

# Treatment of the tibial pilon fractures using the antero-medial fibula approach

## Ten case series

Dong Ren, MD, Tianci Wang, MD, Yueju Liu, MD, Pengbo Liu, MM, Pengcheng Wang, PhD\*

### Abstract

Pilon fractures are always results of the high-energy trauma. They are often accompanied with serious soft tissue injury, and tension blisters happened in most cases. For comminuted fractures and poor soft tissue, how to select the incision is challenging. This study aimed to explore the outcomes of the treatment of ten 43-B/C pilon fractures using an anteromedial fibula approach.

Ten closed pilon fractures combined with fibula fractures were treated in our hospital from January 2015 to July 2016. Six cases were AO/OTA type 43-B and 4 cases were 43-C, including 9 males and 1 female with a mean age of 36.3 years (range: 20–60 years). When the skin wrinkled, all patients were treated by the senior authors with open reduction and internal fixation using an anteromedial fibula approach. Postoperatively, patients were followed up at 1 month, 3 months, 6 months, 12 months, and 18 months, respectively. The incision healing, the American Orthopedic Foot and Ankle Society scores and fracture healing were recorded to get a comprehensive evaluation of the effect for the incision.

All patients were followed from 9 to 18 months (average: 14.1 months). Anatomic reduction was achieved in 7 cases and satisfactory in 3 cases by the Burwell–Charnley radiological criteria evaluation. All patients had complete retention of the dorsal extensor tendon sheath. The most incisions had a good healing without necrosis at 2 weeks after surgery except 1 case. The fractures were healed at a range of 12 to 18 weeks (average:  $13.7 \pm 1.2$  weeks). The American Orthopedic Foot and Ankle Society scores were excellent in 7 cases and good in 3 cases at 1 year after surgery (average:  $85.6 \pm 4.2$  points). The satisfactory outcomes were achieved in most patients.

The anteromedial fibula approach used for pilon fractures can lead to an effective exposure and allow fixation of tibia and fibula fractures with minimal soft tissue injury. It is a safe, simple, and effective approach that allows for satisfactory functional rehabilitation of the ankle joint.

**Level of evidence:** therapeutic Level IV.

**Abbreviations:** AOFAS = American Orthopedic Foot and Ankle Society, CT = computed tomography, SPN = superficial peroneal nerve.

**Keywords:** anteromedial fibula approach, pilon fracture, the distal tibia fracture

## 1. Introduction

Pilon fractures account for 5% to 7% of distal tibial fractures.<sup>[1]</sup> It is caused by an axially-directed compressive force on the tibia, and

the number of fracture fragments is directly related to the rotational force imparted, with 75% to 85% having an associated fibular fracture.<sup>[2]</sup> As distal tibial soft tissue coverage is thin, pilon fractures are often associated with serious soft tissue injury, and the tension blisters is observed in most cases. As a result, these patients often require delayed surgical treatment, and postoperative wound dehiscence or infection may still occur, leading to delayed wound healing, exposed hardware, fixation failure, or even amputation.<sup>[3]</sup> Therefore, the selection of a surgical incision is important, and can effectively reduce postoperative complications.

Multiple approaches have been described in the treatment of pilon fractures, including the medial, anterolateral, and lateral approaches.<sup>[4–6]</sup> Double incisions have been used for most pilon fractures, but may cause additional damage to the injured soft tissue, and the swelling during surgery often causes difficulty in closing the incision or even necrosis due to high skin tension.<sup>[7]</sup> We reviewed a series of surgeries and studied the specimens, we modified the ankle anterolateral approach into anteromedial fibula approach, it can simultaneously provide good exposure and reduction of the tibia and fibula fractures in the single incision. Especially, it could easily repair the anterior and lateral comminuted fracture. Without excessive wound stripping, the implants is good covered by the flap with the extensor tendon sheath. Also, the superficial peroneal nerve (SPN) could be carefully protected in this approach.

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DR and TW contributed equally to this article.

