

A prospective study on functional outcome of distal tibia pilon fracture treated with locking compression plate osteosynthesis

¹Dr. Rahul A N, Assistant Professor, Department of Orthopaedics, Mandya Institute of Medical Sciences, Mandya, India.

²Dr. Kausthubha K P, Senior Resident, Department of Orthopaedics, Mandya Institute of Medical Sciences, Mandya, India.

³Dr. Deeparam, Assistant Professor, Department of Orthopaedic, Haveri Institute of Medical Sciences Haveri Karnataka, India.

Corresponding Author: Dr. Rahul A N, Assistant Professor, Department of Orthopaedics, Mandya Institute of Medical Sciences, Mandya, India.

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Abstract: Distal tibial pilon fractures are complex intra-articular injuries frequently associated with metaphyseal comminution and soft-tissue damage. Locking compression plate osteosynthesis provides angular stability and permits stable fixation while potentially minimizing additional soft-tissue disruption.

Aim: To evaluate the functional and radiological outcome of distal tibial pilon fractures treated with locking compression plate osteosynthesis.

Materials and Methods: This prospective study included 30 consecutive skeletally mature patients with closed distal tibial pilon fractures treated operatively between March 2022 and February 2024. Patients were evaluated clinically and radiologically at 2, 6 and 12 weeks and subsequently according to fracture consolidation and functional recovery. Fractures were classified according

to the Ruedi-Allgower system. Locking compression plate fixation was performed through anterolateral or medial minimally invasive approaches depending on fracture configuration. Functional outcome was assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) score, along with assessment of fracture union, time to weight bearing, duration of hospitalization and postoperative complications.

Results: The majority of patients were 31–40 years old (53.33%), and 80% were male. Road traffic accidents constituted the commonest mechanism of injury (66.66%). Half of the patients underwent surgery within 7–10 days. Fracture union occurred by 3 months in 63.33% of patients, with a reported mean union time of 2.4 ± 0.56 months. The mean AOFAS score improved from 30.76 ± 5.85 preoperatively to 59.56 ± 6.58 at 6

weeks and 87.23 ± 6.19 at final follow-up ($p=0.001$). Weight bearing was initiated at 6–10 weeks in 96.66% of patients. At final assessment, 36.66% had excellent and 60% had good outcomes.

Conclusion: Locking compression plate osteosynthesis provided satisfactory fracture union and substantial functional improvement in this series of selected closed distal tibial pilon fractures. Careful soft-tissue management, appropriate surgical timing, stable fixation and structured rehabilitation appear important for achieving favorable outcomes.

Keywords: Distal Tibia, Pilon Fracture, Locking Compression Plate, Osteosynthesis, AOFAS, Fracture Union, Functional Outcome.

Introduction

Distal tibial pilon fractures are among the most challenging injuries encountered in orthopaedic trauma surgery. The term “pilon,” derived from the French word for pestle, refers to fractures involving the distal tibial plafond, usually produced by axial loading of the talus against the tibial articular surface. These fractures range from relatively simple intra-articular cleavage injuries to severely comminuted fractures involving the metaphysis and ankle joint. Their management is difficult because of the combination of articular surface disruption, metaphyseal comminution, instability and frequent compromise of the surrounding soft-tissue envelope^{1,2}. The distal tibial plafond plays an important role in maintaining ankle joint congruity and transmitting axial loads between the tibia and talus. Unlike many other regions of the tibia, the distal tibia has limited soft-tissue coverage, particularly over its anterior and medial surfaces. Consequently, high-energy trauma can cause extensive injury not only to the bone but also to the skin, subcutaneous tissue, periosteum and local vascular

structures. The severity of soft-tissue injury has a major influence on the timing and method of definitive fracture fixation and on the risk of postoperative complications^{2,3}. The mechanism of injury is an important determinant of the fracture pattern. High-energy axial loading, commonly associated with road traffic accidents and falls from height, can result in extensive fragmentation and displacement of the tibial plafond. In contrast, lower-energy mechanisms may produce less extensive articular and metaphyseal damage. High-energy pilon fractures are particularly problematic because the same force responsible for fracture production may cause severe soft-tissue injury, swelling and fracture blisters, thereby increasing the risk of wound complications following surgery^{3,4}.

Several classification systems have been developed for describing distal tibial pilon fractures. The Rüedi-Allgöwer classification is one of the historically important systems and is based primarily on the degree of displacement and articular comminution. Type I fractures are nondisplaced cleavage fractures of the joint, Type II fractures are displaced with minimal comminution, and Type III fractures are displaced and severely comminuted. The prognosis generally becomes less favorable as the fracture progresses from Type I to Type III because of increasing articular damage and comminution⁵. The AO/OTA classification is another widely used system and categorizes distal tibial fractures into extra-articular, partial-articular and complete-articular patterns, with further subdivisions according to the complexity of the fracture^{1,5}.

