Combined minimally invasive external and internal fixation in the treatment of pilon fractures

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Received 3 March 2014
Accepted 15 April 2014

Egyptian Orthopedic Journal 2014, 49:259–265

Background

Pilon fractures are challenging to treat as they are typically intra-articular fractures with proximal extensions and often associated with fibular fracture and extensive soft tissue damage. There is no universally agreed treatment method. To achieve an optimal outcome, there should be anatomical reconstruction of the joint, restoration of tibial alignment, and stabilization of the fracture to facilitate union. The choice of treatment must take into consideration not only the stabilization of the fracture but also the soft tissue injury that is a frequent cause of subsequent complications. Minimally invasive techniques using closed reduction and percutaneous fixation combined with monoplanar external fixators have the advantage of minimizing soft tissue compromise and preserving the vascularity of the fracture fragments, thus shortening the time for union and decreasing the need for bone grafting.

Aim

The aim of the study was to assess the efficacy of monoplanar external fixators combined with lag screws in restoring and fixing the articular surface as a definitive treatment for either open or closed tibial pilon fractures using the principles of minimally invasive fixation techniques.

Patients and methods

This was a prospective study that included 15 patients with pilon fractures of different types evaluated on the basis of the degree of involvement of the articular surface and the condition of the soft tissue envelop around the fracture. All patients were evaluated clinically and radiologically before surgery and followed up until complete union of the fractures and healing of the soft tissue. Evaluation was based on radiological union, alignment, and ankle joint function using the Iowa Ankle Scoring System.

Results

All fractures united (15/15 cases), representing 100% of cases in this study, with an average time of 17 weeks (range 12–21 weeks) after fixation, with near anatomical restoration of the articular surface in 12/15 cases, representing 80% of cases. Acceptable alignment was seen in both the coronal and sagittal planes in 14/15 cases, representing 93.6% of cases in this study. There was no limitation of joint motion except in two cases (2/15 cases), representing 13.3% of cases in this study. No neurovascular complications or deep soft tissue infection occurred until the last follow-up.

Conclusion

Minimally invasive reduction and percutaneous fixation of the articular surface with lag screws combined with monoplanar external fixators in tibial pilon fractures is advantageous for minimizing soft tissue compromise and preserving the vascularity of the fracture fragments, thus shortening the time for union and decreasing the need for bone grafting.

Keywords:

high-energy trauma, minimally invasive fixation, pilon fractures, soft tissue preservation

Egypt Orthop J 49:259–265

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Introduction

A pilon fracture involves the horizontal articular surface of the distal tibia with proximal extension for ~8–10 cm from the ankle articular surface. Pilon or plafond fractures are the result of high-energy trauma due to rotational or axial-loading forces [1].

Plafond, loosely termed, means ceiling or dome. The tibial plafond is the ceiling or dome over the talus. This creates a smooth surface, allowing the talus to articulate with the distal tibia [2]. The term pilon is often used interchangeably with 'plafond' when discussing these distal tibia fractures. The word pilon, which is derived from the French language, was introduced by Destot in 1911, and refers to a pestle, which is a club-shaped tool for mashing or grinding substances in a mortar, or a large bar to stamp or pound vertically. Destot described these fractures as 'explosive injuries' [2].

These types of fractures can be very challenging to the orthopedic surgeon because of their complicated nature and location, coexistent soft tissue injuries, and involvement of other body systems [3]. Fracture etiology is either low-energy injury like a fall from the same level or high-energy trauma caused by falls from heights or motor vehicle accidents. In these high-energy traumas there is typically remarkable comminution and impaction of the joint surface. It has been evaluated that up to 20% of these fractures are open fractures and they are frequently associated with additional trauma in other areas of the body [4,5].

Several treatment methods have been recommended for the treatment of pilon injuries, including variations of external fixations, and plate fixation, with a recent emphasis on minimally invasive techniques [6,7].

