Ankle and Foot

Pilon fractures

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ABSTRACT

Purpose of review

Pilon fractures are a challenging area of orthopedic trauma. As the number of clinical and basic science studies of these complex fractures increases, it is imperative that orthopedic surgeons remain current in their understanding of these potentially disabling fractures.

Recent findings

Recent literature on this topic focuses on various surgical approaches to the distal tibia. This attempt to improve the outcomes of surgical techniques arises from previous literature that focused on soft tissue management. In response to this understanding of the importance of the soft tissues, many trauma centers have incorporated the use of delayed surgery and minimally invasive techniques in an effort to improve complication rates and overall patient outcomes.

Summary

Recent published findings give insight into various treatment strategies for pilon fractures. Numerous works describe technical approaches that have shown some success with certain types of pilon fractures. In certain cases, multiple treatment options can be used to gain the best outcome from this devastating injury. Pilon fractures remain difficult to treat, even by the most well-trained orthopedic surgeon. Future research with comprehensive prospective studies is still needed to further our understanding of this complicated fracture.

Keywords

fracture, open reduction and internal fixation, pilon, surgical techniques

INTRODUCTION

Pilon fractures continue to represent a challenging area of fracture surgery. Historically, they have been associated with devastating complications that continue to elude even the most seasoned orthopedic surgeon. Often these complications can be traced back to difficult articular reductions or to soft-tissue management. This article reviews the complex nature of these fractures, recent advancements in treatment strategies including soft-tissue management techniques, minimally invasive plating techniques, and the recent advancement of locked plating and outcomes.

Pilon fractures can result from a high-energy axial compression mechanism caused by falls or motor vehicle accidents or lower-energy torsional mechanisms from skiing.[1–4] The high-energy mechanisms have proved to be more challenging, with worse outcomes, and have led to a variety of strategies to avoid the risk of soft-tissue complications.[2,5–7] Although the articular surface and metaphyseal area are important factors regarding outcomes, the soft-tissue component is typically the rate-limiting step in treatment, and can be the primary determinant of outcomes, especially in open fractures.[8••]

Attention to the soft-tissue envelope has led to attempts at limiting surgical trauma with the use of external fixation,[7] limited internal fixation,[9,10] and delayed open reduction and internal fixation (ORIF) of the articular surface with initial ankle-spanning external fixation to allow the soft-tissue injury to improve.[5]

CLASSIFICATION

Multiple classification schemes have been developed for pilon fractures in order to understand fracture patterns better and to help guide treatment options. The most well known is the Rüedi and Allgöwer classification.[3,4,11] This system is based on comminution and articular displacement and is divided into three types; undisplaced-split, displaced-split, displaced-comminuted. Studies have shown that clinical outcomes can be correlated to the type of fracture, with worse outcomes as the severity increases.[2–4,11–13]

The AO/OTA classification system is a more recently devised system that has been used primarily to unify the multiple classifications in the literature. This classification scheme is based on the amount of articular involvement and comminution (Figure 1).[2,12–14] Most pilon fractures are type C. Although fracture classifications typically have poor interobserver and intraobserver reliability, classifying fractures can be useful in helping surgeons understand and

