Original article

Injury mechanism, fracture characteristics and clinical treatment of pilon fracture with intact fibula—A retrospective study of 23 pilon fractures

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ABSTRACT

Objective: The effect of intact fibula on pilon fracture is not completely elucidated. We retrospectively analysed pilon fractures with intact fibula at our hospital over a 4 year period to understand the injury mechanism, fracture characteristics, treatment strategy and prognosis of this fracture.

Methods: Pilon fracture patients with intact fibula treated in our hospital from January 2010 to December 2014 were observed. OA/ATO fracture type, Ruedi–Allgower classification and fracture characteristics were summarised. The following data were collected from the charts: operative time, operative approach, fixation, fracture healing time, ankle joint Mazur scores, Burwell–Charnley fracture reduction scores and postoperative complications.

Results: Twenty-two patients were followed up with a mean follow-up time of 17.6 months (10–27 months). The examination results showed the existence of distal tibiofibular syndesmosis injuries, medial malleolus, posterior malleolar, and anterior tibial fractures, and talus–fibula relationship changes, which accounted for 65.2%, 69.3%, 73.9%, 100% and 26.1%, respectively. 19 cases underwent internal fixation, with an average operation time of 108 min. The mean fracture healing time was 6.74 months. The Mazur ankle score showed excellent and good ratings of 86.9%. The Burwell–Charnley fracture reduction score had good and fair ratings of 95.7%. Skin infection occurred in two cases.

Conclusion: Pilon fracture with intact fibula is mostly caused by medium-low energy injury when the ankle is at neutral or varus position. Multi-part fractures commonly occur at the distal tibial articular surface because the energy is concentrated on the tibia. In general, one single anterior approach can complete open reduction and internal fixation operation with satisfactory clinical outcomes in most cases.

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1. Introduction

Pilon fracture is caused by vertical compression force that primarily involves the tibiotalar joint surface. This injury usually has compressed articular fracture of distal tibia, which are often associated with fibular fracture at the lower segment (about 75%–85%) and severe soft tissue contusion. The mainstream treatment strategy follows the proposal of Ruedi and Allgower,¹ and this fracture is generally classified using the OA/ATO type and the Ruedi and Allgower classification system. Many studies have presented a detailed description of the injury mechanism and treatment strategy of pilon fracture, but these studies mainly focused on the

tibia and so little on the fibula. Restoring the integrity of fibula as the first step in the classic pilon fracture treatment is very important.² Interestingly, about 15%–25% of the total pilon fractures do not have a fibula fracture. The injury mechanism, fracture characteristics and treatment strategy of this type of fracture should be investigated well, but few studies have been carried out. Barei³ reported that tibial pilon fractures with intact fibula are radiographically more severe than those without fibular fracture. Luk⁴ showed this type of fracture was more commonly associated with AO/OTA classification B-type pattern and an intact fibula may be predictive of less comminution of the tibia plafond.

The effect of intact fibula on pilon fracture remains unknown. Distal tibia completely suffers injury mechanism when fibula fracture is absent. Whether distal tibial fracture is more severe than general, whether this type of fracture has different fracture characteristics and whether the treatment strategy is special require further research. We retrospectively analysed the patients

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who underwent treatment with pilon fractures with intact fibula in recent years in our hospital to completely understand the injury mechanism, fracture characteristics and classification, treatment strategies and prognosis of this type of pilon fracture.

2. Materials and methods

2.1. Patient data

We retrospectively analysed patients with pilon fracture and intact fibula treated in our hospital from January 2010 to December 2014. The inclusion criteria were as follows: presence of distal tibial articular surface compression fracture and non-fracture of fibula. The open fractures and patients with multiple injuries were also included. Exclusion criteria were as follows: simple ankle fracture, presence of complicated compartment syndrome, occurrence of pathological fracture, and history of ankle arthritis in limbs by previous history and X-Ray.

Twenty-six patients were initially included in the study. Among these patients, 22 were followed up for more than 6 months and 4 were excluded because of short follow-up time. 1 patient had bilateral pilon fracture. A total of 23 fracture cases were finally included. Of the 22 patients, 18 were males and 4 were females with a mean age of 43 years (23–75 years). The injury causes are as follows: tumbling down in 10 cases, falling down in 7 cases, traffic accident in 4 cases and bruise injury in 1 case. 10 combined injuries and 2 open injuries were also noted (Table 1).