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## 2. Method

### 2.1. Patient population

We performed a single-center, nonrandomized clinical study that was approved by the ethics committee at our institution, and was registered in the China Clinical Trials Center (No. ChiCTR-OOC-16008715). All patients provided informed consent. We excluded:

- (1) Gustilo III open fractures;
- (2) pathological fractures, or severe osteoporotic fractures;
- (3) presence of severe associated trauma or systemic diseases affecting the treatment.

Ten patients with closed pilon fractures patients who were treated in our hospital from June 2016 to December 2017 were evaluated, including 9 males and 1 female, with a mean age of 36.3 years (range 20–60 years). Based on the AO/OTA classification: 6 cases were type 43-B and 3 cases were 43-C. Based on the Rüedi–Allgower classification, 3 case was type I, 3 cases were type II, and 4 cases were type III. Using the Tscherné closed fracture soft tissue classification,<sup>[15]</sup> 1 case was Grade C type I, 4 cases were Grade C type II, and 5 cases were Grade C type III (Table 1).

### 2.2. Outcomes assessment

We evaluated the metaphyseal comminution and osteoporosis of pilon fractures using preoperative X-rays and computed tomography (CT) scans before surgery. When swelling subsided, wrinkle appeared, and tension blisters were healing after the provision of calcaneal tubercle traction and routine anticoagulation, then the anteromedial fibular approach was used. The healing of the incision was recorded at 2 weeks after surgery. We followed up the patients in clinic at approximately 1 month, 3 months, 6 months, 12 months, and 18 months after surgery, instructed patients to perform weight training, and assessed the American Orthopedic Foot and Ankle Society (AOFAS) ankle function score, recorded the ankle motion range, and analyzed the clinical effects of this incision.

### 2.3. Surgical management

All surgeries were conducted by an experienced professor. The patients were placed in the supine position on the operating table, they received general or lumbar anesthesia, a bump was placed under the ipsilateral hip to correct lower limb external rotation

and move the ankle into a neutral position, and a tourniquet was placed on the left thigh and inflated to 300 mm Hg. Using the leading edge of the fibula as an anatomic landmark, a visible depression was encountered between the lateral malleolus and anterior compartment muscle belly. Below this depression was the Chaput fragment and the talus.<sup>[8]</sup> An 8-cm skin incision was made from the depression to the proximal tibia along the anteromedial edge of the fibula (Fig. 1). The SPN was identified and protected because it crossed the surgical approach at the ankle (Fig. 2). With the SPN mobilized and retracted medially, we sharply incised the fascia over the anterior compartment of the distal ankle and the extensor retinaculum along with the crest of the fibula. We bluntly separated the peroneus longus and brevis muscles along the outside of the fibula, and the fibular fracture was revealed (Fig. 3). We followed the fascia of the crest of the fibula, and carefully retracted up the anterior compartment close to the interosseous membrane to visualize the lateral column and part of the medial column of the tibia (Figs. 4 and 5). The perforating peroneal artery would at times be identified due to its pulsation, and we attempted either to protect it or cauterize it.<sup>[9]</sup> The anteroinferior tibiofibular ligament and the anterolateral Chaput fragment were clearly identified. The proximal portion of the incision was not extended more than 8 cm above the ankle because the thick muscles and the widened interosseous membrane made it difficult to visualize the tibia, and the branches of the anterior tibial artery can be accidentally damaged, which can affect distal tibial blood supply. If the fracture was comminuted and the ankle capsule was injured, the talus was visible and was able to be used as a template to help reduce the ankle joint.

