International Journal of Research in Orthopaedics
Appusamy VS et al. Int J Res Orthop. 2019 May;5(3):490-497
http://www.ijoro.org

DOI: http://dx.doi.org/10.18203/issn.2455-4510.IntJResOrthop20191790

Original Research Article

Radiological parameters determining outcome in pilon fractures treated by minimally invasive plate osteosynthesis

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Received: 29 January 2019
Revised: 06 March 2019
Accepted: 07 March 2019

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ABSTRACT

Background: Tibial pilon fractures are one of the challenging fractures to manage in the field of orthopaedics due to its complex fracture patterns as well as associated soft tissue injury. Minimally invasive plate osteosynthesis (MIPO) technique aims to reduce the surgical trauma to the surrounding soft tissues and hence maintain a more biologically favourable environment for fracture healing. The purpose of the study is to analyse the various factors especially radiological parameters determining functional outcome in pilon fractures treated by MIPO technique.
Methods: This is a prospective study conducted from June 2015 to May 2018. The study included 46 patients (33 males, 13 females) with pilon fractures treated by minimally invasive plate osteosynthesis. All patients were followed for average period of 2 years. Functional outcome was assessed using American Orthopedic Foot and Ankle Score (AOFAS).
Results: Among 46 patients, 21 patients (45.65%) had excellent, 16 patients (34.78%) had good and 6 patients (13.04%) had fair functional outcome. The quality of reduction was the most important parameter determining the functional outcome. We found that patients with higher lateral distal tibial angle (LDTA), anterior distal tibial angle (ADTA) and length of lateral malleolus (LLM) had better functional outcome than patients with lower values. The timing of surgery had no significant influence on the functional outcome of the patients.
Conclusions: We like to conclude that apart from the quality of fracture reduction, radiological parameters like ADTA, LDTA, and LLM also play a crucial role in determining the functional outcome in pilon fractures.

Keywords: Pilon fractures, Minimally invasive plate osteosynthesis, Lateral distal tibial angle, Anterior distal tibial angle, Length of lateral malleolus

INTRODUCTION

Pilon fractures which contributes less than 1% of all fractures of lower extremity are the fractures involving weight bearing portion of distal tibia with adjacent metaphysis.[1,2] Pilon fractures usually results from high energy axial compressive and torsional forces. These high energy pilon fractures still remain as a major challenge to the treating surgeon because of the complexity of the fracture pattern and the risk of surgery-related complications.[3]

Treatment options for pilon fractures varies from conservative management in the form of closed reduction and casting to operative management in form of combined intramedullary nailing and plate fixation, external fixation (EF), open reduction and internal fixation (ORIF), minimally invasive plate osteosynthesis (MIPO).[4] Conservative management for stable,

undisplaced fracture requires prolonged immobilisation and may results in joint stiffness, malunion, shortening, early osteoarthritis.[5,6] Wound infection, skin necrosis, delayed union and non-union are some of the complications associated with conventional plating.[7-10] Moreover external fixators are generally not used as definitive fixation method due to pin loosening, delayed union, malunion, pin tract infection resulting in osteomyelitis.[11,12]

In recent times, MIPO using locking compression plate has emerged as the treatment modality of choice for complex pilon fractures which is based on the principles of limited soft tissue stripping, maintenance of osteogenic fracture hematoma and preservation of vascular supply to the fracture fragment.[13] Inspite of biological fixation various factors like age, bone quality, mode of injury, fracture pattern, quality of reduction, timing of surgery, fibula fixation also determines the functional outcome in patients with pilon fractures. So the aim of our study is to critically analyse the various radiological parameters determining the functional outcome in patients with pilon fractures treated by minimally invasive plate osteosynthesis.

METHODS

This is a prospective study conducted at Government Royapettah hospital, Chennai from July 2014 to May 2018. After institutional ethical committee clearance, 46 patients (33 males, 13 females) with age more than 18 years who sustained closed or grade 1 compound tibial pilon fracture (AO type 43A/B/C) were included in the study. Patients with grade 2 or 3 compound fractures, pathological fractures or fracture more than 2 weeks durations were excluded from the study.