2.2. Treatment methods

Patients were admitted to the hospital after diagnosis and then routinely underwent preoperative ankle X-ray and CT scan. X-ray and CT results showed the following features of fracture: distal tibiofibular syndesmosis injury, medial malleolus fracture, posterior malleolar fracture, anterior distal tibial fracture, talus–fibula relative relationship (Fig. 1), OA/ATO fracture type and Ruedi–Allgower fracture type. Two open pilon fracture patients (patients 5 and 9) received emergent debridement and fracture reduction with external and internal fixation treatments. Other cases of fracture received temporary plaster for ankle joint and operation treatments were performed until the local soft tissue conditions

improved. Two patients (patients 6 and 21) underwent open reduction with internal and external fixation treatments because the soft tissue conditions were still not ideal or limb shortening was evident. The other 18 cases of patients underwent open reduction and internal fixation treatment.

2.3. Operation strategy

The operation strategy followed the AO principle of fracture treatments. The operation scheme was designed based on the preoperative imaging results and local soft tissue conditions. Anterior approach was generally performed. Anterior medial or anterolateral approach was selected based on the fracture characteristics. Iliac bone autograft was carried out based on the size of bone defects. Appropriate internal fixation of steel plate was placed. The general choice was an L-shaped locking plate (Zimmer Corp.). In medial tibia fractures, either anatomical locking plate or reconstruction plate (Zimmer Corp.) was selected. In medial malleolus fracture, two cannulated screw fixations were inserted, and in distal tibiofibular syndesmosis injury, one lag screw or syndesmosis screw fixation (Zimmer Corp.) was used. If a comminuted posterior fracture required a posterior approach, the T type plate or reconstruction plate fixation (Zimmer Corp.) was employed. If the use of external fixation was required (Orthofix Corp.), external fixation was performed on the medial side of the leg across the ankle, one- or two-stage operation treatment scheme was carried out based on the patients' exact conditions. Operation approach and time were summarised.

2.4. Postoperative treatment

Patients were required to take one month rest with functional exercise on bed. After one month, patients gradually started functional weight-bearing training of the lower extremity under the guidance of doctors. Full body weight bearing was allowed until the X-ray showed unclear fracture line. Periodic check-ups were carried out at 1, 2, 3, 6, 9 and 12 months after operation. Moreover, X-ray of ankle joint was conducted every check-up and CT examination was conducted when necessary. Clinical and imaging standards were employed to assess the healing time of the ankle joint fracture. The Mazur score⁵ was used to determine the

Table 1
Patients demographics.

No	Age (year)	Gender	Injury type	AO classification	Ruedi-Allgower classification	Complication
1	49	M	bruise	43B2	II	Talar fracture
2	60	M	tumbling down	43C3	III	None
3	75	F	tumbling down	43B2	II	None
4	23	M	tumbling down	43B2	II	None
5	37	M	traffic accident	43C3	III	Open injury
6	29	M	traffic accident	43B3	II	Soft tissue injury
7	55	M	tumbling down	43C3	III	None
8	50	M	tumbling down	43C1	III	None
9	55	M	traffic accident	43C3	III	Open fracture
10	36	M	falling down	43C1	II	None
11	58	F	tumbling down	43B2	II	None
12	57	M	tumbling down	43B2	II	None
13	36	M	falling down	43C2	III	None
14	23	M	falling down	43C3	III	calcaneus fracture
	23	M	falling down	43B2	II	calcaneus fracture
15	53	M	falling down	43C3	III	None
16	23	M	falling down	43C3	III	Multiple fracture
17	26	F	falling down	43B2	II	Calcaneous fracture
18	56	M	tumbling down	43B3	III	None
19	46	M	tumbling down	43B2	II	None
20	23	M	traffic accident	43C2	III	Soft tissue injury
21	27	M	falling down	43B3	II	Calcaneous fracture
22	49	F	tumbling down	43B2	II	None