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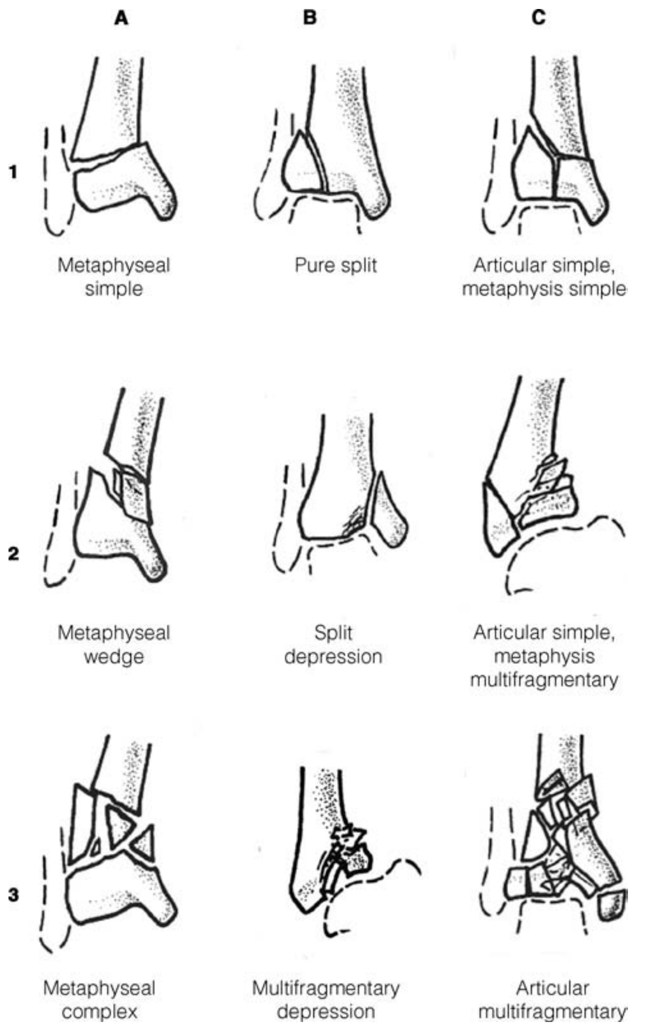

FIGURE 1. AO/OTA classification of tibial pilon fractures. Source: *Journal of Orthopaedic Trauma*, Vol 10, Suppl 1, 1996. Official journal of the Orthopaedic Trauma Association and the International Society for Fracture Repair. ©1996 Lippincott Williams and Wilkins.

communicate fracture patterns and can aid in planning the surgical approach and fixation methods.

EVALUATION AND DIAGNOSIS

A complete medical history must be obtained to identify any preexisting co-morbidities that are associated with poor healing, such as diabetes mellitus, peripheral vascular disease, osteoporosis, tobacco use, and alcoholism.[15] A detailed physical examination of the involved foot and ankle is essential to delineate the extent of soft-tissue injury, the presence or absence of an open injury, neurological status, amount of swelling, and vascular status. It is equally important to avoid missing associated injuries involving the ipsilateral and contralateral extremities, pelvis, and spine. Traumatic wounds associated with open pilon fractures typically occur medially at the level of the tibial metaphyseal component of the fracture.[16] Identifying soft tissue that is 'at risk' secondary to fracture displacement is equally important because displaced fragments exert significant pressure on overlying soft tissues and can lead to skin necrosis or erosion. This is most commonly seen with a posteriorly displaced distal segment and the remaining proximal tibia tents the skin anteriorly.[12,16] Fracture reduction must be performed promptly to avoid and prevent further soft-tissue compromise.

Radiographic assessment begins with three views of the ankle (Figure 2). Full-length tibial and fibular orthogonal views also are suggested. It may also be useful to obtain lateral and mortise radiographs of the contralateral ankle for preoperative planning and postoperative reduction comparison. A computed tomography (CT) scan can provide valuable additional information regarding the fracture pattern, such as the location of fracture lines, location and number of cortical fragments, extent of articular comminution, and degree of impaction or displacement of the articular surface (Figure 3). Tornetta and Gorup[17] demonstrated that a CT scan can be crucial for preoperative planning. The addition of an axial CT scan led to a change in the operative plan in 64% of patients. At our institution, a CT scan is obtained after the spanning external fixator is applied, because reduction of the fracture with ligamentotaxis allows for easier delineation of the fragments, amount of impaction, need for bone graft and surgical approach.

SURGICAL TIMING

A significant postsurgical complication is soft tissue necrosis or wound dehiscence, and recent studies have explored this area. Wound complications of up to 100% have been reported in clinical trials with immediate open reduction and internal fixation.[18–20] This significant risk of wound complications after immediate ORIF led to studies to explore the role played by the timing of surgery and the status of the soft tissues. Watson[21] showed that transcutaneous oxygen delivery to the skin drops rapidly after injury and stays decreased from 6 hours to 10 days after injury in distal tibia fractures.

The pilon fracture is an injury pattern that is a combination of soft tissue injury and fracture. Severe soft-tissue injury decreases the ability of the tissues to heal after an open technique, and even after delaying surgery the injured soft tissues heal with poorer functional results as a result of decreased natural elasticity, dense scarring, decreased normal lymphatic and venous drainage, edema, stiffness and chronic pain. This is worsened if muscle flaps or skin grafts are needed for open injuries, if compartment syndrome develops, or wound necrosis occurs from open techniques.[22] Traumatic arthritis is lessened with more anatomical reduction, but frequently more comminution means more cartilage and bone necrosis, delayed healing, nonunion and malunion and further surgery such as arthrodesis. Osteomyelitis can result in further surgery or amputation.

