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Double plate osteosynthesis in a C1-C2 tibial pilon fracture: two case reports

Mario Paracuollo, Luigi Cioffi, Antonio Allocca

Department of Orthopedics and Traumatology, CTO Hospital, Naples, Italy

Summary

Tibial pilon fractures, despite their infrequency, while accounting for 4-10% of all tibial fractures and less than 1% of all fractures of the lower extremity, still represent a challenge for orthopedic surgeons due to their poor prognosis. We present two case reports of C1-C2 tibial pilon fractures, through which we try to demonstrate that double plate fixation offers a superior stability to the osteosynthesis both in case of articular rim multi-fragmentarity, wherein primary key-fragments can be fixed by anatomically shaped plates, to better restore the articular surface and joint stability, and in the scenario of long spiroid or extended oblique fractures, whereby a buttressing and a supporting plate best domain the vertically directed shear forces that tend to diastase the three pilon columns.

Key Words: tibial pilon fracture, three pilon columns, double plate fixation

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Correspondence
Mario Paracuollo
E-mail: ma.paracuollo@gmail.com

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Introduction

Tibial pilon fractures, despite their infrequency, while accounting for 4-10% of all tibial fractures and less than 1% of all fractures of the lower extremity, still represent a challenge for orthopedic surgeons due to their poor prognosis [1-3]. These fractures are often associated with soft tissue involvement as well as by fibula fracture in about 75-90% of cases [4].

Differently from common ankle fractures, the mechanism of injury of a tibial pilon fracture depends on the association of heavy axial compression with variable angulation deformity, which in turn is influenced by the vectorial direction of the forces and the position of the foot with respect to the ground during the trauma [5]. Therefore, when the foot is in neutral position at the time of the impact, the talus acts as a "pestle" resulting in the destruction of the entire articular surface. The explanation of how the epiphysis "bursts" when a diaphyseal "wedge" penetrates it, upon impact of the talus on the pilon, can be found in the distal tibial bone architecture, which is characterized by a particularly dense metaphysis and a fragile epiphysis with thin cortices [6,7].

Topliss et al. cleared up a biomechanical distinction between *high-energy* fractures, mostly seen in younger patients, which develop along a sagittal plane and derive from placing the foot with a varus angulation at the time of the impact, and *low-energy* fractures, mostly seen in older patients, which manifest their own along a coronal plane by positioning the foot with a valgus angulation [8]. Because of that, pilon fractures are physiopathologically classified into three groups: A) high-energy trauma (motor vehicle injuries), characterized by severe articular involvement and soft tissue lesions; B) rotation trauma (skiing accidents), with limited articular and soft tissue

