Meeting Proceedings

Pilon fractures: Consensus and controversy

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Summary: Pilon fractures are complex injuries that require an individualized approach to treatment to avoid complications and achieve good outcomes. Staged open reduction internal fixation remains the gold standard for most cases to achieve anatomic articular reduction while minimizing soft tissue complications and infection. Careful preoperative planning based on computed tomography dictates the surgical approach for reduction. A subset of cases may be amenable to early definitive or provisional open reduction and internal fixation based on fracture pattern. In some cases of severe articular comminution where reconstruction is not possible, primary ankle arthrodesis may be a good alternative.

Keywords: ankle fracture, pilon fracture, tibial plafond

1. Introduction

Fractures of the distal tibial plafond comprise a broad range of injury mechanisms, patient demographics, and combined soft tissue and osseous lesions. Surgical intervention must be performed with respect for the exceedingly vulnerable soft tissue envelope and with a properly executed osteosynthesis.[1] In the 1960s, open reduction and internal fixation (ORIF) became a widely accepted procedure in fracture care, and Rüedi and Allgöwer[2] reported a series of 84 patients with tibial pilon fractures treated with ORIF. In their series, 73.7% of patients achieved good functional outcomes and only 5% developed deep infections, which by current standards would be considered a highly favorable outcome. However, these favorable results were not reproduced in subsequent series in North America. McFerran et al[3] identified a surgical site complication rate of 34% in 52 patients with tibial plafond fractures treated with immediate ORIF. Similarly, Teeny and Wiss[4] documented a deep infection rate of 37% in 60 patients with tibial pilon fractures who were treated with early ORIF. These adverse experiences brought attention to the importance of appropriate soft tissue management. Subsequently, Sirkin et al[5] proposed the staged protocol for complex pilon fractures that included initial restoration of fibular length and temporary external fixation, followed by anatomic ORIF once soft tissue swelling has decreased. As of today, staged treatment of tibial plafond fractures remains the standard protocol at most trauma centers in North America and worldwide.

Despite these advances, the outcomes in tibial plafond fractures remain limited and leave room for improvement. A recently published systematic review and meta-analysis demonstrated that despite staged soft tissue management, the risk of deep surgical site infection in tibial plafond fractures remains as high as 9%.[6] Moreover, the risk of posttraumatic arthritis in surgically treated tibial plafond fractures has been reported to be 26%.[7] Regarding functional outcomes, Volgas et al[8] found that only 30% of the patients undergoing ORIF of the tibial plafond returned to work within 12 months after their injury. Moreover, only 14% of all blue-collar workers were back at work at 12 months postinjury.[8] These outcome data suggest that there remains a significant subset of patients with less favorable outcomes after ORIF, and some patients may benefit from alternative treatment methods.

Even with proper timing, favorable host factors, and expert surgical technique, restoration of function and avoidance of complications are not always achievable. In the following review, we will discuss some of the surgical approaches to access pilon fractures, controversies in management of pilon fractures, ways we can minimize complications, and what to do in cases when safe and effective ORIF cannot be performed.

2. Surgical Approaches

2.1. Approaches for Provisional Fixation

For the vast majority of high-energy tibial plafond fractures, the first step in treatment is external fixation to restore length, rotation, and alignment until soft tissue swelling decreases sufficiently for definitive fixation.[5,9] The most commonly used frame construct is a delta frame, which comprises 2 tibial pins and a calcaneal transfixion pin connected by medial and lateral bars to control length and alignment (Fig. 1). A midfoot or forefoot pin can be used to maintain a plantigrade foot and decrease the risk of equinus contracture. One of the challenges of this technique is that the bars connecting the tibia to the calcaneal pin generate a posterior vector that may lead to an apex anterior or posterior translation deformity at the fracture site. This can be addressed by placing bumps under the heel to push the distal segment anteriorly or by using the second tibial pin to apply a posterior force on the proximal segment.

There is controversy regarding fibular fixation at the time of external fixation.[10] There are several benefits to fibular fixation.

The authors have no conflicts of interest to report related to this work. The work did not receive funding.

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Symposium at the OTA 2021 Annual Meeting International Trauma Care Forum in Fort Worth, Texas October 20-21, 2021.