We obtained a good visualization and reconstruction of the articular surface through the application of a medium femoral retractor. According to the principles of pilon fracture reduction,<sup>[2]</sup> the first step was to fix the fibula fracture, and we corrected the rotational deformity and the fibular length with a 3.5-mm steel plate on the lateral or anterior fibula. With the anterior full-thickness flap retracted medially, we reconstructed the distal tibia using the talus as a guide. As Samir Mehta has reported, we reduced the fragment(s) in the following order: posterolateral, posteromedial, central, anterior, anterolateral.<sup>[10]</sup> Care was taken to rebuild the integrity of the articular surface during this process. In the reduction of posterior fractures, temporary Kirschner wire fixation was used after a clamp was used to reconstruct the fracture. After reduction of the severe compression of the pilon fracture, a cavity often appeared, and the implantation of artificial bone or autologous bone graft was

**Table 1**  
The patient information.

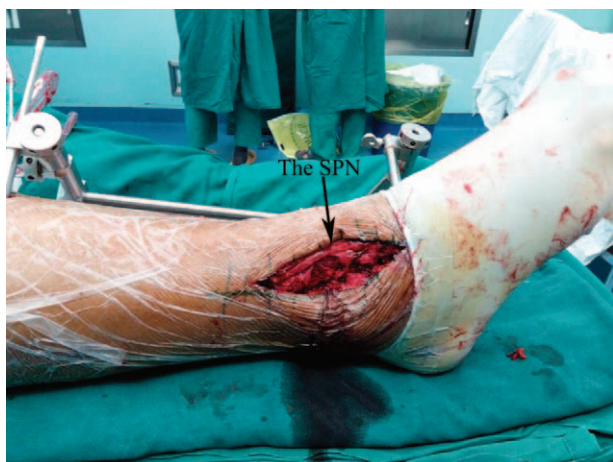
No.	Gender	Age	Injury mechanism	Injury side	AO/OTA classification	R-A classification	Tscherné classification	Days before surgery
1	M	27	Fall	R	43-B3	II	I	0
2	F	35	MVA	R	43-C3	III	III	10
3	M	37	MVA	R	43-C2	III	II	12
4	M	43	Fall	R	43-C1	III	II	8
5	M	50	MVA	R	43-B1	I	III	13
6	M	26	MVA	R	43-C3	III	III	7
7	M	33	Fall	R	43-B1	I	III	10
8	M	36	Fall	R	43-B2	I	III	7
9	M	43	Fall	R	43-C1	II	II	8
10	M	33	Fall	L	43-C1	II	II	8

L=left, MVA= motor vehicle accident, R=right.

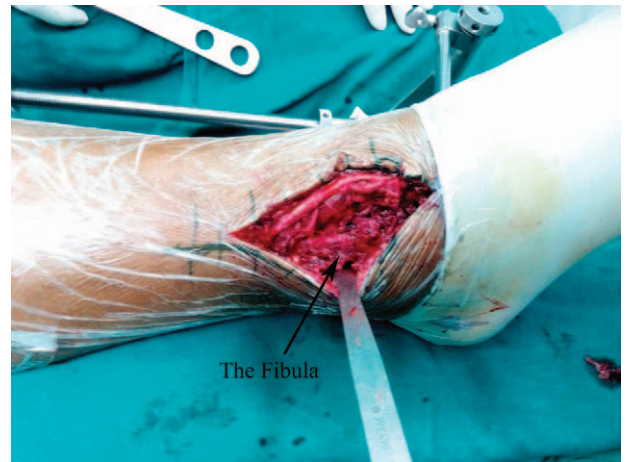


**Figure 1.** We marked the incision along the anteromedial edge of the fibula, under the circle is the Chaput fragment.

frequently necessary. If the medial column was not stable due to a varus fracture, we used minimally invasive percutaneous osteosynthesis with a 2-cm medial incision, then a plate and cortical screws were used to combat the varus deformity.<sup>[11]</sup> With the posterior and medial articular surfaces reduced, the central and anterolateral Chaput fragments were fixed based on direct visualization of the talar articular surface and the continuity of the cortical bone (Fig. 5). On anteroposterior and lateral X-rays, the articular surface displacement should be less than 2 mm based on Burwell-Charnley criteria.<sup>[12]</sup> If the articular surface is found to be incongruous, it should be reconstructed. We generally used the “L-type” locking plate on the distal tibia. It is believed that the plate could maintain the joint surface reduction and minimize loss of reduction more effectively, and it is also conducive to allowing early activity.<sup>[13]</sup> After the fractures of the tibia and fibula were fixed, we removed the femoral retractor and examined the



