MINI SYMPOSIUM

Evolution of Surgical Exposures for the Pilon: What has Changed over the Last 20 Years

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Abstract

Purpose and context: Pilon fractures typically result from traumatic incidents involving significant axial and rotational forces. The primary focus is on anatomical bone injuries and significant damage to soft tissues. The treatment has difficulties in avoiding soft tissue problems following a stage of surgery due to the complexity of surgical methods. Several surgical exposures can be used for the distal tibia and the ankle joint visualization, including anteromedial, anterolateral, medial, posteromedial and its modification, and posterolateral approaches. Each approach has individual advantages and constraints. The choice between single or combination approaches depends on factors such as the characteristics of the fracture, the planned reduction and fixation, and the state of soft tissue management. This review article presents an analysis of the development of surgical exposures, including their indications, benefits, drawbacks, and techniques. There is a current trend indicating that wound problems are not associated with recent surgical incisions published in the past decade. This is attributed to the careful treatment of soft tissues and preservation of angiosomes.

Keywords: Distal tibia, Exposure, Fracture, Incisions, Pilon, Plafond, Surgical approaches.

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Introduction

The treatment of pilon fracture has been suggested in published literature for over 60 years. There has been a consistent reporting of injuries to soft tissues and bones that involve high levels of energy, as well as a high occurrence of problems related to wounds. Complications are associated with surgical exposure to pilon fractures. These surgical exposures have undergone ongoing development in order to limit wound complications and provide high-quality fracture reduction and fixation. This has involved modifying the number, site, and size of incisions. Nevertheless, the surgical exposures of pilon fracture continue to pose substantial difficulties. This review article provides a comprehensive analysis of the surgical approaches used in pilon fractures, with a specific emphasis on their indications, benefits, drawbacks, and procedures.

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The History of Surgical Techniques for Pilon Fractures

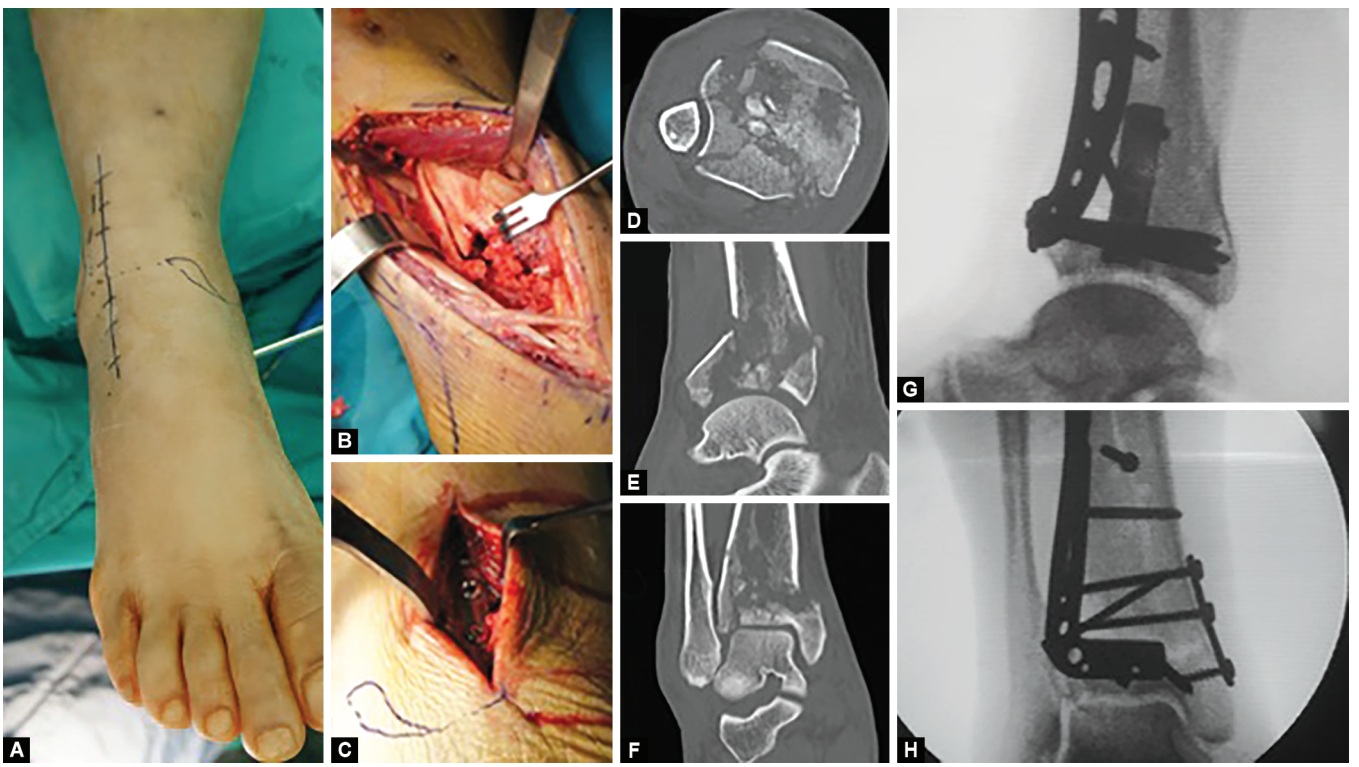
Since 1970, a surgical technique known as the anteromedial approach has been suggested for the treatment of pilon fractures. This treatment is mostly recommended for fractures of the medial column of the tibial plafond.[1] This method involves making a cut along the inner edge of the tibialis anterior tendon. The extensor tendons are laterally retracted in order to facilitate the view of the anterior aspect of the distal tibia. The ankle joint capsule is cut to open to expose the articular surface of the tibia. The benefits of this method include the ability to identify nearly the whole articular surface of the distal tibia and to handle the reduction and fixation of medial malleolar fractures using the same approach. The medial buttress plate is employed to provide support to the fragmented medial physeal section of the fracture. An inherent drawback of this method is the potential for wound dehiscence along the medial edge of the tibial bone. There is a significant likelihood of skin flap covering complications following the treatment of an infected wound. Furthermore, there is a specific challenge when it comes to reducing and fixing the Chaput fragment, particularly when it is separated from the fibula. In such cases, it is not possible to achieve an indirect reduction of the Chaput fragment by reducing the fibular fracture. Sirkin et al. documented a 12.5% incidence of partial thickness wound necrosis in 56 patients who had the anteromedial approach in a staged fashion.[2] Mast et al. reported a wound complication rate of 55% using the anteromedial approach, which was the highest among all approaches (Fig. 1).[3] The reasons are as follows—firstly, the medial tibia has thin skin. Secondly, open wounds typically occur in the medial area. Lastly, the soft tissue in this region is not suitable for plating.