All surgeries were done under regional anaesthesia. Patients were positioned supine on operating table and initially fibula fixation was done using one third tubular plate or recon plate. Later following closed percutaneous reduction of distal tibia, 2cm vertical incision was made over the medial malleolus. Plate was inserted after creating a tunnel in a retrograde manner and fixed with percutaneously placed screws by stab incisions under image intensifier guidance. Patients were advised ankle and knee mobilisation on the 2nd postoperative day. Partial weight bearing was allowed once signs of callus formation were evident radiologically. Later full weight was allowed after assessing the radiological union in follow up x-ray. We defined distal tibial malunion as fracture healing with angulation of 10^{o} or more in any plane, or internal rotation of 10^{o} or more, external rotation of more than 15^{o} or tibial shortening of 2 cm or more.[14] Nonunion was defined as no evidence of fracture healing after 6 months. Following complete fracture union, the functional outcome was assessed using AOFAS score.

Radiological assessment

In immediate postoperative period, standard anterior-posterior (AP) and lateral radiograph of the ankle was taken. The following radiological parameters like quality of reduction, lateral distal tibial angle (LDTA), anterior distal tibial angle (ADTA), length of lateral malleolus were studied.

The quality of reduction was assessed using Ovadia and Beals criteria which includes minimum score of one and maximum score of three for each of the following parameters: lateral malleolus displacement, medial malleolus displacement, posterior malleolus displacement, mortise widening, fibular widening, talar tilt and articular gap. Finally the quality of reduction was graded as anatomical (<8 pts), good (9-11 pts), fair (12-15 pts) and poor (>15 pts) based on total score.[15]

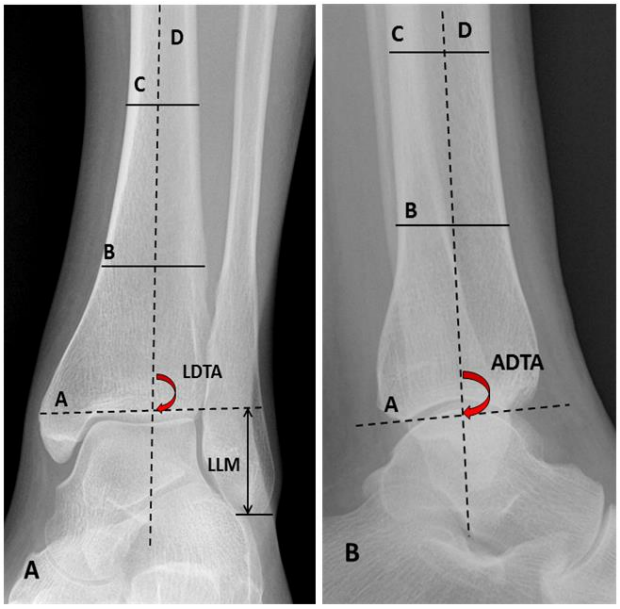

Figure 1: Measurement of lateral distal tibial angle (LDTA) and length of lateral malleolus (LLM) in AP view and measurement of anterior distal tibial angle (ADTA) in lateral view.

LDTA is defined as the angle between the long axis of tibia and the articular surface of the tibial plafond. In the Figure 1A, line A describes the plane of the tibial plafond, and line B was drawn at the metadiaphyseal border of the distal tibia. Line C was drawn proximally parallel to line B with a distance of at least 5 cm. Line D bisects both line B and line C and describes the tibia axis. The angle between line A and D represents LDTA.

Similarly anterior distal tibial angle (ADTA) is the angle between the anatomical axis of tibia and the line connecting the distal points on the anterior and posterior tibial articular surface. In the figure 1B the line A connects the distal points on the anterior and posterior tibial articular surface; line D represents the anatomical

axis of tibia. The angle between line A and D represents ADTA.