**Figure 2.** The superficial peroneal nerve was identified and protected, which always crossed the surgical approach.



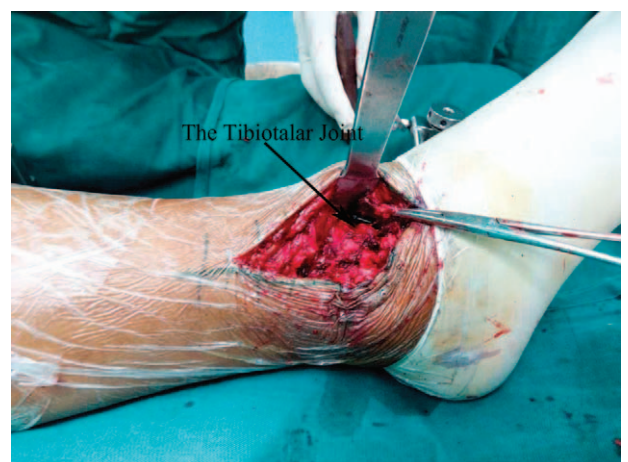
**Figure 3.** We bluntly separated the peroneus longus and brevis muscles, the fibular fracture was revealed to restoration.

stability of the fracture fixation and tibiofibular joint with a Cotton test to determine the need for syndesmotic screws. The skin was closed with interrupted 3-0 nylon sutures (Fig. 6). We paid close attention to wound edge tension, and used a relaxing suture to avoid tension necrosis.

Postoperatively, patients were encouraged to perform early toe activities to avoid thrombosis. Within 1 week after the operation, the weight bearing activity was strictly limited. Two weeks postoperatively, physical therapy with passive range of motion exercises were begun. Sutures were removed at 2 to 3 weeks. Three weeks later, patients were allowed to use double crutches during activity. Full weightbearing was started at around 12 weeks after surgery depending on fracture healing. We scored all healed fractures using the AOFAS foot and ankle function score, which evaluates pain, function, and alignment.<sup>[14]</sup>

### 3. Results

All patients were followed for 9 to 18 months, with a mean follow-up period of 14.1 months. An X-ray and CT were



**Figure 4.** We carefully retracted up the anterior flap from interosseous membrane to visualize the lateral column and part of the medial column of the tibia.



**Figure 5.** Both the tibia and fibular fracture were fixed based on direct visualization of the talar articular surface with the locking plate.



**Figure 6.** The skin was closed with interrupted 3-0 nylon sutures without tension.

obtained postoperatively to assess the reduction of the articular surface. Two cases had medial column fractures and a small medial incision was made for percutaneous minimally invasive plate fixation. No patient had a pin tract infection during traction. The length, force line, and rotation of the most tibia fractures were corrected after surgery. Postoperative ankle CT scans and X-rays were used to carry out a Burwell–Charnley radiological reduction assessment, and an anatomical reduction was obtained in 7 cases and satisfactory reduction was obtained in 3 cases. No patients had neurovascular injury, but 1 patient did have postoperative dorsal foot numbness that resolved within 3 months, which we attributed to SPN neuropraxia. The incisions in 9 of the 10 cases had good healing, and the 1 incision edge formed tension blisters that healed within 2 weeks and did not develop wound edge necrosis. Patients' fractures healed at a mean of  $13.7 \pm 1.2$  weeks after surgery (range: 12–18 weeks). The mean AOFAS ankle function score at the last follow-up was  $85.6 \pm 4.2$  points, with excellent results obtained in 7 cases and good results in 3 cases. One patient had an associated Lisfranc fracture and had an AOFAS score of 84 points at the final follow-up. The patients had mean ankle dorsiflexion of  $13.7^\circ \pm 4.8^\circ$  and mean ankle plantarflexion of  $27.4^\circ \pm 4.9^\circ$  (Table 2). Representative imaging is that of a 33-year-old man who sustained a closed pilon fracture of the right lower extremity in a motor vehicle accident (Figs. 7 and 8).