OTAI (2023) e236

Received: 28 November 2022 / Accepted: 8 December 2022 / Published online 16 June 2023

http://dx.doi.org/10.1097/OI9.0000000000000236

FIGURE 1. Provisional fixation with a delta frame external fixator. Two pins are placed proximally in the tibia. A centrally threaded transfixion pin is placed in the calcaneus to form the “delta.” A fourth pin is placed in the midfoot across the cuneiforms to maintain a plantigrade foot.

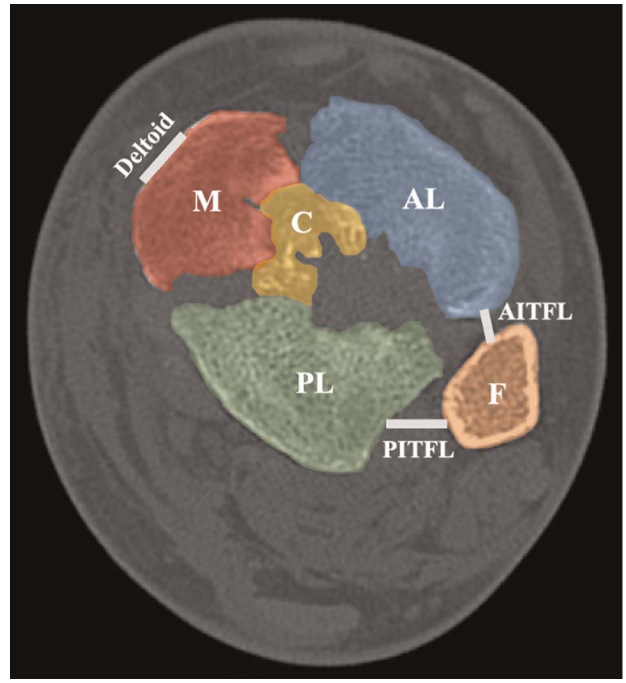

FIGURE 2. Pilon fracture fragments and ligaments. Pilon fragments include the medial malleolus (M), anterolateral (AL), and posterolateral (PL) fragments. Ligaments include the anterior inferior tibiofibular ligament (AITFL), the distal posterior inferior tibiofibular ligament (PITFL), and deltoid ligament. Central compaction (C) and the fibula (F) are also shown.

The first is a more stable construct, which may reduce the risk of malreduction or loss of reduction in the external fixator and aid in soft tissue rest. Length in particular is more easily assessed relative to an anatomically reduced fibula. The posterolateral fragment will be indirectly reduced, greatly facilitating the definitive procedure. However, it is preferable that the surgeon performing fibular fixation be the same surgeon that will perform the definitive procedure to avoid interfering with future approaches and reduction strategies. In addition, it is imperative that the reduction be anatomic because any shortening or malalignment will interfere with tibial reconstruction. Because the approach for definitive ORIF is typically unknown at the time of external fixation, a posterolateral approach is suggested. Unlike a direct lateral approach to the fibula, this approach can be used later as an approach to the tibia and retains a skin bridge adequate for either an anterolateral or posteromedial approach.

In some cases, provisional fixation of the tibia may also be considered. Typically, either the posterolateral fragment is reduced to the shaft through the same approach as the fibular fixation,[11] or in cases of long metaphyseal extension, a soft tissue friendly proximal posteromedial approach can be used.[12] In either case, the goal is to reduce the posterior plafond to the shaft to establish length and create a starting point for later reconstruction.

2.2. Approaches for Definitive Fixation

2.2.1. Preoperative Planning. No classification system for pilon fractures is adequate to choose surgical approaches or reduction strategy. However, the OTA/AO Classification of 43-B (partial articular) or 43-C (complete articular) fracture is a useful starting point. The key distinguishing feature between these 2 patterns is whether any portion of the articular surface is in continuity with the tibial shaft. After external fixation, a CT scan should be obtained to identify the major fragments and associated fracture lines.[13,14] The use of a CT has been shown to alter the treatment plan in a majority of cases; hence, it is compulsory.[15]