The treatment of pilon fractures has undergone substantial evolution. Historically, immediate extensive open reduction and internal fixation was frequently associated with high rates of wound complications, infection,

delayed union and other adverse outcomes, particularly in high-energy injuries with severe soft-tissue compromise. Although restoration of the articular surface and alignment remains an important objective, early experience demonstrated that aggressive surgical exposure through severely traumatized soft tissues could result in significant morbidity^{6,7}.

The recognition of the importance of soft-tissue preservation subsequently resulted in the development of staged treatment protocols. In patients with substantial swelling or soft-tissue injury, temporary stabilization followed by delayed definitive fixation has become an important treatment strategy. Initial stabilization may be achieved using a spanning external fixator, allowing restoration of length and alignment while permitting the soft-tissue envelope to recover. Definitive internal fixation is then performed when swelling has subsided and the skin and soft tissues are considered suitable for surgery^{4,6,8}.

The timing of definitive fixation is therefore an important consideration in the management of pilon fractures. It should be individualized according to the fracture configuration, degree of soft-tissue injury, swelling, skin condition and general condition of the patient. While delayed fixation is frequently preferred for high-energy injuries with significant soft-tissue compromise, selected fractures with favorable soft-tissue conditions may be suitable for earlier definitive fixation. The fundamental principle is to achieve adequate fracture stabilization while minimizing additional injury to the soft-tissue envelope^{8,9}.

Advances in implant technology have further influenced the operative management of distal tibial fractures. Locking compression plates provide angular stability through the interaction between the locking screw and the

threaded plate hole. This creates a fixed-angle construct that can provide stable fixation even when the bone quality is suboptimal or when the distal fragment provides limited space for conventional screw fixation. The locking principle also reduces the requirement for intimate plate-to-bone contact and may help preserve periosteal blood supply compared with traditional compression plating techniques¹⁰. Locking compression plates are particularly useful in distal tibial fractures because the distal fragment often has limited bone stock and a complex articular configuration. The availability of multiple distal locking screw options allows fixation of small or comminuted fragments while maintaining alignment. In addition, locking plates can be applied using minimally invasive techniques, potentially reducing disruption of the periosteum and surrounding soft tissues. Minimally invasive plate osteosynthesis has therefore become an important option in appropriately selected distal tibial fractures^{10,11}. The surgical approach for pilon fractures must be selected carefully according to the fracture morphology, location of articular fragments, soft-tissue condition and planned implant position. Anterolateral and medial approaches are commonly used, and minimally invasive techniques may be employed where appropriate. During surgery, preservation of important neurovascular structures and avoidance of excessive soft-tissue stripping are essential. The objective is to obtain adequate reduction and stable fixation while maintaining the biological environment necessary for fracture healing^{11,12}. The primary objectives of operative treatment are restoration of the mechanical axis, reconstruction of the tibial plafond, restoration of ankle mortise congruity, achievement of stable fixation and preservation of the soft-tissue envelope. Anatomical or near-anatomical restoration of the articular surface is

desirable because persistent incongruity can alter ankle biomechanics and may predispose to post-traumatic degenerative changes. However, functional recovery depends not only on radiographic reduction but also on pain, ankle range of motion, ability to bear weight and return to daily activities^{3,13}.

Pilon fractures are associated with a wide range of postoperative complications. These include wound dehiscence, superficial and deep infection, delayed union, nonunion, malunion, implant-related complications, ankle stiffness, persistent pain and post-traumatic arthritis. The risk of complications is influenced by the initial energy of trauma, fracture severity, degree of soft-tissue injury, timing of surgery, surgical approach, quality of reduction and patient-related factors. Even with modern fixation techniques, severe pilon fractures may result in persistent functional limitations^{7,13,14}. Fracture union is an important indicator of treatment success. The highly comminuted nature of many pilon fractures, combined with soft-tissue injury and metaphyseal bone loss, may delay healing. Stable fixation with appropriate biological preservation can facilitate fracture consolidation while allowing progressive rehabilitation. Assessment of the time required for radiological union, progression of weight bearing and maintenance of alignment therefore provides valuable information regarding the effectiveness of the chosen fixation method^{11,14}.

Functional assessment is equally important in evaluating the final outcome. The American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot score is commonly used for evaluating patients following ankle and hindfoot injuries. It incorporates assessment of pain, function and alignment and can be used during serial follow-up to evaluate improvement over time. In patients

undergoing locking compression plate fixation for pilon fractures, assessment of AOFAS scores along with radiological union, time to weight bearing, duration of hospitalization and postoperative complications provides a comprehensive evaluation of clinical outcome (11,15). Despite advances in fracture classification, imaging, implant design, surgical techniques and perioperative soft-tissue management, distal tibial pilon fractures continue to represent a significant therapeutic challenge. The optimal treatment requires careful patient selection, detailed preoperative planning, appropriate timing of surgery, preservation of the soft-tissue envelope and stable fixation. Locking compression plate osteosynthesis offers the advantages of angular stability and the possibility of biological and minimally invasive fixation, making it a useful treatment option in selected distal tibial pilon fractures^{1,8,10}.

