularly at 3, 6, and 12 months. Fracture union and complications, including pin-tract infection, delayed union, non-union were also evaluated during follow-up.



Figure 3: Ankle ROM at 12months followup

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS version 25.0. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were presented as frequencies and percentages. Changes in AOFAS scores at 3, 6, and 12 months were analyzed using repeated-measures ANOVA. Differences in AOFAS scores among AO C1, C2, and C3 fractures were assessed using one-way ANOVA, while outcomes according to fibular fixation were compared using the independent-samples t-test. A p-value <0.05 was considered statistically significant, and all tests were two-tailed.

RESULTS

A total of 20 patients with closed AO type C tibial pilon fractures treated with hybrid external fixation were included in the study. The age of patients ranged from 21 to 55 years. Fifteen patients (75%) were male and five (25%) were female. Road traffic accidents were the predominant mode of injury, accounting for 17 cases (85%), while three patients (15%) sustained fractures following falls.

Table 1: Demographic and Injury Characteristics of the Study Population

Variable	Category	n	Percentage
Sex	Male	15	75.0
	Female	5	25.0
Mode of injury	Road traffic accident	17	85.0
	Fall	3	15.0
AO classification	C1	3	15.0
	C2	7	35.0
	C3	10	50.0
Fibular fixation	Performed	13	65.0
	Not performed	7	35.0

Among the AO type C fractures, C3 was the most common subtype, observed in 10 patients (50%), followed by C2 in seven (35%) and C1 in three (15%). Fibular fixation was performed in 13 patients (65%). The predominance of C3 fractures and road traffic accidents indicated that the study population largely consisted of high-energy and relatively

complex injuries.

The interval between injury and definitive surgery ranged from 7 to 14 days. Five patients (25%) underwent surgery on the 12th day, while most procedures were performed between the 8th and 12th day after injury following adequate soft-tissue recovery.

Table 2: AOFAS Scores During Follow-up

Follow-up	Mean AOFAS Score	SD	Range	n
3 months	43.10	5.046	33-50	20
6 months	65.05	7.640	51-77	20
12 months	81.25	9.447	64-96	20

There was a progressive improvement in functional outcome throughout follow-up. The mean AOFAS score increased from 43.10 ± 5.05 at 3 months to 65.05 ± 7.64 at 6 months and 81.25 ± 9.45 at 12 months.

Repeated-measures ANOVA demonstrated a statistically significant improvement in AOFAS scores over time ($F=1419.862$, $df=2$, $p<0.001$), indicating substantial functional recovery during the 12-month follow-up period.

Table 3: Final Functional Outcome and Association with AO Fracture Subtype

Parameter	Category	n	Percentage / Mean AOFAS $\pm$ SD
Final outcome	Excellent	4	20.0%
	Good	8	40.0%
	Fair	5	25.0%
	Poor	3	15.0%
AO subtype	C1	3	93.00 ± 1.00
	C2	7	84.14 ± 6.64
	C3	10	75.70 ± 8.49
Overall	—	20	81.25 ± 9.45

At the final follow-up, 12 of 20 patients (60%) achieved good-to-excellent functional outcomes. Four patients (20%) had excellent results, eight (40%) good results, five (25%) fair results, and three (15%) poor results. Functional outcome was significantly influenced by fracture severity. Patients with AO type C1 fractures had the highest mean AOFAS score (93.00 ± 1.00), followed by C2 fractures (84.14 ± 6.64), whereas C3 fractures had the lowest mean score (75.70 ± 8.49). One-way ANOVA demonstrated a significant difference among the three fracture subtypes ($F=7.254$,

$p=0.005$), showing that increasing fracture complexity was associated with poorer functional outcome. Patients without fibular fixation demonstrated higher mean AOFAS scores at all follow-up intervals compared with those who underwent fibular fixation. The respective scores were 47 versus 41 at 3 months, 71 versus 62 at 6 months, and 88 versus 78 at 12 months. However, the available data did not provide a corresponding p-value for this comparison; therefore, statistical significance could not be established.