For OTA/AO 43-B fractures, location of the fracture should dictate approach with the goal to apply a buttress plate over the fracture apex. For example, a posterior B-type pilon fracture would be treated prone with a posterior approach.[16] The approach for OTA/AO 43-C pilon fractures is more nuanced and depends primarily on the reduction strategy. Because the articular visualization is limited using posterior approaches, an anterior approach is nearly always preferred as long as soft tissue allows. In rare cases, such as a tenuous anterior traumatic wound or prior surgical scarring, the posterior approaches may be a safer option as the primary approach, but those cases are exceptional and challenging. For most of the pilon fractures, the choice of anteromedial or anterolateral approach is dictated largely by the location of the anterior fracture exit. By visualizing this fracture line, the anterolateral Chaput fragment can be rotated externally to gain access to the central impaction (Fig. 2).[13] Of critical importance, the approach is dictated by reduction strategy rather than by choice of fixation. An anterolateral plate can be placed through either an anterolateral or anteromedial approach. A medial plate can be placed through an anteromedial approach or using a limited direct medial approach if using an anterolateral approach.

The routine use of posterior approaches in conjunction with one of the anterior approaches for tibial reconstruction in C-type fracture is more controversial. The advantage is direct visualization of the posterolateral Volkmann fragment and hence greater ease in obtaining an anatomic reduction.[11] However, combined approaches may require both repositioning from prone to supine

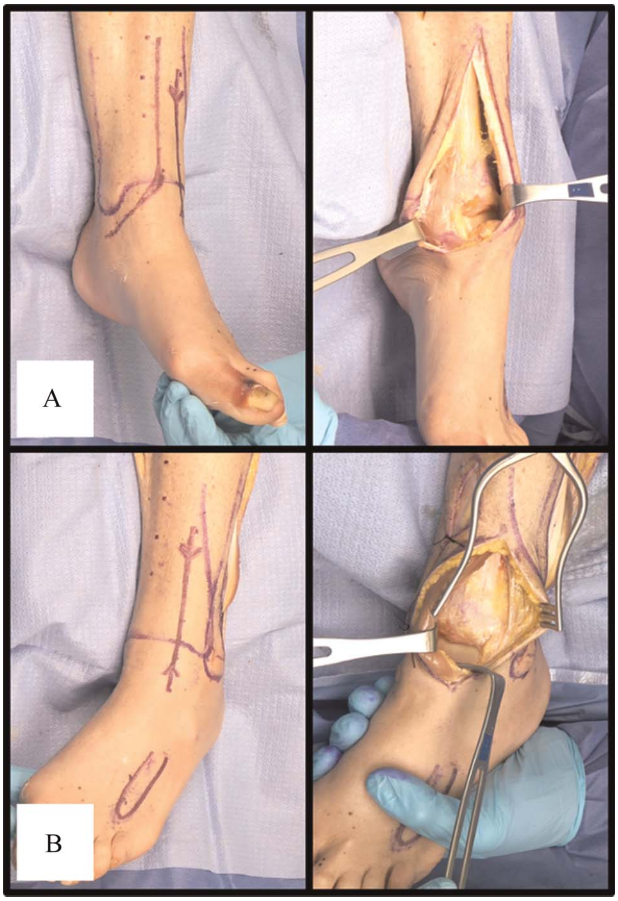

FIGURE 3. Anterior approaches to pilon fracture definitive fixation. The anteromedial (A) and anterolateral (B) are shown. For video demonstrations of these approaches, please visit https://www.youtube.com/c/IGOTPortal/videos.

and have the potential to increase soft tissue stripping and risk for wound healing complications or infection.[17] Therefore, a number of indirect strategies for reducing the posterior fragments through either the anterior approach or percutaneous accessory incisions have been developed.[18,19] Ultimately, the decision to use a posterior approach hinges on the surgeon's confidence preoperatively to achieve an anatomic reduction using one of these indirect techniques.

2.2.2. Common Approaches. The anteromedial approach (Fig. 3A) allows for extensile exposure of the anterior and medial plafond but does not allow for visualization of the lateral gutter or small anterolateral fragments. The approach may also be associated with higher risk for wound healing complications, particularly partial necrosis of the medial flap, but this has not resulted in higher risk of infection in most studies.[17,20] The approach begins with a superficial incision starting 1 cm lateral to the tibial crest and curving medially at the ankle joint to create a flap which provides a wide and extensile exposure. A sharper turn at the ankle creates a larger medial flap and hence greater medial visualization, but it also increases the risk of flap necrosis. The deep interval is medial to the anterior tibial tendon, and the entire anterior compartment is retracted from medial to lateral.