The present prospective study was therefore undertaken to evaluate the functional outcome of distal tibial pilon fractures treated with locking compression plate osteosynthesis. The study evaluates patients treated operatively and assesses fracture union, time to weight bearing, postoperative hospitalization, functional recovery using the AOFAS score and postoperative complications. In the present study, 30 consecutive cases were evaluated over a two-year period from March 2022 to February 2024, with clinical and radiological follow-up after surgery. The study findings are intended to provide an assessment of the functional and radiological outcomes achievable with locking compression plate fixation in appropriately selected patients with distal tibial pilon fractures.

Materials and Methods

Study design and design

The present study was conducted as a prospective study over a period of two years, from March 2022 to February 2024. A total of 30 consecutive patients with distal tibial pilon fractures requiring operative treatment were included.

Inclusion Criteria

1. Skeletally mature patients.
2. Patients considered fit for operative treatment.
3. Patients willing to provide written informed consent.
4. Patients with closed distal tibial pilon fractures.
5. Fractures corresponding to AO/OTA types A, B or C.
6. Rüedi-Allgöwer type I, II and III fractures.
7. Ovadia-Beals type I–V fractures.

Exclusion Criteria

1. Patients aged <18 years or >75 years.
2. Paediatric distal tibial fractures.
3. Open fractures.
4. Pathological fractures.
5. Patients unwilling to provide consent for surgery.
6. Patients medically unfit for surgery.

The original document contains the age criterion in a typographical form (“75 years > Age <18 years”); it has been corrected here to the intended criterion of age below 18 years or above 75 years.

Initial Clinical Evaluation

At first presentation, a detailed history was obtained regarding age, sex, occupation, mechanism of injury, time since injury, associated medical illnesses and pre-injury morbidity. A comprehensive clinical examination was performed, including assessment of the site of trauma, swelling, wounds, condition of the ankle and adjacent joints and neurovascular status of the affected limb. General examination included assessment of vital

parameters and identification of any associated systemic or orthopaedic injuries.

Radiological Evaluation

The fracture was classified according to the Rüedi-Allgöwer classification. Plain radiographs of the ankle were obtained in anteroposterior, lateral and mortise views. The injured limb was initially immobilized in an above-knee splint.

Preoperative Investigations

Routine preoperative investigations included complete blood count, urine routine examination, random blood sugar, kidney function tests, bleeding time, clotting time, coagulation profile and liver function tests. Preoperative fitness was obtained from the physician and anaesthesiologist. Analgesic and anti-inflammatory medications were administered as required.

Operative Technique

Locking compression plate osteosynthesis was performed using appropriate distal tibial plates and locking/cortical screws. An anterolateral or medial minimally invasive approach was selected according to the fracture configuration and soft-tissue condition. The implants and instruments used included distal tibial anterolateral plates, 3.5-mm locking cancellous screws, 3.5-mm cortical screws, 4.5-mm locking cortical screws, drill sleeves, drill bits, depth gauges, bone taps, K-wires and screwdrivers. For the anterolateral approach, the patient was positioned supine with a tourniquet and a sandbag under the ipsilateral buttock. The incision was made anteriorly between the malleoli over the distal tibia. Superficial dissection was performed carefully, with protection of the superficial peroneal nerve. Deep dissection was continued as required to expose the distal tibia and facilitate fracture reduction and fixation.

For the medial minimally invasive approach, the patient was positioned supine and a 3–5 cm incision was made over the medial distal tibia. The greater saphenous vein and nerve were protected during dissection. The plate was introduced through the epiperiosteal plane, preserving the periosteum and minimizing soft-tissue disruption.

Postoperative Management

After fixation, the foot was padded and immobilized with a splint. Intravenous antibiotics were administered postoperatively for up to five days. Dressings were performed on postoperative days 3, 5 and 7. The affected limb was elevated for approximately 2–5 days. Active-assisted physiotherapy was initiated immediately after surgery, followed by progressive mobilization depending on wound healing.

Follow-up and Outcome Assessment

Clinical and radiological follow-up was performed at 2, 6 and 12 weeks. Weight bearing was progressively increased according to radiological consolidation, generally after 6–8 weeks, with full weight bearing planned after approximately three months.

The primary functional outcome was assessed using the AOFAS ankle-hindfoot score. Additional outcomes included fracture union, time to initiation of weight bearing, postoperative hospital stay and complications. Final functional outcomes were categorized as excellent (95–100), good (75–94), fair (51–74) and poor (0–50).