damage; and C) low-energy trauma, typically in elderly people [6].
The classification system of distal tibial fractures, updated over the years, associate the mechanism of injury with the specific pattern of fracture by analyzing different factors like the extent of the comminution and the displacement of the articular surface.
The latest classifications are based on CT and represent a powerful tool to guide the physician toward the choice of the most appropriate surgical approach and the fixation device that best fits the pattern of fracture. Among these, the four-columns classification, proposed by Tand et al., three-dimensionally splits the ankle into a *medial column*, consisting of the medial one-third of the distal tibia, and a *lateral column*, i.e. the distal fibula, rather than dividing the tibial plafond itself into an *anterior* and a *posterior column* through an intermalleolar line that connects the lateral and medial malleolus [9].
Recently, Leonetti and Tigiani have proposed a new CT-based classification based on "architectural" factors like the level of displacement, number of articular fragments, plane of the main fracture line, and degree of comminution [10].
Therefore, a pre-operative CT scan is useful both to understand the fracture lines, tibio-fibular lesions, comminution and depression areas, and in planning the rightest surgical approach, i.e. to determine the likelihood that an anterolateral fixation plate will provide sufficient stability to the medial segment of the distal tibial epiphysis or it would be better to consider an additional medial support, in order to prevent any varus deformity [2,11]. Actually, it is strongly advisable to perform CT after the fracture has been aligned and stabilized in the emergency setting, i.e. after the "damage control" procedures have been accomplished.
The management protocol of a tibial plafond fracture was clearly outlined in 1979 by Ruedi and Allgower, who proposed a four-step procedure, structured in: 1) restoration of fibular length; 2) anatomic reduction of the articular surface; 3) filling the residual bone defect with cortico-cancellous autograft; and 4) stabilization of the medial column. The physiopathology behind this surgical sequence reflects the guiding principles of "how to approach a diaphysis-epiphyseal fracture", consisting of pulling out the cortical wedge while restoring its length, reducing the epiphyseal fragments with restoration of the joint surface and rebuilding the diaphysis-epiphyseal continuity [6]. The stabilization achieved must be strong, capable of both resisting varus stress and restoring the antero-posterior and lateral axes of the tibial distal extremity as well as the foot's external rotation. Any filling of bone substance requires autografting or bone substitutes [12].
The stability of the fixation, according to the extent of the fracture, along with the congruence of the articular surface and the axial alignment of the tibio-talar joint, seems to be an important predictor of functional outcomes [1,2,13-16]. Therefore, a valid osteosynthesis system has to domain the tibial fracture along all its development planes, and sometimes it cannot be achieved with a single fixation device.
Supplementary fixation with additional plates may be necessary, particularly along the medial column, in case of a shear-type pattern of fracture. Low profile plates are generally preferred, since they are associated with fewer wound complications and intolerance to fixation support [17].
This is especially true for A.O./O.T.A. C1-C2 fractures, since a single plate cannot adequately stabilize the three primary fracture fragments that are typically seen in these injuries. Anterolateral plates are superior in addressing, along the coronal plane, the fracture across the apex of the plafond, while medial plates can support and resist compound forces by buttressing the zone of comminution [18].
Summing up, a double plate osteosynthesis should be chosen in two different scenarios: a) articular rim multi-fragmentarity, in which small-fragment plates can better restore the articular surface and joint stability through the fixation of primary key-fragments (i.e. Chaput tubercle) [19,20]; b) long spiroid or oblique fractures, derived from vertically directed shear forces, which tend to diastase the three pilon columns [9].
In the first scenario, small-fragment low-profile plates can enhance the stability of the primary synthesis achieved with an anatomical locking compression plate (LCP), placed antero-medially or antero-laterally to restore diaphysis-epiphyseal continuity, by reducing the traction forces applied onto tibial capsulo-ligament attachments. This is particularly true for the stability of the Chaput tubercle fracture, upon which leading traction is given by the antero-inferior tibio-fibular ligament [21,22].
In the second plot, a vertically long diaphysis-epiphyseal fracture, sometimes twisting along its own axis, tends to separate the tibial blocks along multiple spatial planes, as in the case of an extended spiral fracture which first divides the anterior and posterior columns and ends upon the articular surface by splitting it into divergent fragments. The best osteosynthesis solution in this pattern of fracture would be an association of a buttress plate along the mainly displaced side and a support plate on the opposite one.
Furthermore, along the medial and lateral tibial plates, distal coplanar screws form a crossing system over the articular dome, which is a stronger fixation construct that allows early ankle mobilization and partial weight-bearing, which can be associated with better functional outcomes [23].
It is important to keep in mind that if a double surgical approach is chosen for a double plate tibial fixation, according to anatomical studies on distal lower limb angiosomes (typically 3 – anterior tibial, posterior tibial and peroneal angiosomes), a ~ 7 cm skin bridge is deemed to be a safe distance between the two surgical incisions. However, recent studies have shown that lower distances of ~ 5 cm also seem to be safe, especially when a minimally invasive technique is adopted [24-28].
We present two case reports of C1-C2 tibial pilon fractures, surgically approached with double plate fixation, at the Department of Orthopedics and Traumatology of C.T.O. Hospital in Naples.