Patients and methods

This prospective study was carried out from September 2010 to April 2013 in the Orthopaedic Department of Benha University Hospital and included 15 patients with tibial pilon fractures. All patients were men (100% of cases). Their ages ranged from 22 to 42 years (mean 28 years). Ten patients (66.6% of cases) presented with closed pilon fractures, whereas the remaining five (33.3% of cases) had open pilon fractures. Patients differed with respect to the type of fracture and the severity of soft tissue injury, either open or closed affection.

All patients sustained a high-energy trauma either from falls from a height or from road traffic accidents. Fractures were classified according to the Ruedi and Allgower fracture classification and AO/OTA classification. Open fractures were classified according to the Gustilo and Anderson classification, whereas closed fractures were classified according to Tscherne classifications (Table 1). The ankle and foot were examined for the presence of swelling, contusion severity, presence of abrasions or open wounds, and early blister formation. Fracture blisters can occur within hours or 2–3 days after injury (Fig. 1).

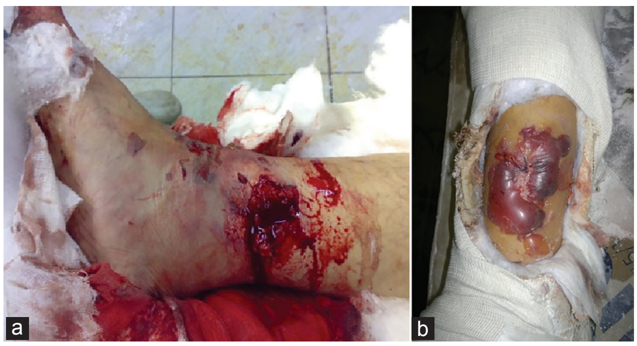
Compartment syndrome should be ruled out during the initial examination using repeated serial examinations. To check the circulatory status of the foot, pedal pulses should be palpated or a Doppler ultrasound should be utilized. The temperature and color of the affected foot should be evaluated using the contralateral side for comparison. The dorsal and plantar aspects of the foot should be examined for sensation again using the unaffected foot as needed for baseline comparison. Particular attention should also be given to the ipsilateral extremity to evaluate for possible calcaneal, tibial plateau, hip, acetabular, or pelvic fractures, as well as the spine for vertebral fractures.

The standard radiographic examination includes anteroposterior, mortise, and lateral projections and must include the entire tibia and fibula and the foot. Computed tomography scanning, with three-dimensional reconstruction, was carried out in all cases to assess the articular surface (Fig. 2).

A plan was put forward for treatment based on the fact that pilon fractures are high-velocity injuries and even in closed cases there is marked soft tissue envelop affection. The second fact is that intra-articular fractures must be anatomically reduced and rigidly fixed mainly by lag screws while extra-articular metaphyseal fractures and fibular fractures can be fixed by a relatively stable fixation method. Fibular fixation using a relative stability technique provides stability while allowing axial micromovement, these being the optimal mechanical conditions for the biology of fracture healing especially if done in a closed manner without exposure of the fracture site and losing the fracture hematoma that will be the future callus.

Open fractures were treated immediately after presentation with emergent irrigation and debridement in the operating room and fixed at the same time by hybrid fixation in the form of percutaneous cannulated lag screws and external fixators, whereas in closed cases

Figure 1



(a) Different varieties of soft tissue injury in pilon fractures. (b) Open fracture.

Table 1 Different patient groups in this study

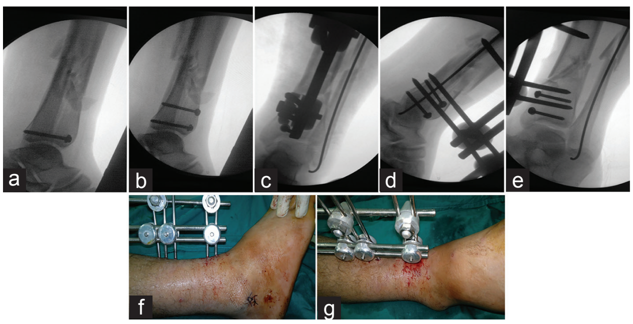
Gustilo and Anderson classification	Tscherne classification for closed fractures	Ruedi and allgower fracture classification	AO/OTA classification
Type I: no cases	Grade I: 3/10 cases	Type I: no cases	43-A: no cases
Type II: 2/5 cases	Grade II: 7/10 cases	Type II: 2/15 cases	43-B: 2/15 cases
Type III: 3/5 cases	Grade III: no cases	Type III: 13/15 cases	43-C: 12/15 cases