Implants used



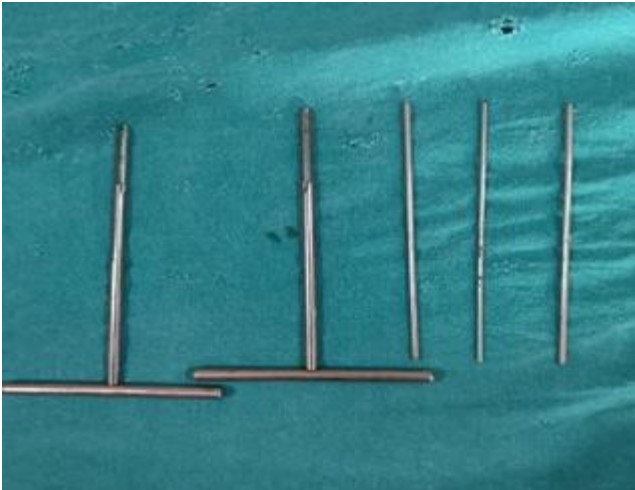
Distal tibia anterolateral plate



Drill sleeve, Drill bit, Depth gauge



Bonita, K wire



Screw Driver



3.5mm Locking cancellous screw



4.5mm Locking cortical screw



3.5mm Cortical screw



Skin Incision



Deep dissection



Results

Table 1: Age Distribution Among Patients

Age group	No. of Patients	Percentage%
18-20	1	3.33%
21-30	6	20%
31-40	16	53.33%
41-50	6	20%
51-60	1	3.33%
>60	0	0
Total	30	100%

Graph 1

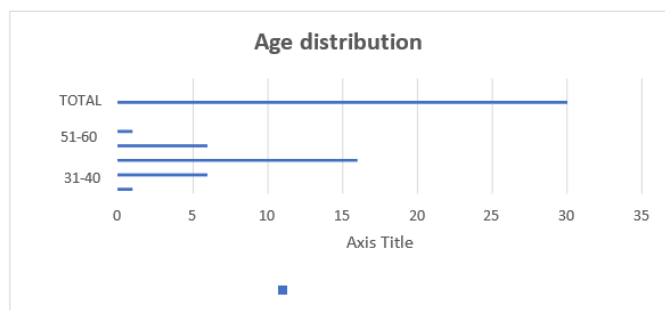


Table 2: Sex distribution among patients

Sex	No. of patients	Percentage%
Male	24	80
Female	6	20
Total	30	100

Graph 2

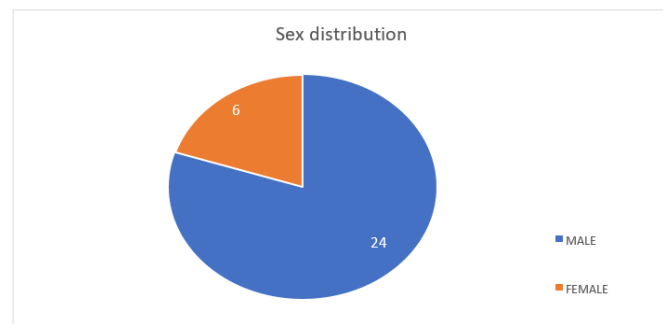


Table 3: Mode of injury among patients

Mode of injury	No. of Patients	Percentage %
RTA	20	66.66
H/O fall from Height	9	30
Others	1	3.33
Total	30	100

Graph 3

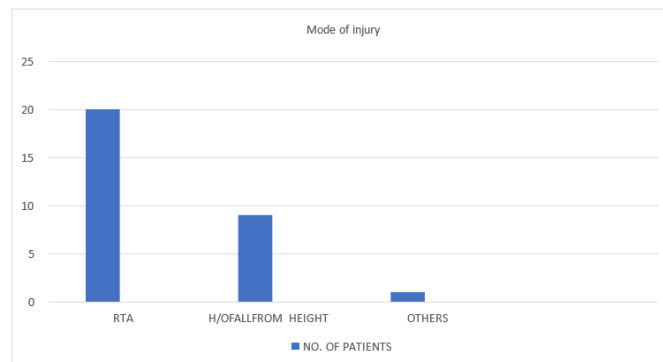


Table 4: Occupation among patients

Occupation	No. of Patients	Percentage %
Farmer	5	16.66
Laborer	6	20
Housewife	4	13.33
Student	2	6.66
Teacher	2	6.66
Office Professionals	5	16.66
Others	6	20
Total	30	100

Graph 4

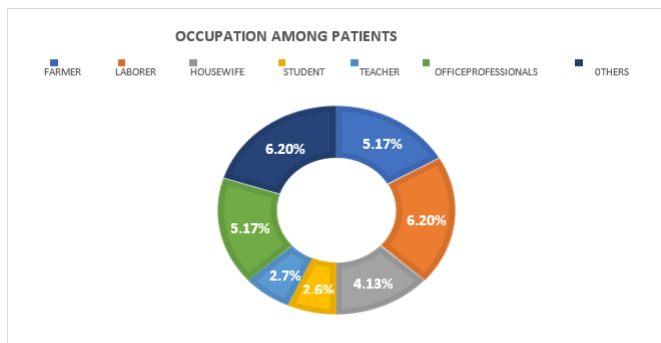


Table 5: Interval between injury and surgery of fracture among patients

Interval (days)	No. of patients	Percentage%
<7	12	40
7-10	15	50
11-14	2	6.66
>14	1	3.33
Total	30	100