The anterolateral approach (Fig. 3B) provides a better visualization in the setting of a smaller anterolateral fragment with a more lateral fracture line. In addition, the anterolateral approach provides visualization of the syndesmosis and is relatively soft tissue friendly. However, the reduction and hardware placement may be technically more difficult because it is not an extensile exposure proximally because of the course of the anterior compartment. In addition, a secondary approach, such as a direct medial or posteromedial approach, is frequently needed, negating some of the benefits of a limited approach. The anterolateral approach begins with a superficial incision midway between the fibula and the tibial crest. The superficial peroneal nerve must be identified and protected. The deep interval is accessed by going through the extensor retinaculum and then sweeping the anterior compartment from lateral to medial.

The posterolateral approach (Fig. 4) allows access to both the fibula and the posterior tibia by working on either side of the peroneal tendons. Although the classical incision has been described as midway between the Achilles tendon and the fibula, one of the authors (D.S.) suggests an incision on the posterior fibula directly over the peroneal tendons. Once the peroneal tendons are identified, they can be retracted posteriorly to view the fibula and retracted anteriorly while retracting flexor hallucis longus medially to access the posterior tibia.

3. Preventing Complications: Contemporary Perioperative Strategies

Recently validated techniques serve to diminish the risk of soft tissue and osseous sepsis while enhancing outcomes.

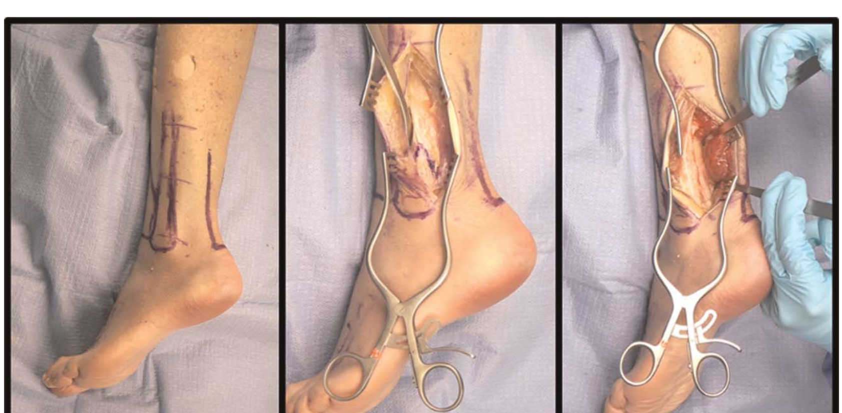

FIGURE 4. Posterolateral approach to pilon fracture definitive fixation. The posterolateral approach with visualization of the tibia and fibula. For video demonstrations of these approaches, please visit https://www.youtube.com/c/IGOTPortal/videos.

3.1. Temporary Transarticular External Fixation

Optimal timing for surgical management of pilon fractures remains controversial. Early transarticular external fixation followed by delayed internal fixation continues to offer favorable and well documented success toward a desirable outcome. Two contemporary aspects merit consideration.

1. Placement of external fixation pins through the proximal bases of the first and second metatarsals places the deep plantar branch of the dorsalis pedis artery at risk. Given the clinical importance of this artery, transmetatarsal pinning in this fashion is not advised. Other methods including introduction of pins within the cuneiforms may be preferable to avoid vascular injury.[21]
2. Placement of definitive plate fixation overlapping previous external fixator pin sites and its impact (if any) on subsequent infection remains controversial. Studies of similar design have offered conflicting results.[22–24]

3.2. Immediate/Early Fixation

Several studies have advocated early primary ORIF as a viable strategy for managing both open and closed pilon fractures.[25–27] The primary benefit other than diminished cost is an observed ease of reduction when compared with staged efforts and diminished operative time. These studies reported no observed increase in deep infections in the immediate fixation group when compared with traditional delayed methods of management. Early fixation will unlikely generate acceptable results in patients with notable regional or systemic comorbidities and is discouraged in those with regional contamination and in the presence of hemorrhagic fracture blisters. The pursuit of early definitive fixation should only be considered under the direction of an orthopaedic traumatologist and in cases in which patient status and resources permit intervention within 12 hours. We have observed similar success (particularly regarding ease of reduction) but have used this strategy with caution. Our experience has been limited to closed fractures, typically in patients who have sustained isolated injuries and most often those of low-energy injury.