Table 4: Complications During Follow-up

Complication	Present, n (%)	Absent, n (%)
Pin-tract infection	4 (20.0)	16 (80.0)
Delayed union	2 (10.0)	18 (90.0)
Non-union	0 (0.0)	20 (100.0)

Pin-tract infection was the most frequent complication and occurred in four patients (20%). These infections were managed with local pin-site care and antibiotics. Delayed union was observed in two patients (10%), while no case of non-union was encountered. All 20 patients eventually achieved fracture union.

Overall, hybrid external fixation resulted in progressive and statistically significant improvement in ankle function, with 60% of patients achieving good-to-excellent results at one year. Better outcomes were observed in less comminuted AO C1 and C2 fractures, while C3 fractures showed comparatively lower functional scores. The complication profile was acceptable, with superficial pin-tract infection being the most common adverse event.

DISCUSSION

Tibial pilon fractures are severe intra-articular injuries in which successful treatment depends not only on restoration of the articular surface but also on careful preservation of the surrounding soft tissues. In the present study, 20 patients with closed AO type C tibial pilon fractures were treated with hybrid external fixation and followed for one year. Functional outcome improved progressively, with mean AOFAS scores increasing from 43.10 at 3 months to 65.05 at 6 months and 81.25 at 12 months. This improvement was statistically significant ($p<0.001$).

Staged and minimally invasive treatment strategies have been advocated for high-energy pilon fractures because extensive early dissection may increase soft-tissue complications. Patterson and Cole⁹ demonstrated the value of delayed definitive fixation after improvement of the soft-tissue envelope. Similarly, French and Tornetta,^[10] emphasized that hybrid external fixation provides stable fracture stabilization with limited additional soft-tissue trauma.

In the present study, 60% of patients achieved good-to-excellent functional results at final follow-up, while 25% had fair and 15% had poor outcomes. Pollak et al,^[11] reported that high-energy tibial plafond fractures may result in substantial long-term functional disability, with final outcome influenced by fracture severity and associated soft-tissue

damage. Sirkin et al,^[12] also emphasized soft-tissue management as an important determinant of complications and outcome.

Fracture severity significantly influenced functional recovery in our study. Mean 12-month AOFAS scores were 93.00 for C1, 84.14 for C2, and 75.70 for C3 fractures, with a statistically significant difference among the groups ($p=0.005$). These findings are in agreement with the observations of Rüedi,^[13] and Galante et al,^[14] who showed that increasing articular comminution and fracture complexity adversely affect functional outcome.

Hybrid and circular external fixation techniques are particularly useful in complex pilon fractures because they provide stable fixation while preserving the biological environment of the fracture. Bacon et al,^[15] demonstrated satisfactory results with external fixation in comminuted intra-articular tibial plafond fractures. Endres et al,^[16] likewise reported advantages of minimally invasive reduction and hybrid fixation, particularly in severe C2 and C3 fractures.

Pin-tract infection was the most common complication in the present series, occurring in 20% of patients, while delayed union was observed in 10%. No patient developed non-union, and all fractures eventually united. Similar complications have been described following external fixation, but preservation of the soft-tissue envelope may reduce the risk of serious wound complications associated with extensive open fixation. Koulouvaris et al,^[17] also emphasized that long-term outcome depends on both fracture severity and treatment-related complications. Biz et al,^[18] demonstrated that satisfactory clinical outcomes can be achieved following appropriately selected operative strategies for intra-articular pilon fractures.

Overall, the present findings support hybrid external fixation as a useful treatment option for closed AO type C tibial pilon fractures. The technique provided satisfactory fracture union and progressive functional recovery while avoiding extensive soft-tissue dissection. However, more severe C3 fracture patterns remained associated with comparatively poorer functional results.

CONCLUSION

Hybrid external fixation was found to be an effective and reliable method for the management of closed AO type C tibial pilon

fractures. Functional outcome improved significantly throughout the follow-up period, with the mean AOFAS score reaching 81.25 at 12 months and 60% of patients achieving good-to-excellent results.

Fracture severity significantly influenced the final outcome, with C1 fractures demonstrating better functional scores than C2 and C3 fractures. Pin-tract infection and delayed union were the main complications; however, no non-union was observed.

Hybrid external fixation therefore provides stable fixation, satisfactory fracture union, preservation of the soft-tissue envelope, and acceptable functional recovery, particularly in complex pilon fractures where extensive internal fixation may carry a greater risk of soft-tissue complications.

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Conflicts of interest

There are no conflicts of interest.

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