Graph 5

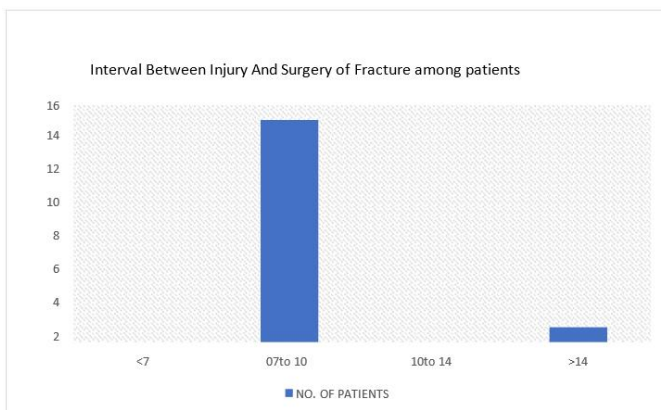


Table 6: Time of fracture union among patients

Time (months)	No. of patients	Percentage%
1	0	0
2	2	6.66
3	19	63.33
>3	9	30
Total	30	100
Meantime(months)	2.4±0.56	

Graph 6

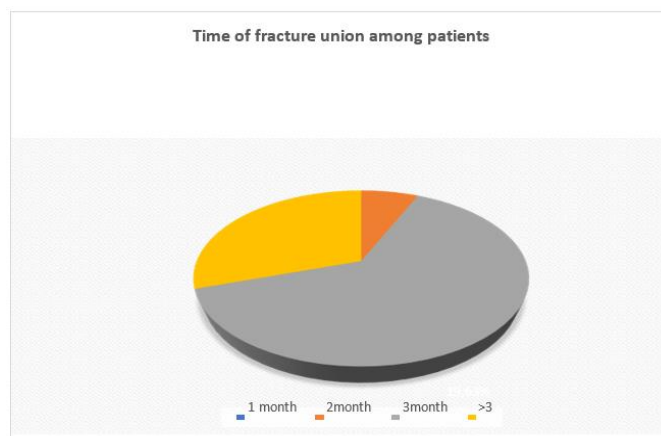


Table 7: Days of post-operative hospitalization among patients:

Hospitalization (days)	No. of patients	Percentage%
1-5	27	90
6-10	3	10
11-15	0	0
Total	30	100
Mean(days)	3.76±3.72	

Graph 7

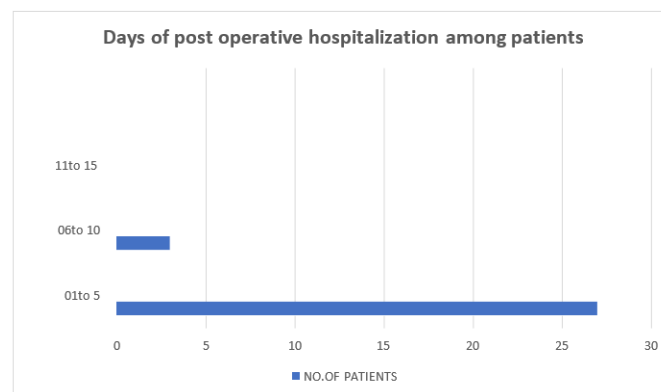


Table 8: Comparison of AOFAS Scale among patients at different intervals

A of as scale		P-Value
Pre-Operative	30.76±5.85	0.001
At6 Weeks	59.56±6.58	
At final follow-up	87.23±6.19	

Table 9: Comparison of weight bearing started among patients

Weight bearing (Weeks)	No. of Patients	Percentage%
<6	0	0
6-10	29	96.66
>10weeks	1	3.33
Total	30	100

Graph 8

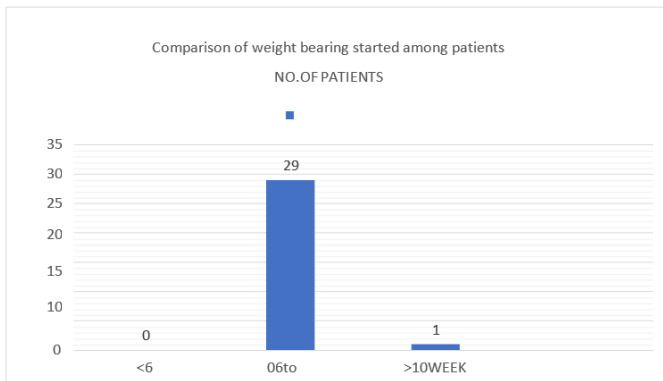


Table 10: Comparison of final outcome among patients

Outcome	No. of patients	Percentage%
Excellent(95-100)	11	36.66
Good(75-94)	18	60
Fair(51-74)	1	3.33
Poor(0 -50)	0	0
Total	30	100