The anterolateral approach to pilon fracture was first described in 1992.[4] It is indicated for fractures of the anterior and lateral columns. This approach avoids the fragility of the medial soft tissue. Improved vision of the front portion of the distal tibia and fibula enables precise alignment and stabilization, particularly for the Chaput fragment and the articular surface. Furthermore, the

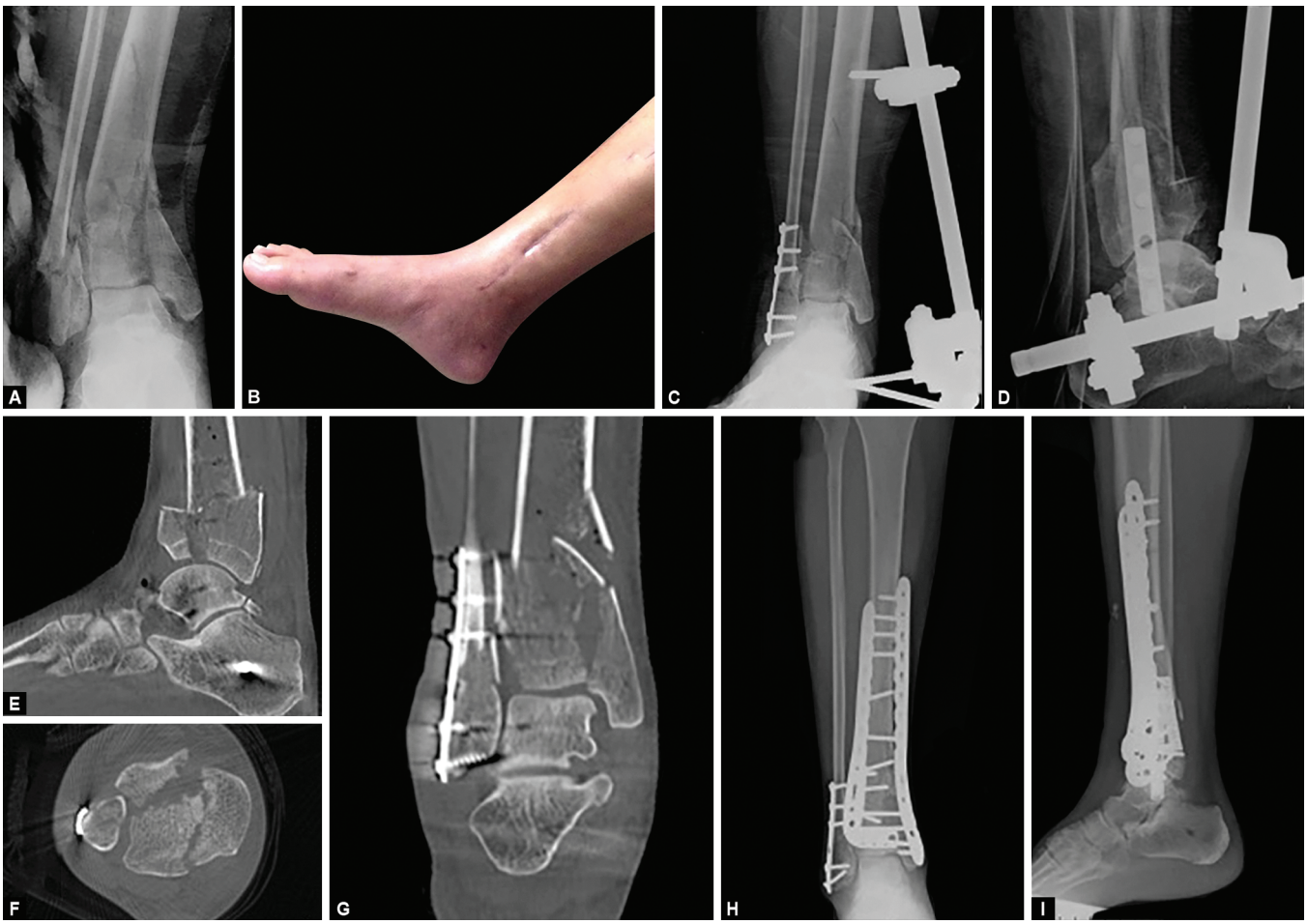
extended reach of anterolateral incision enables the treatment of foot and ankle injuries, including fractures of the front part of the talus bone, the talonavicular, and calcaneocuboid joints, as well as fractures in the bases of the third and fourth metatarsal bones. The skin incision commences at the lateral aspect of the peroneus tertius muscle, located above the ankle joint line, at a distance of approximately 7 cm.[5] It then proceeds in a parallel manner toward the distal end of the fourth metatarsal. It is important to carefully protect full-thickness skin flaps. The superficial peroneal nerve is susceptible to damage during the approach. It is positioned exactly below the incision made in the skin and intersects the surgical route with some degree of variance.[6] The incidence of superficial peroneal nerve damage in the anterolateral approach is around 6.3%.[4] It is imperative to meticulously identify and mobilize it throughout the surgical operation. Next, the extensor retinaculum is cut with precision. The peroneus tertius, extensor digitorum longus, and other tendons in the anterior compartment are displaced toward the midline. The ankle capsule is meticulously cut open to reveal the articular surface. To prevent excessive devascularization of many fracture pieces, it is important to avoid overly aggressive arthrotomy. To enhance visualization of a pilon fracture, a distractor pin can be inserted through the talar neck (Fig. 2). The drawbacks of this method include restricted visibility of the medial ankle joint and the potential for damage to the superficial peroneal nerve. Furthermore, the utilization of both anterolateral and additional medial methods to access the entire distal tibia and articular surface may provide a danger of skin slough, especially when there is significant soft tissue damage following an injury. Multiple studies have documented wound healing problems ranging from 5.1 to 10%.[7] They included eschars, minor wounds, severe wounds, and abscesses. The incidence of surgical debridement was approximately 2.7%.

Fig. 1: A photograph of anteromedial approach to pilon fracture with wound infection

Since the year 2000, effectively preventing and managing soft tissue and wound problems has been a big concern (Fig. 3). Minimally invasive surgery for a fracture of the medial malleolus involves making several small incisions or changing the technique of incision with angiosome avoidance. The surgeon can access the articular surface fracture by either creating a medial incision directly through the fracture site (known as the medial malleolar window approach)[8] (Fig. 4) or by using an inverted J-shaped incision that starts from the posterior-medial side and moves toward the anterior side. This approach, which involves minimizing soft tissue dissection, creating a flap that extends from the skin



Figs 2A to H: Photographs and radiographs of a 25-year-old male who experienced a pilon fracture with anterior angulation. (A) An anterolateral approach; (B) An anterolateral exposure and superficial peroneal nerve exposure; (C) A medial approach; (D to F) Preoperative CT scans showed an intraarticular fracture with displacement; (G and H) An intraoperative fixation