The length of lateral malleolus (LLM) is measured as the distance between the plane of tibial plafond and the tip of lateral malleolus.[16] In Figure 1A, the length of LLM is the distance between the line A to the lateral malleolus tip.

Statistical analysis

The statistical analysis in our study was performed using SPSS software version 20.0 and the various factors influencing the functional outcome like quality of reduction, LDTA, ADTA, LLM, timing of surgery were analysed using Pearson Chi-Square analysis. All data were analyzed at a significance level of $p<0.05$.

RESULTS

Demographic characteristics, various observations including AO fracture types, mode of injury, type of injury, fibula fracture, timing of presentation, timing of surgery, average surgery duration, functional outcome based on AOFAS score are given in (Table 1). The average follow up period in our study was 2 years. Fracture consolidation was seen by mean period of 19.2 weeks (16-25 weeks) (Figure 2). We came across the following complications in our study population: 4 cases of superficial wound infection, 3 cases of skin necrosis which required flap cover, 2 cases of delayed union which required bone grafting, 2 cases of malunion and 1 case with breakage of implant (Figure 3).

Figure 2: 56 years old male with AO type 43A3 pilon fracture (A) preoperative AP view, (B) preoperative lateral view, (C) Immediate postoperative AP view with LDTA of 94.9 ^{o} and LLM of 28.5 mm, (D) Immediate postoperative lateral view with ADTA of 81.5^{o} (E) final follow up X ray AP view and (F) final follow up X-ray lateral view with complete union.

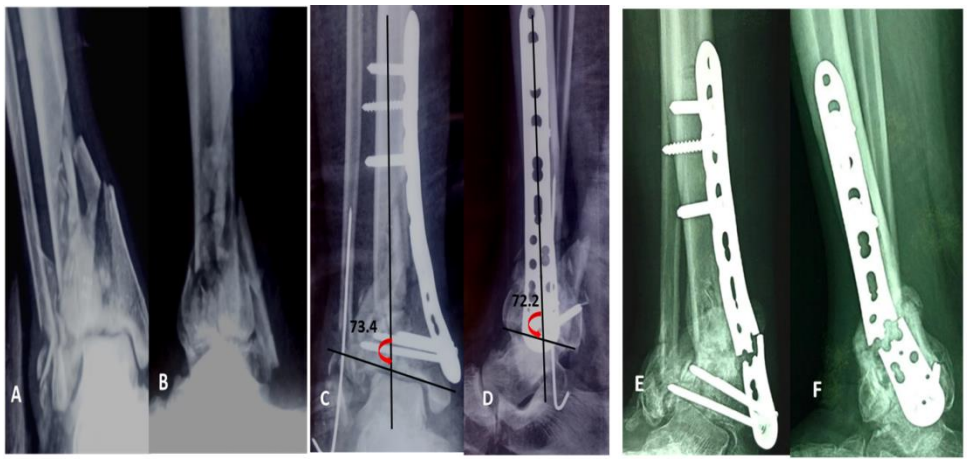

Figure 3: 42 years old female with AO type 43C2 pilon fracture (A) preoperative AP view, (B) preoperative lateral view, (C) Immediate postoperative AP view with LDTA of 73.4^{o} and LLM of 18.5 mm, (D) Immediate postoperative lateral view with ADTA of 72.2^{o} E) 8 months follow up AP view and F) 8 months follow up lateral view showing breakage of implant with secondary arthritis

Table 1: Demographic characteristics.