Graph 9

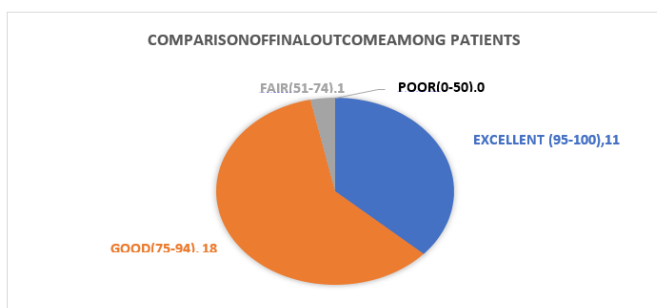


Table 11: Distribution of complications among patients

Complications	No. of patients(N=30)	Percentage%
Delayed union	2	6.66
Heel varus	0	3.33
Infection	2	6.66
Persistent heel pain	0	0
Peroneal tendinitis	0	0
Wound dehiscence	1	3.33
Post Traumatic Arthritis	0	0
Re-Operative	0	0

A total of 30 patients with distal tibial pilon fractures were included in the present study. The age distribution showed that the majority of patients belonged to the 31–40-year age group, comprising 16 patients (53.33%). Six patients (20%) were aged 21–30 years and another six patients (20%) were aged 41–50 years. One patient each belonged to the 18–20-year and 51–60-year age groups

(3.33% each), while no patient was older than 60 years. There was a marked male predominance. Of the 30 patients, 24 (80%) were male and 6 (20%) were female, giving a male-to-female ratio of 4:1. Road traffic accidents were the most common mechanism of injury, accounting for 20 cases (66.66%). Falls from height were responsible for 9 cases (30%), while other mechanisms accounted for 1 case (3.33%). Thus, high-energy trauma, particularly road traffic accidents, constituted the predominant mechanism of distal tibial pilon fracture in the study population. With regard to occupation, laborers and the category of other occupations each contributed 6 patients (20%). Farmers and office professionals accounted for 5 patients each (16.66%), while 4 patients (13.33%) were housewives. Students and teachers contributed 2 patients each (6.66%). The interval between injury and definitive surgery was less than 7 days in 12 patients (40%), while the largest group, comprising 15 patients (50%), underwent surgery within 7–10 days. Two patients (6.66%) underwent surgery within 11–14 days and one patient (3.33%) underwent surgery after more than 14 days. Thus, 90% of patients underwent operative treatment within 10 days of injury. Regarding fracture union, no patient achieved union within one month. Two patients (6.66%) achieved union by two months, while the majority, 19 patients (63.33%), achieved fracture union by three months. Nine patients (30%) required more than three months for union. The reported mean time to fracture union was 2.4 ± 0.56 months. Postoperative hospitalization was relatively short in the majority of patients. Twenty-seven patients (90%) were discharged within 1–5 days, whereas 3 patients (10%) remained hospitalized for 6–10 days. No patient required hospitalization for 11–15 days. The reported mean duration of postoperative hospitalization was 3.76 ± 3.72

days. Functional recovery demonstrated substantial improvement following surgery. The mean preoperative AOFAS score was 30.76 ± 5.85 , which improved to 59.56 ± 6.58 at 6 weeks and further increased to 87.23 ± 6.19 at final follow-up. The reported comparison showed a statistically significant improvement, with a p-value of 0.001.

Weight bearing was initiated between 6 and 10 weeks in 29 patients (96.66%), while one patient (3.33%) started weight bearing after more than 10 weeks. No patient started weight bearing before six weeks. These findings indicate that the majority of patients were able to commence progressive weight bearing within 6–10 weeks following fixation. At final follow-up, 11 patients (36.66%) achieved an excellent outcome, with an AOFAS score of 95–100, while 18 patients (60%) had a good outcome, with scores between 75 and 94. One patient (3.33%) had a fair outcome, with a score between 51 and 74, and no patient had a poor outcome. Therefore, 29 of the 30 patients (96.66%) achieved good or excellent functional outcomes at final follow-up. Postoperative complications were observed in a small proportion of patients. Delayed union occurred in 2 patients (6.66%), while infection was reported in 2 patients (6.66%). Wound dehiscence occurred in 1 patient (3.33%). Persistent heel pain, peroneal tendinitis, post-traumatic arthritis and re-operative procedures were reported as absent. The source table reports heel varus as 0 patients with 3.33%, which is internally inconsistent and should be verified against the original patient records before final submission.

Discussion

Distal tibial pilon fractures remain challenging injuries because they combine intra-articular damage, metaphyseal comminution and variable degrees of soft-

tissue injury. The present study evaluated 30 patients treated with locking compression plate osteosynthesis and demonstrated substantial improvement in functional outcome, with a mean final AOFAS score of 87.23 ± 6.19 and good or excellent results in 96.66% of patients. These findings should be interpreted in the context of the selected population, which consisted of closed fractures in patients considered fit for surgery.

Age Distribution

In the present series, the largest proportion of patients belonged to the 31–40-year age group, accounting for 16 patients (53.33%). Patients aged 21–30 and 41–50 years each represented 20% of the cohort. No patient was older than 60 years.

This distribution is consistent with the fact that pilon fractures are frequently associated with high-energy trauma affecting working-age adults. The literature emphasizes that the mechanism of injury and energy transferred to the distal tibia are major determinants of fracture severity and soft-tissue damage. High-energy axial loading can produce extensive articular comminution and metaphyseal impaction, particularly in younger adults exposed to road traffic accidents or falls from height (1,2).