#### 4. Discussion

The anteromedial fibula approach can help protect soft tissues, reduce wound complications, visualize and fix distal tibiofibular fractures, reset the ankle joint surface, protect the SPN, retain the extensor tendon sheath, reduce unnecessary tendon adhesion, and maximally restore functional activities of the ankle.

McFerran used early open reduction and internal fixation for treating complex pilon fractures, and 34% of 35 patients had wound complications and deep infections.<sup>[16]</sup> However, delayed surgery to treat pilon fractures can significantly reduce complications of incision necrosis, and improve ankle function recovery satisfaction.<sup>[17]</sup> We used bone traction to relieve the patients' pain until the swelling resolved, and then pursued internal fixation. Among the 10 patients, there were 5 cases with a Tscherny type 3 soft tissue injury, and there were no pin tract infections and no postoperative wound dehiscence or deep infections, and the incisions were healed within 2 weeks. The single anteromedial fibula approach is beneficial to reduce soft tissue damage.

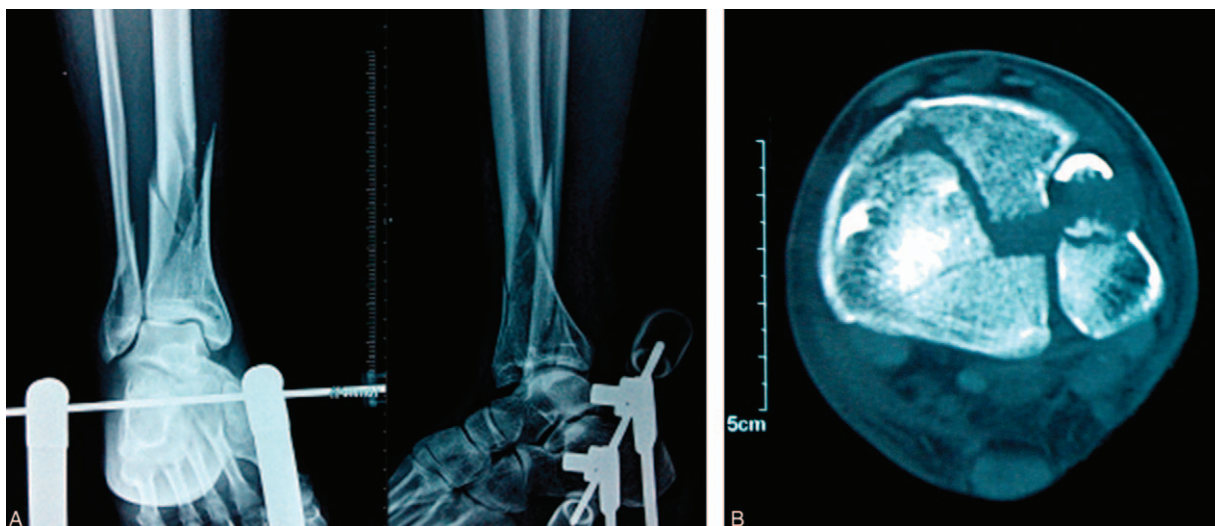
The choice of surgical approach for pilon fractures is closely related to the type of fracture.<sup>[13]</sup> In a study using CT scans to describe fracture lines in 38 patients, Cole found that the main compressed area in 36 pilon fractures was located at the central portion of the anterolateral column.<sup>[18]</sup> By analyzing imaging