the injury–surgery interval ranged from 10 to 72 h depending on the general condition of the patient and preparation for surgery. All procedures were performed under spinal anesthesia without a tourniquet. The minimally invasive technique used in this work was based on achieving indirect reduction of the fracture ends and fixing them without exposure of the fracture site. The spectrum of stability ranged from absolute stability of the intra-articular component to relative stability for both the fibular and the tibial metaphyseal fractures. The first step was to reduce and fix the articular fragment by using a joy-stick technique for manipulation, followed by fixation with cannulated lag screws after assessing the reduction on the C-arm or even on a portable radiograph. The second step was to fix the fibular fracture in a closed manner by inserting a K-wire from the tip of the fibula distally without exposure of the fracture site. Fixation of the fibula allows better alignment of the ankle and leg and also allows keeping the fibular length of the fibula. Finally, the tibial fracture is fixed by application of a monoplanar external fixator, either spanning the ankle or not depending on the size of the distal tibial fragment (Figs. 3 and 4).

Figure 2

(a) Radiographs for pilon fractures showing articular and juxta-articular affection. (b) Computed tomography cuts with three-dimensional reconstruction for pilon fractures.

Figure 4



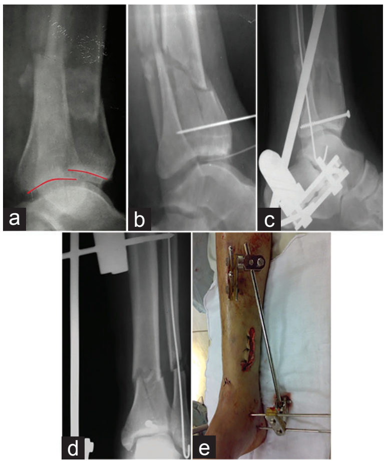
(a) Cannulated screws inserted to fix the articular fragment. (b) Cannulated screws inserted to fix the articular fragment. (c) Fibular fixation and fixator application. (d) Fibular fixation and fixator application. (e) Fibular fixation and fixator application. (f) Minimally invasive fixation done in a closed manner. (g) Minimally invasive fixation done in a closed manner.

The postoperative regimen

Immediately after surgery, patients with nonspanning fixators were started on active range of motion (ROM) of the ankle joint with foot elevation during rest to avoid edema and congestion; patients with open pilon fractures were started on daily dressing using normal saline solution and glycerine with alcohol for Schanz screws to prevent pin track infection. Absolute non-weight-bearing until the early appearance of callus and then partial weight-bearing as tolerated by the patient was implemented.

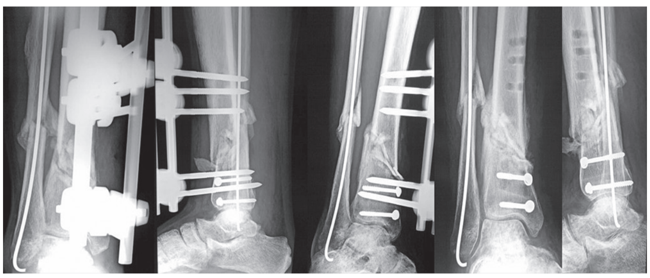
In most of the cases the appearance of early callus approximately coincided with the healing of soft tissues in open cases. Follow-up by radiography at

Figure 3



(a) Surface incongruity – articular step. (b) Joy-stick technique for manipulation, followed by fixation. (c) Fixation by cannulated lag screw and fibular fixation by K-wire. (d) Fixation by cannulated lag screw and fibular fixation by K-wire. (e) Application of the fixator.