Case 1

A 42-tear-old man, during a car accident, suffered a 43-C2 distal tibial fracture, engaging both the anterior and the medial column and consequently displacing the ankle into a valgus position. A CT scan showed an important comminution of the anterior wall, a discontinuity of the posterior distal diaphysis and a free antero-lateral fragment still attached to the fibula through the antero-inferior tibio-fibular ligament (Fig. 1).
A double antero-lateral and medial approach was chosen to expose the entire anterior articular rim and the Chaput tubercle, in order to clearly see and manage the anterior and medial columns. The articular surface was carefully reduced under direct vision and temporarily fixed with k-wires. Next, one lag screw was implanted along an anterior-to-posterior and lateral-to-medial fashion, above the joint plane, to stabilize the Chaput fragment. Subsequently, the medial column fragment was reduced first and fixed by a medial anatomic LCP, placing the distal screws as shaping a shelf along the articular dome, then managing the anterior column with an antero-lateral anatomic LCP, through which the posterior cortex was caught and reduced. Intraoperative fluoroscopy showed a well-reduced fracture with a flat joint surface. (Fig. 2)
In this scenario, the main indication for a double plate osteosynthesis is to improve the stability of the diaphysis-epiphyseal block by scaffolding it along both sides and to counteract the displacing forces applied upon the Chaput tubercle fragment, led by the antero-inferior tibio-fibular ligament.

A rehabilitation protocol was started early, with foot massages and drainage to reduce edema, as well as restoration of ankle mobility, on the second day after surgery. The patient was kept out of load until radiographically confirmed bone union, at 60 days post-operative.

Case 2

A 31-year-old man, after a fall from a height, suffered a severe 43-C1 distal diaphysis-epiphysial tibial fracture. A CT scan showed an obliquely longitudinal displacement of the pilon with a 2 cm ascent of the large medial fragment along with the talus (Fig. 3).
A medial approach was chosen to domain the "ad longitudinem" displacement of the medial block and, through a minimal antero-lateral window, the distal tibia was reduced under direct vision, while the articular surface was dealt under fluoroscopic control and temporarily fixed. The final synthesis was obtained with a long medial anatomic LCP along the "stressed" side and supporting the contralateral one with a pre-bent straight plate, slid though the antero-lateral window, according to a minimally invasive approach (Fig. 4).
In this scenario, the primary goal of a double plate osteosynthesis is to enhance the stability of an extended spiral fracture, through which the articular surface is split into two fragments diverging along multiple planes, by an association of a buttress plate along the primarily displaced side and a support plate on the opposite one.

Figure 1. 43-C2 distal tibial fracture, displacing the ankle into a valgus position (A); CT scan shows an important comminution of the anterior wall, a discontinuity of the posterior distal diaphysis and a free antero-lateral fragment still attached to the fibula through the antero-inferior tibio-fibular ligament (B).