As a result of the risk of complications, recent studies have indicated that proper surgical timing is critical in the successful management of pilon fractures. When operative intervention is performed too early, not enough time is allowed for the soft-tissue injury to evolve, stabilize and resolve. This can lead to difficulty in primary wound closure or wound closure under tension, which can lead to further soft-tissue compromise and increased wound complications.

FIGURE 2. Anteroposterior (A), mortise (B), and lateral (C) radiograph of an AO/OTA type C2 pilon fracture.

Current treatment recommendations for pilon fractures involve a two-staged protocol in which an ankle-spanning external fixator is placed to stabilize the fracture until the soft-tissue injury resolves.[5,7] In addition, fixation of a present fibular fracture at the index procedure allows for the restoration of length of the lateral column and assists in reduction of the distal tibia by ligamentotaxis. After the soft-tissue injury and swelling resolve (which can require 10–21 days or even longer), the second stage is completed, with definitive ORIF of the pilon fracture and external fixator removal.[5,7,23]

FIGURE 3. Computed tomography axial view of an AO/OTA type C2 pilon fracture after fibula open reduction and internal fixation and ankle-spanning external fixator placement.

Many authors have used this two-staged protocol and shown a decrease in soft-tissue complications.[5,7,23] Patterson and Cole[7] retrospectively reported the outcomes of 22 type C3 pilon fractures at 22 months. They had no infections or soft-tissue complications. They also reported subjective and objective outcome measurements as 77% good results, 14% fair results, and 9% poor results. Likewise, Sirkin *et al.*[24] reported 56 fractures including 22 open fractures. Five of 34 patients (15%) with closed fractures had partial skin necrosis that healed with local wound care, and one patient had a chronic draining sinus from osteomyelitis that resolved after fracture healing. In the open fracture group, four out of 22 patients (18%) had complications with two only having partial skin necrosis that resolved with local wound care. One of the remaining two patients required a below-the-knee amputation. The authors believed there was only a minimal risk of soft-tissue or surgical wound complications as evidenced by the lack of skin grafts, rotation flaps, or free-tissue transfers in this series of patients. Dickson *et al.*,[23] in a similar study, retrospectively examined the outcome of staged treatment of 37 Rüedi types II and III pilon fractures. These patients did not have the external fixator removed until the fracture was healed at approximately 16 weeks. Infection occurred in only 8% of patients (one patient had bilateral open fractures and accounted for two of these infections). The outcomes included no limp, minimal pain, no narcotic use and return to previous occupation. On the basis of those criteria, good to excellent outcomes were achieved in 81% of patients.

FIGURE 4. Anterolateral approach with minimally invasive fixation of the fibula and the proximal portion of the tibial fixation.

FIGURE 5. The superficial peroneal nerve as seen through the anterolateral approach.

SURGICAL TREATMENT

Surgical intervention is indicated when there are more than 2 mm of articular displacement, unacceptable axial alignment, and an open fracture. The goals of surgical stabilization include anatomical reconstruction of the articular surface, early joint motion and surgical wound and ligamentous healing.[16]

There are several surgical treatment options for pilon fractures, including ORIF (staged with temporary spanning external fixation), minimally invasive plating, external fixation with limited internal fixation, and hybrid external fixation. As mentioned earlier, a staged protocol of treatment with temporary spanning external fixation followed by delayed ORIF has been gaining in popularity as a result of improved outcomes and a decreased incidence of soft-tissue complications.

The surgical approach remains a potential challenge in adequate fracture and articular surface exposure as well as avoiding anatomical structures at risk. Although the anteromedial incision classically has been used for ORIF, alternative approaches have been described, such as the anterolateral approach (Figures 4–7). Herscovici *et al.*[25] described the Böhler incision as an extensile anterolateral approach to the ankle that allows exposure of the entire anterior aspect of the distal tibia and specifically the Chaput fragment (Figure 6). This incision starts 5 cm proximal to the Chaput tubercle and ends distally between the shafts of the third and fourth metatarsals. In 2007, Chen *et al.*[26•] reported their experience with a two-incision approach. Using a two-staged delayed ORIF technique, a medial or lateral approach was used for definitive ORIF. This series reported only an 8% wound complication rate compared with other published rates of 0–20%.