Fig 1. The analysis method of fracture characteristics. A. The cross section CT scan of ankle: distal tibial was divided into 4 parts, the white zone was the anterior fracture fragment marked with the white arrow; the red zone was the medial malleolus fracture fragment marked with the red arrow; the black zone was the anterior tibiofibular syndesmosis tubercle fracture fragment marked with the black arrow; the brown zone was the posterior malleolus fracture fragment marked with the brown arrow. B. The sagittal section CT: the brown zone was the posterior malleolus fracture fragment with a compression splitting type; the red zone was the anterior distal tibial fracture fragment with a compression splitting type. C. Coronal section CT: the double-head black arrow marked the talus shifts from fibula; the white zone was the medial malleolus fracture fragment; the red zone was the anterior distal tibial fracture fragment, shifts upwards obviously; the black zone was the anterior tibiofibular syndesmosis tubercle fracture fragment.

function of ankle joint. The Burwell-Charnley evaluation system⁶ was used to assess the fracture reduction and summarise the occurrence of postoperative complications.

3. Results

22 patients were followed up for an average of 17.6 months (10–27 months). 12 cases of OA/ATO type 43B fracture, 11 cases of type 43C fracture, 12 cases of Ruedi-Allgower type II fracture, 11 cases of type III fracture were observed based on the examination

results prior to the operation. Distal tibiofibular syndesmosis injury and medial malleolus fracture accounted for 15 (65.2%) and 16 (69.6%) cases, respectively. Posterior malleolus fracture accounted for 17 (73.9%) cases, and anterior distal tibial articular fracture accounted for 23 (100%) cases. The existence of talus–fibula relationship changes accounted for six (26.1%) cases (Table 2). In patient 14 with bilateral fracture, he had an AO/OTA type B2 and a type C3 fractures. The type B2 fracture had a medial and anterior distal tibial fracture, and the type C3 fracture had all four parts fracture. We supposed the ankle with type C3

Table 2
Fracture characteristics of patients.

No	Follow-up time (month)	Syndesmosis injury	Medial malleolus fracture	Posterior Malleolus fracture	Anterior tibial articular fracture	Talus-fibula relationship
1	19	Yes	None	None	compressive splitting	Normal
2	24	Yes	Yes	compression	compressive splitting	Talar shifts
3	15	None	Yes	None	compressive splitting	Normal
4	25	None	Yes	None	compressive splitting	Normal
5	22	Yes	Yes	compressive splitting	compressive splitting	Talar shifts
6	19	None	Yes	Splitting	compressive splitting	Normal
7	10	Yes	Yes	compressive splitting	compressive splitting	Talar shifts
8	16	Yes	None	compressive splitting	splitting	Normal
9	19	Yes	Yes	compressive splitting	compressive splitting	Talar shifts
10	12	Yes	None	splitting	compressive splitting	Normal
11	18	None	Yes	splitting		Normal

fracture firstly landed and suffered more energy and then

Fig. 2. Patient 5 with severe soft tissue injury and comminuted fracture was treated with external fixation and internal fixation. A&B. preoperative X-rays of the ankle joint, fractures of the distal tibia comminuted, limb shortening, talus shifts significantly; C&D. postoperative X rays of ankle showed a cross ankle external fixation to maintain limb alignment and length and an anatomical locking plate to fix tibial fracture.

the ankle with type B2 fracture secondly landed when falling down.

4 cases of fracture were treated with internal and external fixations (Fig. 2), and 19 cases of fracture were treated with internal fixations (Fig. 3). 1 patient (patient10) was treated with combined anterior and posterior approaches. 1 patient (patient16) was treated with medial incision and anterior lateral approach. Other cases were treated with a simple anterior approach. 8 cases (34.8%) underwent intraoperative autologous iliac bone graft. The average operation time was 108 min (60–220 min).

Fracture healing was achieved in all patients at the last follow-up. The average healing time was 6.74 months (4–11 months). The

average time of external fixation removal was 4.5 months (2–6 months). Skin infection occurred in 2 cases and recovered after debridement and dressing. No other complications, such as amputation or arthrodesis, occurred at the last follow-up. The ankle joint Mazur score was excellent in 13 cases (56.5%), good in 7 cases (30.4%), fair in 1 (4.3%) case and poor in 2 (8.7%) cases. Excellent and good rates accounted for 86.9%. The fracture reduction evaluation system of Burwell–Charnley showed good in 16 cases, accounting for 69.6%; fair in 6 cases, accounting for 26.1%; and poor in 1 case, accounting for 4.3%. Good and fair ratings accounted for 95.7% (Table 3).