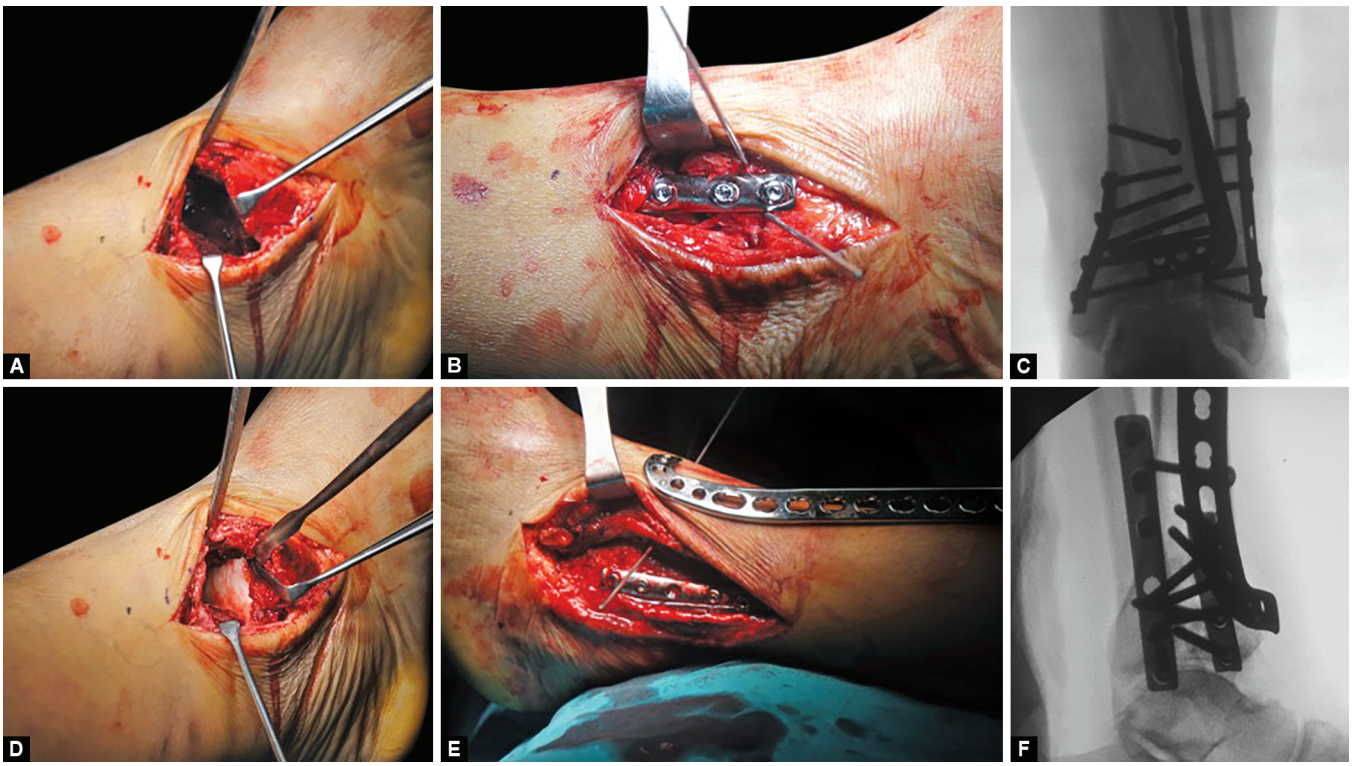


Figs 3A to I: Photographs and radiographs of a 22-year-old male who experienced a pilon fracture with varus angulation. (A) Preoperative X-ray radiographs showed a pilon fracture and fibular fracture; (B) Medial skin incision with full-thickness flap; (C and D) A first stage surgery of ankle spanning; (E to G) CT scans showed intraarticular fracture with medial cortical comminution; (H and I) Postoperative four column fixation

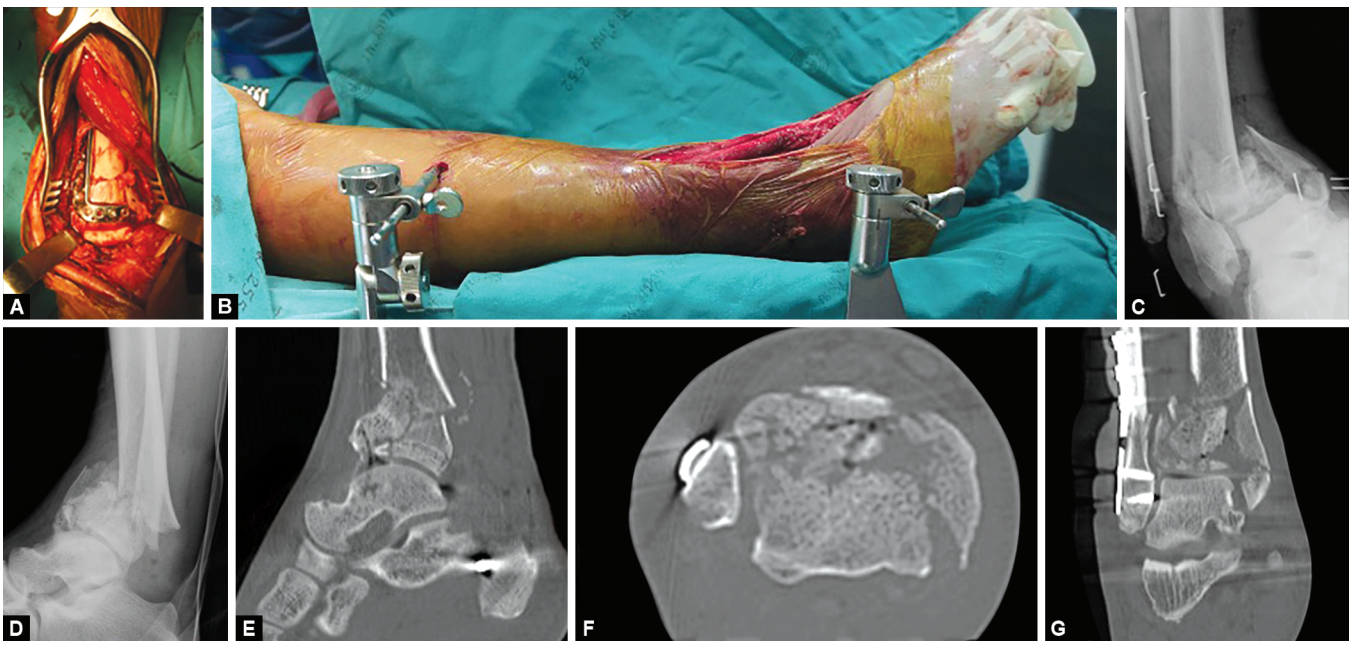
to the periosteum, protecting and retracting the neurovascular bundle anteriorly, and preserving the saphenous vein, has been suggested to have a low rate of wound complications. Specifically, out of 45 cases, only two (4%) experienced wound complications.[9] The surgical cut follows a longitudinal path down the inner border of the tibia, then curves around the inner ankle bone, and finally extends to the front and outer side of the ankle joint, passing across the extensor tendons. The proximal incision can be made in the proximal location, extending as far as the presence of the fracture. This strategy has been suggested to ensure the safety of the blood supply to the anterior skin flap by conserving the anterior tibial artery, as well as to the posterior skin flap by protecting the posterior tibial artery. The limitations of this method are significant fractures accompanied by considerable injury to the soft tissues, particularly in the medial distal tibia.