Figure 5



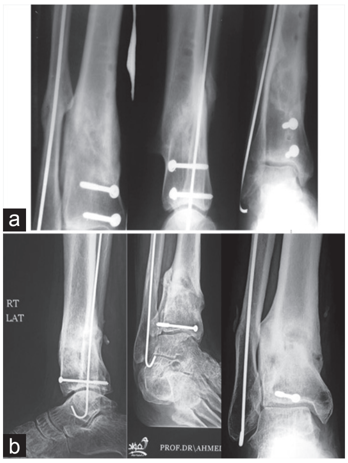
Visible bridging callus was seen in at least three cortices in anteroposterior and lateral radiographs.

2-week intervals to assess the progression of union was done until a secure union was achieved. Then, only the external fixators were removed without anesthesia in the clinic and a protective cast or brace was used until complete union (Fig. 5).

Results

Patients were followed up for an average of 16 months (range 10–19 months). Results in this study were assessed both radiologically and clinically. Fracture was considered united when callus formation and maturation with absence of the fracture line occurred on at least three of the four faces of the fracture on anteroposterior and lateral radiographs. All fractures united with an average time of 17 weeks (range 12–21 weeks) after application of the fixator with acceptable alignment in the coronal and sagittal planes with the anatomically reduced articular surface completely united in 12 of the 15 cases, representing 80% of the studied group (Fig. 6). The remaining three cases representing 20% – although united – had articular surface incongruity and alignment beyond the acceptable criteria for anatomical reduction, which are varus–valgus angulation less than 5° and anteroposterior angulation less than 10° and shortening of less than 15 mm. Ankle joint function was evaluated by means of a physical examination and survey, using the Iowa Ankle Rating System, at the last follow-up. Four classified categories were investigated: function of the ankle joint, absence of pain, gait, swelling, and ROM. Out of a possible total score of 100 scores 90–100 were considered excellent, scores 80–89 were good, scores 70–79 were considered fair and scores 60–69 were considered poor (Table 2).

Figure 6



(a, b) Completely united fractures after removal of the fixators with acceptable alignment in the coronal and sagittal planes with the anatomically reduced articular surface completely united.

Excellent results (score ≥ 90) were obtained in 12 of the 15, representing 80% of the studied group, and good results (score 80–90) were reported in one case, representing 6.7%.

A fair result (score 70–79) was obtained in two cases, representing 13.3%, and no patients with poor results (score < 70) were reported in this study. Thus, satisfactory results (excellent and good results) were obtained in 13 cases, representing 86.7% of the studied group (Fig. 7). No cases developed neurovascular injury. No cases developed deep infection even in open cases. No cases needed bone grafting or another operative intervention to achieve union. No cases needed skin grafts of flaps.

Results were also analyzed from the point of view of the type of fracture, either open or closed, and the type of monoplanar fixator applied, either spanning the ankle or not. The best results were achieved in closed cases with minimal articular comminution that were treated by nonspanning external fixators that allowed early active ROM of the ankle and early weight-bearing. Patients with open pilon fractures with very small distal fragments that were fixed by a spanning external fixator had less favorable results compared with the previous group regarding the early restoration of the ankle ROM, the development

Table 2 Results of the study using the Iowa Ankle Rating System at the last follow-up

Ratings	Clinical results
Excellent (90–100)	No pain, no swelling, normal gait, normal range of motion (12/15 cases)
Good (80–89)	Minimal pain, trivial swelling, normal gait, normal range of motion (1/15 cases)
Fair (70–79)	Pain with walking, mild swelling, NSAID use (2/15 cases)
Poor (60–69)	Pain with walking or rest, limping, marked swelling, limited range of motion, deformity (no cases)

Figure 7

(a-b) completely united fractures after removal of the fixators with acceptable alignment in the coronal and sagittal planes with the anatomically reduced articular surface completely united.

of postoperative Sudeck's atrophy, angulation, and malunion.