Sex Distribution

A marked male predominance was observed, with 24 males (80%) and 6 females (20%). This male predominance may reflect greater exposure to high-energy occupational and road-traffic trauma among working-age men. Similar demographic patterns have been described in clinical series of pilon fractures, although the exact sex distribution varies according to population and mechanism of injury^{2,3}.

Mechanism of Injury

Road traffic accidents were the predominant mechanism in the present study, accounting for 20 patients (66.66%), followed by falls from height in 9 patients (30%). Only one patient sustained the injury through another mechanism.

The predominance of road traffic accidents supports the established association between pilon fractures and high-energy axial loading. Such injuries may cause severe articular impaction and soft-tissue trauma, which directly influence treatment planning and prognosis^{4,5}. Teeny and Wiss emphasized that the severity of the initial fracture and soft-tissue injury contributes substantially to postoperative complications and poor outcomes⁵. McFerran et al. similarly demonstrated that complications remain a major concern in pilon fracture treatment⁶.

Timing of Surgery

In the present study, 12 patients (40%) underwent surgery within seven days, while 15 patients (50%) underwent surgery between 7 and 10 days. Thus, 90% of the patients underwent definitive operative treatment within 10 days of injury.

The timing of definitive fixation is particularly important in pilon fractures because surgery performed through a severely swollen or compromised soft-tissue envelope can increase wound complications. Patterson and Cole demonstrated acceptable outcomes using a two-stage strategy for severe C3 pilon fractures, while Sirkin et al. reported favorable wound healing with staged treatment designed around soft-tissue recovery^{7,8}.

Blauth et al. also reported favorable functional characteristics with a two-stage approach in severe injuries and subsequently preferred staged treatment when extensive soft-tissue damage was present⁹. Current reviews continue to emphasize that treatment timing

should be individualized according to fracture morphology and soft-tissue condition rather than determined solely by the radiographic fracture pattern^{10,11}.

Rationale for Locking Compression Plate Fixation

Locking compression plates provide angular stability and are particularly useful in distal tibial fractures where distal bone stock is limited and conventional screw fixation may provide inadequate stability. The locking construct permits screws to function as fixed-angle elements while reducing the need for extensive plate-to-bone contact. Wagner described the biological and mechanical principles underlying the locking compression plate concept, emphasizing its ability to combine stable fixation with preservation of local biology¹².

Minimally invasive locked plating has subsequently become an important technique for distal tibial fractures because of the limited soft-tissue coverage around the distal tibia. Ronga et al. described minimally invasive osteosynthesis with locking plates as a technique capable of providing satisfactory union while limiting additional soft-tissue injury¹³. Shifflett et al. reported high union rates and favorable AOFAS scores following percutaneous locking plate treatment of distal tibial fractures, supporting the functional potential of this fixation strategy¹⁴.

Functional Outcome

The most important finding of the present study was the progressive improvement in AOFAS score. The mean preoperative score was 30.76 ± 5.85 , increasing to 59.56 ± 6.58 at six weeks and 87.23 ± 6.19 at final follow-up. The improvement was statistically significant ($p=0.001$). The final functional results were favorable: 11 patients (36.66%) had excellent results, 18 patients (60%) had good results, and only one patient (3.33%) had a fair result. No patient had a poor outcome. Consequently,

96.66% of patients achieved either a good or excellent AOFAS outcome.

These findings are comparable with the favorable functional outcomes reported in selected patients treated using locking plate techniques. Shifflett et al. reported an average AOFAS ankle score of 88.8 after percutaneous locking plate fixation, which is close to the final mean AOFAS score observed in the present study¹⁴.

However, pilon fracture outcomes are strongly influenced by fracture severity and quality of reduction. Liu et al. demonstrated that surgical approach may influence complication rates, while clinical series have shown that more severe Rüedi-Allgöwer patterns are associated with poorer functional outcomes¹⁵.

Fracture Union

In the present study, 19 patients (63.33%) achieved fracture union by three months, two patients (6.66%) by two months and nine patients (30%) after three months. The reported mean union time was 2.4 ± 0.56 months.

The relatively favorable union pattern may be related to the selection of closed fractures and the use of stable fixation with preservation of the periosteal environment. Nevertheless, pilon fractures can be associated with delayed union because of metaphyseal comminution, bone loss, soft-tissue injury and biological compromise. Shifflett et al. reported that 16 of 18 distal tibial fractures achieved union following percutaneous locking plate treatment, with an average union time of 23.1 weeks, although delayed union occurred in three cases (14). The difference between their union time and the present study may be related to differences in fracture pattern, patient selection, definition of union and follow-up protocol.

Weight Bearing

In the present study, 29 patients (96.66%) began weight bearing between 6 and 10 weeks, while only one patient

required more than 10 weeks. No patient began weight bearing before six weeks.