The extensile technique has been published since 2007.[10] It is indicated for pilon fractures involving the anterior and medial columns. The main benefit of this strategy is the ability to reach the entire distal tibia fracture using a single method. The surgical cut commences 10 mm away from the tibial crest of the tibia, on the lateral side of the tibial diaphysis. It proceeds downward toward the ankle joint line, and then takes a 110° turn, crossing the ankle joint horizontally. Finally, it ends 10 mm below the top of the medial malleolus. The dissection proceeds to the extensor retinaculum. A vertical incision is made in the retinaculum. The tibialis anterior tendon and its sheath are safeguarded. The extensor tendons located at the front of the body are pulled to the side. The capsule is incised along its length to reveal the articular surface (Fig. 5).

In 2007, a direct lateral technique was introduced for pilon fractures to prevent skin injury caused by closely spaced incisions and to ensure sufficient surgical exposure for pilon fractures, particularly those with an irreducible Chaput fragment following fibular fixation.[11] An additional benefit of using the direct lateral approach for pilon fractures is the ability to increase the visibility of the posterior region for posterior malleolar fractures and syndesmotic injuries. The skin incision is done directly and laterally along the back and side border of the fibula. The surgical cut extends from the top of the fibula toward the bottom of the fourth metatarsal and continues upward along the fibula until it reaches the site of the fibula fracture. The dissection is extended to the fibula, penetrating the submuscular and supraperiosteal layers, and continues anteriorly to reach the anterior interosseous fiber. The superior extensor retinaculum is detached abruptly from the front edge of the fibula. The anterior extensor muscles are retracted medially while taking care to avoid injury to the anterior perforating branch of the peroneal artery. The superficial peroneal nerve, which emerges from the fascia around 12 cm above the distal end of the fibula and courses in an anteroinferior direction relative to the ankle joint, is safeguarded by the dense anterior skin flap. The procedure involves mobilizing the skin flap



Figs 4A to F: Photographs and radiographs of a 36-year-old male who experienced a pilon fracture. (A and B) Intraoperative medial malleolar window approach application; (C) Medial buttressing plate; (D) Fibular fixation and minimally invasive plate osteosynthesis with locking compression plate through a direct lateral approach; (E and F) Intraoperative X-ray showed a satisfactory reduction of the fracture



Figs 5A to G: Photographs and radiographs of a 30-year-old male who experienced a pilon fracture. (A and B) An extensile approach; (C and D) Preoperative X-ray shooed comminuted pilon fracture with varus angulation; (E to G) Preoperative CT scans showed an intraarticular fracture with anterior angulation

without the requirement of dissecting superficial nerves. The front surfaces of the lower end of the tibia and the protective covering are completely visible for the purpose of aligning and stabilizing the bone. The medial malleolar fracture can be observed and treated using the same incision. Percutaneous fixation or a small incision on the medial side may be necessary. In this method, the two cuts are positioned at a distance of 7 cm or greater from each other (Fig. 6). Grose et al. found that 9% of the 44 pilon fracture

