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Tibial pilon fractures: Which method of treatment?

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ABSTRACT

A comprehensive review of the existing literature, related to treatment options and management principles of pilon fractures was performed, and its results are presented.

The identified series advocate in favour of a number of different treatment strategies and fixation methods. Decision making was mostly dependent on the severity of the local injury, the fracture pattern, the condition of the soft tissues, patient's profile and surgical expertise. External fixation and conservative treatment did not provide sufficient articular congruence in many cases. Internal fixation allowed excellent restoration of joint congruity in Rüedi type I and II fractures. A staged approach, consisting of fibular plating and temporary bridging external fixation, later substituted by an internal minimal invasive osteosynthesis or by a definitive external fixation, was favourable for Rüedi type III fractures. Closed pilon fractures with bad soft tissue conditions (Tscherne ≥ 3) or open pilon fractures are regarded as contraindication of open reduction plate fixation.

Anatomic reduction of the fracture, restoration of joint's congruence, reconstruction of the posterior column, with minimal soft tissue insult, were all highlighted as of paramount importance.

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Introduction

The pilon fracture is a comminuted fracture of the distal tibia; the first recorded use of the word "pilon" in the orthopaedic literature was in 1911, by Étienne Destot, describing the anatomical region extending 5 cm from the joint line.[34] In 1950 Bonnin, focusing on the involvement of tibiotalar articular cartilage, named these lesions as "plafond fractures".[16]

The fracture consists of a long oblique break extending medial to lateral, involving the dome of the distal tibial articular surface, and extending along the adjacent metaphysis. The fibula may or not be involved.[78] Pilon fractures can be partial (a part of the epiphysis is in continuity to the diaphysis) or complete. The partial can be divided into anterior: either simple (characterised by a single large articular fragment usually anterolateral, in this case the epiphysis is posteriorly connected to the diaphysis) (Fig. 1a), or complex characterised by multiple articular fracture lines (Fig. 1b); and posterior with usually only one large fragment (Fig. 1c).[16] In complete articular fractures the Tillaux-Chaput tubercle is the only useful marker for the correct anatomical reduction of the fracture. This remains attached to the fibula through the syndesmosis (Fig. 2). These fractures are often multi-fragmentary and there is the possibility of anterior, central or posterior subluxation. They result from axial loading, when a combination of compression and shearing forces are produced in-between the talar dome and the distal tibial articular surface, often resulting into significant fragmentation and displacement. They are usually associated with massive swelling of the foot and ankle, as well as with open wounds, even skin defects. The swelling may cause significant decrease of the blood flow to the foot, impairment of nerve function compartment syndrome of the foot or calf, blistering and skin breakdown. The initial management of these injuries is of paramount importance often determining the final outcome.[101]

Distal tibial fractures involving the articular surface are fortunately rare injuries, accounting for approximately 7–10% of all tibial fractures, and less than 1% of fractures of the lower limbs.[21] Nevertheless, their numbers are rising following the rise of the incidence of road traffic accidents, RTAs (45.5% of all pilon fractures are attributed to RTAs) and of high energy falls.[21] These mechanisms produce significant comminution with multiple displaced fracture fragments, accompanied by severe soft tissue closed or open trauma. In 85% of high energy tibial pilon fractures the fibula is fractured as well.[19] As expected, from the high energy absorption during these accidents the occurrence of associated

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Fig. 1. Fracture type I (Rüedi and Allgöwer classification) – (a) anterior: simple partial fracture with only one anterolateral large fragment and tibial malleolus fracture; (b) anterior: complex fracture; (c) posterior: fracture with only one large posterior fragment.

skeletal or visceral trauma is probable, making the management of these cases more demanding. The population of these types of injuries is usually young adults with high demands and expectations for their recovery and final function.

Low-energy pilon fractures are also increasing in numbers, proportionally to the aging of the world population and, of the increased level of activities of the elderly. Osteoporotic distal tibial fractures pose by themselves a challenging type of injuries. The soft tissue envelope in these cases may be inherently compromised due to comorbidities i.e. diabetes, vascular disorders, chronic intake of corticosteroids or other medication. In osteopenic bone achieving a stable osteosynthesis is difficult, healing process is slower and post-operative rehabilitation is prolonged. However, usually the bone fragments are fewer, occasionally with a spiral configuration, with relatively minimal displacement. The use of contemporary locking plating systems, minimal invasive reduction and when needed of a staged approach has been associated with fairly satisfying results.[18,48,105,106]

Fig. 2. Fracture type III (Rüedi and Allgöwer classification): intra-articular displacement with marked comminution. Highlight the Tillaux-Chaput tubercle, essential marker for a correct articular reconstruction.