Another extensile approach has recently been described by Assal *et al.*[27•] in 2007. The incision starts 10 mm below the medial malleolar tip and is carried transversely across the ankle just lateral to the midline. The incision then makes a 105–110° angle proximally to approximately 10 mm lateral to the tibial crest. The authors described their experience with 21 patients who sustained a high-energy closed pilon

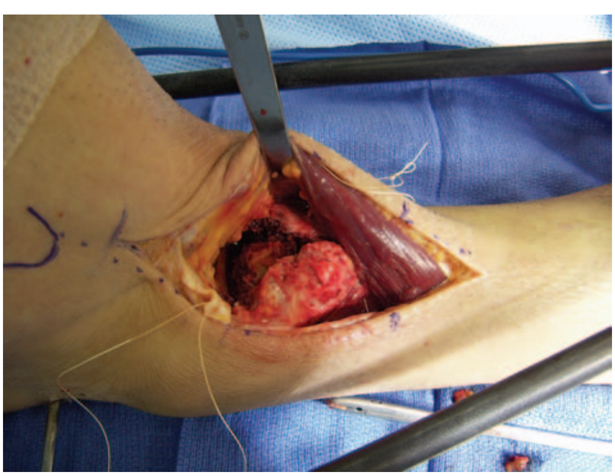

FIGURE 6. Dissection through the anterolateral approach. A step-wise Z-cut has been made in the extensor retinaculum, which is tagged for repair at closure. The extensor digitorum longus is retracted medially to allow for exposure of the large Chaput fragment.

FIGURE 7. Closure of the anterolateral approach using horizontal mattress sutures to invert skin edges.

fracture. The fibular fracture was fixed in only 11% of patients. Twenty-one patients were followed up for 12 months, with an average time to definitive fixation of 16.4 days. All patients showed soft-tissue healing at 3 months. Only one patient had a local infection, which the authors attributed to the proximal aspect of the incision being within 1 cm of a previous external fixator pin site.

In addition, a recently published article reported the results of using a lateral approach. Grose *et al.*[28•] retrospectively reviewed 44 fractures treated with ORIF using primarily a lateral approach with an average follow-up of 13.7 months. They began the incision along the anterior border of the fibula from the level of the most proximal fracture line to approximately 3–4 cm distal to the joint line. Blunt dissection was carried down to the posterior aspect of tibia with care to avoid the superficial peroneal nerve. The tibial fracture was treated first so that the fibular fracture could be manipulated to approach the tibia. A plane was bluntly developed between the interosseous membrane and the anterior compartment. The anteroinferior tibiofibular ligament was followed back to the anterolateral Chaput fragment, which was displaced to allow the reduction of posterior fragments. Their results showed 93% good reduction as determined by the radiographic scoring system outlined by Teeny and Wiss.[18] Significant complications included 4.5% deep infection, 4.5% wound dehiscence, 9% nonunions. There were no amputations; however, 27% of cases had a secondary surgery, including symptomatic fibular hardware removal, planned syndesmotic screw removal, nonunion, and infection. Forty-one percent of the patients required a secondary medial incision to gain complete fracture reduction.

SOFT TISSUE MANAGEMENT STRATEGIES

Soft-tissue management continues to be problematical in high-energy pilon fractures. A recently published randomized study evaluated the use of negative-pressure wound therapy (NPWT). Stannard *et al.*[29••] reported the results of randomly assigning 44 patients with lower extremity fractures (including four pilon fractures) either to receiving standard postoperative dressing or NPWT. Their results showed no difference in infection rates or wound breakdown but did show a significant difference in the drainage time. The NPWT group stopped draining 3 days earlier than the standard dressing group. The use of NPWT has greatly increased over recent years and has been an important adjunct to wound management.