Figs 6A to H: Photographs and radiographs of a 28-year-old male who experienced a distal tibia fracture with distal extension. (A) Preoperative X-ray radiographs showed a distal tibia fracture and fibular fracture; (B and C) Soft tissue ecchymosis on the anterior and medial aspects; (D) A direct lateral incision; (E and F) Fibular and tibial exposures; (G and H) Functional outcome

cases treated with a direct lateral approach experienced wound problems.[12] Hu et al. found that two out of 35 patients (5.7%) with open pilon fractures, specifically Gustilo I and II, who were treated with the direct lateral technique, had superficial wound infections. No instances of profound infection or skin necrosis were seen.[13]

The posteromedial method for pilon fracture was first documented in 2008.[14] The skin incision commences 3 cm superior to the calcaneal tuberosity and extends proximally into the posteromedial region of the distal tibia. The incision is located precisely halfway between the Achilles tendon and the posterior margin of the medial malleolus. To prevent the skin from losing its blood supply, the dissection should be performed in close proximity to the Achilles tendon. The dissection progresses toward the fascia of the deep compartment. Next, a longitudinal incision is made into the transverse intermuscular septum. The neurovascular bundle is surrounded by fatty tissue and is pulled toward the center, whereas the flexor hallucis tendon is pulled toward the side. The posteromedial and posterior regions of the distal tibia are visible. Precise retraction of neurovascular bundles and tendons is crucial in order to prevent wound complications. Excessive traction of tissue may lead to the development of scars and issues with soft tissues.[15,16] The posteromedial method has several benefits, including the ability to reduce and fix a tiny posteromedial fragment, address malunion or nonunion of the posterior distal tibia, and treat pilon fractures with significant soft tissue damage around the lateral part of the ankle.

The modified posteromedial technique has been suggested as a means to enhance the view of the posterior distal tibia without the need for substantial retraction of soft tissues, resulting in favorable clinical outcomes.[17] The incision is made directly above the point where the Achilles tendon attaches, 1 cm toward the inside of its edge, and then upward for a distance of 12 cm. The dissection incises the superficial fascia, revealing the Achilles tendon and soleus muscle. Next, the transverse intermuscular septum is uncovered and cut vertically. The flexor hallucis tendon and tibial nerve are observable. The flexor hallucis tendon is displaced to the side, whereas the neurovascular bundles are displaced toward the center. The complete metaphyseal region of the distal tibia is observed, together with the posterior ankle capsule. To address the posterior section of the fibula, one can retract the flexor hallucis tendon medially and the peroneal tendons laterally.[15] When comparing the posteromedial and modified posteromedial approaches, the modified posteromedial approach provided a visualization area of 91% of the entire posterior distal tibia with a tension force of 7.0 N on the flap traction. In contrast, the

posteromedial approach only allowed visualization of 64% of the area with a tension force of 21.5 N on the flap traction.[18]

The posterolateral method was first suggested in 2011.[19,20] This method is recommended for cases of pilon fracture with significant posterior displacement or pilon fracture with extensive soft tissue destruction on the anterior distal tibia. Approximately, 20% of pilon fractures exhibit a posterior fragment or displacement of the posterior fragment in the proximal direction, necessitating the use of a posterior approach.[21,22] The method involves making an incision through the ample soft tissue covering the back part of the lower end of the tibia. The occurrence of wound dehiscence is minimized by performing a thorough dissection of thick soft tissue flaps and ensuring adequate covering after wound closure. The incision is made between the posterior margin of the fibula and the Achilles tendon. The cut extends toward the body in a direction parallel to the fibular bone to provide better visibility of the fibula. The incision extends distally and proceeds in an anterolateral direction beneath the point of the fibula. The sural nerve is the structure that is endangered by this method. It extends in a direction away from the midcalf area, namely toward the outer side. The sural nerve traverses the posterolateral incision in a subcutaneous manner. The dissection and retraction process must be performed with meticulous care following the incision of the skin. The dissection in the proximal area is extended toward the fibula, causing it to become exposed. The peroneal tendons are then moved toward the middle to allow for better visibility of the fibular fracture, which can then be realigned and stabilized. An incision is made in the deep fascia that separates the superficial and deep posterior compartments. The flexor hallucis muscle is located and moved beneath the muscle to the inner side. The posterior region of the lower end of the tibia is located. The posterior capsule is typically undamaged. The identification of the articular surface from a posterior view is restricted solely to the posterior column of a pilon fracture. The core piece of the pilon fracture can be treated by directly accessing the fracture site. The proximal plating fixation can be achieved either through a prolonged incision proximally or by using a minimally invasive approach (Fig. 7). The benefits of this method lie in its ability to effectively address pilon fractures accompanied by anterior soft tissue damage and provide ample covering for thick soft tissues. The drawbacks include limited visibility of the articular surface and the potential for sural nerve damage. In a study conducted by Gao et al., it was found that only one patient out of a total of 23 (4.3%) had a wound infection following a posterior pilon fracture.[23]