Fig. 3. Patient 15 treated with internal fixation. A&B, preoperative X-rays of the ankle joint; C&D, CT showed that the distal tibial articular surface compressed marked with the black arrow; E&F, the X-rays after operation showed the locking plate and reconstruction plate used.

Table 3

Clinical results.

No	Fixation method	Surgical approach	Operation Time(min)	bonegraft	Healing time(month)	Complication	Mazur score	Burwell-Charnley evaluation
1	internal fixation	anteriorlateral	120	None	4	None	Excellent	Good
2	internal fixation	anteriorlateral	100	Yes	5	None	Good	Fair
3	internal fixation	anteriorlateral	60	None	5	None	Excellent	Good
4	internal+external	anteriorlateral	80	None	4	None	Poor	Good
5	internal+external	anteriorlateral	150	None	9	Skin infection	Good	Fair
6	internal fixation	anteriorlateral	105	None	7	None	Good	Fair
7	internal fixation	anteriorlateral	100	Yes	10	None	Excellent	Good
8	internal+external	anteriorlateral	80	None	8	None	Poor	Good
9	internal fixation	anteriorlateral	140	None	11	None	Excellent	Poor
10	internal fixation	two incisions	90	None	7	None	Good	Good
11	internal fixation	anteriorlateral	120	Yes	9	None	Excellent	Fair
12	internal fixation	anteriorlateral	80	None	5	None	Excellent	Good
13	internal fixation	anteriorlateral	80	None	5	None	Good	Good
14	internal fixation	anteriorlateral	220	Yes	6	None	Excellent	Good
15	internal fixation	anteriorlateral	220	None	4	None	Excellent	Good
16	internal fixation	anteriorlateral	90	Yes	6	None	Fair	Good
17	internal fixation	two incisions	120	Yes	10	Skin infection	Good	Fair
18	internal fixation	anteriorlateral	120	None	8	None	Excellent	Fair
19	internal fixation	anteriorlateral	100	None	6	None	Excellent	Good
20	internal+external	anteriorlateral	90	None	5	None	Good	Good
21	internal fixation	anteriorlateral	140	Yes	10	None	Excellent	Good
22	internal fixation	anteriorlateral	120	Yes	6	None	Excellent	Good
23	internal fixation	anteriorlateral	80	None	5	None	Excellent	Good

4. Discussion

This study focused on pilon fracture with intact fibula, which has not been commonly reported in previous studies. Barei³ and Luk⁴ described this type of fracture characteristics, but none of the injury mechanism, treatment strategy and prognosis of this pilon fracture were summarised. According to our research, this type of fracture showed several unique characteristics.

4.1. Injury mechanism

Pilon fracture injury mechanism is a distal tibial articular surface compression force. According to Dujardin,⁷ pilon fracture can be divided into three groups: (1) high energy damage with severe joint and soft tissue injury; (2) rotational force damage with spiral fracture and joint separation; and (3) medium-low energy damage with mild joint and soft tissue injury. In this study, such fractures are more common in men than in women. This result is attributed to the fact that women are less likely to exercise and perform physical activity than men. No presence of fibular fracture existed suggesting that the patients' ankle joint was at neutral or varus position in the injury. Injured ankle should be at varus position in patients with medial malleolus fractures.⁸ Most patients could not accurately describe the injured ankle joint position, but few patients could still clearly describe the ankle joint at neutral or varus position, which is consistent with our assumption. Only 2 open fractures existed. Among the 22 patients, 4 cases were due to road traffic accidents and 7 cases were due to falls with the highest falling height of 2 m. The degree of fracture and soft tissue injury in most patients was mild. This result suggests that the fracture is a medium-low energy injury mechanism with the injured ankle joint at neutral or varus position.

4.2. Fracture characteristics

According to our research, intact fibula does not change the classification type because the two classification systems (OA/ATO and Ruedi–Allgower type) are performed based on distal tibia fracture. The differences of fracture type are mainly due to the different fracture morphologies of the distal tibial articular surface.