Total no. of patients	n=46 (males-33, females- 13)			
Age distribution in years	<50 9 patients (19.6%)	50-60 22 patients (47.8%)	60-70 11 patients (23.9%)	>70 4 patients (8.7%)
Fracture type (AO type)	43 (A1/A2/A3) 1/4/5	43 (B1/B2/B3) 3/1/4	43 (C1/C2/C3) 10/10/8	
Mode of injury	Self fall 12 patients (26.1%)	RTA 27 patients (58.7%)	FFH 7 patients (15.2%)	
Timing of presentation	<24 hrs 31 patients (67.4%)	24–72 hrs 12 patients (26.1%)	>72 hrs 3 patients (6.5%)	
Timing of surgery	<3 days 15 patients (32.6%)	3-7 days 22 patients (47.8%)	>7 days 9 patients (19.6%)	
Type of injury	Closed type 40 patients (87.0%)	Open type 6 patients (13.0%)		
Fibula fracture	Present 41 patients (89.1%)	Absent 5 patients (10.9%)		
Average surgery time	45 mins (range: 60-120 mins)			
Follow up period	18 months- 36 months			
Functional outcome (AOFAS scale)	Excellent 21 patients (45.7%)	Good 16 patients (34.8%)	Fair 6 patients (13.0%)	Poor 3 patients (6.5%)

RTA- road traffic accident, FFH- fall from height.

Table 2: Patients demographic and postoperative data in relation to quality of reduction.

Quality of reduction (Ovadia and Beals criteria)	Anatomical (<8 pts)	Good (9-11 pts)	Fair (12-15 pts)	Poor (>15 pts)
	N (%)	N (%)	N (%)	N (%)
No. of cases	28 (60.9)	11 (23.9)	5 (10.9)	2 (4.3)
Fracture type				
43 A	10 (35.7)	0 (0)	0 (0)	0 (0)
43 B	5 (17.9)	2 (18.2)	1 (20)	0 (0)
43 C	13 (46.4)	9 (81.8)	4 (80)	2 (100)
Functional outcome				
Excellent + good	26 (92.9)	10 (90.9)	0 (0)	0 (0)
Fair + poor	2 (7.1)	1 (9.1)	5 (100)	2 (100)
Skin complications (superficial infection, skin necrosis)	2 (7.1)	3 (27.3)	2 (40)	0 (0)
Fracture complication (delayed union, malunion)	0 (0)	1 (9.1)	2 (40)	2 (100)

Table 3: Patients demographic and postoperative data in relation to lateral distal tibial angle (LDTA).

Lateral distal tibial angle (LDTA)	LDTA (<85^0)	LDTA (85^0–90^0)	LDTA (>90^0)
	N (%)	N (%)	N (%)
No. of cases	9 (19.6)	22 (47.8)	15 (32.6)
Fracture type			
43 A	2 (22.2)	6 (27.3)	2 (13.3)
43 B	1 (11.1)	4 (18.2)	3 (20)
43 C	6 (66.7)	12 (54.5)	10 (66.7)
Functional outcome			
Excellent + good	2 (22.2)	20 (90.9)	15 (100)
Fair + poor	7 (77.8)	2 (9.1)	0 (0)
Skin complications (superficial infection, skin necrosis)	3 (33.3)	3 (13.6)	1 (6.7)
Fracture complication (delayed union, malunion)	4 (44.4)	1 (4.5)	0 (0.0)

Table 4: Patients demographic and postoperative data in relation to anterior distal tibial angle (ADTA).

Anterior distal tibial angle (ADTA)	ADTA (<75 ^{0})	ADTA (75^0 -80^0)	ADTA (>80^0)
	N (%)	N (%)	N (%)
No. of cases	6 (13.0)	19 (41.3)	21 (45.7)
Fracture type			
43 A	0 (0.0)	4 (21.1)	6 (28.6)
43 B	2 (33.3)	3 (15.8)	3 (14.3)
43 C	4 (66.7)	12 (63.1)	12 (57.1)
Functional outcome			
Excellent + good	2 (33.3)	14 (73.7)	21 (100)
Fair + poor	4 (66.7)	5 (26.3)	0 (0.0)
Skin complications (superficial infection, skin necrosis)	1 (16.7)	6 (31.6)	0 (0)
Fracture complication (delayed union, malunion)	4 (66.7)	1 (5.3)	0 (0)

Table 5: Patients demographic and postoperative data in relation to length of lateral malleolus (LLM).