Discussion

This article provides a comprehensive analysis of the evolution of surgical approaches for pilon fractures, including their indications, benefits, drawbacks, and surgical methods. Over the past 2 decades, numerous issues have emerged that must be taken into account while considering surgical techniques. Following the initial phase of therapy, which includes external fixation and computed tomography (CT) scan, the surgical strategies will be carefully devised, taking into consideration factors such as the number, size, and locations of the surgical exposures. In addition to the surgeon's preference for surgical approaches, one crucial thing to consider is the angiosomes of the soft tissue, which might vary depending on the severity of the injury. The angiosomes principle and vascular anatomy of the skin around the ankle should be considered while deciding on surgical exposure for a pilon fracture. The dimensions of the incisions, including their length, quantity, and spacing, are determined by the circulatory supply provided by the perforating arteries. The skin bridge connecting the edge of the skin flap to the pedicle is of equal importance to the actual distance between the two surgical incisions (Fig. 8).[14] In order to select the most suitable surgical methods, surgeons should initially prioritize

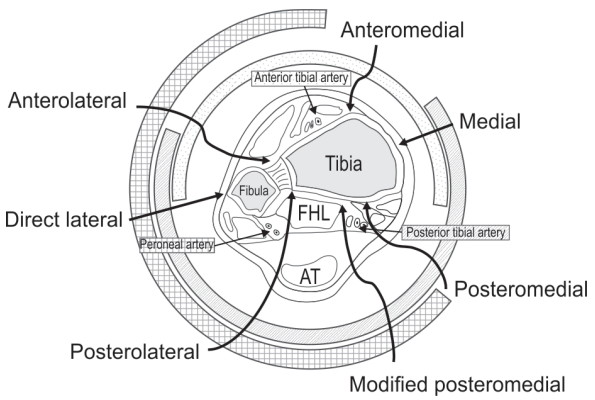
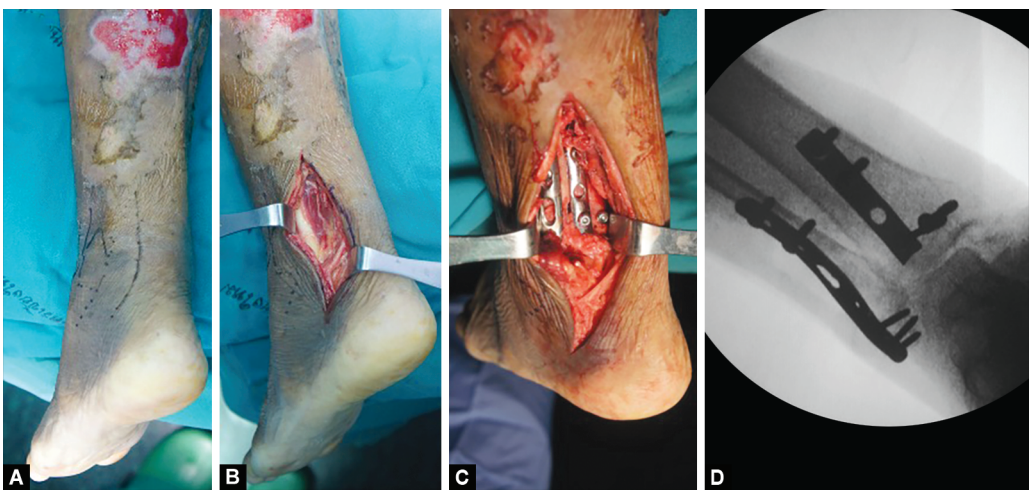


Fig. 8: An Illustration of surgical approaches of a pilon fracture with perfusion area of anterior tibial (dotted pattern), posterior tibial (diagonal stripes pattern), and peroneal (large grid pattern) arteries



Figs 7A to D: Photographs and radiographs of a 23-year-old male who experienced a pilon fracture with posterior angulation. (A) A posterolateral approach; (B) A posterolateral exposure and sural nerve exposure; (C) Intraoperative fibular plating and posterior tibia plating; (D) An intraoperative fixation