MINIMALLY INVASIVE PLATING AND LOCKING-PLATE TECHNOLOGY

With the advancement of locking-plate technology and an improved understanding of the biology of fracture healing, minimally invasive plating is another treatment strategy gaining popularity. Farouk *et al.*[30] reported a cadaver injection study that showed superior vascularity in minimally invasive femoral plating compared with conventional plate osteosynthesis. Historical studies have also shown improved healing with minimal dissection and periosteal stripping.[31]

With the increasing popularity of the anterolateral Böhler's approach, precontoured anterolateral locking and nonlocking plates have become available. These plate designs allow for minimally invasive submuscular plating above the area used for joint reconstruction (Figure 8). Their design treats the Chaput, posterior malleolar and medial malleolar fragments.

Using a new plate design, Borens *et al.*[32•] reported their preliminary experience with a medially based low-profile scalloped plate modified for use in percutaneous fixation of Rüedi–Allgöwer I and II pilon fractures. A retrospective review of 17 cases, including 65% high-energy and two open fractures, had an average follow-up of 17 months. Using a modified grading scale of functional and radiographic data, 47% had an 'excellent' outcome. With a range of 61–100 and the higher score representing a better outcome, the average American Orthopedic Foot and Ankle Society ankle–hindfoot score was 86.8. The medially applied plate, however, could only hold articular reduction in 24%. Wound complications occurred in 11.8%, all with delayed healing of the lateral incision. Interestingly, no infections were reported. Overall, the authors concluded that the medial percutaneous plate can be used as an adjunct to the fixation of pilon fractures. For the more severe Rüedi–Allgöwer type III injuries, the plate can act as a temporizing internal splint for subsequent staged procedures.

VALIDATED TREATMENT OUTCOMES

Validated outcome measures have become an important way to compare results between studies, injury types, and the general population. Very few studies involving pilon fractures have used these validated measures. Sands *et al.*[33] used the Short Form-36 to evaluate pilon fractures and discovered significantly lower physical function and physical role scores than in controls. This prompted an investigation into the overall outcome of these fractures, and since then more recent outcome studies have been published. Pollack *et al.*[34] retrospectively reviewed 80 high-energy pilon fractures using five primary outcomes to assess patients at a mean of 3.2 years. These outcomes included the validated Short Form-36, Sickness Impact Profile, American Medical Association range of motion impairment, visual analog scale, and stair climbing ability. The authors concluded that general health was significantly poorer compared with age and sex-matched controls. Patients with a lower income or level of education significantly showed poorer health and function scores. Regarding treatment methods, external fixation with or without limited internal fixation had significantly less range of motion, more pain, and more ambulatory dysfunction than those treated with ORIF.

In 2006, Harris *et al.*[35••] reviewed 79 high-energy fractures at an average of 26 months. They reported an overall complication rate of 14%, including 2.5% wound complication, 4% infection, 2.5% nonunion, 5.1% malunion, and 39% posttraumatic arthritis. The majority of complications occurred in AO/OTA type C3 fractures, and the majority of these fractures were treated with external fixation with limited ORIF. Using the validated Foot Function Index and the Musculoskeletal Function Assessment, significantly

FIGURE 8. One-year follow-up lateral (A), anteroposterior (B), and mortise (C) radiographs of the patient from Figure 2 who underwent an anterolateral approach and fixation with an anterolateral precontoured locking plate.

lower scores were seen in patients with AO/OTA type C3 fractures and external fixation treatment.

CONCLUSION

The pilon fracture is an injury pattern that combines soft-tissue injury and fracture. Severe soft-tissue injury decreases the ability of the tissues to heal, increases the risk of surgical treatment even after delaying surgery, and typically leads to worse functional outcomes. Traumatic arthritis is lessened with more anatomical reduction, but cartilage damage and bone necrosis secondary to comminution can lead to delayed union, nonunion, and malunion and further surgery such as arthrodesis. Likewise, soft-tissue infection and osteomyelitis can result in further surgery or amputation.

Although pilon fractures have been studied extensively and treatment strategies have evolved, these complex injuries remain difficult to treat and can lead to many complications, including amputation. Most complications arise from difficult reductions and soft-tissue management. These complications can be minimized by diligent preoperative planning and meticulous handling of damaged soft tissue surrounding these fractures. The overall understanding of pilon fractures over the years has greatly increased, but surgeons must remain vigilant in their knowledge and ability to treat these potentially devastating injuries successfully.

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