The treatment of pilon tibial fractures has evolved over the last century. A wide variety of treatment strategies, implants, and approaches have been utilised in order to manage this type of fractures with broad range of results.[12,48,49,58,88,110,113,123]

The aim of this study was to review the existing evidence of the literature and comprehensively report on principles of management of tibial pilon fractures and the published clinical results of the established treatment options.

Materials and methods

Using the PubMed search engine a research of the published series on pilon fractures was performed at the 10th of January 2010. The following keywords were used: "distal tibial", OR "pilon", OR "plafond", AND "ORIF", OR "MIPO", OR "MIPPO", OR "external fixation". The exclusion criteria were: case reports, series of less than 20 cases, or referring to children (age < 16 years), editorials, letters, review studies, and articles in languages other than English,

Data from the accumulated manuscripts were collected mainly addressing the issues of principles/stages of management, methods of fixation, clinical outcome and complication rates. When possible, descriptive statistical means were used to comprehensively present the reviewed evidence.

Results

From a considerable number of initially retrieved abstracts (397), based on the inclusion/exclusion criteria described previously, we have concluded to the most cited and larger of these studies (70), which will be summarised in chronological order.[1–8,10,13,14,17,26,29,31,32,35–38,40,42–46,49,50,52,53,55,57–59,61–66,68–70,72,79,83–85,89–91,94–101,112,114,115,123–127,129–131] The development of novel

treatment concepts and fixation devices is continuous. Mostly three surgical options, different for indication and technique, are frequently reported in literature reviews[10]:

- ORIF, Open Reduction Internal "rigid" Fixation
- ExFix, External Fixation with or without minimal osteosynthesis of articular joint
- CRIF, Closed Reduction Internal "biological" Fixation, with minimal periosteal stripping and preservation of soft tissues (MIPO Technique)

In 1959 Jergesen asserted that open reduction and stabilisation of serious tibial pilon fractures was impossible.[54] So for years cast immobilisation has been the most popular method of treatment.[86] Conservative management gave way to surgical intervention when implants became available, but poor outcomes led to a return to cast immobilisation or limited internal fixation of the fibula only.[121] Nowadays, few authors still advocate for the non-operative treatment, using casts/pin traction/plaster in selected, inoperable cases.[30,54,85,111]

Since the mid-60s the introduction of general guidelines for the treatment of fractures by the AO/ASIF,[108] for the first time structured the existing knowledge related to the management of distal tibial fractures along with the rest of the appendicular skeleton. The reconstruction of the articular congruity,[103,107] the restoration of the length by internal fixation of the fibula,[128] the grafting of any bone loss at the metaphyseal site,[15,106] the stability of the fixation of the metaphysis to the diaphysis,[25,48] and the allowance of early return to function were set as the pillars of a successful surgical intervention.

The following two decades, the development of newer and advanced surgical techniques, led to more and more fixation of these fractures, gradually leaving behind non-operative methods.[92,105,106] Many authors following the pioneers of the AO/ASIF group, routinely practiced and published on the principles of anatomic reduction and rigid fixation with favourable results in up to 90% of the cases.[3,15,22,23,30,47,49,51,54,73,74,80,86,93,102,104,106,107,111,120] Good outcomes were uniformly reported when these principles were used for low-energy injuries (Rüedi type I or II injuries).[3,15,20,22,23,56,74,86,106,120] In more severe injuries or in the presence of comorbidities and local pathologies a number of complications occurred and were gradually identified as major problems. According to McFerran et al. 40% of these fractures resulted in relevant complications after ORIF treatment.[77] Similarly, over a longer period of follow-up of 52 fractures the complication rate reached up to 54% of all cases.[77] Teeny and Wiss[120] identified wound dehiscence, infection, nonunion, malunion or implant failure in half of their 60 cases treated according to the AO principles for ORIF. Especially, for the Rüedi type III (bad condition of soft tissue envelope) the complication rate reached the 70%, with 37% of them being deep infections.[102–106] The impact on the fracture healing process (delayed union/nonunion), wound breakdown, soft tissue and deep infections, algodystrophy, ankle joint stiffness, and poor functional outcomes were repeatedly reported by many clinicians.[5,22,24,41,56,75,80,86,93,101,116,119,121] These complications were attributed to the iatrogenic trauma to the soft tissue envelope, the poor vascularity of the bone fragments following the osteosynthesis, and the prolongation of the surgical procedure.[9,82,101,115] The strict adherence to the meticulous reduction and rigid fixation of all bony fragments in high energy pilon fractures, through extensive surgical approaches, was gradually conceived as detrimental for the prognosis of the injured extremity,[24,56,77,86,120] making the clinician reluctant to the universal use of ORIF and to search for other alternatives (Table 1).