Length of lateral malleolus (LLM)	LLM (<25 mm)	LLM (25–27.5 mm)	LLM (>27.5 mm)
	N (%)	N (%)	N (%)
No. of cases	5 (10.9)	18 (39.1)	23 (50.0)
Fracture type			
43 A	1 (20)	5 (27.8)	4 (17.4)
43 B	0 (0)	3 (16.7)	5 (21.7)
43 C	4 (80)	10 (55.5)	14 (60.9)
Functional outcome			
Excellent + good	0 (0)	15 (83.3)	22 (95.7)
Fair + poor	5 (100)	3 (16.7)	1 (4.3)
Skin complications (superficial infection, skin necrosis)	2 (40)	4 (22.2)	1 (4.3)
Fracture complication (delayed union, malunion)	2 (40)	3 (16.7)	0 (0)

Table 6: Patients demographic and postoperative data in relation to timing of surgery.

Timing of surgery	<3 days	3–7 days	>7 days
	N (%)	N (%)	N (%)
No. of cases	15 (32.6)	22 (47.8)	9 (19.6)
Fracture type			
43 A	5 (33.3)	3 (13.6)	2 (22.2)
43 B	4 (26.7)	1 (4.6)	3 (33.3)
43 C	6 (40)	18 (81.8)	4 (44.5)
Functional outcome			
Excellent + good	13 (86.7)	20 (90.9)	5 (55.6)
Fair + poor	2 (13.3)	2 (9.1)	4 (44.4)
Skin complications (superficial infection, skin necrosis)	4 (26.7)	2 (9.1)	1 (11.1)
Fracture complication (delayed union, malunion)	0 (0)	3 (13.6)	2 (22.2)

The quality of reduction had statistical significance ($p<0.001$) with the functional outcome of the patients, were patients with anatomical and good fracture reduction quality had better functional outcome than patients with fair and poor reduction quality (Table 2). Similarly, LDTA, ADTA and LLM were statistically significant with the final functional outcome, were patients with higher values had better outcome than patients with lower value (Table 3-5). But the timing of surgery had no statistical significance ($p=0.111$) with the functional outcome of the patient (Table 6 and 7).

Table 7: Comparison of significance of various factors with final functional outcome.

Factors	Functional outcome		Total	P value
	Excellent + good	Fair + poor		
	N (%)	N (%)		
Quality of reduction				
Anatomical	26 (92.9)	2 (7.1)	28	< 0.001
Good	10 (90.0)	1 (9.1)	11	
Fair	0 (0)	5 (100)	5	
Poor	0 (0)	2 (100)	2	
Timing of surgery				
<3 days	13 (86.7)	2 (13.3)	15	0.111
3-7 days	20 (90.9)	2 (9.1)	22	
>7 days	5 (55.6)	4 (44.4)	9	
LDTA				
<85	2 (22.2	7 (77.8)	9	< 0.001
85–90	20 (90.9)	2 (9.1)	22	
>90	15 (100)	0 (0)	15	
ADTA				
<75	2 (33.3)	4 (66.7)	6	0.001
75–80	14 (73.7)	5 (26.3)	19	
>80	21 (100)	0 (0)	21	
LLM				
<25 mm	0 (0)	5 (100)	5	< 0.001
25–27.5 mm	15 (83.3)	3 (16.7)	18	
>27.5 mm	22 (95.7)	1 (4.3)	23	

DISCUSSION

Pilon fractures contributes nearly 7-10% of all tibial fractures.[17] Fibular fractures accompany nearly 85% of high energy pilon fractures. The main purpose of treating pilon fracture is to achieve joint mobility as soon as possible, by stable fixation and restoration of joint articular surface. There are several factors that complicate the treatment of pilon fractures. One of such factors is the insufficiency of soft tissue support and blood supply at the fracture area.[18,19] MIPO has recently gained importance in the surgical management of pilon fractures. It relies primarily on the indirect reduction using various techniques. In this way, the fracture environment is better preserved, with less surgical trauma to the surrounding soft tissue.[20]