Complications

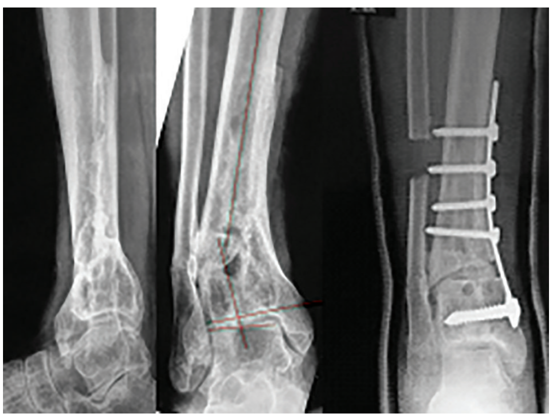
Complications in the management of pilon fractures can occur intraoperatively or in the early or late postoperative period. Perioperative complications include malreduction, inadequate fixation, and intra-articular penetration of hardware, all of which may be minimized by preoperative planning and a meticulous operative technique. Open injuries can lead to deep infection, with potentially catastrophic consequences. Late complications, such as stiffness and post-traumatic arthritis, correlate with the severity of the initial injury and the accuracy of reduction.

In this study, one case developed deformity in the form of varus angulation deformity more than 15° with shortening of about 1.5 cm due to massive tibial metaphyseal comminution and early weight-bearing by the patient (Fig. 8). This patient also had articular surface incongruity due to massive articular impaction and comminution and was treated after 6 months with supramalleolar osteotomy and joint decompression by removal of the anterior impinging bony hump. Another patient developed an arthritic ankle with marked limitation of his ankle ROM, recurrent swelling, and limping.

Discussion

Distal tibial fractures constitute a wide spectrum of lesions from simple metaphyseal and diaphyseal fractures to metaphyseal collapse with articular surface impaction and severe compromise of soft tissue. As the degree of complexity, fragmentation, and trauma energy increases, there is progressive increase in consolidation time, associated soft tissue injuries, and a higher rate of concomitant regional fractures [8].

Figure 8



Varus angulation deformity more than 15° with shortening of about 1.5 cm. Supramalleolar osteotomy and fixation with plate and screws with bone grafting was performed to correct deformity and restore length.

The main objectives of the treatment of tibial pilon fractures are the maintenance of length, recreation of the joint surfaces, and restoration of limb alignment [9].

The treatment of pilon tibial fractures has evolved over the last century. A wide variety of treatment strategies, implants, and approaches have been utilized to manage this type of fractures, with a broad range of results.

Open reduction and internal fixation was used initially but it is now known that open reduction increases the risk of complications after high-energy trauma [10,11]. To minimize the risk of postoperative complications, methods combining external fixation with minimally invasive fixation materials were developed. Today, various external fixation methods such as circular, unilateral, and hybrid exist [12–15]. External fixation aims to reduce fractures by ligamentotaxis [14,15], but it is difficult for an external fixator to reduce the tibial articular surface alone.

The role of external fixation as a definitive treatment for pilon fractures has been of interest in recent years [16–18], particularly for the benefits it provides with respect to minimal interference with the soft tissue [19]. Failing to appreciate the soft tissue condition will invariably complicate the injury with infection, wound dehiscence, or nonunion.

The early use of external fixators aimed to provide points of fixation that were far from the injured area of the distal tibia, with indirect means of reduction and spanning the ankle joint or not. It rapidly gained wide acceptance in the management of open fractures, or closed fractures with poor condition of the soft tissues.

Although 'closed' reduction techniques such as percutaneous and external fixation would be least traumatizing to the tissue, inadequate anatomic joint reduction can be a complication, particularly in the more complicated pilon fracture patterns [20]. Pugh *et al.* [21] found that external fixation resulted in a decrease in soft tissue complications but was complicated by inadequate articular reduction.