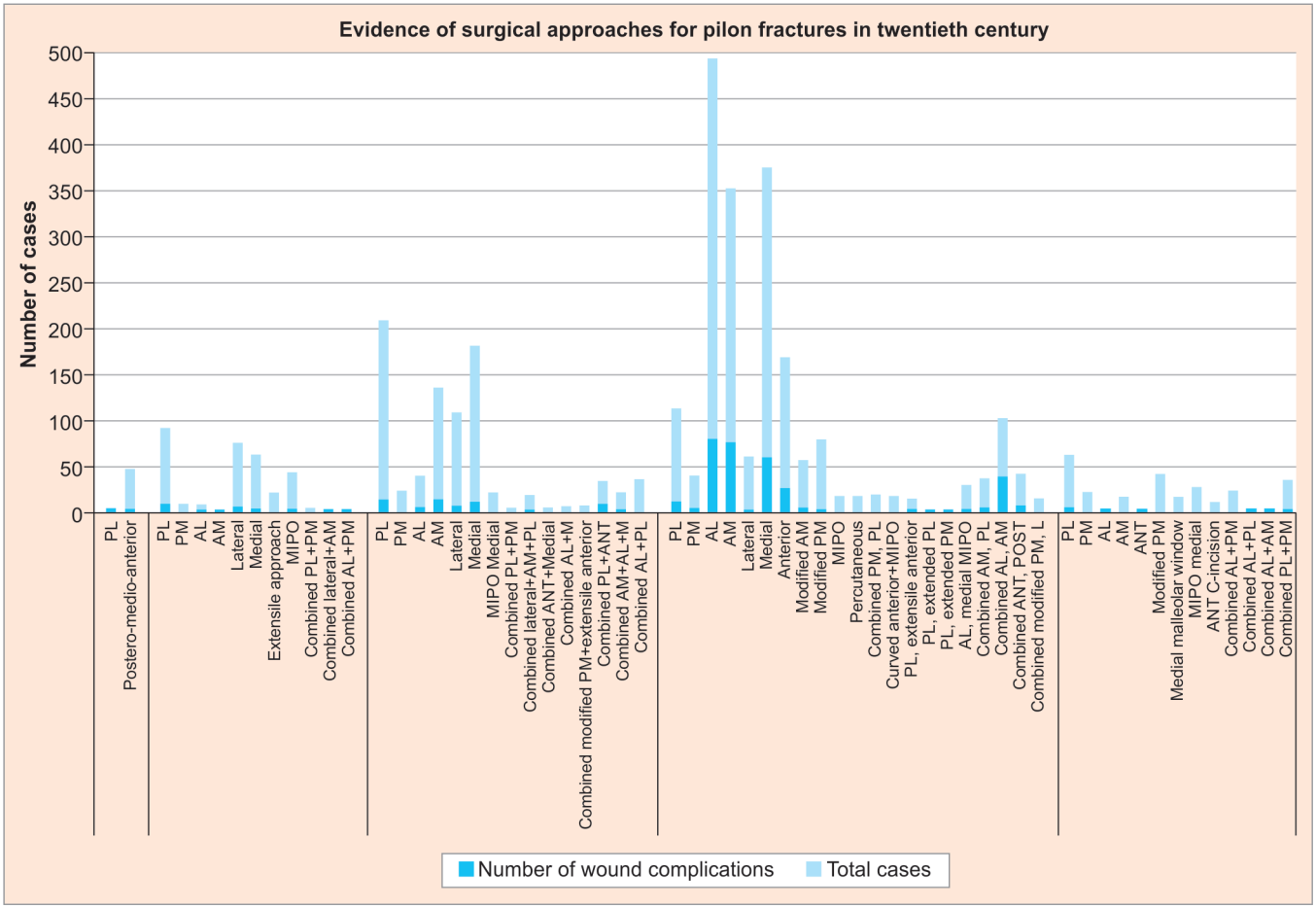


Fig. 9: A graph showed numbers and wound complications of individual surgical approaches published in the 20th century

reduction and fixation after conducting a CT scan. Subsequently, the procedures that align with this treatment plan can be determined, while ensuring the preservation of the remaining artery supply to the skin flap. In the past 20 years, several integrated methods have been developed to reduce the size and length of incisions by taking into account the angiosomes. Simultaneously, there have been consistent reports of a decrease in wound consequences, such as eschar, superficial and deep infection, and skin necrosis. The type of surgical approach did not seem to have a major impact on the incidence of wound complications. However, the surgical approaches through the medial or anteromedial and combination of medial or anteromedial and others seem to have increasing rates of wound complications, especially in the last 20 years (Fig. 9). One of the reasons may be explained by angiosomes concepts. The anteromedial and the medial approaches were made through the areas that have only one perfusion arterial supply which is the anterior tibial artery as shown in Figure 8. In addition, other factors such as smoking and the necessity for soft tissue coverage due to severe soft tissue envelopment were found to be significantly connected to the occurrence of these issues.[15,24–28]

Conclusion

According to the reviewed literature, the anterolateral approach is the most often used surgical exposure for pilon fractures. It has gained significant popularity in a theatrical context. It provides enhanced soft tissue covering and has a reduced incidence of postoperative wound infection. Far medial and far posterior column fractures may necessitate the use of supplementary surgical techniques, such as limited medial incision or posterolateral incision, to handle them effectively. The modified posteromedial and posteromedial approaches are also beneficial for alternative surgical management. The straight lateral approach is an alternative method used when there is a requirement for extended surgical exposure while preserving the blood flow to the skin through angiosomes. The use of minimally invasive techniques during the second stage of treatment, which includes a thorough examination of the joint, has become the usual approach to reduce the risk of wound complications. Additionally, it is necessary to conduct extensive research comparing surgical exposures in each subtype of pilon fracture in order to determine the general frequencies of complications and evaluate the functional results of patients.

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