Functional outcome of these fractures mainly depends on the severity of injury, type of fracture, quality of surgical reduction and stability of the fixation. Apart from these other factors like timing of surgery, fibula fixation, radiological parameters like lateral distal tibial angle, anterior distal tibial angle, length of lateral malleolus may also play significant role in determining the functional outcome of pilon fractures.[16]

Carbonell-Escobar et al in their study concluded that incidence of fair and poor functional outcome (AOFAS) was obtained in patients with a suboptimal quality of reduction (>2 mm articular step-off).[21] Similarly Korkmaz et al concluded that the most important factor determining the functional outcome in pilon fractures was the fracture reduction quality.[22] Even our study results also highlights that the quality of reduction is the prime factor determining the functional outcome.

There are very few studies in the literature, discussing the significance of LDTA, ADTA, and LLM in pilon fractures. Sommer et al in their study analyzed the fracture reduction quality in pilon fracture by 13 radiological parameters and found out that the following four factors namely the LLM, ADTA, anterior talar shift (ATS), and length of medial malleolus (LMM) were more reliable parameters in determining the functional outcome.[16] Similarly in our study the importance of ADTA, LDTA, LLM were analysed and we found that they were statistically significant to the final functional outcome. Patients with higher values of LDTA, ADTA and LLM had better functional outcome than patients with lesser values. Restoration of the length of lateral malleolus is very essential as it helps to prevent varus tilt and rotational malalignment of distal tibia. Most authors agree that the distal fibula plays a key role in the stability of ankle joint because lateral displacement of talus by 1 mm decreases the tibiotalar contact surface by 42%.[14]

Lee et al in their study concluded that fixation of the fractured fibula with the plate had a better outcome than nonoperative management. It also plays an important role in decreasing the incidence of tibial malunion and post traumatic ankle arthrosis.[14] In a study by Korkmaz.A et al, 40 patients presented with pilon fractures and among

them 35 patients presented with associated fibula fractures. Twenty two fibula fractures were treated with plate osteosynthesis, 4 fibula fractures treated with intramedullary Kirschner wire and remaining conservatively. They found out that the functional scores were significantly better in patients with plate osteosynthesis of fibula (p=0.02). They concluded that fibular malalignment and shortening may be another important factor causing poor functional results apart from poor fracture reduction quality.[22] Similarly in our study, patients with plate fixation of fractured fibula had better outcome than patients managed conservatively.

Regarding the timing of surgery, there are different views among various authors. While one group favours two staged procedure where ORIF is delayed by 10 days to 3 weeks post injury, whereas other group favours one stage procedure in less than 48 hrs. In a study by White et al. similar results were obtained by definitive surgery in less than 24–48 hrs compared with a later surgical procedure.[23] Tang et al found no significant differences in soft-tissue complications, nonunions rate between definitive surgery in <36 hrs and delayed surgery between 10 days and 3 weeks post injury. They finally concluded that if the surrounding skin condition is optimal, the results of both early and delayed fixation are similar.[24] Lomax et al obtained comparable results between surgery performed in less than 48 hrs and that performed later with incidence of 1.6% deep infection, 6.3% superficial infection, 7.8% nonunion.[25] Similarly in our study there was no statistical significance between the timing of surgery and wound complications as well as final functional outcome.

CONCLUSION

In this study we identified that in addition to the quality of reduction criteria by Ovadia and Beals, other radiological parameters like lateral distal tibial angle (LDTA), anterior distal tibial angle (ADTA), and length of lateral malleolus (LLM) plays an important role in determining the functional outcome in pilon fractures. Stabilisation of fractured fibula helps in decreasing the incidence of distal tibial malunion as well as improvement of functional outcome. Finally the timing of surgery is of less significance in determining the functional outcome in patients with pilon fractures operated by biological fixation methods like LLM where the surrounding soft tissue is duly respected.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the institutional ethics committee

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Cite this article as: Appusamy VS, Ramachandran K, Kumbakrishnakumar AM. Radiological parameters determining outcome in pilon fractures treated by minimally invasive plate osteosynthesis. Int J Res Orthop 2019;5:490-7.