The controlled progression of weight bearing is important in pilon fractures because premature loading may jeopardize fracture alignment or fixation, whereas prolonged immobilization can contribute to ankle stiffness and functional limitation. Stable locking fixation can facilitate progressive rehabilitation while allowing weight bearing to be individualized according to radiological evidence of consolidation.

Complications

The present study demonstrated a relatively low frequency of recorded complications. Delayed union occurred in two patients (6.66%), infection in two patients (6.66%) and wound dehiscence in one patient (3.33%). No post-traumatic arthritis, peroneal tendinitis, persistent heel pain or reoperation was recorded in the study table.

The complication profile is clinically relevant because wound problems and infection remain among the major concerns following pilon fracture fixation. Kline et al. reported considerably higher complication rates among diabetic patients undergoing operative pilon fracture treatment, highlighting the influence of patient-related risk factors on infection and delayed/nonunion.

The original Table 11 contains an internal inconsistency for heel varus, reporting 0 patients but 3.33%. Mathematically, 0 patients among 30 corresponds to 0%. Therefore, this entry should be checked against the original case records before final submission rather than silently assuming the percentage.

Comparison with Long-Term Literature

Long-term outcomes following pilon fractures may be less favorable than early postoperative functional scores suggest. Chen et al. reported that severe Rüedi-Allgöwer type III fractures were associated with poorer reduction

and increasing post-traumatic ankle arthrosis over long-term follow-up¹⁶.

Similarly, van der Vliet et al. reported impaired long-term ankle function and health-related quality of life following operative treatment of pilon fractures, emphasizing that successful union does not necessarily imply complete functional recovery¹⁷.

Lee et al. found that appropriate stabilization of associated fibular fractures could improve alignment and clinical outcome in selected patients with pilon fractures¹⁸. Conversely, Kurylo et al. reported that fibular fixation is not universally necessary in complex pilon fractures and should be individualized according to reduction requirements and stability¹⁹.

Locking Plates and Minimally Invasive Techniques

The biological advantage of minimally invasive plating is particularly relevant to distal tibial fractures because of the limited soft-tissue coverage. Ronga et al. demonstrated that minimally invasive locked plating can achieve fracture union while avoiding the extensive exposure associated with conventional plating¹³. The present study similarly used anterolateral and medial minimally invasive approaches where appropriate, with preservation of the periosteum described in the operative protocol.

Martin Fuentes et al. reported favorable outcomes with percutaneous osteosynthesis in selected distal tibial fractures, although differences in fracture characteristics and fixation methods should be considered when comparing studies.

Comparison with Other Fixation Methods

ORIF with plate fixation is not the only treatment option for pilon fractures. Circular external fixation and staged fixation may be preferred in selected high-energy injuries, particularly when soft-tissue conditions are unfavorable.

A systematic review and meta-analysis by Malik-Tabassum et al. found broadly comparable rates of nonunion, malunion and infection between ORIF and circular external fixation, although ORIF was associated with higher rates of unplanned metalwork removal and lower rates of post-traumatic arthritis in the included studies²⁰.

Contemporary reviews therefore emphasize individualized treatment rather than a single universal fixation strategy. Flores et al. noted that staged ORIF remains a standard strategy for many pilon fractures, while selected injuries may be suitable for early definitive fixation depending on fracture morphology and soft-tissue condition²¹.

Recent evidence continues to question whether every patient requires delayed fixation. A 2026 systematic review and meta-analysis found no significant difference in infection/wound complications, malunion or nonunion between early and delayed/staged plate fixation, although the certainty of evidence was low to very low²². This reinforces the principle that timing should be individualized rather than universally fixed. The present study demonstrates that locking compression plate osteosynthesis can provide satisfactory functional recovery in appropriately selected patients with closed distal tibial pilon fractures. The marked improvement in AOFAS score, high proportion of good/excellent final outcomes, relatively early fracture union and low recorded complication rate suggest that stable fixation combined with appropriate soft-tissue management can achieve favorable short- to intermediate-term results.

Nevertheless, the results should not be generalized to open fractures, elderly patients, pathological fractures or patients with severe soft-tissue compromise because these groups were excluded from the present study. Modern

literature emphasizes that fracture severity, soft-tissue damage, quality of reduction, surgical timing and patient-related factors all influence final outcome.²³⁻²⁵

Conclusion

Locking compression plate osteosynthesis provided satisfactory radiological union and significant functional improvement in the present series of 30 selected patients with closed distal tibial pilon fractures. The mean AOFAS score improved significantly from 30.76 preoperatively to 87.23 at final follow-up, with 96.66% of patients achieving good or excellent functional outcomes. Appropriate patient selection, careful soft-tissue handling, appropriate timing of surgery, stable locking plate fixation, progressive weight bearing and supervised rehabilitation are important for achieving favorable outcomes.

Limitations

The study was limited by its small sample size of 30 patients, single-center design and relatively limited follow-up, which may restrict generalizability of the findings.

Declarations

Consent to participate: There is consent to participate.

Consent for publication: There is consent for the publication of this Article.

Authors' contributions: Author equally contributed the work.

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