**Table 2**

#### Outcomes after surgery.

No.	Approach	R	WD	Fracture-healing(wk)	Follow-up (mo)	PF (°)	DF (°)	AOFAS
1	F	Better	Good	12	15	38	24	95
2	F+M	Good	Good	14	16	32	19	90
3	F	Better	Good	16	12	27	12	85
4	F	Good	Good	13	18	24	11	83
5	F	Better	Good	15	18	26	11	83
6	F+M	Better	Good	14	18	30	16	90
7	F	Better	Good	12	12	28	14	83
8	F	Better	Good	14	10	23	12	82
9	F	Good	Good	14	11	22	8	83
10	F	Better	Good	13	11	24	10	82

AOFAS = American Orthopedic Foot and Ankle Society, AP = approach, BU = bone union, DF = dorsiflexion, F = the anterolateral fibular approach, M = the minimal medial approach, PF = plantar flexion, R = Burwell–Charnley evaluation of reduction, WH = wound healing.



**Figure 7.** Injury images (1): standard radiographs: anteroposterior and lateral views of a pilon fracture with extension to the diaphysis. CT scan (2): coronal and sagittal views showing displacement. CT = computed tomography.

data of 126 patients with fractures, Topless found that high energy injuries were predominantly valgus type, and that 56% of patients had fracture lines in the coronal plane, with the medial column having mostly simple fractures.<sup>[19]</sup> These studies found that pilon fractures are often associated with injury to the distal tibiofibular joint, and the incision can help to reset the anterolateral column under direct visualization, rebuild the tibia and fibula joint articular surfaces, and restore the width of ankle, which is most appropriate for valgus fractures caused by severe trauma. This mainly strengthens the distal tibial anteroposterior support, and can provide stable fixation of a coronal fracture. The anteromedial fibula incision determines that fracture fixation is in the anterolateral and posteromedial directions, so assisted inner pressure plate fixation is needed when a medial malleolus fracture is combined with anterolateral and posteromedial fracture lines. Seven of the 10 patients had a single anterior fibular incision, and in all 7 of these patients an anatomical reduction was obtained; the 3 other patients also had a small medial incision for percutaneous minimally invasive internal fixation.

In the treatment of pilon fractures with associated fibular fractures, the anteromedial and posterolateral incisions have been traditionally adopted, with the skin bridge width required to be at least 7cm to prevent soft tissue necrosis. However, double incisions have a high suture tension, large soft tissue injury, and a poor incision healing rate, and can lead to deep infection of the bone and soft tissue.<sup>[17,20]</sup> Although the medial and lateral incisions provide a wide exposure, it is relatively difficult to reveal the Chaput bone block and reset anterolateral column fractures. Two incisions disrupt part of the blood supply to the skin, resulting in increased damage. Thus, we used a single lateral incision to protect the damaged soft tissue, directly expose the Chaput bone block and the distal tibial anterolateral column, and to fix the distal tibia and fibula. Because this allowed for a relatively small stripping range, it was conducive to reducing the incidence of deep infection. Although some of the peroneal artery perforations were disrupted, branches of the anterior and posterior tibial arteries on both sides of the incision are able to supply blood, so it would not increase the risk for wound necrosis.

Sanders reported a single anterolateral incision that can be effective in exposing the distal tibial articular surface, and can be used in the treatment of distal tibial and talar fractures.<sup>[8]</sup> He designed a surgical incision located on the medial side of the intermediate dorsal cutaneous nerve of the foot, but extending it upward can lead to damage of the SPN and can also expose and separate the tibial extensor tendon group. The anterolateral fibula approach is much closer to the fibula as determined by the Chaput fragments. It involves 6 to 8cm of lateral and upward extension along the extensor tendon group, and it is necessary to carefully protect the SPN, to only cut the retinaculum above the ankle, to protect the tendon sheath, and to pull the tendon group and the skin laterally as a whole. This is conducive to protecting the tendons and reducing adhesions, and allows for early ankle activities.