However, Barei³ and Luk⁴ showed that OA/ATO type B or Ruedi–Allgower type II is the majority fracture type in their study, which difference may be caused by the small number of samples or subjective judgment different. Distal tibia was previously divided into three columns, namely medial, lateral and posterior,⁹ but the distal tibial articular surface was divided into four parts in the current study to achieve more details. This type of fracture is mainly involved in the anterior distal tibial articular surface with three or four part fractures accounted for the majority by concentrated energy, which easily damages all parts of the distal tibial articular surface. A certain relationship exists between the fracture characteristics and the injury mechanism and foot position.¹⁰ Analysis of this fracture characteristics revealed that patients had foot dorsal flexion, which caused anterior tibial fracture at the time of injury. If an injury receives sufficient energy, then posterior ankle fracture is generated.⁸ Tibiofibular syndesmosis is easily injured when distal tibial metaphyseal is damaged with the intact fibular by rotating injury of supination-external rotation or supination-abduction.¹¹ Due to the vertical force, talus can lead to distal tibiofibular syndesmosis injury or medial malleolus longitudinal fracture according to the different positions of the talus.¹² Although many posterior ankle fractures existed, posterior ankle fractures are relatively simple; this fracture is characterized by a single large fragment because of the medium-low energy injury caused the partial pilon fracture.¹³ Therefore, we speculate that this type of fracture is partial pilon fracture caused by medium-low energy injury with ankle at neutral or varus position, mostly with the dorsiflex foot.

4.3. Treatment strategy

Operation method was mainly determined by the characteristics of fracture and soft tissue conditions. 19 cases were treated with internal fixation and 4 cases were treated with internal and external fixations. Operation approach is determined based on fracture characteristics, reduction and internal fixation.¹⁴ 16 cases with anterior distal tibial fractures and syndesmosis injury were treated by anterolateral approach,¹⁵ and 5 cases were treated with 1 anterior medial approach. The anterior medial approach was performed in a few patients with comminuted medial fracture that needed plate fixation. If medial malleolus fracture only needs two

cannulated screws, a small incision was used.¹⁶ Posterior approach was unnecessary in most situations because posterior bone fragment could achieve satisfactory exposure and fixation through the anterior approach when the anterior fracture fragment was turned over. The posterior malleolus fracture was always simple, so this bone fragment could be satisfactory fixed by the anterior row-screw technique. No matter the size of the posterior malleolus fracture, it could always be fixed. External and internal fixations were used in 4 cases with inappropriate soft tissue conditions or obvious shortening limbs. External fixation could achieve early stability and maintain limb alignment and length in open injury or severely comminuted fracture of articular surface.¹⁷ The external fixations of the current study were located in the medial, whereas across the ankle as previous reports.¹⁸ The operation method of associated internal fixation depended on the fracture characteristics.^{19,20}

4.4. Prognosis

Non-union, internal fixation loosening and other complications were not observed. Postoperative complications were statistically reduced compared with previous study.²¹ The overall clinical results were more satisfactory compared with other previous studies.^{22–24} The satisfactory clinical results were attributed to the following reasons. Most injury mechanisms were medium-low energy in the present study. The fracture comminution degree of distal tibia articular surface was not severe. Restoring limb length and maintaining limb alignment were easy because of the intact fibula. Fracture reduction was not difficult for the main fracture fragment located in the front with one single approach to perform sufficient exposure and good fixation. The soft tissue conditions of the majority of patients were ideal with relatively less postoperative complications. Patients received early functional exercise after operation.

4.5. Study limits

The number of patients and the sample size were insufficient. The follow-up time was short. Follow-up was not performed for more than 3 years, and most patients showed near-to mid-term follow-up results. We did not initially focus on the ankle position at the time of injury; thus, most patients were unable to provide a good description of the injury mechanism during follow-up. Most of the patients were not examined through magnetic resonance imaging; thus, a correct description of the ligament and soft tissue damage around the ankle was not obtained.

5. Conclusion

Pilon fracture with intact fibula is mostly caused by medium-low energy injury when the ankle is at neutral or varus position. Multi-part fractures commonly occur at the distal tibial articular surface because the energy is concentrated on the tibia. In general, one single anterior approach can complete open reduction and internal fixation operation with satisfactory clinical outcomes in most cases.

Conflicts of interest

All the authors do not have any possible conflicts of interest. It is a research involving Human Participants and the informed consent was obtained from all individual participants included in the study.

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