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. It rapidly gained wide acceptance in the management of open fractures, or those with poor condition of the soft tissues (Tscherne > 3), Table 1.[13,14,41,57,67,68,76,88,100,127] A randomized prospective comparative study between ORIF and external fixation concluded that external fixation was associated with significantly fewer complications when treating high energy plafond injuries.[96,131] A recent systematic review of the literature[88] 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. The use of circular frames, either Ilizarov's[6,40,64,65,76,84,124] or hybrid systems[1,2,4,8,39,52,83,94] in comparison to unilateral simple frames are considered to allow improved indirect reduction, earlier mobilisation and weight bearing, progressive correction of deformities and offer improved results. A retrospective review of 60 tibial plafond fractures,[84] treated by either 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.

In order to combine the benefits of ORIF (direct visualisation and manipulation of fragments) with the advantages of external fixation (indirect reduction, soft tissue protection), a staged approach has been introduced,[10,36,90,114,115,126,127] Table 1. Patterson and Cole[90] reported on 21 patients with 22 type C3 plafond fractures treated using a 2-steps approach, consisting of fibular plating and spanning external fixation followed by exchange of the external fixator to a definite internal fixation days later when the soft tissue allowed. Similarly, Sirkin et al.[115] in a large series of 226 pilon fractures treated in two stages within 14 days reported an decreased incidence of deep infection at 3.4% (10.5% in the subgroup of open fractures), when compared to historical controls of single stage ORIF. In two publications,[9,10] another group of investigators compared different management strategies of open and closed type C pilon fractures. The patients were treated either with ORIF, or with External Fixation supplemented with mini fixation via stab incisions, or in stages with a primary reduction and internal fixation of the articular surface using stab incisions, screws, and K-wires and a temporary spanning external fixation followed by internal fixation with a medial approach. No significant correlation was found between the initial soft tissue damage or the type of surgical treatment and the incidence of post-traumatic arthritis. The range of ankle movement, pain, return to pre-injury level of leisure and work activities were all better for the patients treated in 2 stages. Moreover, the infection rates were significantly lower in the 2-step procedures in comparison to the other groups (Table 1).

Closed reduction and application of percutaneous/less invasive fixation methods was introduced at the early 90s.[109] Following the initial description and the increased availability of modern plating systems, a large number of authors published their encouraging results using the so-called "Minimal Invasive Percutaneous Osteosynthesis/Minimal Invasive Percutaneous Plate Osteosynthesis/Minimal Invasive Locking Plate Osteosynthesis" (MIPO/MIPPO/MILPO).[7,18,26,28,43,45,46,50,59,62,87,98] They represent an attractive alternative, that allows stable fixation in a "biological" manner, via less extensive approaches, with no stripping of the periosteum, bridging the fracture area, leading to fewer soft tissue and healing complications[27,28,50,51,118] (Fig. 3). The advantages of this approach either as a primary procedure or as the second stage following spanning external fixation and soft tissue resuscitation, were investigated by a number of authors.

Table 1
Studies reporting on the two-stage protocol of treatment of pilon fractures.