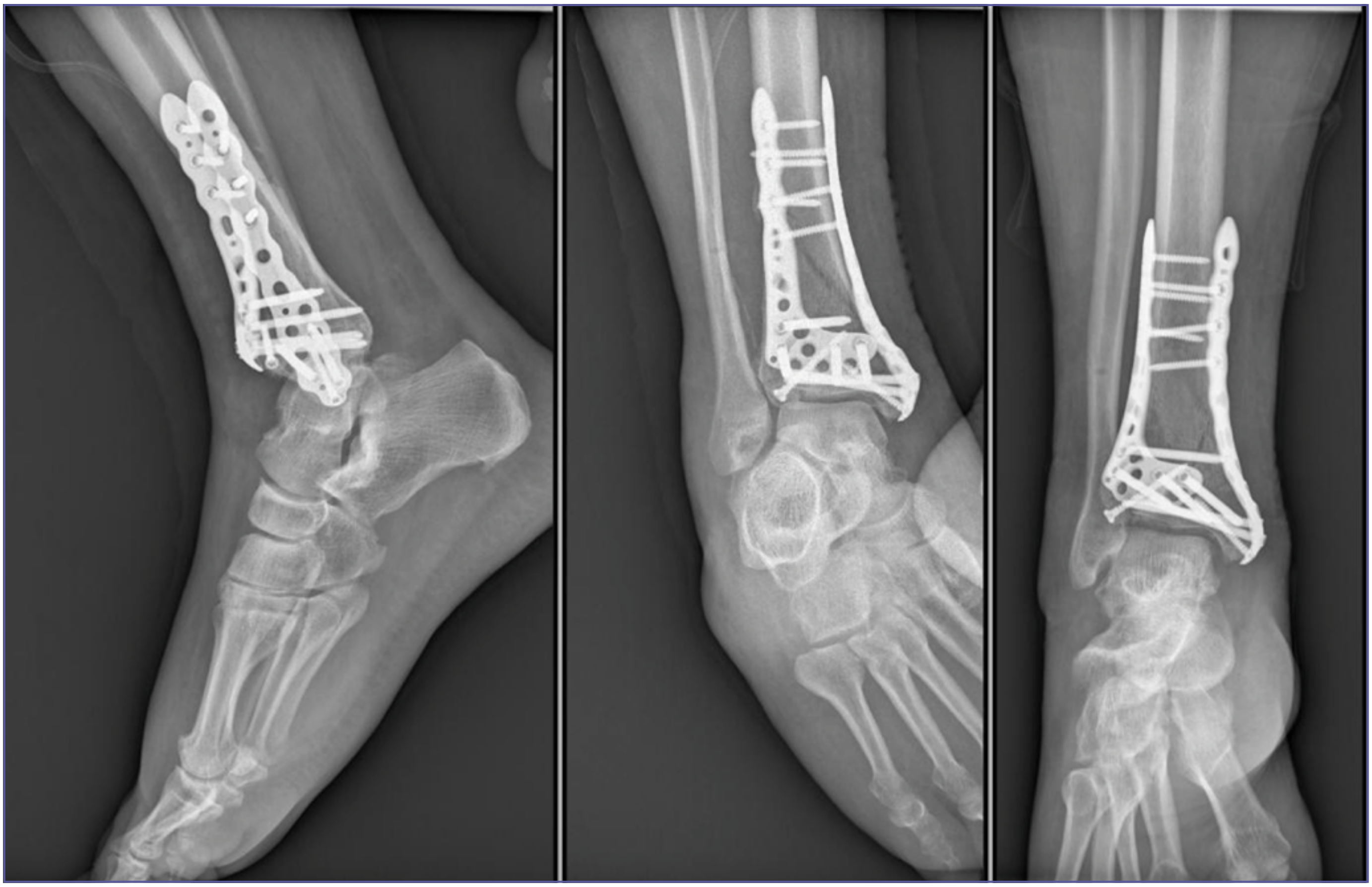

Figure 2. Post-operative X-ray: the Chaput fragment is stabilized by a lag screw, the medial column fragment is fixed by a medial anatomic LCP, placing the distal screws as shaping a shelf along the articular dome, and anterior column with an antero-lateral anatomic LCP, throw which the posterior cortex is cought and reduced.

Despite the fact that, according to literature, after a surgical procedure in a complex tibial pilon fracture, the patient should generally be kept out of load for approximately 3 months, the stable fixation reached in this case with a double opposed plates allowed the patient to start a cautious partial weight bearing just a few days post-operative [23].

Discussion

There is general agreement that the goal of all surgically-treated tibial pilon fractures should be an anatomical reconstruction of the tibial joint surface and that excessive soft-tissue dissection should be avoided [29]. However, there is no single ideal method of fixation for all pilon fractures that is suitable for all patients. Successful management requires knowledge of the mechanism of injury, the pattern of fracture and the state of the soft tissue, otherwise a wrong choice of fixation can lead to an increase of the risk of complications [30]. Among these, it is possible to consider acute soft-tissue complications, like cutaneous necrosis and surgical wound infection, along with subacute-chronic skeletal deformities, like secondary displacement, metaphyseal malunion or nonunion and tibiotalar arthritis [6,31]. Actually, the incidence of sagittal plane deformities, which remain the most common complications in a tibial pilon fracture, strictly depends on the quality of surgical reduction and stability of the fixation [32]. Indeed, the main biomechanical problem in tibial pilon osteosynthesis is the secondary loss of reduction, which is due to an insufficient hold of screws in the area of a comminuted fracture of a mainly cancellous bone, leading to a loss of reduction in up to 11% and tibiotalar arthritis rates of 9-11% [29,33].