3.3. Open Fractures With Metaphyseal Deficits

High-energy pilon fractures, particularly those with associated open lesions, often present with deficient osteoarticular components and marginally salvageable and occasionally absent metaphyseal components. They remain fraught with complication and the potential for refractory infection and nonunion. Gardner et al[28] adopted a successful protocol to manage open pilon fractures, including many with metaphyseal bone loss owing to extrusion or devitalization. Their review demonstrated results yielding favorable outcomes and an acceptable infection rate. The first stage focused on immediate debridement of devitalized osseous and soft tissue elements, in addition to the application of a temporizing ankle-spanning external fixator. Adequate debridement with eradication of all devitalized tissues, both soft and osseous, was emphasized. These debridement efforts were performed through traumatic wound extensions or anticipated subsequent surgical incisions. After recovery of soft tissues (usually within 1–3 weeks) and in the absence of obvious signs of infection, soft tissue coverage was next performed with inclusion of antibiotic bead placement and contemporary plate fixation. Several months later, elective bone grafting was performed with bead extraction.

3.4. Surgical Approach

Discussed in greater detail above, numerous surgical access strategies have been offered, each with unique limitations, attributes, and characteristics. Various combinations of approaches have been described, which have led to concerns regarding their proximity to one another.[29] Three vertically oriented angiosomes exist, supplying the overlying soft tissue envelope of the lower leg and ankle. Surgical incisions placed in parallel between these angiosomes pose no threat to the resultant skin bridge.[30] The skin bridge and the source vessels in the overlying cutaneous blood supply seem tolerant of this. This is in sharp contrast to the risks posed by transverse incisions. The technique of deep surgical dissection likely has a greater influence on wound healing and evolution of infection than the proximity of the incisions to each other. Recently, the anterolateral (Böhler) approach has proven resilient when combined with either medial or posterolateral approaches.[19]

3.5. Minimally Invasive Fixation Methods

Several studies have sought to assess the efficacy of minimally invasive subcutaneous instrumentation methods to address pilon fractures and associated wound healing complications.[31,32] Such efforts are largely limited to medial column restoration using percutaneous techniques. Percutaneously introduced plates seem to result in less disruption to the extraosseous blood supply, particularly in the medial aspect of the distal tibia. By contrast, Lau et al[33] observed a concerningly high rate of late superficial infection, primarily with medial subcutaneous plates. They maintained, however, that this had insignificant effect on the outcome. These infections were successfully managed with a brief course of antimicrobial therapy and, on occasion, implant extraction. Although minimally invasive methods of fixation demonstrated diminished rates of infection, obstacles remain, including nonunion and malreduction with angular deformity.

3.6. Upgrading and Sequential Fixation

Techniques of early or immediate partial definitive fixation have been described as a means to limit soft tissue compromise and assist in ease of reduction during subsequent definitive internal fixation. Dunbar et al[12] demonstrated that fixation of remote diaphyseal extensions offers the opportunity to convert an OTA/AO type C fracture to a type B fracture ("upgrading"). Plating of these extensions is performed using soft tissue friendly remote adjuvant incisions at the time of temporary external fixator application. Similarly, pilon fractures with posterior malleolus components may benefit with "sequential fixation" in which acute posterior plating in a prone position is performed at the time of placement of an external fixator. This is then followed with definitive anterior fixation access options on recovery of soft tissues and further resolution of associated swelling. A group of investigators expressing initial optimism with this protocol subsequently offered concerns regarding the evolution of regional nonunion.[11,34]

3.7. Transsyndesmotic Fixation

Low-energy pilon fracture variants with primarily medial compounding wounds in patients with considerable comorbidities are common. A novel approach of laterally applied fixed angle transsyndesmotic fixation offers minimal introduction of surgical insult, particularly to compromised medial soft tissues. Fixation is achieved through the less traumatized and more resilient lateral soft tissues in the form of a "comb construct," in which a laterally applied fibula plate secures both fibular and tibial fracture components with multiple screws traversing the syndesmosis.[35] Transsyndesmotic locking screws are placed in the distal limit of the fibular plate, engaging the distal tibia in a quadricortical fashion. Bicortical fibular or similar quadricortical fibular–tibial screws are introduced proximally. This construct serves to bridge the tibial component of the fracture pattern.