Author	Treatment	*N*	I	II	III	Open frxs	Complications	Wound dehiscence	Malunion	Nonunion	Infection	Arthrodesis	Amputation	Healing	Good outcomes
McFerran et al.[77]	ORIF	52	27%	33%	40%	21%	54%	24%	6%	4%	17% 11 open frxs	0%	0%	90%	n/a
Teeny and Wiss[120]	ORIF	60	5%	45%	50%	20%	n/a	17% in type I–II 37% in type III	3% in type I–II 23% in type III	7% in type I–II 27% in type III	10% in type I–II 37% in type III	10% in type I–II 25% in type III	n/a	50%	25%
Wyrsch et al.[131]	ORIF ExFix	18 21	36%	20%	44%	26%	n/a	33% 5%	2% 13%	n/a	33% 5%	n/a	16% 0%	n/a	n/a
Bone et al.[14]	ExFix	21	52%	14%	34%	57%	n/a	n/a	0%	14%	0%	9%	0%	100%	n/a
McDonald et al.[76]	ExFix	13	n/a	n/a	n/a	61%	n/a	n/a	23%	8%	69%	8%	0%	52%	n/a
Papdokostakis et al.[88]	ExFix	465	n/a	n/a	n/a	35%	n/a	n/a	9%[a]	5%[a]	27% minor infection 2% major infection	n/a	n/a	n/a	n/a
Anglen[2]	Hybrid ExFix ORIF	29 19	n/a	n/a	n/a	n/a	2%	n/a	n/a	21%	21% pinsite 2% arthritis	n/a	n/a	n/a	52% 79%
Tornetta et al.[123]	Hybrid ExFix + minimal ORIF	26	n/a	n/a	n/a	n/a	n/a	n/a	4%	n/a	4% superficial 4% deep	n/a	n/a	n/a	81%
Blauth et al.[10]	ORIF 2-Steps procedure	15 8	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	26% 0%	n/a	n/a 100%	n/a 75%
Sirkin et al.[114]	2-Steps procedure	56	5%	23%	12%	39%	n/a	10% skin necrosis 2 in open frxs	3%	6%	5% 2 in open frxs	0%	n/a	n/a	n/a
Patterson and Cole[90]	2-Steps procedure	22	0%	0%	100%	27%	n/a	0%	4%	4%	0%	8%	n/a	n/a	n/a

[a] Data available only on 361 fractures.

Fig. 3. CRIF (close reduction internal fixation): plate angular stability introduced with MIPO technique.

MIPO has proven its safety and efficacy as a management principle showing better results than standard ORIF.[7,43,45,62,98] In a comparative study with 3 investigation arms,[10] a staged approach with the use of MIPO as a definite fixation method was identified as superior to other concepts including ExFix and ORIF. There have been also contradicting reports raising concerns regarding the application of MIPO using modern locking plating systems. They referred either to the specific plate design,[43] the prolongation of the healing time when bridging techniques were used in simple fracture types,[45] the medial approach, skin impingement and late wound infections,[62] as well as its overall superiority.[26] Certain limitations as to the design of all these studies, selection bias, and differences to the methodology, timing of interventions, and surgical experience can easily be identified which restrict an all inclusive meta-analysis and the draw of robust conclusions.

Comparing some studies[2,10,14,76,77,88,90,114,120,123,131] concerning tibial pilon fractures we observed a total success rate of 64% on 156 fractures submitted to RIF, in particular differentiating type I, II and III. We estimated a 81% rate of successful treatment in 55 fractures treated with hybrid fixation whereas; a 2-step procedure pointed out 92% of good outcomes in 86 cases. The use of external fixation led to successful healing of 330 out of 416 fractures.

We also observed that the incidence of post-traumatic arthrodesis for osteoarthritis, nonunion and infection is reduced in the 2-steps approach vs ORIF technique. As reported by Pollak et al.[95] at more than three years after the injury, pilon fractures can have persistent and devastating consequences on patients' health and well-being. Limitation of range of motion was higher in the subgroup treated with external fixation than in the other cases (27% vs 12%). According to these authors the outcome varied depending on[95]:

- The severity of bone and soft tissues injury
- Delay from injury to presentation, especially in open fractures
- 'Patients' general condition and compliance
- Other associated injuries
- Surgeon's experience

Moreover, the cartilage damage caused at the time of the injury often determines the bad outcome despite the often anatomic radiographic joint reconstruction. The implication of severe complications as the compartment syndrome especially if diagnosed with delay, the deep infection, and nonunion that requires secondary procedures and prolongs the immobilisation period increases further number of cases with poor outcome.[17,55,62,77,119,120] Satisfactory long-term outcomes are expected in approximately 70% of high energy fractures. Good-to-excellent results have been reported in nearly 80% of low-energy fractures. Results for secondary ankle arthrodesis after attempted ORIF of type 3 fractures approaches 30%. Ankle fusions may be required in approximately 3–27% of post-traumatic arthritis. Ankle replacement can be an option in selected individuals.[33]

Discussion

A comprehensive meta-analysis and comparison of the major published series is difficult due to the lack of consensus in the classifications and evaluation methods.[111] The classification of Rüedi and Allgöwer[105–107] has been the most commonly used over the years, but has low inter-rater reliability, especially between types II and III (Fig. 1). The AO/OTA classification,[71] which followed, was proven to have superior inter-rater agreement,[117] and has gradually prevailed.