The biggest weakness of this approach is that anteromedial fibula approach has a risk of injury to the SPN, so it must be carefully protected during surgery.<sup>[21]</sup> The inferior portion of the incision is close to the SPN, and Herron study found that the SPN is located between an area 1cm medial to the fibula to 1cm medial to the tibia at the ankle joint line, which is an area of risk during surgery.<sup>[22]</sup> For our incision, we cut the skin 1cm along the medial margin of the lateral fibular margin of the extensor digitorum longus, and the dorsal intermediate branch was at risk during the extension of the incision to the ankle joint. Therefore, to expose the fracture, we laterally stripped the subcutaneous superficial fascia, separated the dorsal intermediate branch, revealed the fibula fracture, stripped the soft tissue from the anterior margin of the fibula, and separated the extensor tendon sheath closely along interosseous membrane, which can help to avoid SPN injury. Among the 10 patients, 1 case had iatrogenic injury to the intermediate branch of the SPN, leading to dorsal foot numbness, but this gradually resolved within 3 weeks. As the sural nerve and the medial and intermediate branches of the SPN have some overlap in their skin innervation, the sural nerve and medial branch of the SPN can often compensate for damage to the intermediate branch of the SPN.

In conclusion, the clinical effects of pilon fractures are closely related to many factors, including the type of fracture, soft tissue



**Figure 8.** Postoperative radiographs: anteroposterior and lateral radiographs at 2 weeks after surgery (A) and at 12 mo after surgery (B).

injury, and the quality of surgical reduction.<sup>[23]</sup> Though patients may undergo surgery at the appropriate time, have good healing of their incisions and an anatomical reduction of the bone articular surface, it is nevertheless difficult to achieve satisfactory clinical outcomes. Traumatic arthritis frequently occurs due to associated severe articular cartilage injury and scar formation in the injured soft tissues around the ankle after injury.<sup>[24,25]</sup> So, the anteromedial fibula approach just give us a reliable choice to improve the outcomes of pilon fractures.

The shortcomings of this study were that there were only a limited number of cases and there was no control group. All of the

surgeries in our patients were completed by the same surgeon, which ensured the quality and consistency of the procedures. We would continue to use this approach for more patients to get much more data for this research and benefit more patients.

## 5. Conclusions

The anteromedial fibula approach is suitable for treating most severe pilon fractures and effectively reducing and fixing fractures of the tibia and fibula together. It can also help to protect the extensor tendon sheath, and leads to few wound complications for all patients achieve a satisfactory functional outcome of the ankle. In further research, randomized controlled trial is necessary to prove the advantage over traditional surgical approach.