3.8. Acute Shortening

Metadiaphyseal comminution frequently associated with high-energy injury patterns may complicate overlying soft tissue coverage when attempting to achieve an osseous reduction. The application of an external fixator with the ambition of limb length restoration may cause wound diastasis and preclude primary closure. In patients who are poor candidates for complex soft tissue reconstructions, acute shortening (nonarticular osseous debridement in combination with fibular shortening) facilitates closure of the traumatic wound and simultaneously addresses osseous defects encouraging both osseous and soft tissue healing without the necessity for complex reconstruction and regenerative efforts to either.[36] This can be performed by acutely shortening and plating defects up to 3–4 cm.[37] Alternatively, in an effort to avoid limb length discrepancy in more competent hosts, one may consider gradual shortening with a tensioned wire circular frame in combination with distraction osteogenesis of the proximal tibia.[38]

4. Open Reduction and Internal Fixation versus Fusion

The quality of articular reduction intuitively should correlate with both radiographic and clinical outcome. The latter, however, is not necessarily supported by rigid clinical science. The end result from a patient-perceived outcome may be more dependent on the energy of the injury sustained and other confounders not within the surgeon's control. While the goal of articular restoration and congruency is a desirable and worthy goal, extreme comminution may defy such endeavors. Extensive soft tissue dissection in the pursuit of an anatomic reduction does not assure an enhanced functional outcome and may instead predispose to increased risk of infection and nonunion. In the event of recalcitrant infection, loss of limb may ensue. In such scenarios, temporary external fixation followed by acute primary arthrodesis may obviate disastrous soft tissue complications while still offering a satisfying outcome.[39,40]

Primary arthrodesis for a select group of patients with tibial plafond fractures has been suggested.[41] However, peer-reviewed literature on ankle arthrodesis for tibial plafond fractures is sparse and remains limited to case reports and smaller case series. Beaman and Gellman[39] reported on 14 patients undergoing primary arthrodesis of their tibial plafond fractures. The authors reported good-to-excellent outcomes in 88% of their patients. Of note, the authors reported that any tibial plafond fracture with 50% articular involvement was indicated for primary arthrodesis which accounted for approximately 20% of all pilon fractures treated by the investigators during the study period.[39] We suggest that this protocol may be considered a relatively aggressive indication for primary arthrodesis. By contrast, Bozic et al[42] reported on 14 patients with tibial plafond fractures undergoing posterior blade plate fusions as a primary treatment approach. This subgroup of patients represented approximately 5% of all pilon fractures treated by the authors during the 12-year study period, suggesting a more conservative indication for primary arthrodesis. Within this subset of patients, the authors recorded only 1 case of infection and 1 case of hardware failure.[42] In another study by Zelle et al,[40] functional outcomes were evaluated in 20 patients treated with primary posterior blade plate fusion for severely comminuted tibial plafond fractures over a 16-year period. A total of 17 patients were followed up for at least 2 years after surgery. At final follow-up, all patients were ambulatory, one patient developed an aseptic nonunion, and no cases of infection or wound dehiscence were found. The authors suggested this treatment approach as a reliable method for a select subgroup of tibial plafond fractures that they considered nonreconstructable (ie, "the worst of the worst").[40] A recently published systematic review of the literature from 1990 to 2020 identified a total of only 52 patients undergoing primary arthrodesis of their tibial plafond fractures.[43] Given the relatively low case number reported in the literature, the authors of this systematic review did not identify any differences between the outcomes of primary arthrodesis versus ORIF. The results of this systematic review also emphasize the relatively rare indication of this approach that is typically reserved for a select subgroup of patients.

In conclusion, primary ankle arthrodesis is a reliable and safe method of treatment for a subset of devastating tibial plafond fractures when articular reconstruction does not seem feasible in the hands of a fellowship-trained orthopaedic trauma surgeon or foot and ankle surgeon with experience and a practice scope that includes the treatment of tibial plafond fractures. Yet, it remains controversial which particular subgroup of patients benefits from this approach. Moreover, further investigation is required to establish the functional outcomes of this approach.

5. Conclusion

To optimize outcomes in patients with pilon fractures, the orthopaedic traumatologist must be familiar with an assortment of operative strategies to best manage the diverse variables associated with these injuries. These include well-established and validated techniques originating from the past as well as contemporary evolving techniques described herein that offer a promising future.

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