Wyrsch *et al.* [22] conducted a prospective randomized study comparing external fixation with ORIF, indicating superior results in the ex-fix cohort.

Another randomized prospective comparative study between open reduction and internal fixation (ORIF) and external fixation concluded that external fixation was associated with significantly fewer complications when treating high-energy plafond injuries [21,22]. A recent systematic review of the literature regarding the use of an external fixation device in the management of 465 of these fractures did not identify significant differences between constructs that spanned or spared the ankle joint with respect to infection, nonunion, and time to union. However, those spanning the ankle were associated with more malunions and worse ankle joint function [18,23].

The use of circular frames, either Ilizarov's or hybrid systems in comparison with unilateral simple frames, is believed to improve indirect reduction, earlier mobilization and weight-bearing, progressive correction of deformities, and improved results. A retrospective review of 60 tibial plafond fractures treated by either an ankle-sparing diaphyseal–epiphyseal Ilizarov ring fixator or by an ankle spanning unilateral articulated external fixator recorded no significant differences between the groups with regard to radiographic score and late complications [24,25].

In our study 100% of the cases showed radiologic union within an average time of 17 weeks (range 12–21 weeks). Longer duration for union occurred in cases with open pilon fractures, highly comminuted fractures, and in cases fixed by spanning external fixators. These results are quite comparable to other studies.

Ksekili *et al*. [26] reported a mean duration of radiological union of 20.7 weeks (range 16–28 weeks) in open and 17.9 weeks (range 10–26 weeks) in closed fractures. Shrestha *et al*. [27] reported an average duration of 18.5 weeks (range 14–28 weeks) for the fracture segment union. No cases developed osteomyelitis. No cases needed bone graft.

Our results were also comparable to the results of cases in other studies treated by open reduction and internal fixation using plates. In a study conducted by Shabbir *et al*. [28] all fractures achieved union. Forty-nine (67.1%) cases showed union between 9 and 12 weeks, and 24 (32.9%) showed union between 13 and 16 weeks. The average period of union was 13 weeks. Sixty-eight (93.1%) cases had excellent outcome, whereas five (6.9%) had excellent to good outcome in terms of radiological appearance. No case required bone grafting. Shrestha *et al*. [27] reported an average duration of 18.5 weeks (range 14–28 weeks) for the fracture segment union.

Khoury *et al*. [29] achieved consolidation in all of their 24 patients at 12 weeks using a dynamic compression plate (DCP), performing indirect articular reduction and compressive screw fixation. Only two patients had loss of reduction. Our results were also comparable to the results seen in patients in other studies treated by a staged protocol using minimally invasive plate osteosynthesis (MIPO); Yang *et al*. [30] reported satisfactory bone union, on average, in the 19th week after having conducted a staged protocol, using MIPO, on open distal tibia fracture patients.

Conclusion

(1) Any case of high-energy pilon fracture should be considered a soft tissue injury accompanied by bone break. Therefore, cases should be considered as pilon fractures with closed soft tissue injuries or pilon fractures with open soft tissue injuries.
(2) The choice of treatment must take into account not only the stabilization of the fracture but also the management of the soft tissue injury, which is a frequent cause of subsequent complications.
(3) For an optimal outcome to be achieved there should be anatomical reconstruction of the joint surface, restoration of the fibular length, restoration of tibial alignment, and stabilization of the fracture to facilitate union.
(4) Minimally invasive techniques using closed reduction and percutaneous fixation of the articular surface combined with monoplanar external fixators in tibial pilon fractures are advantageous in that they minimize soft tissue compromise and devascularization of the fracture fragments, thus shortening the time for union and decreasing the need for bone grafting.
(5) The results are very satisfactory and significantly in favor of using this easy, rapidly applied simple fixation method in the treatment of tibial pilon fractures.
(6) The results are also comparable to other methods of treatment, such as ORIF, MIPO, or LISS, and circular external fixators or staged procedures in open fractures.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

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