In other words, the problems the orthopedic surgeons have to face are: 1) to choose a device that potentially has a brilliant grip strength on cancellous bone in order to accomplish an osteosynthesis construct with a high biomechanical validity; and 2) to exploit these tools to domain the fracture along all the displacement plans.

About the first point, the scenario of distal tibial fracture management has radically changed since locking plates have been introduced according to the MIPO technique, since it provides

Figure 3. 43-C1 distal diaphyso-epiphysial tibial fracture (A); a 3-D CT scan shows an obliquely longitudinal displacement of the pilon with a 2 cm ascent of the huge medial fragment along with the talus (B).

higher stability and minimizes loss-of-reduction [29,34]. Furthermore, subcutaneously applied plates have little or no effect on soft tissue and periosteal bloody supply, which leads to fewer soft tissue and healing complications [35].

Several studies conducted on Rüedi type II and III pilon fractures, treated with minimally-invasive low-profile LCP, concluded that MIPO technique was an effective treatment choice with less invasiveness, faster bone union and quicker recovery in ankle function [17,36-38].

In reference to the planning of an approach to a three-dimensionally displaced fracture, without prejudice to the choice of fixation device, it should be mandatory to domain the fracture along all the planes into which the displacement occurs. This sometimes means the necessity of adopting a multi-device strategy of osteosynthesis. The multi-device approach mainly studied in the literature is hybrid fixation, obtained by combining an ExFix with LCP MIPO, which is associated with higher healing rates and better functional outcomes compared to a mono-LCP ORIF approach alone in case of Rüedi type II and III pilon fractures [30,39,40].

No study has been published on the biomechanical and functional implications of using a "double plate" fixation approach in case of multi-planar displacement of the distal tibia.

Therefore, the purpose of these case reports was to promote idea that double plate fixation offers superior stability in C1-C2 tibial pilon fractures, and the multi-device ORIF approach should be adopted in two circumstances: 1) in case of articular rim multi-fragmentarity, wherein primary key-fragments can be fixed by anatomically shaped plates to better restore articular surface and joint stability; and 2) in the scenario of long spiroid or extended oblique fractures, whereby a buttressing plate and a supporting one best domain the vertically directed shear forces that tend to diastase the three pilon columns.

In summary, we believe that AO C1-C2 tibial pilon fractures allow the application of a double plate ORIF approach, aiming for anatomic reduction, powerful stability and early function of the ankle joint.

Obviously, a case-control study should be conducted in order to demonstrate the superiority of a "double plate" approach over a mono-LCP ORIF one in case of a multi-plane displaced tibial pilon fracture.

Conclusions

Choosing the right approach for each fracture pattern is important to get the best possible visualization and therefore to obtain anatomical reduction of the tibial articular surface and create a stable fixation construct. The quality of fracture reduction, in terms

Figure 4. Post-operative X-ray: osteosynthesis is obtained with a long medial anatomic LCP along the "stressed" side and supporting the contralateral one with a pre-bent straight plate.

of joint congruence, as well as the restoration of fracture length, alignment and rotation, is the key to treating a C1-C2 tibial pilon fracture. In conclusion, new devices combined with multiple surgical techniques will help orthopedic surgeons to best manage this difficult type of fracture and reduce the rate of complications.

Conflict of interest statement
The authors declare no conflict of interest.

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Author contributions
MP (first author): mainly wrote this manuscript and performed the acquisition, analysis and interpretation of data; LC, AA (corresponding authors): mainly performed the conception and design of this study. All Authors read and approved the final manuscript.

Ethical consideration
The research was conducted ethically, with all study procedures being performed in accordance with the requirements of the World Medical Association's Declaration of Helsinki. Written informed consent was obtained from each patient for study participation and data publication.

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