Regarding the initial assessment of a pilon fracture there is a general consensus, which includes the examination of the distal neurovascular status, the evaluation of the soft tissue envelope for swelling, bruising or blisters, the condition of the skin of the lower extremity, the exclusion of the occurrence of compartment syndrome. The diagnostic algorithm of these injuries includes a series of radiological investigations. On admission, standard two-plane X-rays centred over the ankle, provide the initial diagnosis of the location and the basic characteristics of the fracture. Full-length X-rays of the lower leg, including the knee and ankle, are necessary to assess the alignment of the tibia and the extension of the fragmentation to the adjacent joints. Nowadays, the use of CT-scanning of the distal tibia and the ankle joint, as well as of reconstruction images in sagittal and coronal planes, is common practice. They are considered as gold standard for the evaluation of the fracture's configuration, comminution, displacement, and the impaction of articular segments.[113,121–123] In selected cases x-rays of the contralateral ankle assist the templating of the reconstruction that will follow. Angiography is required if vascular compromise is suspected.

Regarding the optimal treatment method there is the general belief that there is not a single method of fixation ideal for all pilon fractures suitable for all patients. The wide variety of instruments and techniques that are available provide satisfactory and comparable results when used for specific indications and by experienced surgeons.[19,119] The successful management requires to be aware of the mechanism of injury[116] while the choice of fixation depends on the fracture pattern, the condition of soft tissues, and often by the mental state of the patient. A poor evaluation of the soft tissue status may result in disastrous complications. The improvements in plastic surgery and soft tissue management, the new implants (ORIF, ExFix) and the new percutaneous and limited incision exposure techniques (MIPO) can reduce the wound complication rates. In this scenario one of the most important parameters is to identify the correct timing of surgery. When necessary a two-stage protocol can be adopted to promote recovery of the traumatized soft tissues before definitive fixation.

In some selected cases where extensive fragmentation and deformation are present, a tibiotalar arthrodesis can be performed. In the younger patient with this injury pattern, osteoarticular allograft reconstruction may be a reasonable option.

If the fracture is characterised by a complex articular comminution that could influence the final result of the reduction, it is best to seek restoration of axial alignment obtaining metadiaphyseal union, and choosing a stabilising technique that does not preclude a later ankle joint arthrodesis. This can be obtained using an external fixator or MIPO.

Rarely, however, in cases with extensive soft tissue damage, poor bone stock and associated comorbidities a below-the-knee

amputation could be the only procedure available providing a good functional option.

In summary we believe that Rüedi type I and II fractures, (with no soft tissue damage), allow the application of a minimal invasive internal fixation at the first 12–24 h, aiming for anatomic reduction and early function of the ankle joint.[60,81]

Rüedi type III, or Tscherne type 3, or open fractures dictate a 2-step approach: temporary bridging external fixation, later substituted by an internal biological osteosynthesis or by a definitive external fixation using mostly a circular frame spanning or not the ankle joint. The choice of implant should be based on the states of the soft tissues and the surgeon's preference. Early involvement of the plastic surgeons is often mandatory to allow optimisation of the soft tissue envelope. Non-operative management and casting still has a role and can be utilised in patients who have low demands or severe comorbidities and have minimal displacement of the fragments.[11,75]

Conclusions

The tibial pilon fractures continue to be very challenging injuries. There is not a treatment that can be considered the gold standard, even if in Ruedi type III fractures the 2-steps procedure seems to give the best results. Decisions should be taken not only on the basis of the clinical and radiographic situation but also on the basis of the expertise of the surgeon. New devices and new surgical technique will help us to better solve this difficult type of fracture reducing the rate of complications.

Conflict of Interest Statement

There is no conflict of interest for all the authors of the manuscript.

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