## Author contributions

**Conceptualization:** Dong Ren, Pengcheng Wang.

**Data curation:** Dong Ren, Tianci Wang, Yueju Liu, Pengbo Liu.

**Formal analysis:** Yueju Liu.

**Investigation:** Tianci Wang, Yueju Liu, Pengbo Liu.

**Methodology:** Pengcheng Wang.

**Project administration:** Pengcheng Wang.

**Resources:** Tianci Wang, Pengbo Liu, Pengcheng Wang.

**Visualization:** Yueju Liu, Pengbo Liu.

**Writing – original draft:** Dong Ren.

**Writing – review & editing:** Pengcheng Wang.

## References

- [1] Bartlett CS, Amato MJ, Weiner LS, et al. Fractures of the tibial Pilon. *Skeletal Trauma* 1998;2:2295.
- [2] Ruedi TP, Allgower M. The operative treatment of intra-articular fractures of the lower end of the tibia. *Clin Orthop Relat Res* 1979;1: 105–10.
- [3] Patterson MJ, Cole JD. Two-staged delayed open re-reduction and internal fixation of severe pilon fractures. *J Orthop Trauma* 1999;13:85–91.
- [4] Manninen MJ, Lindahl J, Kankare J, et al. Lateral approach for fixation of the fractures of the distal tibia: outcome of 20 patients. *Arch Orthop Trauma Surg* 2007;127:349–53.
- [5] Hickerson LE, Verbeek DO, Klinger CE, et al. Anterolateral approach to the pilon. *J Orthop Trauma* 2016;30:S39–40.
- [6] Grose A, Gardner MJ, Hettrich C, et al. Open reduction and internal fixation of tibial pilon fractures using a lateral approach. *J Orthop Trauma* 2007;21:530–7.
- [7] Zhenhai Wang, Wenqing Qu, Liu T, et al. Two-stage protocol with vacuum sealing drainage for the treatment of type C pilon fractures. *J Foot Ankle Surg* 2016;55:1117–20.
- [8] Herscovici DJr, Sanders RW, Infante A, et al. Bohler incision: an extensile anterolateral approach to the foot and ankle. *J Orthop Trauma* 2000;14: 429–32.
- [9] Femino JE, Vaseenon T. The direct lateral approach to the distal tibia and fibula: a single incision technique for distal tibial and pilon fractures. *Iowa Orthop J* 2009;29:143–8.
- [10] Nork SE, Stannard JP. Distal tibia fractures. *Surgical Treatment of Orthopaedic Trauma* Stuttgart, Germany: Thieme; 2007;767–91.
- [11] Salton HL, Rush S, Schuberth J. Tibial plafond fractures: limited incision reduction with percutaneous fixation. *J Foot Ankle Surg* 2007;46:261–9.
- [12] Mehta S, Gardner MJ, Barei DP, et al. Reduction strategies through the anterolateral exposure for fixation of type B and C pilon fractures. *J Orthop Trauma* 2011;25:116–22.
- [13] Aneja A, Luo TD, Liu B, et al. Anterolateral distal tibia locking plate osteosynthesis and their ability to capture OTAC3 pilon fragments. *Injury* 2017;16:S0020–1383.
- [14] Assal M, Ray A, Fasel JH, et al. A modified posteromedial approach combined with extensile anterior for the treatment of complex tibial pilon fractures (AO/OTA 43-C). *J Orthop Trauma* 2014;28: e138–45.

- [15] Tscherne H, Gotzen L. *Fractures with Soft Tissue Injuries*. Springer-Verlag 1984.
- [16] McFerran MA, Smith SW, Boulas HJ, et al. Complications encountered in the treatment of pilon fractures. *J Orthop Trauma* 1992;6:195–200.
- [17] Sirkin M, Sanders R, DiPasquale T, et al. A staged protocol for soft tissue management in the treatment of complex pilon fractures. *J Orthop Trauma* 2004;18:32–8.
- [18] Cole PA, Mehrle RK, Bhandari M, et al. The pilon map: fracture lines and comminution zones in OTA/AO type 43C3 pilon fractures. *J Orthop Trauma* 2013;27:e152–6.
- [19] Topliss CJ, Jackson M, Atkins RM. Anatomy of pilon fractures of the distal tibia. *J Bone Joint Surg Br* 2005;87:692–7.
- [20] Sommer C, Ruedi T. Tibia: distal (pilon). In: *AO Principles of Fracture Management*. Stuttgart, Germany: Thieme Medical; 2000:539–556.
- [21] Huene DB, Bunnell WP. Operative anatomy of nerves encountered in the lateral approach to the distal part of the fibula. *J Bone Joint Surg Am* 1995;77:1021–4.
- [22] Herron M, Langkamer VG, Atkins RM. The anatomical variations of the distal course of the superficial peroneal nerve: recommendations to avoid injury during surgical procedures. *Foot* 1993;3:38–42.
- [23] Babis GC, Vayanos ED, Papaioannou N, et al. Results of surgical treatment of tibial plafond fractures. *Clin Orthop Relat Res* 1997;8:99–105.
- [24] Murray MM, Zurakowski D, Vrahas MS. The death of articular chondrocytes after intra-articular fracture in humans. *J Trauma* 2004;56:128–31.
- [25] Tarkin IS, Mormino MA, Clare MP, et al. Anterior plate supplementation increases ankle arthrodesis construct rigidity. *Foot Ankle Int* 2007;28:219–23.